Department of Design Sciences
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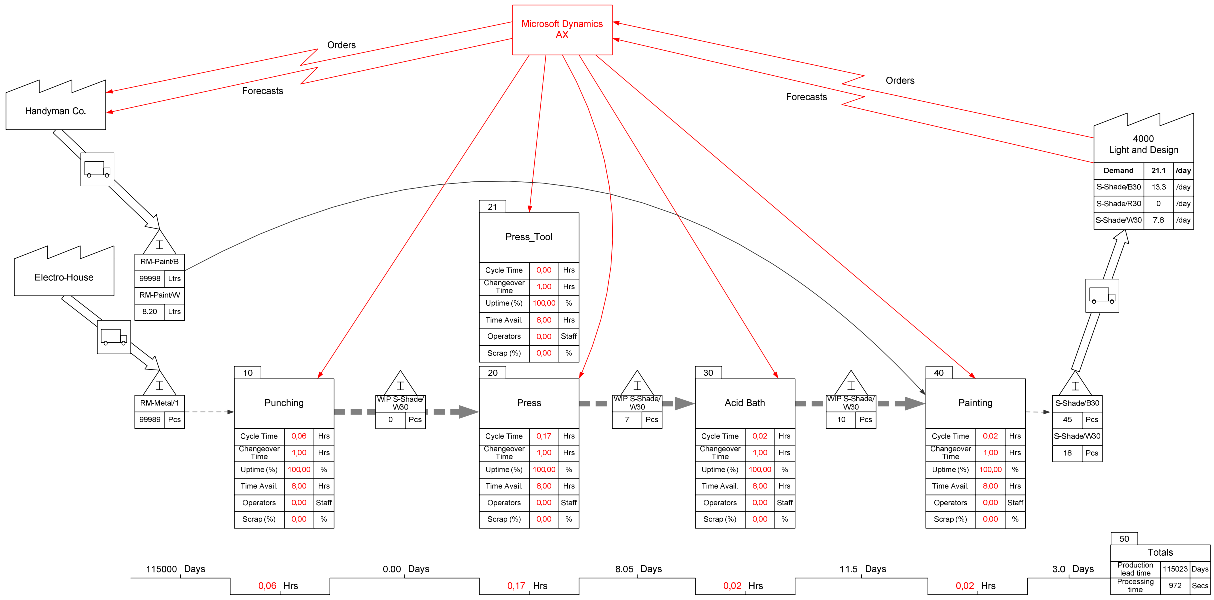
Value Stream Mapping with Microsoft Dynamics AX



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Thomas Vest, Microsoft Development Center Copenhagen

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Abstract

Microsoft Dynamics AX (AX) is an Enterprise Resource Planning (ERP) system, and like ERP systems in general, it supports the lean production philosophy only to a limited extent. One way to provide a better support for lean production would be a feature for value stream mapping with AX as data source.

The purpose of this study was to examine if plant level current state value stream maps could be created with an existing software using AX as data source. The relevance of such maps in order to gain a realistic representation of the value stream has also been evaluated.

In order to fulfil the purpose, a comprehensive literature study has been conducted. From established theories, the information needed for mapping of a value stream has been identified. Next it has been investigated to what extent this information is available in AX, and how it can be visualized. Finally it is investigated how relevant this visualization is for realistically describing the actual value stream. A number of additional value stream mapping tools are also examined, in relation to the existing data in AX.

It is concluded that plant level current state value stream maps can be created with data from AX and that this method of producing value stream maps has some advantages in relation to the conventional method: A time saving potential, clearness, and a single source of data. Disadvantages are also identified, including: Risk for lack of specific data, approximations of data, reliance on user input and frequent updating.

It is also concluded that this method of value stream mapping is limited in relation to the lean principles, mainly due to two facts: Strategic product families can not be identified, and AX does not support the way production is controlled in a lean production environment. Therefore further research is suggested, before a feature for value stream mapping is implemented.

Sammanfattning

Microsoft Dynamics AX (AX) är ett affärssystem och likt affärssystem i allmänhet stödjer det produktionsfilosofin lean production i begränsad utsträckning. Ett sätt att förbättra systemets stöd för lean production skulle vara en funktion för *value stream mapping* med AX som datakälla.

Syftet med denna studie var att undersöka om nulägeskartor av värdeflöden på fabriksnivå kan ritas med befintlig mjukvara och med AX som datakälla. Vidare var syftet att undersöka hur relevanta sådana kartor är för att ge en realistisk bild av det verkliga värdeflödet.

För att uppfylla syftet har en omfattande litteraturstudie gjorts. Ur etablerad teori om value stream mapping har den information som behövs för att kartlägga värdeflöden identifierats. Sedan har det undersökts i vilken utsträckning denna information finns tillgänglig i AX och hur den ska kunna visualiseras. Slutligen har det undersökts hur relevant denna visualisering är för att på ett realistiskt sätt beskriva det verkliga flödet av värde. Ytterligare ett antal verktyg för value stream mapping har undersökts, med utgångspunkt i de data som finns tillgängliga i AX.

Slutsatsen är att det är möjligt att skapa en nulägeskarta av värdeflöde på fabriksnivå med AX som datakälla och att denna metod har fördelar jämfört med det konventionella sättet för kartläggning: Tidsbesparingspotential, tydlighet och data från en och samma källa. Nackdelar med metoden som har upptäckts är: Risk att specifik data saknas, tvivelaktiga uppskattningar av data, beroende av användarnas inrapportering av data och att det krävs frekventa uppdateringar.

Det fastslås även att denna metod för value stream mapping är begränsad i hänseende till lean production-filosofin, främst av två skäl: Det är inte möjligt att definiera strategiska produktfamiljer och AX stödjer inte det sätt på vilket produktionen styrs i en lean production-miljö. Därför föreslås vidare forskning innan en funktion för value stream mapping implementeras.

Table of Contents

1 Introduction

This first chapter will provide a background and a general understanding of the problem underlying this thesis. The purpose and delimitations of the study are also presented.

1.1 Background

The business environment is constantly changing. In order to meet the new market demands and to keep up with the rapidly changing technologies, firms need to specialize on their core competences and establish networks with suitable partners. These networks compete with other networks rather than with single firms. Technologies, such as the Internet and ERP systems, have opened new ways to overcome organizational boundaries and to face this new and global competition.[1]

In the 1920's, Henry Ford and General Motors' Alfred Sloan moved world manufacture from craft production to mass production, making the United States the leader of global economy. The common mass producer used narrowly skilled professionals to design products made by unskilled workers that used single-purposed machines. The machinery was expensive and intolerant to disturbances. Buffers, extra supplies, extra workers and extra space were created to guarantee smooth mass production of standardized products that were pushed out on the market.[2]

In the 1940's, Eji Toyoda and Taiichi Ohno introduced the concept of lean production at the Toyota Motor Company in Japan. Other Japanese companies also implemented the concept of lean production, rapidly turning Japan into one of the world's leading economies.

Lean workers are multi-skilled, work in teams, and use highly flexible, automated machines to produce volumes of products in massive variety. Compared to mass production, lean production uses less of everything; far less inventory, half the human effort in the factory, half the manufacturing space, half the investment in tools and half the engineering hours to develop a new product in half the time. The finished goods have a wider and growing variety of characteristics and yet fewer defects. In contrast to mass producers, who allow an acceptable number of defects, a highest acceptable level of inventories, and a narrow range of standardized products, lean producers frequently decline costs, aim for zero defects, zero inventories and a great spectrum of product variety.[3]

In order to go from mass production to lean production, a fundamental change in the organization of manufacturing is required.[4] It has been observed how Western companies have failed this process when attempting to selectively adopt elements of lean production. When the Japanese organizational culture has been lifted out of its social setting, important elements have been neglected. For example, in Japan, employers develop in their workers a commitment to the organization through lifetime employment and wages rising with age and tenure. When Western companies have selectively imitated methods such as the just-in-time system and flexible work rules, but left out employment guarantees or continuous challenges, the work has become more stressful for the employees, with decreased well-being, loss of productivity, and increased costs as a result.[5]

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[1] Schary, P; Skjøtt-Larsen, T (2001)
[2] Womack, J et al (1991)
[3] Womack, J et al (1991)
[4] Jones, Daniel T. (1990)
[5] Spithoven A.H.G.M. (2001)

The planning engine in many traditional Enterprise Resource Planning (ERP) systems has been Manufacturing Resource Planning (MRP II), which base production levels on sales forecasts, while lean ties production level to the actual demand. Thus, traditional ERP systems are push oriented, whereas lean is pull oriented.[6]

Many people are of the opinion that lean can not be tied in with ERP or MRP systems, while others claim that lean has evolved under a cloud of anti-computer bias. However, the computer is here to stay, and the question is: *Is it possible to develop system tools that support the objectives of lean*?[7]

1.2 Problem Analysis

Microsoft Dynamics AX (hereafter referred to as AX) is a comprehensive Enterprise Resource Planning (ERP) software with the potential to support competitiveness in various areas of a business. However, the underlying logic is different from the logic of the lean philosophy. Like ERP systems in general, AX helps with planning and reporting, whereas lean production is oriented towards execution. Lean production encourages local solutions, while AX provides an enterprise-wide approach. Consequently, this requires a large amount of data, while lean promotes a minimization of the need for data. The extensive data handling requires a multitude of transactions. In a lean environment, transactions are seen as non-value-adding, that is to say *waste*. In AX, production is executed with work orders, while visual kanban is used in lean.

Hence, AX, like most ERP systems today, supports the lean philosophy only to a limited extent, and Microsoft has experienced how their customers have difficulties to see how they can benefit from the capacity of AX in a lean environment.[8] As lean production is growing in popularity, it is necessary for Microsoft to offer their customers a way of benefiting from AX in a lean environment.

There are a number of lean tools that may possibly be incorporated in AX. This could offer a potential benefit to companies wishing to implement or improve lean practices. However, lean production is not just a set of tools; it is a system. A random insertion of lean tools into AX will not help companies that have a genuine wish to adopt the lean production management system.

Instead, it makes sense to incorporate those techniques that will help companies to understand what lean is all about, so that they themselves can start their lean journey. Value stream mapping is such a technique. It helps companies to see their business from a lean perspective. It can also be used as a tool for continuous improvements in a lean environment. Traditionally, value stream maps are produced manually, but considering the amount of data available, it is interesting to investigate how AX can be used for this purpose. Today AX offers no support for value stream mapping activities.

Can AX support value stream mapping? To answer this question, we first of all need to examine what information is necessary to draw a value stream map. The next thing is to examine which of this information that can be obtained from existing data inside AX, and

[6] Bartholomew D (1999)
[7] Dixon, D (2004)
[8] Arthur Greef (2006-10-03)

which additional data that may be required. When data is identified, how can it be collected from AX, and how can it be transformed into metrics applicable for a value stream map? Are there existing software solutions applicable to visualize these metrics in a value stream map?

1.3 Purpose

Considering the interest in the potentials of exploiting ERP systems in a lean environment, the purpose of this study is to examine if value stream maps can be created from data in AX. If so, how relevant are these maps to gain a realistic representation of the value stream? More specifically, the purpose, based on a theoretical frame of reference, is to examine which metrics that are needed for value stream mapping, and to what extent AX can provide information about these metrics. One aspect of this is to identify, extract, and analyze data in AX, in order to obtain valid metrics for a value stream map. The purpose is also to evaluate the quality of this information and to understand which external data that is required for value stream mapping. We also aim at investigate whether an existing software solution can be used to visualize a value stream map with data from AX. This method for creating value stream maps is then evaluated in relation to the lean production principles, and potential advantages and disadvantages compared to the conventional method for value stream mapping are discussed. In addition to the tool value stream mapping itself, the potentials of some other value stream mapping tools in relation to AX are also examined.

1.4 Focus and Delimitations

The present study highlights the interface between two subjects: Value stream mapping and AX. An understanding of their contexts and interrelationship is facilitated by a broader theoretical framework, in which value stream mapping is presented in relation to the overall lean principles and ERP systems in general.

Value stream mapping is a method, which involves an analysis of the current state, a construction of a desired future state and the realization of the future state. Although this is explained in the theoretical frame of reference, with the intention to present the full concept of it, this study is limited to current state value stream mapping. Value stream mapping can be applied on a level that comprises the entire supply chain, but in the interest of research depth, this study is limited to door-to-door activities, i.e. activities within a single manufacturing plant. In addition to the method value stream mapping itself, other value stream mapping tools exist. Those which are relevant for door-to-door level mapping are also covered in this study and their applicability with AX as data source is investigated. These limitations were set and agreed upon by the authors and the assigner.

1.5 Target Group

This study is primarily intended for the manufacturing department of the Dynamics AX division of Microsoft Development Center Copenhagen, and in particular for the program managers responsible for specifying the functionality of AX. Another major target group is students and academic researchers with an interest in ERP systems or lean production.

2 Presentation of Microsoft

Microsoft is a multinational computer technology corporation founded in 1976 by Bill Gates and Paul Allen. It develops and markets software and hardware for business organizations as well as individuals through a network of partners. In July 2006 it had approximately 71,000 employees in 102 countries and global revenue of US$ 44.28 billion. The head office is located in Redmond, Washington, USA.[9] Microsoft's mission is "to enable people and businesses throughout the world to realize their full potential."

Microsoft recently reshaped its organization, as seven business groups reorganized into three core business divisions: Platform & Services, Entertainment & Devices, and Business.

The Platform & Services division supplies the Windows operating system, the server operating system Windows Server 2003, along with other server products, and online services such as the instant messenger MSN and the web mail service MSN Hotmail. The Entertainment & Devices Division is mainly concerned with mobile and embedded devices as well as computer games and the game console Xbox.

With the acquisition of the accounting software Great Plains in 2001, Microsoft entered the ERP software business. The following year, Navision Software A/S was acquired to provide a similar entry into the European market, with the ERP system Navision. Prior to the acquisition, Navision had merged with Damgaard Data A/S, the developer of another ERP system, Axapta, which was originally released in 1998 in the Danish and U.S. markets.

Presently, the Business division of Microsoft supplies five business software products under the name of Microsoft Dynamics, including AX (formerly Axapta) and NAV (formerly Navision). These two ERP systems are developed at Microsoft Development Center Copenhagen. NAV is designed for smaller companies, whereas AX is aimed at midsize and larger companies, with better support for manufacturing companies.

[9] www.microsoft.com (2006-11-20)

3 Methodology

In scientific research, the choice of methodological approach influences how well the purpose of any study is fulfilled. Accordingly, it is important with a deliberate selection of methods. This should be clearly stated and supported in order to give the research its necessity credibility. In this chapter the chosen method for this study will be presented and supported.

3.1 Methodological Approach

The methodological approach relates to the basic views and beliefs that the researchers have concerning the subject of their research. It includes assumptions and ideas that affect the selection of research methods, and for this reason, awareness of the methodological approach is important. Although individual researchers may have personal preferences, standard classifications can be used to specify the methodological approach. There are three different approaches to research in the area of business; the analytical approach, the systems approach, and the actor approach.[10]

3.1.1 The Analytical Approach

In order to fulfil the purpose (see chapter 1.3) to the greatest possible extent within the limitations set by available resources, this study has an analytical approach. In contrast to the systems and actor approaches, the analytical approach is particularly suitable for this study, due to two distinctive assumptions: First, reality has a summative character, i.e. the whole is the sum of its parts. This allows researchers to focus on one part at a time, and then adding them up to get the total picture. Second, knowledge obtained with the analytical approach is considered independent of the observer. Knowledge obtained with this approach originates from formal logic that is independent of individual subjective experience, and hence the knowledge is consistent, i.e. it does not change over time.[11]

An analytical approach means considering and analysing measurable quantitative data in order to draw conclusions about the different parts, and subsequently the whole field. This approach, where neither sub-optimization nor synergy effects are possible due to the assumption of the summative character of reality, works well for the construction of a current state value stream map. However, when future state value stream maps are constructed, there is always a risk of sub-optimization, and synergy effects are in fact sought after. Therefore, another approach is needed for the construction of future state maps.

3.2 Research Methods

It is of great importance to select a proper research method to scientifically reach conclusions.[12] Therefore the research method will now be specified and described.

3.2.1 Hypothetico-deductive Method

For this study a hypothetico-deductive research method was chosen. In this case, a hypothesis is a theoretically formed statement that goes beyond today’s knowledge and is to be tested empirically.[13] Thus, we hypothesized that data available in Microsoft Dynamics AX, together with some external data, could be used to create a current state value stream map with an existing value stream mapping software. This was based on available information regarding

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[10] Arbnor I; Bjerke B (1997)
[11] Arbnor I; Bjerke B (1997)
[12] Ejvegård R (2003)
[13] Wallén G (1996)

existing data in ERP systems and value stream mapping theory, upon which the frame of reference was founded.

The hypothesis was then tested empirically in two parts: First, a trial version of Dynamics AX configured for a virtual company was used to identify available data in the system and to spot additional external information required to create a value stream map. We also investigated how this data could be illustrated with a software solution for value stream mapping. Next, a case study was performed at a real company with an installed version of Dynamics AX. In the case study, the process was repeated and the data identified in the first empirical part will be searched for again, but this time in a real manufacturing situation. By this way, the applicability of the method to create value stream maps was verified and the findings from both empirical parts provided a basis for evaluation of the hypothesis.

3.2.2 Quantitative and Qualitative Method

Anything that is counted, expressed by numbers or terms corresponding to numbers is quantified. Quantified data can be treated statistically and analyzed, which can help us to draw conclusions regarding collected material.[14] For research and data collection in this study, a quantitative method was used. From the theory about value stream mapping, a specific number of measures were deduced. Every measure was then searched for in Dynamics AX and categorized into one if the following:

- Has to be entered externally.
- Exists in AX.
- Can be calculated.
- Can be approximated.
- Can approximately be calculated.

This categorization facilitates an overview of to what extent AX can provide the data needed for value stream mapping. How accurately the measures describe the real value stream was assessed qualitatively. With a larger data collection it would have been possible to use a quantitative method also for this assessment. However, due to limited time and access to manufacturing companies using Dynamics AX, a qualitative method was selected for this purpose.

3.2.3 Primary and Secondary Information

The frame of reference chapter is based on previously collected material and may therefore be regarded as secondary information[15]. When using secondary information it is important to consider the reliability and objectivity of the source. The empiric chapter, on the other hand, mainly consists of new data, primary information[16], collected by direct observations, calculations in Microsoft Dynamics AX and interviews. Using primary information helps to ensure relevance and controls reliability to some extent.

[14] Ejvegård R (2003)
[15] Arbnor I; Bjerke B (1996)
[16] Arbnor I; Bjerke B (1996)

3.3 Data Collection

In this study data has been collected in several different ways:

The theoretical frame of reference is based on studies of the existing literature on lean production and ERP systems. In order to ensure a comprehensive coverage of the existing research, relevant literature was searched for in the following way: Scientific articles were collected by searching the ELIN and ABI Inform databases. Search words included *lean production, value stream mapping, VSM, ERP* and *lean + ERP*, which yielded articles related to lean production, value stream mapping and the interface between lean production and ERP systems. These articles provided an introduction to the area, and further depth was been achieved via library searches, where references in the articles were extracted.

The empirical investigation of Dynamics AX required an introduction to the system. By participating in an online course held by the Royal Institute of Technology in Stockholm, we gained access to lectures, presentations and manuals for Dynamics AX. This provided a general understanding of the system, and a basis for an effective method of data search inside the system. Interviews with Microsoft employees and the internal help file in Dynamics AX have provided for information about specific details not covered by the online course.

Presently, there are no available research reports concerning how to extract data from an ERP system to enable the creation of a value stream. We designed our search in accordance with the theory about how traditional value stream mapping is conducted. At the case study, interviews were conducted to collect information for a qualitative analysis of the accuracy of the identified data and the value stream map.

The supply of existing software solutions for value stream mapping was investigated through internet searches with the following search words: *value stream mapping software* and *electronic value stream mapping*. There is an array of software solutions available on the market, in the form of free-standing applications, Microsoft Excel templates or as Microsoft Visio add-ons. Examples of these are presented in *Table 3.1*.

Developer	Name	Type
GumshoeKI, Inc.	eVSM	Visio add-on
Orlando Software Group	LeanView	Visio add-on
Automated Learning Corporation	ValueStreamDesigner	Free-standing application
Systems2win	VSM Excel template 3	Excel template

Table 3.1 *Electronic value stream mapping software.*

The above products provide similar methods for computer-aided value stream mapping, and any one of them could be used in this study. However, when comparing the different types, it was estimated that a free-standing application would require more time and effort in learning to use and integrating with data from AX. The Excel template did not provide the required accessibility and clarity. The facts that AX can be integrated with other Microsoft products and that the time limitation of this study required user-friendly software, motivate the choice of a Visio add-on for the visualization of the value stream in this study.

The final choice of which software to use was based on the need for consistency between the theoretical frame of reference and the visualization of the value stream based on data from

AX. eVSM has been designed to complement the lean implementation methodologies in "Learning To See".[17] For this reason, it was selected as a visualization tool in this study.

3.4 Credibility

Credibility is an issue that must be addressed in any research situation. As mentioned, this study, which was undertaken with an analytical approach, is both quantitatively and qualitatively oriented. To address its credibility, the aspects of validity, reliability and objectivity are here discussed.

3.4.1 Validity

Validity is the extent to which a measure accurately reflects the concept that it is intended to be measured. This is provided for through clear definitions of concepts, understanding of background factors and cause-effect relations, and thorough planning of experiments.[18]

A clear definition of concepts, an understanding of background factors and cause-effect relations are ensured by a broad theoretical framework, where value stream mapping is put in relation to lean production.

The method used to search data in AX must be designed in a way allowing us to achieve all the appropriate information. This is ensured by a thorough examination of the system, where we have identified several alternative methods in order to find the data that best corresponds to the theory about value stream mapping. Interviews have also been conducted in order to validate that the identified data really corresponds to the metrics in the theory and that the data that is not found really does not exist in the system.

Another aspect of validity is the question whether the identified data in AX actually corresponds to a real value stream. This issue is illustrated in *Figure 3.1*:

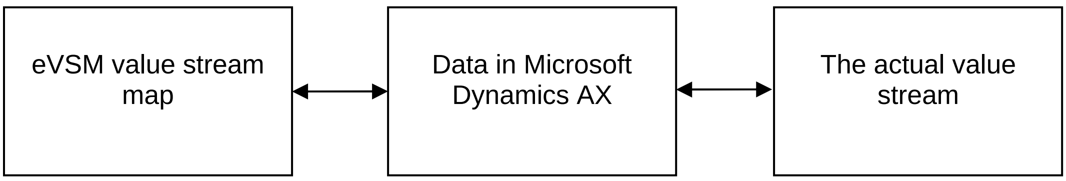


Figure 3.1 *Illustration of our method for creating a value stream map by eVSM and data from AX.*

To reach a high level of validity, each data found in AX qualitatively have been analysed in relation to how it corresponds to an actual value stream.

3.4.2 Reliability

Reliability designates the trustworthiness and applicability of the measurement method.[19] In this study the reliability is largely dependent on the method of data collection and handling in AX. The quantitative part of this study facilitates the evaluation of the reliability of the results. However, the measurement method has never been used before, so there are no documented reliable results available from previous studies with this method. This fact motivates a thorough assessment of the reliability of the measurement method. For this reason

[17] www.evsm.com (2007-03-07)
[18] Wallén G (1996)
[19] Ejvegård R (2003)

the measurement method includes a control mechanism in the form of a case study, where its applicability and trustworthiness is tested.

3.4.3 Objectivity

With the analytical approach, we wished to chart and perform objective measurements on objective data from real life. Ideally, the results of a scientific study should not be affected by any personal opinions or biases. In order to provide results as objective as possible, we have done our outmost to certify the primary as well as the secondary information used in this study. The objectivity of the secondary information was assessed by validating possible conflicts of interest and intentions by the authors. To further ensure objectivity we aimed to cover a majority of the available value stream tools in the frame of reference. The assessments are presented in relation to the empirical findings in the analysis chapter. The primary information used in this study is primarily of quantitative, and hence more, objective character. The risk of subjective primary information is greatest in the case study. It should also be noted that the assigner's wishes may have influenced the results. Awareness of these aspects is important in order to avoid subjective results, and all information from the assigner has been evaluated for this reason.

4 Frame of Reference

In this chapter we present a theoretical background of the study to provide a basis for the analysis of the empirical findings and the conclusions drawn. All theoretical concepts and definitions used in the study are specified here.

4.1 Reference Structure

In order to ensure the validity of the results obtained in this study, a solid theoretical foundation was constructed from relevant established theories. The issues examined are found in the interface of two complementary theoretical fields, both of which need to be incorporated in the frame of reference. A broad perspective of each theoretical field served as a background for the more far-reaching theories used. Thus, the reference structure has a bi-funnel form, *see Figure 4.1*.

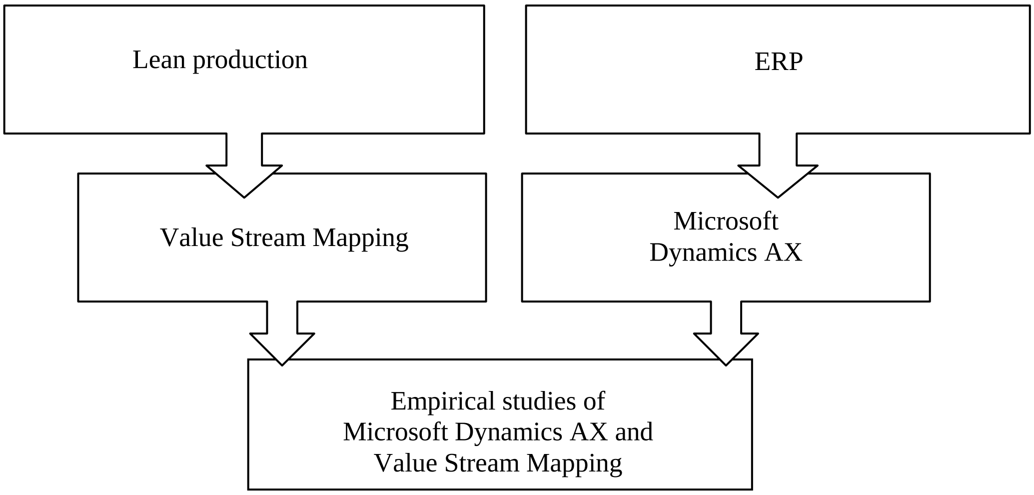


Figure 4.1 *Structure of the reference frame.*

4.2 Lean Production

The principles of lean production originate from Japan in the 1940's. The approach has since grown in popularity, as it is regarded as an efficient way to cost reduction by eliminating waste (Muda) in production. However, lean is more than just a set of tools. It is a holistic, enterprise-wide program designed to be integrated into the organization's core strategy.

4.2.1 The Five Lean Principles

There are five key principles in lean production[20]:

1. Specify value
2. Identify the value stream
3. Make the value flow
4. Let the customer pull
5. Pursue perfection

Value should be specified from the point of view of the customer. "In competitive terms, value is the amount buyers are willing to pay for what a firm provides them. Value is

[20] Womack J; Jones D (1996)

measured by total revenue, a reflection of the price a firm's product commands and the units it can sell."[21] From a lean perspective, however, present value must be distinguished from future value. Present value is what today's customers are willing to pay for, and this is the usual way of identifying waste. Future value – what tomorrow's customers are willing to pay for – applies to research and development. Hence, there are different value streams in a company, which should be evaluated differently.[22]

The value stream is the sequence of processes from raw material source to final customer. Hence, the value stream goes beyond the boundaries of single companies, and it should be noted that from a lean perspective supply chains compete, rather than single companies. The value stream should be mapped, and this is a central element in this thesis, see chapter 4.3.

Flow allows value to be added steadily at the customer rate. This means avoiding batch and queue, with the ambition of keeping a one-piece flow. *Takt* time is derived from the actual demand, and is used to set the pace of the flow. Flow reduces waiting and inventory, and discourages amplification of demand. A golden rule for making value flow is to never delay a value adding activity with a non-value adding activity.

Value should not only flow, but also be *pulled* through the supply chain. However, most organizations need to let forecasts drive production up to a certain point, before customer driven pull can take over. The idea is to push this point further and further upstream. Decision point analysis is a tool that can be used for this purpose, see chapter 4.3.6

Perfection should be aimed at through continuous improvements. Perfection means producing exactly what the customer wants, exactly when, at a fair price and with minimum waste.

4.2.2 Customer Demand

Understanding of the customer demand is important in the lean philosophy. Flow is based on the rate of the customer demand, and pull is achieved by letting the actual customer demand drive production. However, lean is inherently a deterministic method, and important characteristics of many manufacturing systems are random variables, for example customer demand.[23]

In order to cope with the variability of demand, policies for achieving a smooth demand are presented. These include: Discounts for regular orders rather than quantity orders, "variety as late as possible" concepts, and "build to order" policies. [24]

4.2.3 Waste

Waste is defined as "anything other than the minimum amount of equipment, materials, parts, space, and worker's time, which are absolutely essential to add value to the product."[25]

However, there are two different types of waste. Type 1 Muda are activities that the customer are not willing to pay for, although necessary to maintain operations. This waste should be reduced by simplification. Type 2 Muda only destroys value and should be eliminated.[26]

[21] Porter M (1985)
[22] Bicheno J (2004)
[23] Standride, C; Marvel, J (2006)
[24] Bicheno, J (2004)
[25] Suzaki, K (1987)
[26] Bicheno, J (2004)

The seven wastes:[27]

1. Overproduction.
2. Waiting.
3. Transportation.
4. Inappropriate Processing.
5. Unnecessary Inventory.
6. Unnecessary Motion.
7. Defects.

Overproduction is regarded as the most serious type of waste because it discourages a smooth flow. It leads to excessive lead and storage times, and it is likely to reduce quality and inhibit productivity. Waste of overproduction is created by producing goods over and above the amount required by the market, which is quite a common situation in today's factories, partly due to bonus systems that encourages output above the necessary. When this happens, more raw materials are consumed, wages are paid for unneeded work, and extra inventory is created. This in turn requires even more resources, such as space and people. Furthermore, overproduction makes operators and machines seem busy, which may lead to false assumptions and bad decisions, such as the procurement of extra equipment. Overproduction is consequently often a source of other types of waste and should be eliminated.

The waste of waiting time has a direct effect on lead times and flow. This waste occurs any time that materials or components are not moving or being worked upon. A bottleneck operation that is waiting for work is a particularly serious waste. Waste of waiting time also applies to operators that spend time waiting for work to do. Waiting time for workers should be used for training, maintenance, *kaizen* (continuous improvements) activities, or even deliberate relaxation, and should not result in overproduction.

Transportation of materials or components is something that customers are not willing to pay for, and is therefore regarded as waste. However, it is a waste that is impossible to fully eliminate, yet possible and desirable to decrease continually. Furthermore, double handling and excessive movements are likely to cause damage and deterioration, and long transportation distances discourage communication, with decreased quality and productivity as a result.

Inappropriate processing refers to the waste of using overly complex solutions for simple procedures, such as using a large inflexible machine instead of several small flexible ones. Large and complex machines are often kept as busy as possible to recover the large investment, which encourages overproduction. It may also lead to poor layout, which results in excessive transports and poor communication. Another aspect of inappropriate processing is when machines and processes are not qualitatively capable, something that can be avoided through correct training, tools and standards, as well as *poka yoke* (mistake proofing) devices.

Unnecessary inventory is costly. It requires extra handling, extra space, extra interest charges, extra people, and so on. Furthermore, excess inventory tends to hide more serious problems. Therefore, reducing the inventory levels will reveal important issues that need to be dealt with, *see Figure 4.2*.

[27] Suzaki, K (1987)

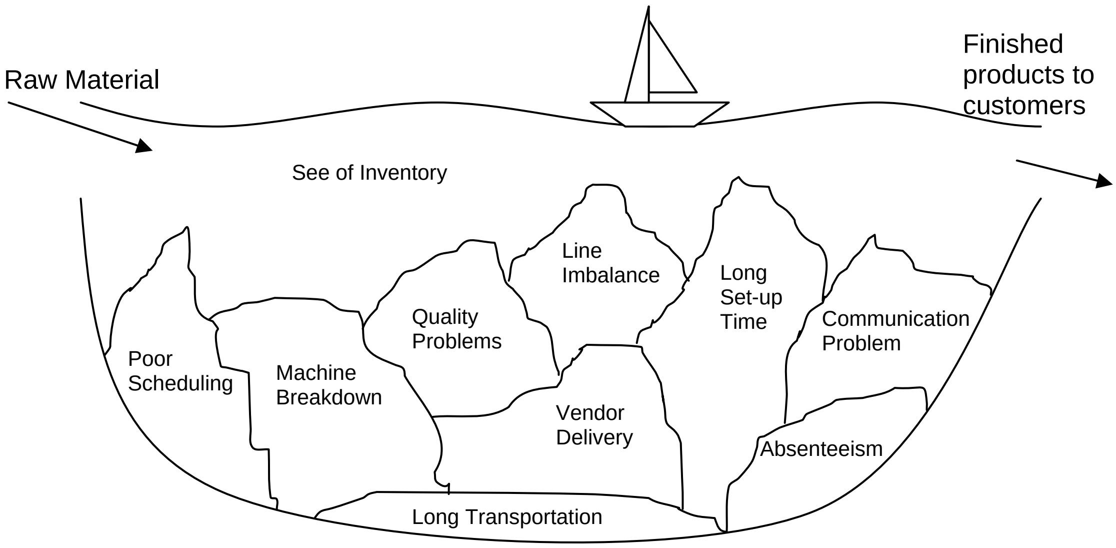


Figure 4.2 *Inventory covers problems.*[28]

Waste of unnecessary motion refers to both man and machine. It involves the ergonomics of production where operators have to stretch, bend, or pick up, whenever this could be avoided. It is tiring for employees and ultimately leads to poor productivity and quality. For machines, waste of motion involves poor workplace layout which leads to micro-wastes in repeated operations.

Defects is waste that directly cost money when they occur at a station in the production. Operator at subsequent stations will then have to waste time waiting, thereby adding cost to the product, while the production lead time increases. Defect costs tend to escalate the longer they remain undetected and the worst case is when customers find defects after delivery. Then warranty costs and additional delivery costs are incurred, but perhaps most importantly customer goodwill is impaired.

4.2.4 Lean Organization

Implementation of lean practices results in significant changes in an organization. New types of relations are required, both between workers and between workers and management. Reduction of inventory buffers and continuous flow enable tight coordination between employees, creating interdependencies. This leads to a higher degree of collaboration, which is reflected in the flexibility of allocation of tasks and removal of boundaries between functions.[29] In fact, the lean principles create increased interdependency between all actors involved in the production process and accordingly, work must be organized in a way that favors flexibility and involvement of the workers themselves. This can be achieved by:

- lowering the level at which decisions are taken;
- managing by process rather than by function;
- increasing integration of tasks;

[28] Suzaki, K (1987)
[29] Mehta V; Shah H (2005)

- emphasizing the crucial importance of trust and group work;
- developing a horizontal system of communications.[30]

In general, a lean production system involves multi-skilled operators, typically organized into small teams responsible of quality, continuous improvement, and problem solving.[31] Another important characteristic of lean production is standard work. In contrast to work-study imposed job specifications associated with classic mass production, the standards of lean production are not as rigid. Operators themselves establish standards for work time, work sequence, and work-in-progress, as conditioned by takt time and available capacity. Standards are continuously refined as improvements are identified.[32] Some authors argue that employee participation in improvement and problem solving results in good effects such as job enlargement, cross-training and challenge[33], while other researchers indicate negative consequences for the employee.[34]

4.3 Value Stream Mapping

Value stream mapping (VSM) is a technique to gain a holistic view of how a company functions. Combining material processing steps, information flows and other important data, potential areas for improvements are exposed. Hence, VSM is an important tool for companies that wish to implement the lean philosophy, or to improve their already present lean practices.

In a VSM activity, the first step should be to define the scope of the value stream that is under examination. A facility level map includes the value stream that goes through the door-to-door process. A departmental or interdepartmental VSM is considered a process level map. A further expanded examination that comprises the entire value stream from raw material to final customer is described as an extended level map. To prevent sub-optimization, diagramming a facility level map is recommended before attempting to map a process level or extended level map.[35] This paper will focus on the facility level value stream mapping.

The process of value stream mapping can be summarized in four steps:[36]

- Determine the process family.
- Draw the current state map.
- Determine and draw the future state map.
- Realize the future state.

4.3.1 Product Family Analysis

There are usually a number of different streams of value that can be identified on the facility level in a company. The attempt to map all of these value streams on a single map is likely to result in a complex picture where potential improvement areas are hard to identify. Instead, it is recommended to focus on the value stream of one specific product or product family, a group of products with similar characteristics.[37] When performing product family analyses

[30] Biazzo S; Roberto P (2000)
[31] Mehta, V; Shah H (2005)
[32] Bicheno J (2004)
[33] Womack J et al (1991)
[34] Mehta V; Shah H (2005)
[35] Manos T (2006)
[36] Rother M; Shook J (2005)
[37] Rother M; Shook J (2005)

both strategic and technical considerations should be made. Before defining technical product families, it could be wise to analyze strategic opportunities.[38]

To achieve satisfactory and clear outcomes of the strategic discussion, a company must understand its markets. The dimensions that give the markets their characteristics must therefore be specified clearly. Order-winners and qualifiers are two dimensions that are both time and market specific, and they will change over time for a given market.[39]

- *Qualifiers* are criteria that a company must reach for a potential customer to even consider them as a possible supplier.
- *Order-winners* are criteria for winning orders.

The lean guru James Womack once missed this strategic concern of defining order-winning and qualifying criteria, when he worked with a manufacturer of customized titanium bicycle frames.[40] By helping the company go lean he reduced expensive stockholdings and he also reduced the customer lead times. Reducing the customer lead time was not an order winning criterion from the costumer's point of view. On the contrary, they appreciated waiting for something that was especially made for them. When lead times were reduced some customers believed that the products were supplied directly from the shelf and not tailored for them. This example shows the importance of strategic considerations when forming product families. Strategically organized product families arrange operations so that they are dedicated to a particular customer segment.[41]

When the strategic considerations have been sorted out, the technical remain.[42] This aims to visualize which operations the different products go through and group products with similar operations into families. An example of a product family analysis is shown in *Figure 4.3*.

		Operations							
		1	2	3	4	5	6	7	8
Products	A	X	X	X		X	X		
	B	X	X	X	X	X	X		
	C	X	X	X		X	X	X	
	D		X	X	X			X	X
	E		X	X	X			X	X
	F	X		X		X	X	X	
	G	X		X		X	X	X	
	H	X	X		X		X	X	

One product family

Figure 4.3 *Product family analysis.*[43]

It is possible to start mapping the value for any given product family, but it makes sense to begin with the product family that has the highest probability to be successful, for example a high reduction in lead time or inventory.[44]

38 Bicheno (2004)
39 Hill T (2000)
40 Baker P (2003)
41 Bicheno J (2004)
42 Bicheno J (2004)
43 Rother M; Shook J (2005)
44 Hines et al (2000)

4.3.2 Current State Value Stream Map

The design of future value flow begins with an analysis of the current situation, and therefore, it is important that the current state map reflects the real situation in the factory to the greatest possible extent. However value stream maps do not include variability information.[45] The aim is to illustrate the momentary situation of the factory. Most authors propose that current state value stream maps should be drawn using pencil and paper while walking around in the factory and following the flow of value. This method is referred to as "walking the flow". This way, the materials and information flows can be understood and mapped, without the interference of handling problems with gadgets or computers. When walking the flow, one should start at the activity furthest downstream, i.e. directly linked with the customer needs, and work one's way upstream while collecting data.[46]

One problem with this approach is that it is often difficult to collect data that genuinely depicts the real situation in the factory. Employees and managers often work hard to keep higher-level managers happy, and naturally, they tend to conceal or explain away problems that are encountered while mapping.[47]

Every improvement effort should begin with a clear specification of the product's value in the eyes of the customer. Otherwise, there is a risk that the value stream is improved in such a way that it will effectively provide the customers with something they do not want. When value is defined this way, it is possible to determine whether an activity is actually adding value or waste.

For the construction of value stream maps, standard symbols are used.[48] The first set of data that needs to be collected is the customer demands. It is expressed as a quantity per month. The customer demands includes special variations of products and how they are to be packaged. A symbol for the customer is drawn on the map according to *Figure 4.4*:

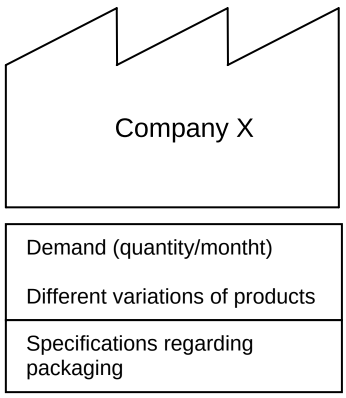


Figure 4.4 *Symbol for customer and customer demand.*

Next is to outline the sequence of manufacturing operations on the map. In conjunction with the symbols that represent the manufacturing operations, fact boxes are placed. These boxes should contain all relevant data for the corresponding operations in the map. In *Figure 4.5*, a symbol for an operation is displayed together with a fact box containing some typical metrics for describing the characteristics of an operation.

[45] Standride, C; Marvel, J (2006)
[46] Rother M; Shook J (2005)
[47] Womack J (2006)
[48] Rother M; Shook J (2005)

Operation		
Cycle time	120	Secs
Changeover time	2	Hrs
Uptime	100	%
Available time	8	Hrs
EPE Interval	2	Shifts
Operators	2	Staff
Scrap	1	%
Rework	0	%

Figure 4.5 *Symbol for operation with fact box.*

Definitions of the fact box metrics together with definitions of value adding time and lead time are summarized in *Table 4.1*.

Cycle time (Cy/T)	The time it takes for an article or product to undergo a process. Time is measured by observation.
Value adding time (VA/T)	The time in a process when value, that the customer is prepared to pay for, is added.
Lead time (L/T)	The time needed for accomplishing an activity, from identification of a need to the satisfaction and reporting of it. Lead time is often defined as the time from ordering to delivery.
Changeover time (Ch/T)	The time it takes to change from production of one variant of product into another.
Every-part-every-interval (EPEI)	The time that is used for running all the different items going through a process.
Uptime	The percentage of time that the machine is available for processing.
Number of operators	The number of operators needed to run the process.
Number of product variation	The number of the different product items.
Available time	The working hours per shift minus time for breaks, meetings and tidying.
Scrap	Material unfit for further processing.
Rework	Work that just has been done and needs corrections because it was incorrect from a technical standpoint or failed to meet the needs and expectations of the buyer.

Table 4.1 *Typical process facts.*[49]

All manufacturing operations and inventories are illustrated as of the specific moment the current state value stream map is produced. Before, after, and between the manufacturing operations, the current inventories of raw material, work in progress and finished goods are exposed with triangles. Under the triangles the quantities of each item is specified. It is hence necessary to know each ingoing material for every product variation of the product family that is mapped, as well as in which operation the different ingoing material is processed. A bill of

[49] Rother M; Shook J (2005)

material (BOM) is a precise list of every part that is needed to manufacture a specific product.[50]

Arrows between the inventories and operations show the flow of material and indicate whether the flow is pushed or pulled through the process. Supply and delivery is represented by arrows with specific mode of delivery symbols labeled with frequency of delivery. *See Figure 4.6.*

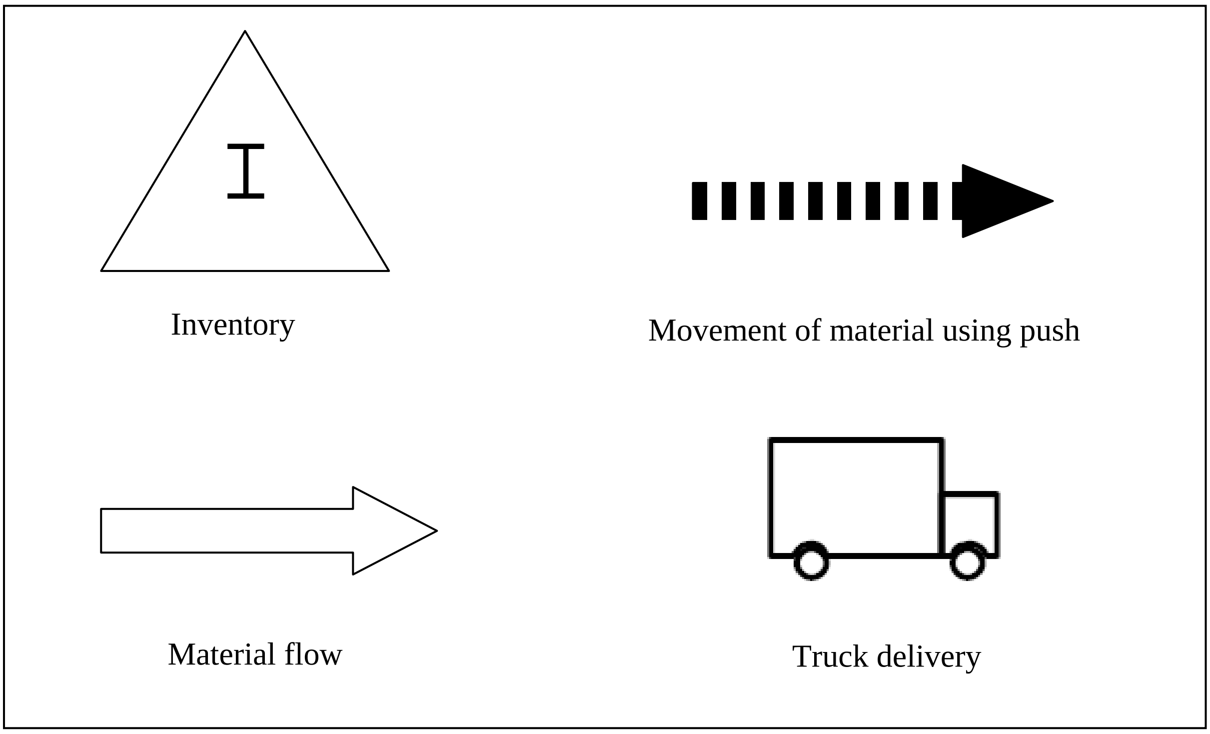


Figure 4.6 *Symbols for material inventory, flow of material, and supply and delivery.*

A timeline line that corresponds to the different operations is drawn at the bottom of the map. In segments, value-adding and non-value-adding times are displayed. In essence, value-adding times are calculated from the machine-cycle time or unit-assembly times. Non-value-adding times are calculated from inventory quantities in units divided by the daily customer demand. This way, the inventories are expressed as a time. In order to get the inventory time in days, the customer demand must be expressed as demand per actual working day. On the value stream map, the monthly customer demand is displayed. This metric has to be converted to demand per day, by dividing it by the numbers of days in a month that the production is operating.[51]

Next, the flow of information is analyzed. Narrow arrows connecting the customer and supplier to the production control indicate forecasts and orders. The frequency is shown in corresponding data boxes. Arrows between production control and the different manufacturing stages illustrate how the schedule is communicated to the factory floor, *see Figure 4.7*.[52]

[50] Womack, J.; Jones, D (1996)
[51] Rother M; Shook J (2005)
[52] Bicheno J (2004)

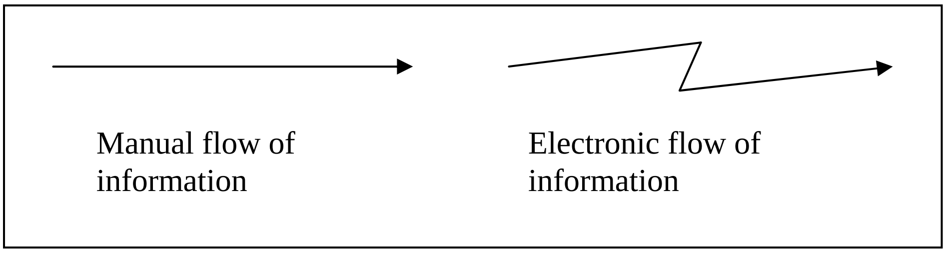
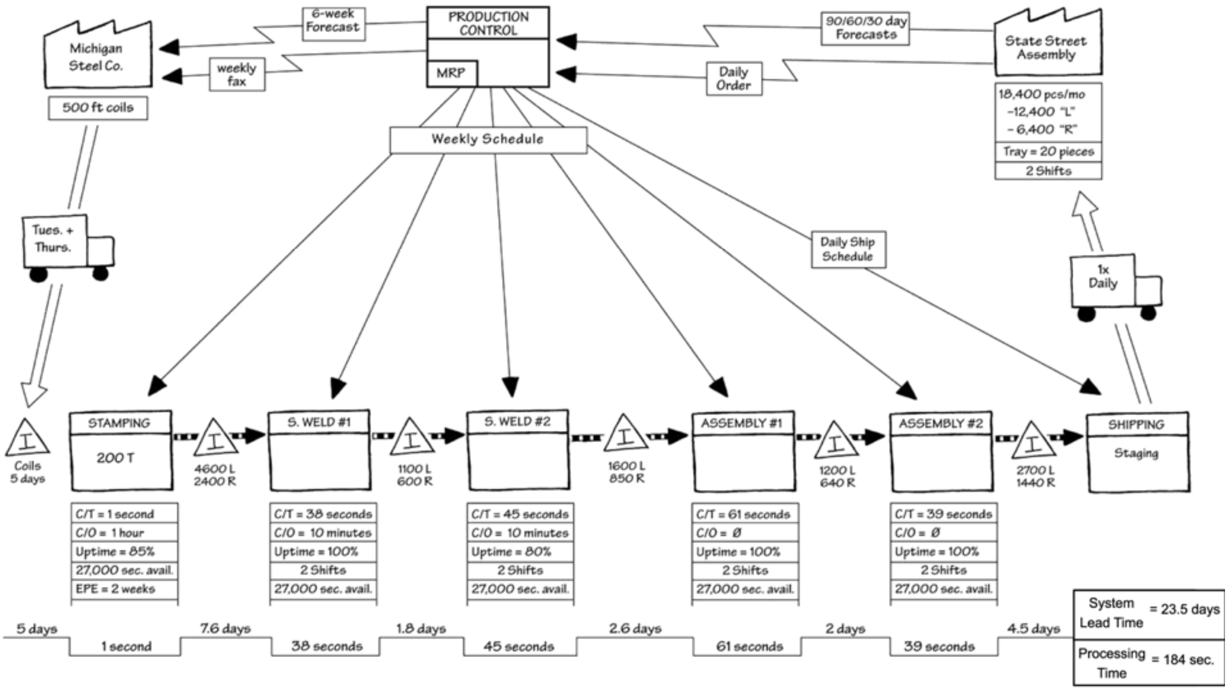


Figure 4.7 *Information arrows.*

Figure 4.8 illustrates a typical current state map.



Note: C/T = cycle time; C/O = change-over time; EPE = every part every ____

Figure 4.8 *Typical current state map.*[53]

4.3.3 Future State Value Stream Map

Once the current state map is complete, it is time to look for possible improvements and start outlining a future state map. The first step is to identify elements on the current state map where any form of the seven wastes, see chapter 4.2.3, is clearly located. These elements are highlighted with kaizen bursts, *see Figure 4.9*, to signal the need for improvement. Of course, this requires knowledge of the lean production principles, and previous experience from value stream mapping activities will facilitate the task further. External competence may be employed for the development of the future state map, but as a matter of fact, doing it yourself is a valuable learning experience.

[53] www.emeraldinsight.com (2007-03-06)

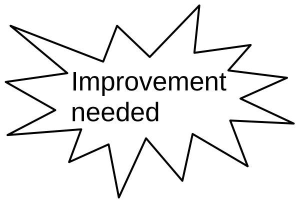


Figure 4.9 *Kaizen burst.*

As described in chapter 4.2.3, the most serious type of waste is related to over-production. A constant attention to avoiding overproduction is what clearly differentiates the value streams of lean production from the value streams of companies that exercise mass production. Accordingly, the future state map should be characterized by manufacturing operations that only produce what the next process step needs, when it needs it. Moreover, all processes should be linked, from end user and upstream to raw material, in a smooth and straight flow that generates the shortest lead-time, highest quality and lowest cost possible. There are seven guidelines that can help companies achieve this kind of future state value streams[54]:

1. Produce in accordance to your takt time.

The takt time indicates how often a product or component should be manufactured, based on actual sales, to satisfy customer demand. It is calculated by dividing the available time per day, in seconds, by the customer demand per actual working day, in units, which gives the drumbeat cycle of the rate of the flow of products.

$$Takt\ time = \frac{Available\ time\ per\ day\ (\mathrm{sec}onds)}{Customer\ demand\ per\ day\ (units)}$$

The available time is the actual work time apart from time for planned stoppages such as planned maintenance, team briefings, breaks, etc. Changeover time should not be included when calculating the takt time, since the takt drumbeat must be maintained throughout the plant, including changeovers. Producing at takt time requires constant efforts to reduce changeover time, eliminating causes of unplanned production stoppages, and to solve unexpected problems quickly, within the takt time. Allowing for an overall equipment effectiveness (OEE) percentage is neither a good practice, since waste is then built into the takt time.[55]

It should be noted, that takt time is not cycle time. A cycle time that exceeds the takt time is a constraint which requires parallel processes or an additional shift. When the cycle time for a certain machine is less than the takt time, this machine must slow down in order to produce at the takt time. Then queues will not build up after this operation, and due to the synchronization, the total lead-time will decrease. [56] On the future state map, the takt time is indicated in the data box.

2. Develop a continuous flow

Continuous flow means that components are produced one by one, and each component progresses instantly from one operation to the next without having to wait in a buffer in between. A process box is used as a symbol for an area with continuous flow on the value stream map. This means that when introducing continuous flow, several boxes on the current

[54] Rother M; Shook J (2005)
[55] Bicheno J (2004)
[56] Bicheno J (2004)

state map, each representing an operation without continuous flow, will be combined into one single process box, representing an area of continuous flow. Where continuous flow cannot be utilized, a first in, first out (FIFO) pull system can be a complement to continuous flow, *see Figure 4.10*.

Figure 4.10 *Representation of first-in-first-out sequence.*

3. Use supermarkets to control production where it is not possible to expand the continuous flow upstream.
There are parts of the value stream where continuous flow is impossible, and a certain amount of inventory is inevitable. There may be several reasons for this. Processes with very long lead times, or for other reasons being inappropriate to link directly to further processes in the value stream, require a certain amount of inventory. For example, when processes are located at a distance from the manufacturing plant, deliveries of single units are often unrealistic.

In processes where continuous flow cannot be applied, it is important that they are not planned by an independent planning function, in order to avoid estimates of the demand of downstream processes, and hence excess inventory. Instead, these processes should be controlled by a supermarket that connects them to the downstream processes, *see Figure 4.11*. A supermarket is a controlled inventory replenishment system, where the downstream process removes items from the shelf, and the process-owner upstream replenishes that amount to the supermarket.[57]

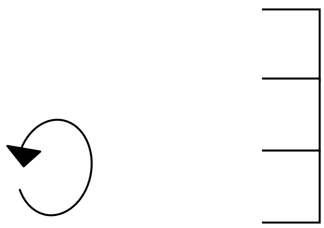


Figure 4.11 *Representation of withdrawal and supermarket.*

Supermarkets form a pull system when they are used together with kanban, which is the signalling device. There are several different types of kanbans, *see Figure 4.12*. Withdrawal kanbans are used when items need to be withdrawn from the supermarket or external supplier. Production kanbans trigger the production of articles in the upstream process. Signal kanbans indicate changeovers.[58]

[57] Manos T (2006)
[58] Bicheno J (2004)

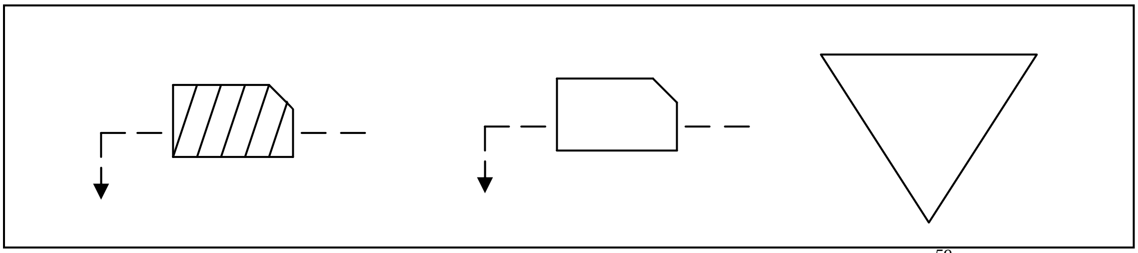


Figure 4.12 *Symbols for withdrawal, production, and signal kanbans.*[59]

Before supermarkets are set up, it has to be ensured that as many process steps with continuous flow as possible are introduced. Supermarkets should be the last resort, as they do keep inventory and require material handling.

4. Choose a pacemaker

When a pull system is in place, with continuous flow and supermarkets where needed, the door-to-door value stream can be scheduled at just one stage. This stage is called the pacemaker. The production volume in this process affects the capacity need in all upstream processes. The pacemaker is often, but not always, a bottleneck operation. Normally, a process close to the customer is chosen as pacemaker, allowing products to be pulled through upstream operations. Having one pacemaker avoids amplification of demand and creates synchronization.[60]

5. Level the production mix

Scheduling large batches may reduce the number of changeovers, but it creates serious problems to the rest of the value stream. Processes grouped together for a certain product type of which all articles are produced at the same time makes it more difficult to service customers when discrepancies from plans arise. To compensate for this, a higher level of finished goods inventory is required. Furthermore, large batches of products require large batches of semi-finished goods and material in the upstream processes, so the level of work in progress inventory also increases. When changes occur in the production plans for the final assembly operations, the fluctuations of demand have a tendency to amplify on their way upstream.

Leveling the production mix means distributing the manufacturing of different product variations evenly over a fixed period of time. Also referred to as mixed model scheduling, it means scheduling ABC, ABC, ABC… in a repeating sequence rather than in three large batches. The sequences are derived from the product mix demand. On a future state map a symbol, *see Figure 4.13*, is placed on the information arrows where mixed model scheduling is wanted.

Figure 4.13 *Mixed model scheduling symbol.*

6. Level the production volume

In order to achieve a smooth load, where the takt of the demand is clearly visible and the value is being pulled towards the downstream customer, work orders must be small and

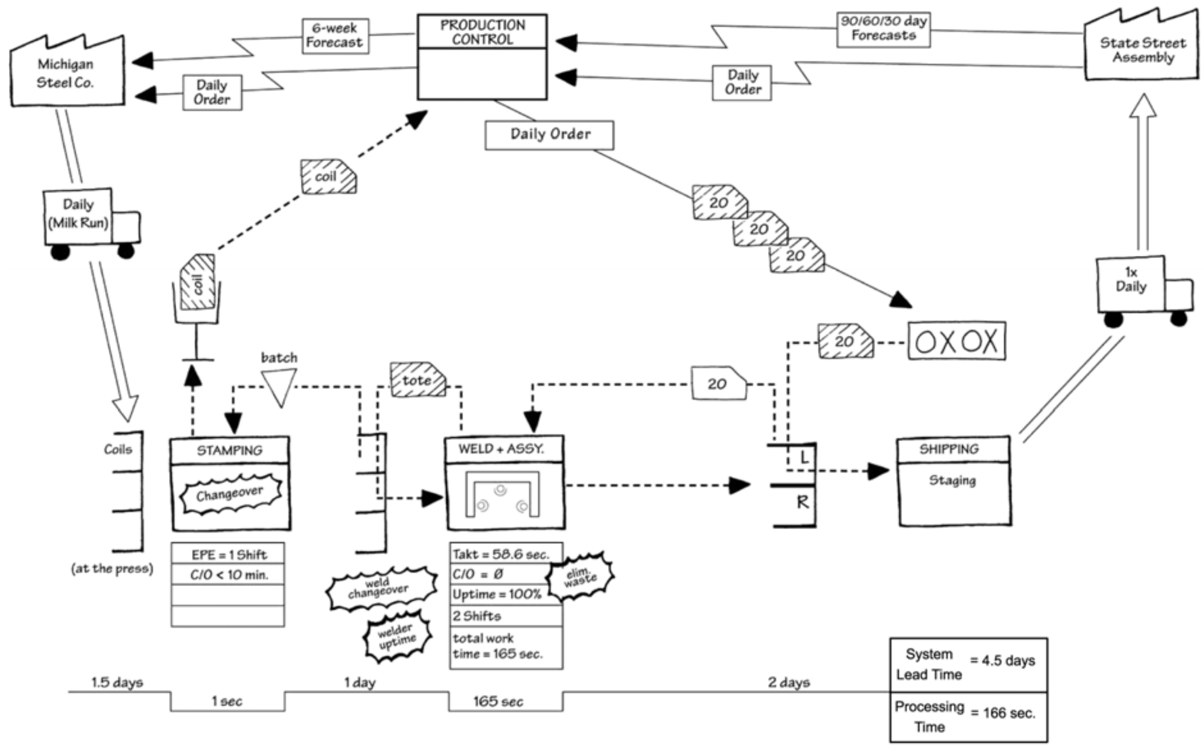
[59] Rother M; Shook J (2005)
[60] Bicheno J (2004)

regular. Small and regular work orders allow for an easier assessment of whether or not the schedule is met, and easier adjustments to changes in customers' orders.

7. Each-product-every-interval (EPEI) Batch Sizing

With reduced changeover times and batch sizes, the upstream manufacturing processes become more flexible to changing demands downstream. In return, the upstream processes will require a smaller amount of inventories standing in their supermarkets. The EPEI concept is used to achieve this. The batch size is made as small as possible by doing as many changeovers as possible in a predetermined portion of the available time, typically 10%. For a further reduction in batch size, changeover time must be continually challenged.[61] EPEI establishes a regular repeating cycle where every product is run every week, day, shift or hour. In the future state value stream map, the EPEI is recorded. In this case the EPEI value shows, in time measured, the capacity required for running all different items that go through a process, and this is used to determine how much time is available for changeover time.[62]

Figure 4.14 illustrates an example of a typical future state map.



Note: C/T = cycle time; C/O = change-over time; EPE = every part every ____; Take (time) = rate of customer demand

Figure 4.14 *Typical future state value stream map.*[63]

4.3.4 Future state realization[64]

Once the future state VSM is complete, it is time to start the process of realizing the future state. The future state VSM gives a complete picture over the desired future state including all activities in the factory, and in most circumstances it is not possible to put the entire concept

[61] Bicheno, J (2004)
[62] www.grayresearch.com (2006-11-24)
[63] www.emeraldinsight.com (2007-03-06)
[64] Rother M; Shook J (2005)

into effect at once. Instead, it is recommended to split up the implementation into several smaller steps.

One way of doing this is to let the project leader divide the value stream into different loops, and concentrating on one loop at a time. The pacemaker loop is of particular interest. It comprises the flow of material and information between customers and the pacemaker process, and the way this loop is controlled directly affects all upstream processes. Upstream from the pacemaker process, there are loops of material and information with each element of the production process. Supermarkets constitute the interfaces between loops. On the future state map, all identified loops should be marked, as they illustrate a logical division of the total value flow into sections that are of manageable size for the improvement work.

In addition to the future state value stream map, another document is needed, namely a draft plan to arrive at the future state. The draft plan gives information about the order of loops to be worked on. Generally, it is a good idea to begin with the pacemaker loop. However, as with all change management, it is important that the people involved develop confidence for the methods used, and for this reason a loop with potential for improvements with a quick result may be chosen when initiating the change.

More specifically, the draft plan includes what activities are planned, when they are planned, names of the project leader and team members, and budgets. It also provides goals and milestones as well as names of those responsible for reaching goals. Graphically the draft plan resembles a Gantt-chart, with a time horizon of one year. The yearly draft plan should be integrated with other business plans in order to achieve successful results. It should be evaluated quarterly with the ambition not only to focus on what is already done, but more importantly, on deviations from plans and what is yet to achieve.

4.3.5 eVSM

Microsoft Visio is a diagramming program and Microsoft Excel is a spreadsheet program, both included in the Microsoft Office suite. eVSM is an add-on application to Visio, which is designed to visualize and analyze value streams. It provides standard shapes for drawing current state value stream maps which are based on the same theory as presented in the frame of reference for this study. It also provides functionality for linking data in the map to an Excel spreadsheet. Value stream data can be entered directly in the value stream map, or equations can be entered in Excel and the results display in the map. eVSM also has functionality for visualizing special conditions in the current state, e.g. constraints, and for creating future state maps.[65]

4.3.6 Other Value Stream Mapping Tools

Apart from value stream mapping itself, there are several additional value stream mapping tools which can be used to visualize value-adding and none value adding processes along the value stream. In order to be able to generate a clear picture of the actual value stream, value stream mapping tools which can be used within door-to-door activities are now presented.

The *Process Activity Map*[66] is a more detailed map than the value stream map, and should be used only on sub-processes where there are particular concerns. The process chart lists every step that is involved in the manufacture of a product.

[65] www.evsm.com (2007-03-15)
[66] Bicheno J (2004)

The process activity mapping approach has five stages:

1. The study of the flow of processes
2. The identification of waste
3. A consideration of whether it is possible to rearrange the processes into a more efficient order.
4. A consideration of arranging a better flow layout or transportation routing.
5. A consideration of whether all activities in each process are necessary and what would happen if they were removed.

To facilitate a process activity map, the first step is to take on a preliminary analysis of the process. This is followed by a detailed recording of all the activities, which will result in a map of the process. Each activity is categorized into one of the following activity types: Operation, transportation, inspection, storage or delay activity. The machine or area that is used for its respective activity is recorded together with the distance moved, time taken and number of people involved, *see Table 4.2*. This information can be used for further analysis and continual improvement. One useful analysis technique is 5W1H (Why does an activity occur? Who does it? On What machine? Where, When and How?). This aims to eliminate unnecessary activities, simplify or combine others and look for changes that reduce waste.

Step	Area	Dist (m)	Time (min)	People	Operation	Transportation	Inspect	Store	Delay	Notes
Unload truck	Outside		8	1	O					
Placed at bay	Outside		3	0					D	Temporary store
Move to line	Outside/ Line	50	5	1		T				
Store at line	Line		300	0				S		
Press	Line		50	1	O					
Store in container	Line		12	0					D	

Table 4.2 *Process activity map.*

The *Quality Filter Mapping*[67] approach is designed to identify where quality problems of different kinds occur in the supply chain. The quality problems are divided into product defects, service defects and internal scrap. Products defects are defects in goods produced that are not identified by any inspection, and therefore are delivered to customers. Service defects are problems that are related to the service coming together with the sold goods, such as inappropriate delivery (late or early). Internal scrap is defects that are discovered during manufacturing and are not passed on to customers. The different types of defects are mapped along the supply chain, and illustrated by a graph showing the parts per million (ppm) rate of defects along the supply chain, *see Figure 4.15*. The information is used for subsequent improvement activities.

[67] Hines et al (2000)

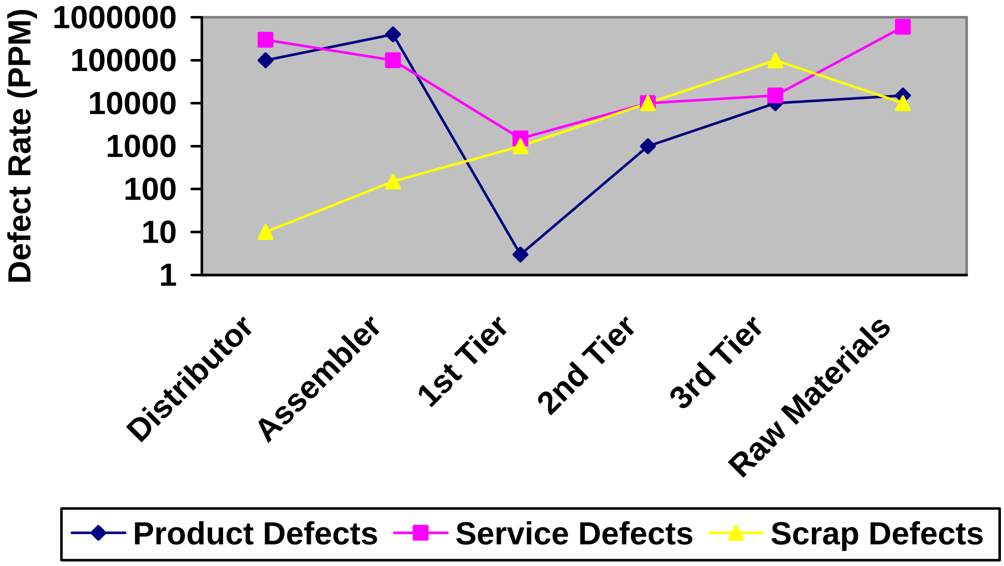


Figure 4.15 *Quality filter map for a supply chain.*

The quality filter mapping tool can also be applied to track the rates and sources of defects along the internal process route of a company.[68] In this case scrap and rework are recorded at the operation stages where they occur, and the graph shows the ppm rate against the operations, *see Figure 4.16.*

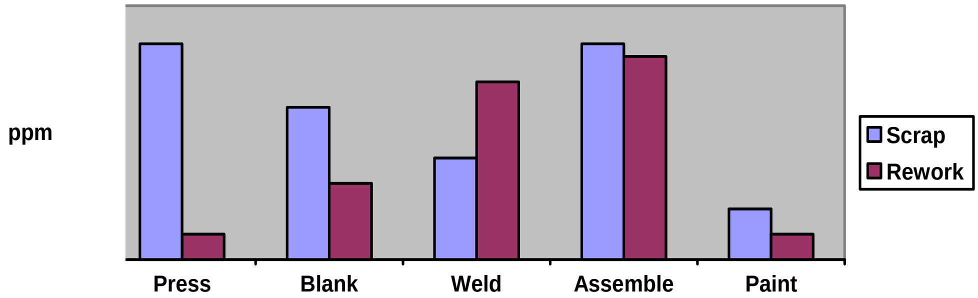


Figure 4.16 *Quality filter map for an internal process route*

First time through (FTT) is a metric for internal quality that is calculated as part of the quality filter map:

$$FFT = \frac{100 * (parts\ shipped - (parts\ reworked + parts\ scrapped))}{parts\ shipped}$$

Demand Amplification Mapping[69] is a method for understanding the effects of variation in demand. When demand is transmitted along a supply chain through a series of inventories using stock control ordering, the variation of demand will increase with each transfer.

[68] Bicheno J (2004)
[69] Bicheno J (2004)

For instance, a fairly regular or linear customer demand is translated into batch orders by a retailer, and is then subjected to additional modifications by a distributor adjusting safety stocks, then amplified further by a manufacturer who may have long changeovers and big batches, and subsequently modified again by a supplier who orders in yet larger batches to get quantity discounts.

This is known as the bullwhip effect, or the law of industrial dynamics, which in unmodified supply chains results in excess inventory, production, labour and capacity. Furthermore, manufacturers may not be able to meet the demand a given day, even though they on average produce more goods than they sell. In order to avoid the bad effects of demand amplification, a number of mapping techniques have been developed, to indicate how demand changes along the supply chain, and to provide information for analysis and decision making.

The risk of bullwhip effects is also present within a single manufacturing plant of the supply chain. A demand amplification map for door-to-door processes is plotted day-by-day across a month. For this, data usually need to be obtained from purchasing, receiving dock, order entry, from completions at various stages, and from dispatch.[70]

Figure 4.17 shows an in-house example of how a demand amplification map can be used. TDS is a customer who puts fairly regular orders. The final assembly department tracks TDS's demand pretty well. The press on the other hand has to produce in batches, due to changeovers. However, the sizes of the batches are irregular, and unevenly spaced. This indicates that there might have been some troubles, such as breakdowns and several different schedules to handle. The amplification map also denotes overproduction, and erratic orderings from the supplier. Obviously the benefits of regular orders from customers are devastated.

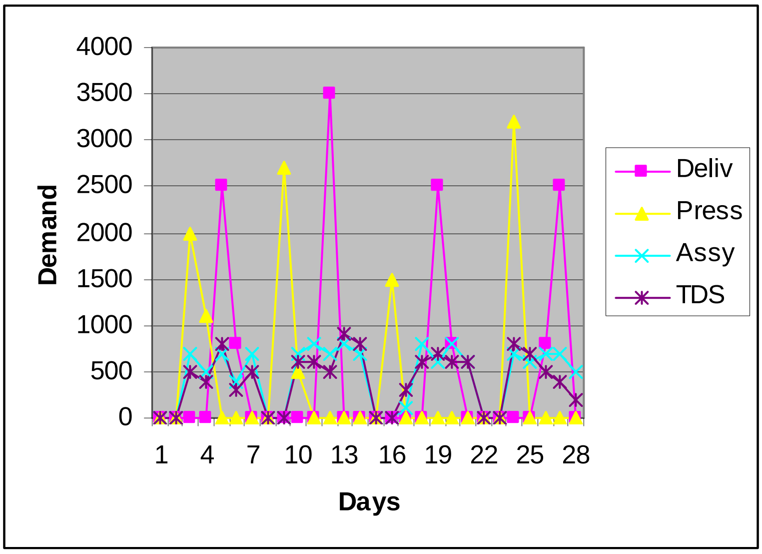


Figure 4.17 *In-house example of a demand amplification map.* [71]

The in-house demand amplification map is a useful tool to master scheduling issues. It is also applicable when evaluating the process of lean implementation by forming a periodic report to management.

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[70] Bicheno J (2004)
[71] Bicheno J (2004)

Decision Point Analysis[72] is particularly useful for plants that produce a wide range of products from a restricted number of components, typically within the electronics and household appliances industries, but it may be used in other types of industries as well. Products are pulled from the customer through the production up until the decision point. Further upstream, production is forecast driven; hence the products are pushed down. Decision point analysis is used to ensure that processes on both sides are aligned with the relevant pull or push philosophy. In lean production, the aim is to move the decision point as far upstream as possible.

The purpose of the *Overall Lead Time Map*[73] is to gain an understanding of the various elements of the total lead time, through tracking, quantifying and prioritizing them. The lead time map is arranged as a Gantt chart and as a Pareto diagram to illustrate where time is being spent or lost, *see Figure 4.18*. Another important aspect is to determine variations of lead time. For this, histograms can be used for each element and for the overall lead time. Typically, an overall lead time map will reveal that information processing is a major contributor to lead time.

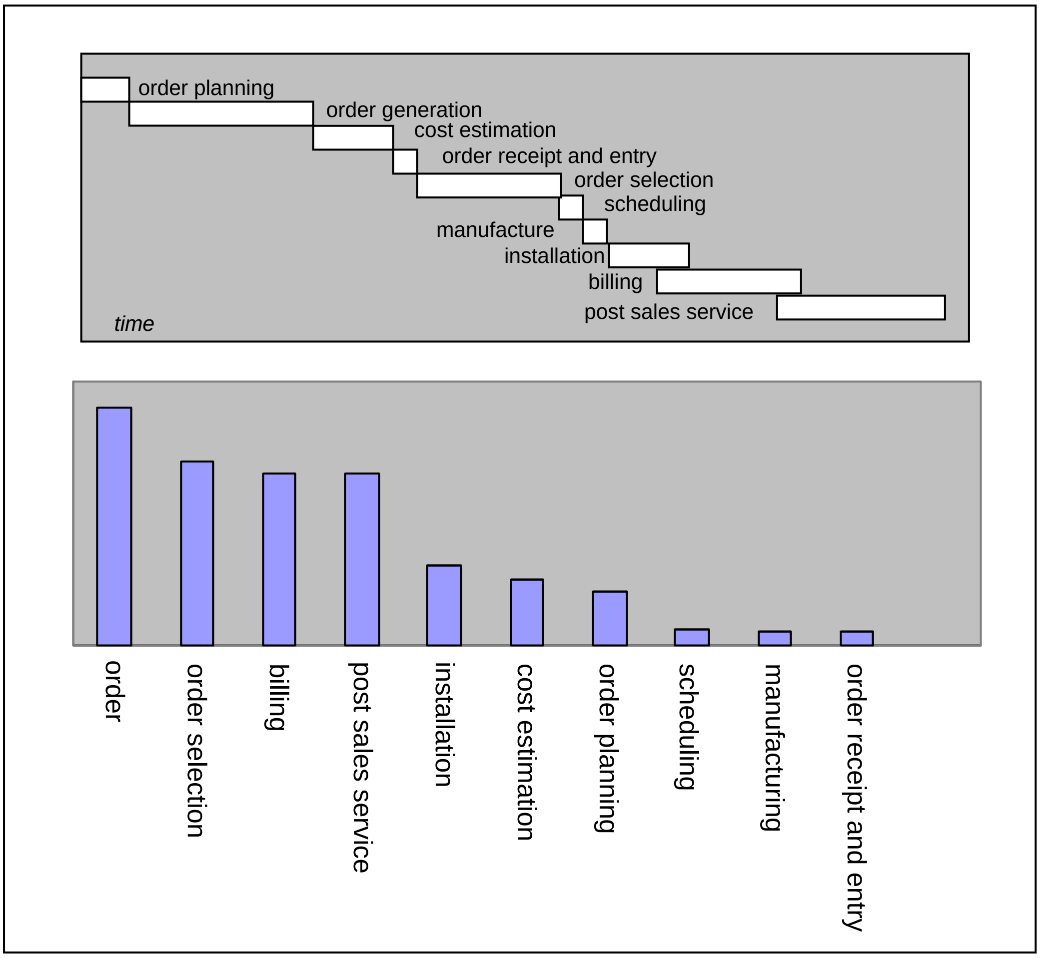


Figure 4.18 *Overall lead time map.*

[72] Hines et al (2000)
[73] Bicheno J (2004)

The elements of overall lead time are:

- Order entry time: The time form receipt of order to entry into the manufacturing and planning system.
- Schedule assembly time: Needed to consolidate orders into balanced assembly sequences
- Configuration time: The time from entry into the system to completion of the configuration.
- Procurement time: the time to procure materials and components.
- Non-specific manufacturing time: The time taken for postponement strategy manufacturing stages, where components are not specific to a final product or order.
- Order-specific manufacturing time: The time taken for order-specific or customer-specific manufacturing stages.
- Post-production move and storing time: The time from completion of manufacture to the start of delivery.
- Delivery time: May include final configuration if products are bundled together.

A *Spaghetti Diagram*[74] gives information about the geography of the plant and can consequently give information about wastes of transportation and motion. Therefore it could complement the current state value stream map, which does not provide this information. A spaghetti diagram, *see Figure 4.19,* is constructed by tracing the physical flow of the product on a layout diagram of the plant. Locations of inventory storage points are marked on the diagram. All rework loops, inspection points and weigh points are diagrammed. Now the total length of flow can be calculated, and wasteful movement and poor layout become clearly apparent. The spaghetti diagram does not show vertical movements, so in order to become aware of these, one must walk the path of the flow and record vertical movements.

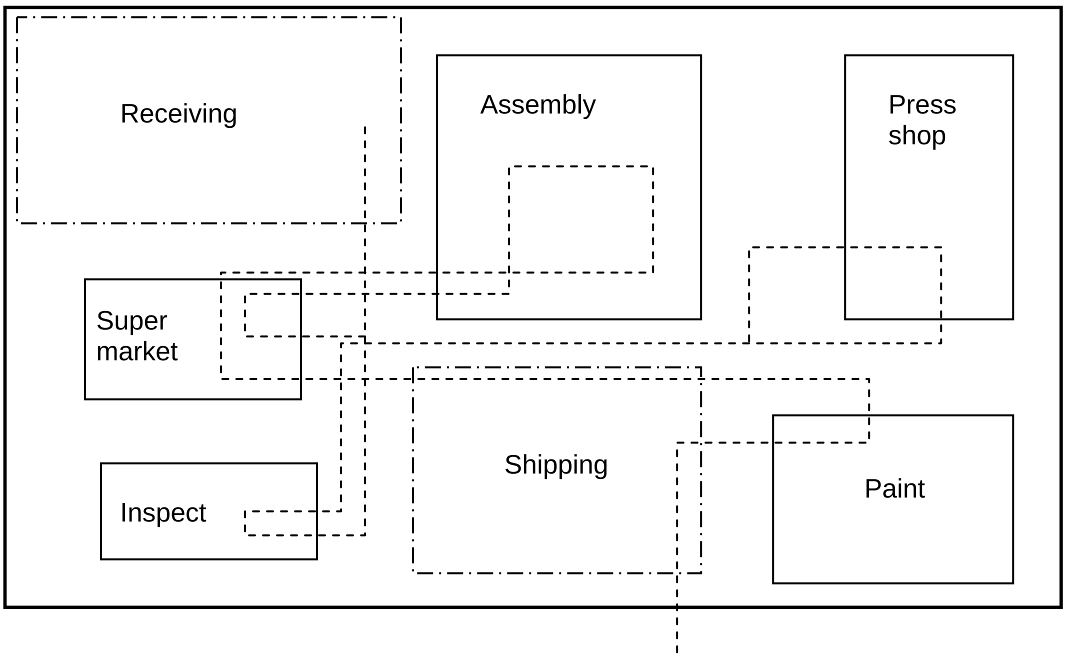


Figure 4.19 *Spaghetti diagram.*

[74] Bicheno J (2004)

4.4 ERP

A typical ERP system uses one single database to integrate the major activities in a company. Depending on the organisation's business, different modules are used. Manufacturing, financials, human resource, warehouse management, customer relationship, and supply chain are examples of modules in an ERP system.[75]

The fact that the whole company process is run from a single database means that all individual elements keep in step with one another and multiple information no more needs to be updated or synchronized. Functional and departmental boundaries are crossed and paper documentation is minimized. Even though ERP has led to great advantages, there are also some disadvantages. The implementation of the ERP software is usually very expensive and demands a change of the organisation to fit the software. The more companies that arrange their organisation processes to match the ERP processes, the harder it gets to differentiate from each other and customized ERP systems require high costs in programming and program maintenance.[76] However, others claim that ERP systems are built upon best practices, which simply is the best way to perform a process.[77] To understand from where the ERP systems of today have arisen, a brief presentation of its history will follow.

4.4.1 ERP History[78]

In 1957 the educational society for resource management (APICS) was founded. The founders felt that there was a need for education, training, and formalization of the best methods to control the most critical resources in an enterprise, such as inventory and direct labour. They set up standards that allowed systems to quickly evolve and improve in functionality.

In the 1960's the first bill of material (BOM) processor was created, which listed all physical items required to make a particular part. This made it possible to ensure that the correct parts were purchased in the correct quantities.

In the later 1960's the first material requirements planning (MRP) systems were developed. MRP was a giant step forward in the planning process. MRP consisted of a schedule of what was going to be produced and also a list of materials required for the finished item. A computer calculated the total need and compared it to what was already available or committed to arrive. This could result in a suggestion for an activity, such as placing an order, cancelling orders already placed, or changing the timing of existing orders. The planner could now be proactive and time phase orders, rather than reactive and wait until a shortage had occurred. To allow the computers of that time to make the required calculations, some simplifying assumptions had to be made. One of those was that orders should be started at the last possible date to supply for minimal inventory but still serve the customer's need on time. This is called backward scheduling. An effect of this was that the earliest date an operation could start was the same as the latest date an operation could start, with no slack time in the schedule. This meant that if anything went wrong in the execution of the plan, the order would be late to the customer. To build in slack into the schedule, conservative lead times were planned.

[75] Alter S (1999)
[76] Schary P B; Skjött-Larsen, T (2001)
[77] Sumner, M (2004)
[78] Ptak, C A; Schragenheim E (2000)

As the usage of MRP methodology increased, people realized that an additional plan regarding the company capacity was needed, in order to secure that the job would be done. MRP was combined with a plan for the capacity, and the closed MRP loop was born. In addition to the list of materials for the finished parts, defined paths for the production process were required. In order to schedule and plan the capacity and load, the paths cleared what machines the parts would be built upon. Even though this system also was built on a few assumptions, because of the limited computer capacity, the closed MRP loop helped to identify where overload conditions could arise and proactively resolve these problems.

Technology improved and people started to realize that when a piece of inventory moved, finance moved as well. The integrated system tracking the inventory movement and the financial activity was named ‘manufacturing resource planning’ (MRP II, *see Figure 4.20*). MRP II is not just a financial accounting system; it is also a financial management system that plans and controls all resources of a manufacturing company. Companies now had an integrated business system that showed what needs there were for material and capacity according to their desired operations plan, handled input of detailed activities, translated the activities to a financial statement, and gave suggestions of actions to deal with the items that were not coordinated with the desired plan.

The MRP II Concept

Manufacturing and resource planning is normally organized in a hierarchic structure of planning functions, with different time horizons and detail specifications. The MRP II concept consists of four different planning functions; business planning, master scheduling, materials planning and shop-floor controlling. There are two conditions that must be fulfilled in order to make the MRP II concept work. Decisions made on a lower level have to be made within the frame that is set on a higher level. The frame decisions made on a higher level must be able to be transmittable to a lower level.

Business planning is based on the company's business concept, their future strategies and their overall business targets. Forecasts and other types of estimates regarding future demand are used to plan future sales and deliveries.

Master scheduling deals with plans for delivery and production of the company products. This is based on actual orders and/or forecasts in consideration to the company supply. Quantities concerning products to be produced and delivered for the planning period are planned for each product.

Materials planning corresponds to the material supply and makes sure that raw materials or semi-manufactured articles are purchased or made in correct quantities and at the right point in time, so that the production plans made up by the master scheduling can be retained.

Shop-floor controlling comprises planning of new production orders releases, controlling that raw materials are available and planning the sequence of operations that order releases shall be executed. This is the planning level immediate before the implementation itself.

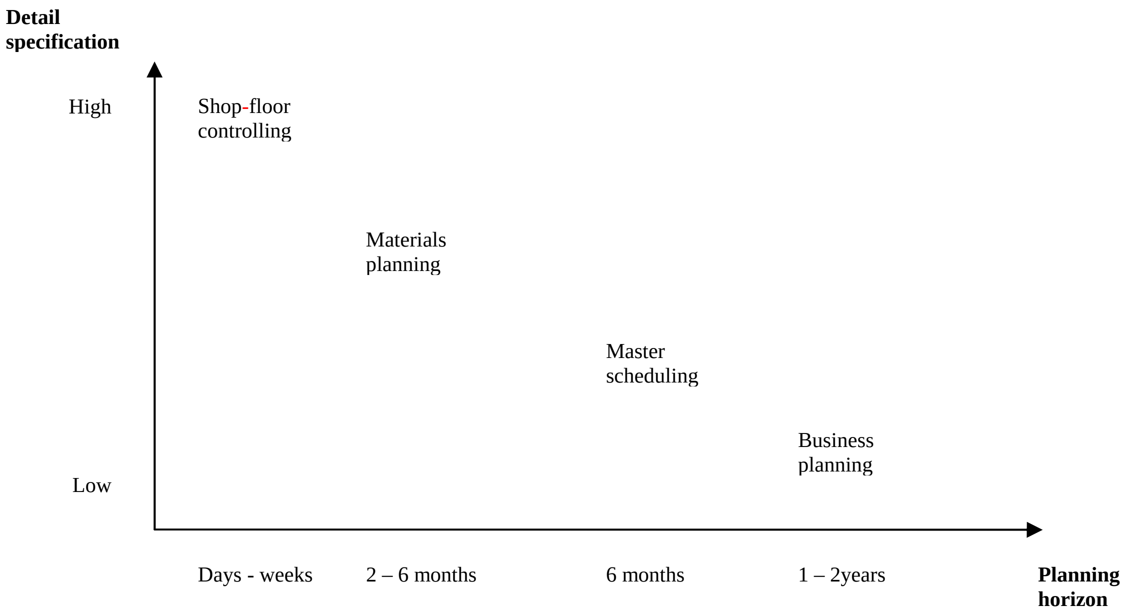


Figure 4.20 *The MRP II concept.*[79]

In the end of the 1980's and the early 1990's "time to market" was getting increasingly shorter, the cost of sold goods mainly derived from materials instead of labour, and customers demanded to have their products delivered when, where and how they wanted them. APICS shifted from a "MRP crusade" to a "zero inventory crusade". To remain competitive, companies began to apply "just in time" and "supplier partnerships" philosophies. It was no longer the production department alone that was responsible for the competitiveness and profitability, instead integrated resource management was in focus for a competitive company.

[79] Mattson, S A; Jonsson P (2003)

To take fast actions and decisions, empowerment of the employees was needed, and they needed access to good information to make good decisions. This required a management system that would be a source of data and provide valuable information on demand. The cost of technology plummeted and the power of small personal computers now exceeded the power of the large mainframes that were routine a few years earlier. This made it possible to run a fully integrated MRP II system on a small personal computer. The relatively low cost of systems now allowed even small companies to use this integrated solution, and larger companies moved from the centralized mainframe systems into more agile client-server systems. Enterprise resource planning (ERP) had now evolved.

4.4.2 Lean Production and ERP

Most ERP systems of today have evolved from MRP II, where manufacturers base production levels on sales forecasts. This contrasts to the lean concept, which ties production levels to actual demand.[80] It is not only the planning of production that differs lean from traditional ERP. In *Table 4.3* some of the different directions are proclaimed.

Lean	**MRP/ERP**
Local solutions	Enterprise solutions
Physical process visibility	Green bar reports
Helps with execution	Helps with planning and reporting
Executes with visual kanban	Executes with work orders
Reduces or eliminates complexity	Manages complexity with IT
Limits transactions	Promotes transactions
Minimizes data needs	Needs lots of data
People measure themselves	Management measures people

Table 4.3 *Differences between lean and ERP.*[81]

These contradictions have resulted in believes that ERP is an enemy to the lean philosophy, and sales forecast systems are looked upon as waste of time. This has led to that some companies that have applied the concepts of lean have found it beneficial to disconnect their MRP system.[82]

Others are by the opinion that lean never has been given a chance to become an integrated part of the ERP system. This is due to a negative attitude against computers, which have partly evolved from ERP systems which have driven more costs than profits, compared to lean techniques which have proven to increase the company performance.[83] There are manufacturers who have not had any major conflicts in integrating lean into MRP, and connection points between lean and ERP have been identified.[84]

The ERP system can also evolve into a tool that analyses value streams and identifies data in the system that reveals non-value-adding activities. Other lean concepts can be supported by different IT solutions and this is shown in *Table 4.4*.

[80] Bartholomew D (1999)
[81] Dixon, D (2004)
[82] Bartholomew D (1999)
[83] Dixon, D (2004)
[84] Bartholomew D (1999)

Lean concept	IT application support
Value stream mapping	Custom Visio applications. Data capture from ERP (planning) or process execution (actuals).
Fast setup	Continuous measurement and reporting of actual setup time. Comparisons of actual setup vs. objectives.
Focused layouts	Spreadsheets for line balancing and capacity analysis supported by data from ERP system. CAD.
Small lots	Continuous lot size analysis. Comparison of actual lot size to objectives (by material class).
Pull systems	Total supply chain capability for data capture at time of visual determination of reorder points; electronic transfer of replenishment signals; printing of kanban signals; electronic posting of kanban signals; and updating of ERP system and required reporting.
Takt time/Line balancing	Automatic capture of line/cell completions. Real-time measurement of performance to takt time and linearity goals. Spreadsheets for calculating line/load balance and total labor requirement. Labor utilization measurement as an indicator of effective line/load balancing.
Packaging and handling	Real-time, incremental measurement of transportation and wait time in plant and over the road.
5S housekeeping	Electronic score sheets with embedded formulas to ensure timely updates.
Standard work	Electronic work instructions with color coding, digital photos or video, and real time ECO implementation.
Error proofing	Electronic work instructions with color coding and embedded checks.
Increased productivity	Output-per-unit-of-input measurements at cell, operations, and corporate levels: completed units per man-hour, revenue per employee per unit of time.
Withdrawal buffers	Measurement of inventory turnover by line or cell. Actual turnover vs. objectives.
Visible quality control	Integration of quality measurements into comprehensive performance measurement package. Effective, custom measurement of the cost of quality.
Reduced lead-time	Measurement of inventory turnover by line or cell. Actual turnover vs. Objectives.

Table 4.4 *IT solutions for lean techniques.*[85]

Today no software supplier offers all these applications, even though data capture, manipulation and reporting capabilities are available. Some argue that the connection between lean techniques and IT will lead to great possibilities, and that those who claim the opposite run the risk to be left behind.[86]

Earlier lean thinking focused on physical processes, and some researchers mean that this is a limited approach with several serious shortcomings:

- Management strategies and objectives do not relate to process improvements which could be motivated by information technology.
- Lean physical processes are not supported by management decision processes.
- Information systems are not supported by or linked to physical process lean improvements.

To overcome these obstacles it is suggested that lean principles, tools and practices should be used to continuously improve management decisions and information processes as well as their linkage to the lean physical processes. The computer should act as a processor of data that supports other system processes both in the lean enterprise sense and in the information sense. In the system processes management decisions, information and the physical processes

[85] Dixon, D (2004)
[86] Dixon, D (2004)

all are included. Still the computer does not act as the process itself but as the enabler of a lean process.[87]

4.5 Microsoft Dynamics AX

In Microsoft Dynamics AX there are a number of modules, which are fully integrated with each other. This means that when data is treated in one module in AX, all other appropriate modules will be updated as well. For example, by posting a completed production order, inventory is instantly updated, which will make it visual for the salespeople that inventory is available to the customers, at the same time costing for the production order will be calculated, and the general ledger account will be updated.[88] *Figure 4.21* is a schematic representation of the integrated modules.

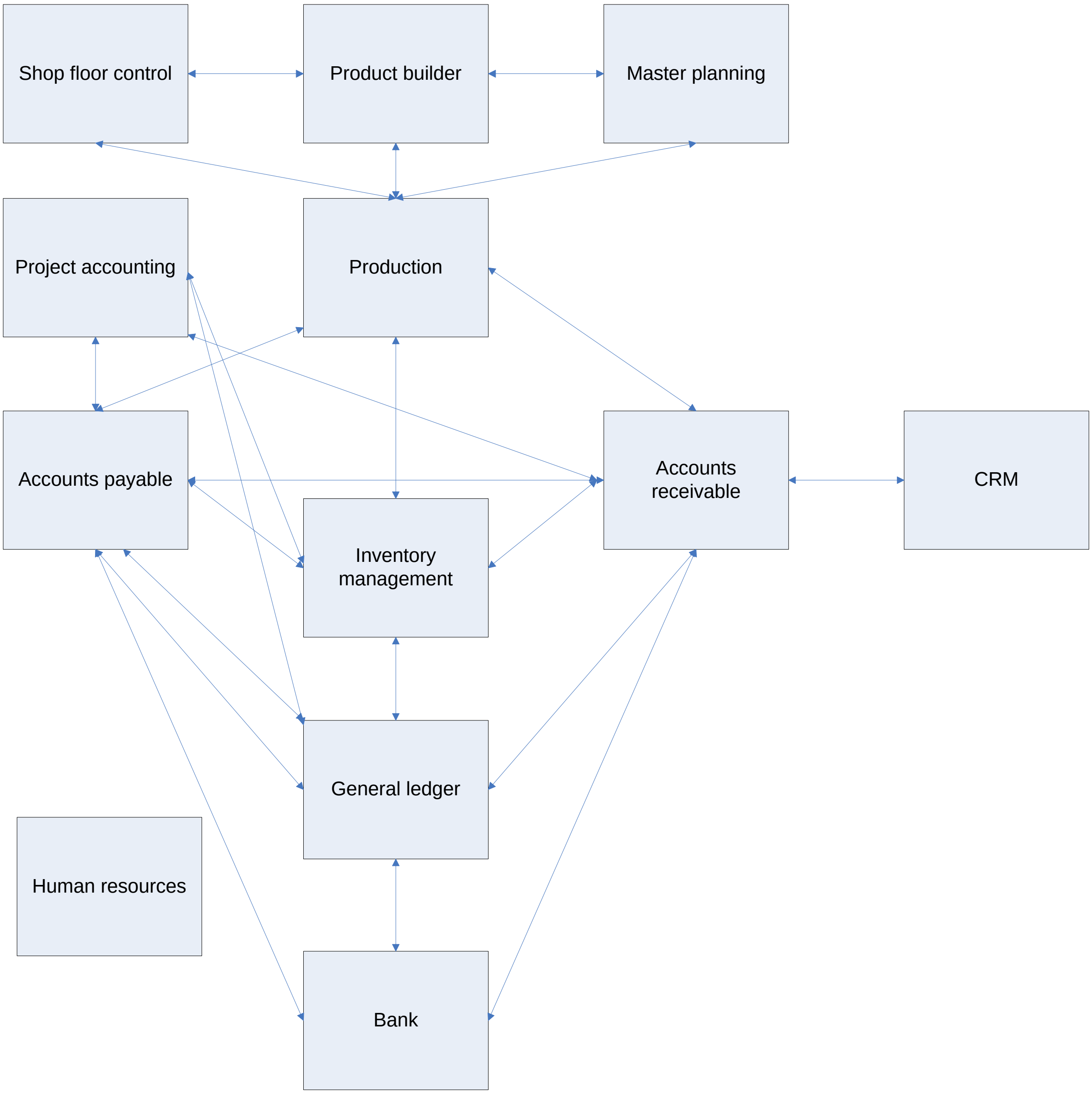


Figure 4.21 *Schematic representation of the integrated modules.*

Following is a brief description of some important modules in Microsoft Dynamics AX:

[87] Carroll, B J (2002)
[88] Microsoft Business Solutions – Axapta 3.0 Course 8329: Introduction (2004)

The financial and accounts reports are found in the *General ledger*. Here you will find the chart of accounts, budget models and information about fixed assets. You can also choose from different set-ups regarding taxes, periods, and journals.

In the *Bank* module, information concerning bank accounts and checks, etc. is available.

In the *CRM* module, information about business relations is available. It also includes a work book in which various activities and projects can be planned and communicated.

Sales order and customers are controlled in the *Accounts receivable* module. Set-ups for posting profiles (which controls postings in the general ledger), sales orders, payment conditions, and customers are managed here.

The *Accounts payable* module handles purchase orders and vendors. The set up in this module organize posting profiles, vendors, and purchase orders.

Inventories are handled in the *Inventory managemen*t module. Information, such as how many items and bills of material (BOM) that are on hand and where they are located, is available in this module. Set-ups for each item can also be managed, such as item name, price and ABC classification. ABC codes are used to classify the items according to their importance in relation to value, margin, revenue or carrying cost.[89]

The *Master planning* module is used to manage and plan production orders.

Information regarding production orders, routes and the production itself is to be found in the *Production* module.

Planning and managing the collection of employee time, project and production data is done in the *Shop floor* module. It also provides a detailed insight in the production environment.[90]

The *Human resources* module handles the personal administration.

Web based questionnaires can be managed by the *Questionnaire* module.

General information is found in the *Basic* module. This manages information about employees, work centre groups, calendars, addresses and dimensions.

The *Administration* module is used to administrate the set up of the system. It handles users and company accounts created in the AX system etc.

[89] Juell-Skielse G (2006)
[90] http://download.microsoft.com/download/a/a/8/aa84173f-56d0-4e73-b024-3289c71fc555/Axapta_ShopFloorControl.doc (2007-02-06)

5 Empirical Study

The empirics of this study consist of three main elements:

- *First, it was identified where in AX data for creating current state value stream maps can be found. We also aimed at explaining how eVSM can be used to draw maps based on these data. The fact that value stream mapping is a tool for continuous improvements led us to identify data theoretically related to typical future state value stream maps. Data that could be used for other value stream mapping tools was also searched for, since the other tools could complement the current state value stream map.*
- *In order to see what data that can be found in AX when it is applied in a real production environment, a case study at Note was performed.*
- *The quality of these data was then evaluated by interviews with Note employees and an inspection of the production facility.*

5.1 Data for Current State Value Stream Mapping in Microsoft Dynamics AX

As explained in chapter 4.3, current state value stream maps are typically created manually, through walking the flow of value in a plant while recording times, quantities, etc. In this chapter, we examine to what extent such data is available in AX, and how this information can be used to create a value stream map with the aid of eVSM. For this purpose a demo version of Microsoft Business Solutions - Axapta was used. In this version, a company account called Training Company (TRN) exists for training purposes, which is used as a basis in this first empirical investigation.

5.1.1 Product Family Analysis

A product family analysis includes the consideration of both strategic and technical issues. In Dynamics AX there is no available information that can be used for determining strategic product families. In order to conduct a technical product family analysis, as explained in chapter 4.3, the following information is needed:

- A register of all product varieties.
- A list of the operations required to produce every product variety.

In the production module of Microsoft Dynamics AX, different *routes* are listed. A route is a list of operations required to finish a certain product variety or group of product varieties. For every route, there is a record of the products which use this route. In *Figure 5.1* an example of a route for a product family of three articles is displayed:

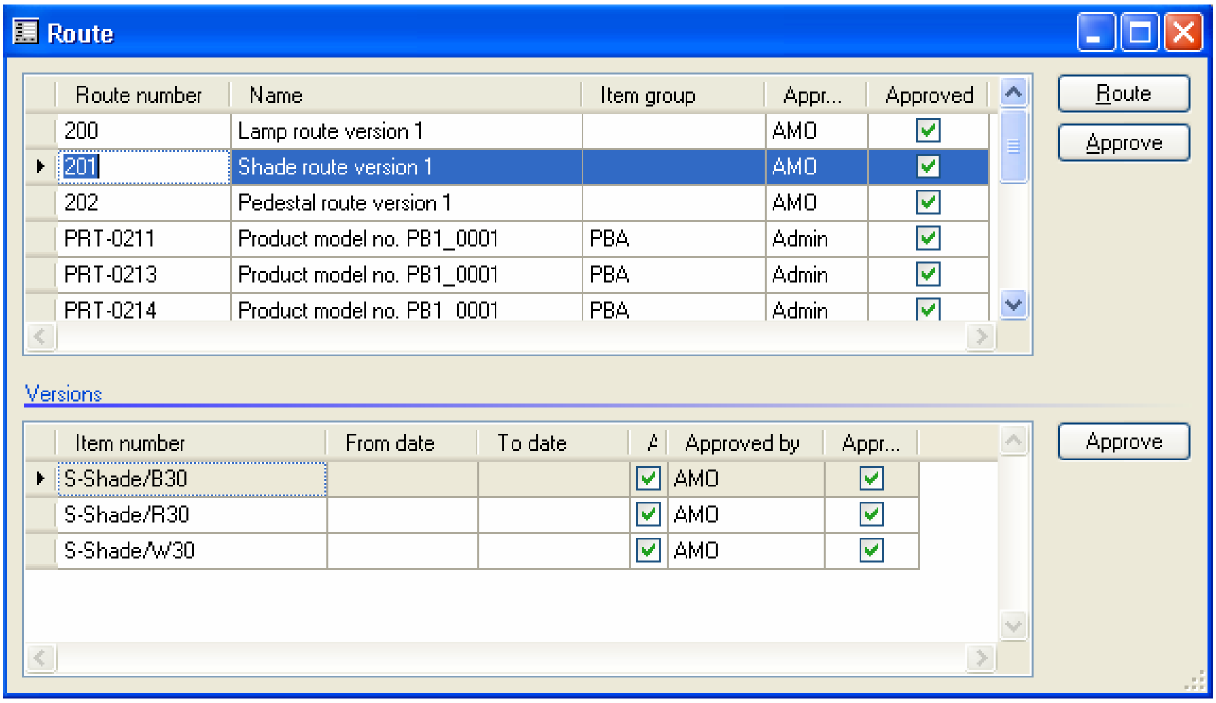


Figure 5.1 *Different routes.*

There is no explicit information available in Dynamics AX concerning which of the product families that has the greatest potential for lead time or inventory reduction.

Once a process family has been selected, it is time to map the current state value stream. In this chapter we map the product family displayed above (Route number 201). It contains three different products (S-Shade/B30, S-Shade/R30 and S-Shade/W30). However, in order to provide for a better overview, we only present where data for one of these products (S-Shade/W30) is found.

As presented in chapter 4.3.2, the following information is needed to produce a current state value stream map, *see Table 5.1:*

Customer	Name of Customer
Customer Demand	Quantity/month Product variations Packaging demands
Operations	Sequence of operations
Fact boxes	Cycle time Changeover time Uptime Available time EPE Interval Number of operators Scrap Rework
Inventories	BOM information Inventory levels (quantity) Inventory levels (time)
Inbound Deliveries	Frequency Mode of delivery
Outbound Deliveries	Frequency Mode of delivery
Information flow	Order frequency from customers Forecast frequency from customers Order frequency to vendors Forecast frequency to vendors Type of communication Communication flow from production control to operations

Table 5.1 *Current state value stream map information.*

5.1.2 Customer Demand

On a value stream map, the customer demand for the product should be expressed as a quantity per month. In AX, there is no information about the demand in this form for the different products. However, we identified three possible methods to calculate the demand per different time units, based on data in AX. This metric then had to be manually entered into an NVU (name, value, unit) bar connected to the standard symbol "outside source", which is used to represent customers on an eVSM value stream map, *see Figure 5.2*. When mapping a product family containing more than one product variation, the demand for every variation was entered into rows of NVU bars.

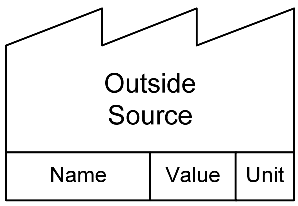


Figure 5.2 *Representation of customer.*

Information about customers is found in the *Accounts receivable* module. An overview of the historical demand for a given product over a certain period of time is found in *Reports*. Here it is possible to view the sales statistics either sorted by item or by customer. For example, the total historical demand for the product is available in *Item/Customer statistics*. A time period may here be selected, to view the total ordered quantity per customer for this period. By dividing the total amount ordered of a specific product by the number of days in the period, the demand for this product can be expressed as a quantity per day.

The customers can be placed on the value stream map, as “outside source” symbols, labeled with the names of the customers, according to the information in the *Item/Customer statistics*.

In *Accounts receivable – Reports – Transactions – Sales order* a report called *Order lines* is available. By selecting the item number and printing the report, all sales orders available in the system, with order and delivery dates as well as ordered and delivered quantities, are made available.

By summing all sales order quantities for every month in this report, an average demand per month can be calculated. The monthly quantities can also be visualised in a diagram for further analysis.

The data that the *Item/Customer statistics* and *Order lines* reports print is located in the database of the system, and it would probably be possible to access it directly for further calculations. Due to limited resources during this study, we chose to print the reports to access the data for calculations.

In *Inventory management*, the current demand is displayed in *Net requirements* as a requirement profile for every item, deriving from both forecast and master plans, *see Figure 5.3.* A summation period may be selected in order to obtain the requirements for a specific day, week, month or year. If no summation period is selected, all records in the requirement profile are totaled. Every record has a reference field, which shows the origin of the transfer.[91] When the reference is a sales order, its number is also specified. This way it is possible to find out which customer that has placed the order. When basing the customer demand on the information in *Net requirements*, the name of the customer on the value stream map can be based on the same information.

[91] Microsoft Business Solutions – Axapta help file

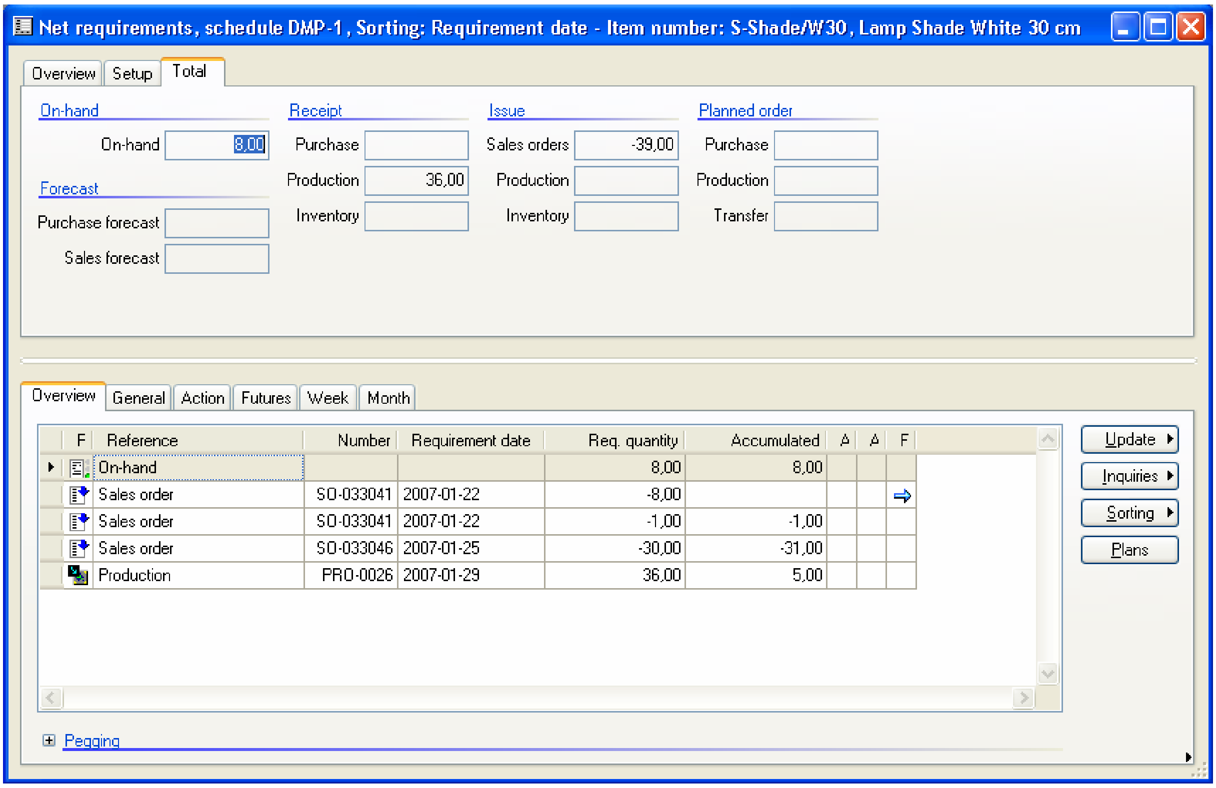


Figure 5.3 *Net requirements.*

By dividing the total sales orders requirements by the time period from now until the last requirement date, customer demand can be expressed as quantity per time unit. The requirement profile is the most appropriate information available in Dynamics AX, in order to express the current customer demand.[92] In the example in this chapter, we chose this way to express the customer demand. If today's date would be 2007-01-20, the customer demand is 7.8 units per day (39 units divided by 5 days). In *Figure* 5.5 the demand for each product variation of the product family based on net requirements is displayed, as well as the name and account number of the customer.

In AX, we have found no information about packaging demands that the customers may have.

5.1.3 Operations

In order to find the sequence of operations that a chosen product goes through, we must know its route. In *Routes*, this information is provided for. For every route, the ingoing operations are labeled with numbers, which indicate the order of operations. Parallel operations are given the same operation numbers.

[92] Vest, T (2007-01-22)

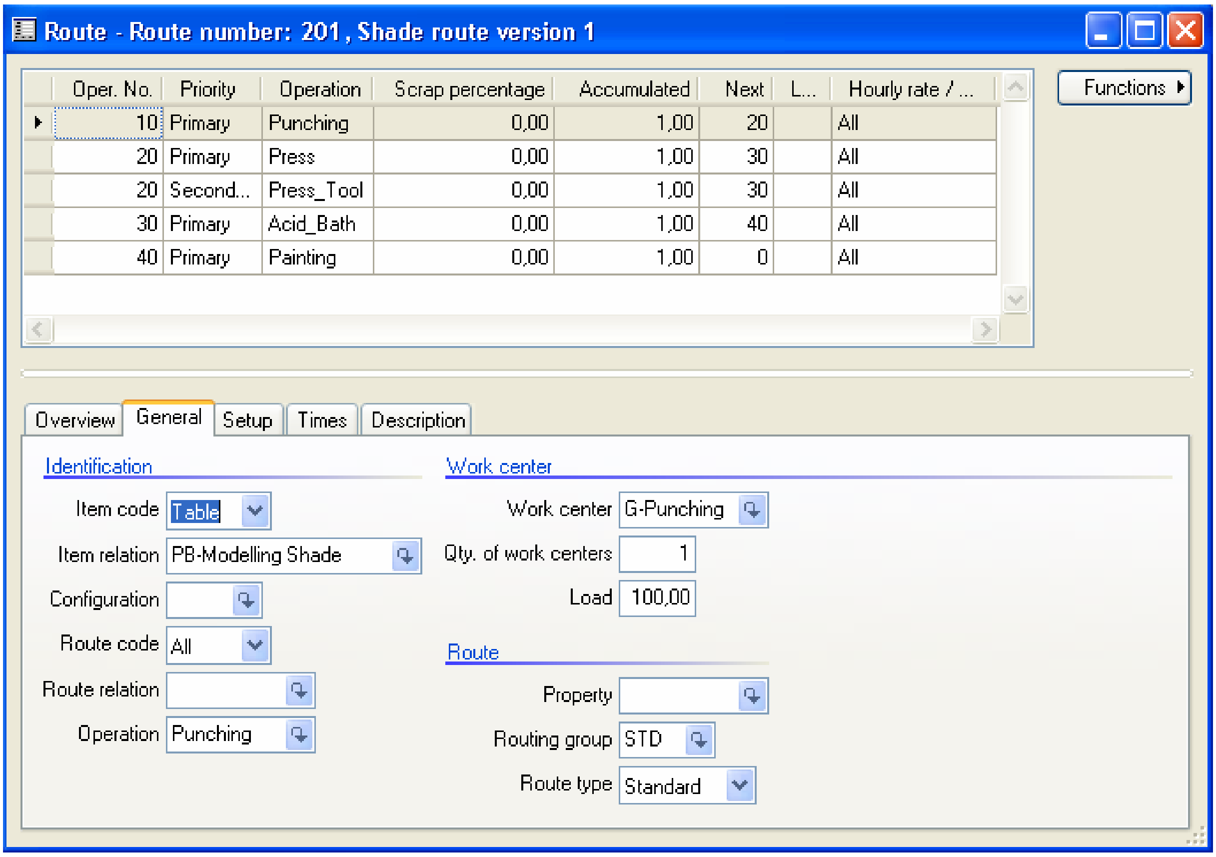


Figure 5.4 *Route.*

According to the operations in the route in Figure 5.4, we can now place standard operation boxes on to the value stream map in eVSM and label them with the corresponding operation names, *seeFigure 5.5.*

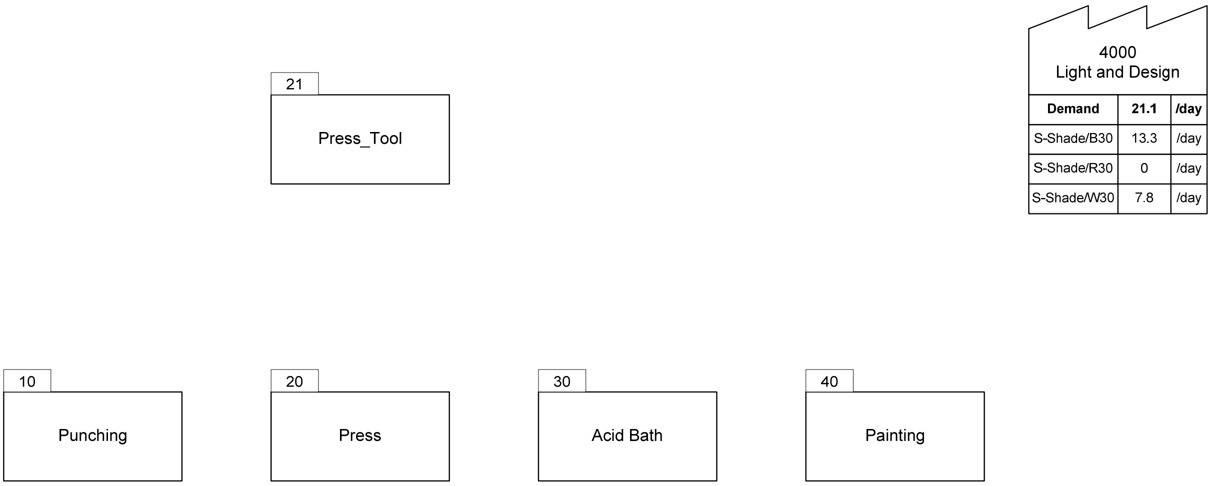


Figure 5.5 *Value stream map with AX and eVSM, 1.*

5.1.4 Fact Boxes

Next is to add fact boxes to each operation. As explained in chapter 4.3.2, the fact boxes should contain all relevant metrics for describing the operations. Since there is no method for determining what is relevant in the general case, we looked for the typical metrics to describe the operations according to the theory: Cycle time, changeover time, uptime, available time, number of operators, scrap and EPE interval.

In the route, it is possible to view times and process quantities for every operation. Fields for queue time before, setup time, run time, transit time, and queue time after are available here, as seen in *Figure 5.6*:

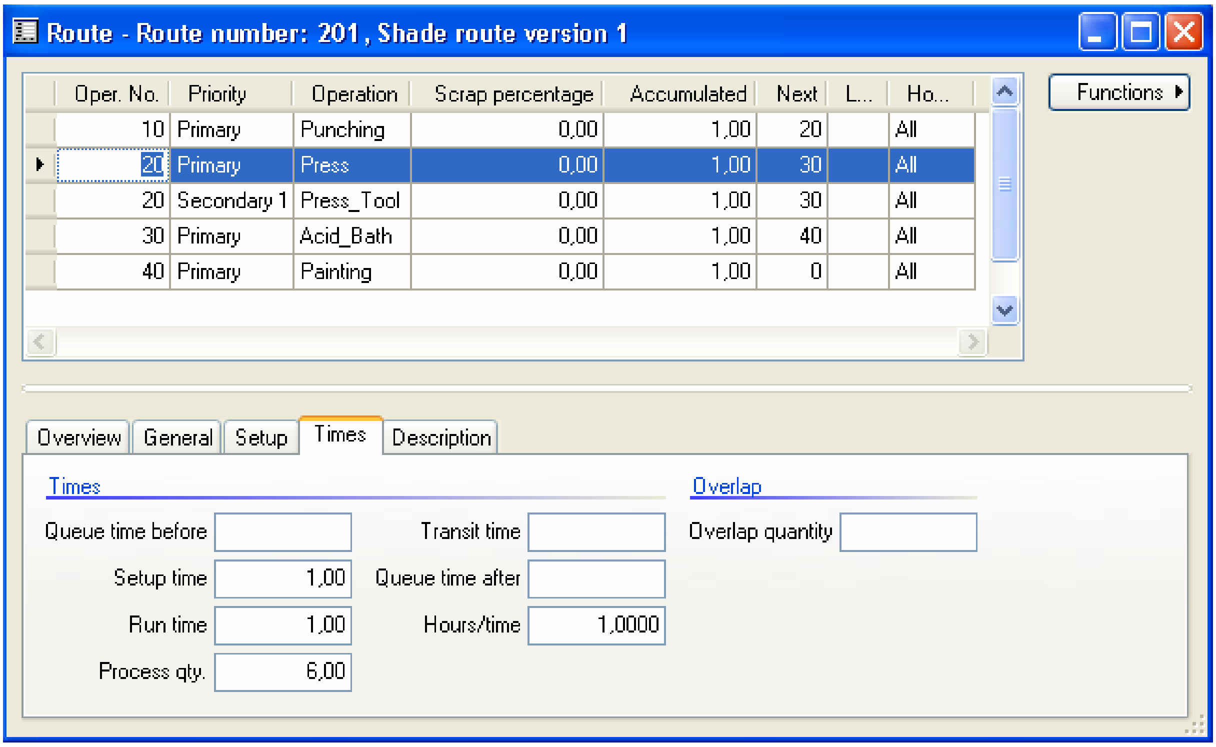


Figure 5.6 *Times for production routes.*

Cycle time for an operation is its run time divided by its process quantity.[93]

The *Hours/time* field is a factor to convert a specified operation time into hours with two decimals. In this case, the Hours/time is 1.0000 which means that the times are indicated in hours. If the operation time would be in minutes, the Hours/time would be set to 0.0167. Thus, for an operation time of 30 minutes, the time becomes 0.50 hours when the conversion factor is applied. The time calculation is then: 30.00 * 0.0167 = 0.50 hours.

For every operation, a work center is specified, and its load or percentage of the maximum capacity of this work center that has been reserved, see *Figure 5.7*. This is specified in the general settings for the operation.

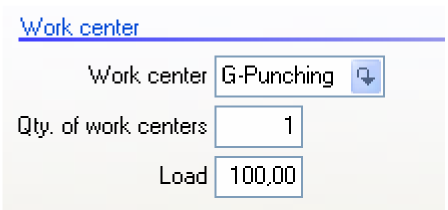


Figure 5.7 *Work center.*

[93] Vest, T (2007-01-29)

A work center may be a machine, a tool, or a number of employees. Information about the number of operators involved in an operation can be obtained from the specification of the respective operation's work center, as seen in *Figure 5.8*:

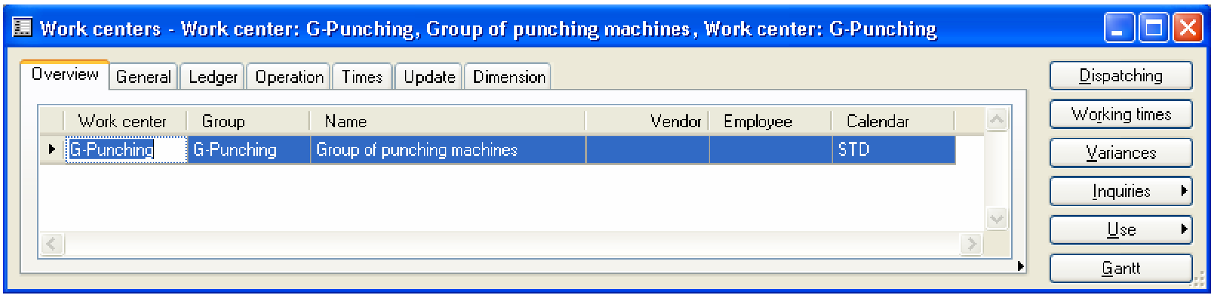


Figure 5.8 *Specification of work center.*

So, operation number 10 has no operators. Here we also find information about which calendar that is used for the work center. The available time for an operation is specified in the corresponding work center's calendar, in the *Hours* field, *see Figure 5.9*.

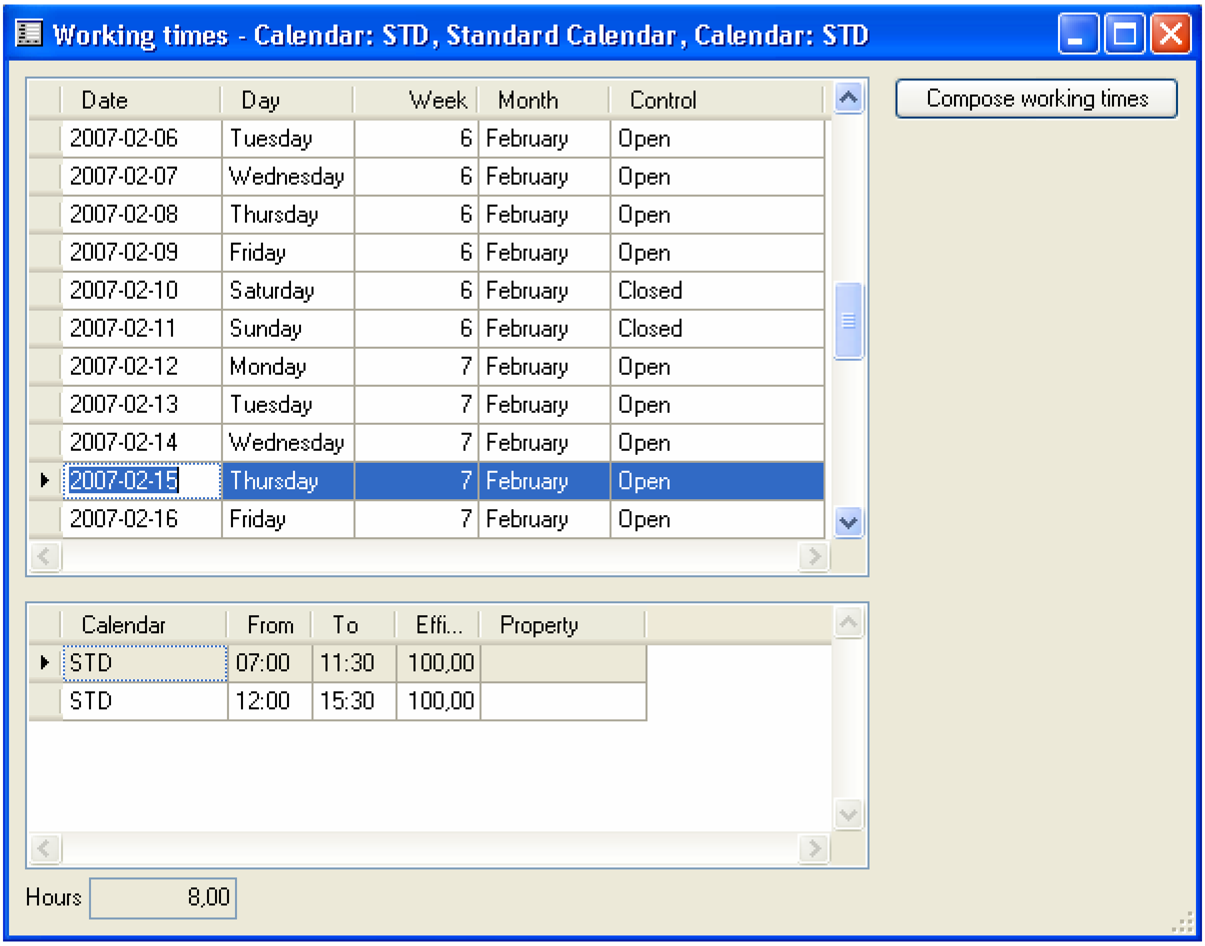


Figure 5.9 *Working times.*

Uptime for an operation can be approximated as the corresponding work center's efficiency percentage. This is specified in the general settings for the work center, *see Figure 5.10*.

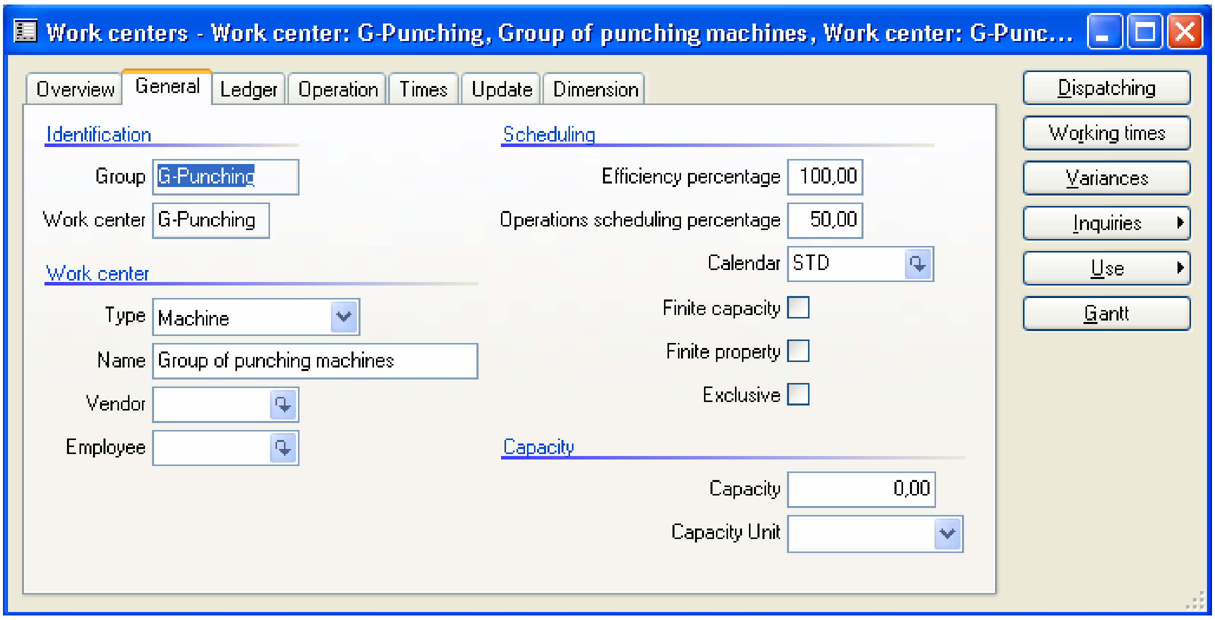


Figure 5.10 *General settings for a work center.*

As defined in AX, efficiency percentages reduce or increase the time reserved for the work center. Consequently, lead times are also reduced or increased. The following equation shows how it works:

*Scheduling time = Time * 100/Efficiency percentage*

The time included in the formula includes both processing time and setup-time. An exact measure of an operation's uptime requires additional information. Every instance when an operation is idle, it must be investigated whether this is because there is a disturbance or because of that there are no orders for it to process. This information is not available in Dynamics AX.

Parallel operations are characterized by the fact that they appropriate several work centers at the same time. These operations have the same operation number but different priorities. The primary operation is the operation loading the work center that is regarded as the bottleneck for simultaneous operations. This way, one operation can be allotted several work centers, for example a machine and human resources.

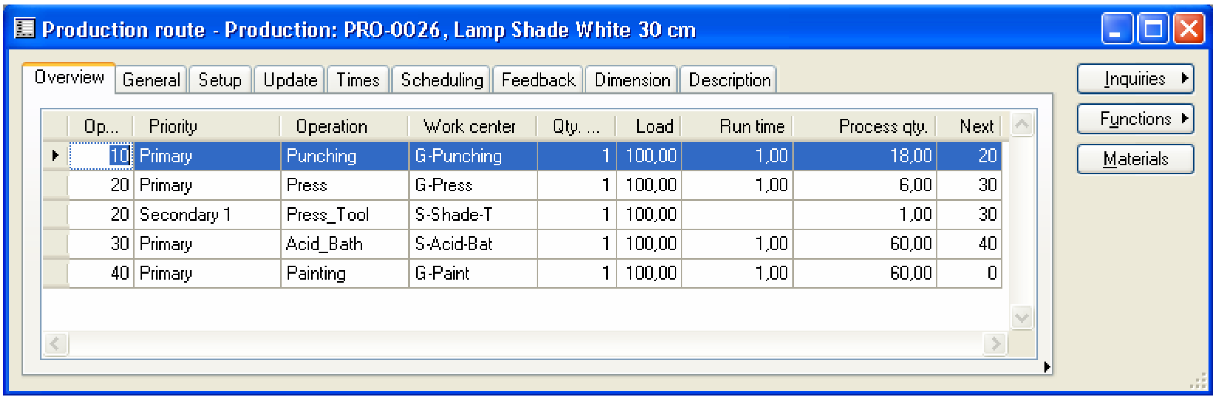
As seen in *Figure 5.6*, every operation is marked with a scrap percentage, which defines the expected over-consumption of materials and work for this operation. If several operations in a route have expected scrap percentages, the summed percentage for previous operations and the current operation are displayed as accumulated scrap. In the feedback section of the route of a production order, error quantities for each operation can be found. In the error quantities field, the actual amount of scrap can be reported. There is no information about reworks in AX.[94]

A summary of all products and their respective routes is available in a report called *Route versions* in the *Production* module. In order to calculate the EPE interval, we must examine the number of product variations that is processed in a certain operation, and the frequency of changeovers between the different products. In an adjacent report called *Operation use*,

[94] Vest, T (2007-02-28)

routes, all operations are listed together with a record of the routes that require the respective operation. In *Routes*, the different product variations that use each route are listed. By tracking the times of a certain operation for every production order where any of these product variations has been produced, the EPE interval for the operation can be estimated. But this requires that old production orders stays in the system. When a production order is updated to status "Ended" it can be deleted. There is no rule that states how long production orders have to stay in the system.[95] Consequently, there is no reliable way to express the EPE interval by looking at old production orders.

In eVSM, a fact box is constructed by adding NVU bars to the operation shape. The operation is then fitted with a tag, which designates the operation's relative row number in an Excel spreadsheet. When the eVSM calculator is run, the operations appear in the rows of an Excel spreadsheet, with place for fact box metrics for each operation. So, the data identified above can be directly linked from Excel to the fact boxes in eVSM. As seen in *Figure 5.6*, the information about operations in routes is in a table format. It is possible to copy this table into an Excel spreadsheet. This way, scrap percentages can be made available for eVSM. In order to bring the other data into Excel, there are two possible approaches: By following the instructions above, each piece of information can manually be entered into Excel. A more convenient method is to locate a production order for the product in the *Production* module and find its production route, *see Figure 5.11*:



Op...	Priority	Operation	Work center	Qty. ...	Load	Run time	Process qty.	Next
10	Primary	Punching	G-Punching	1	100,00	1,00	18,00	20
20	Primary	Press	G-Press	1	100,00	1,00	6,00	30
20	Secondary 1	Press_Tool	S-Shade-T	1	100,00		1,00	30
30	Primary	Acid_Bath	S-Acid-Bat	1	100,00	1,00	60,00	40
40	Primary	Painting	G-Paint	1	100,00	1,00	60,00	0

Figure 5.11 *Production route.*

When the table in the production route is copied into Excel, the data visible above, together with some extra data is transferred to Excel. In the Excel spreadsheet created by the eVSM calculator, standard Excel calculations can be used in order to obtain cycle times from run times and process quantities. Uptime, available time and number of operators still need to be entered manually in Excel.

All metrics identified for the operations are entered into Excel, *see Figure 5.12*, and transferred to eVSM via the eVSM calculator, *see Figure 5.13*.

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Tag	Operation	Data	Data	Data	Data	Data	Data
		changeover time	cycle time	operators	scrap (%)	time avail.	uptime (%)
		hrs	hrs	staff	%	hrs	%
1000,00	Punching	1,00	0,06	0,00	0,00	8,00	100,00
2000,00	Press	1,00	0,17	0,00	0,00	8,00	100,00
2001,00	Press_Tool	1,00	0,00	0,00	0,00	8,00	100,00
3000,00	Acid Bath	0,00	0,02	0,00	0,00	8,00	100,00
4000,00	Painting	1,00	0,02	0,00	0,00	8,00	100,00

Figure 5.12 *Operation data.*

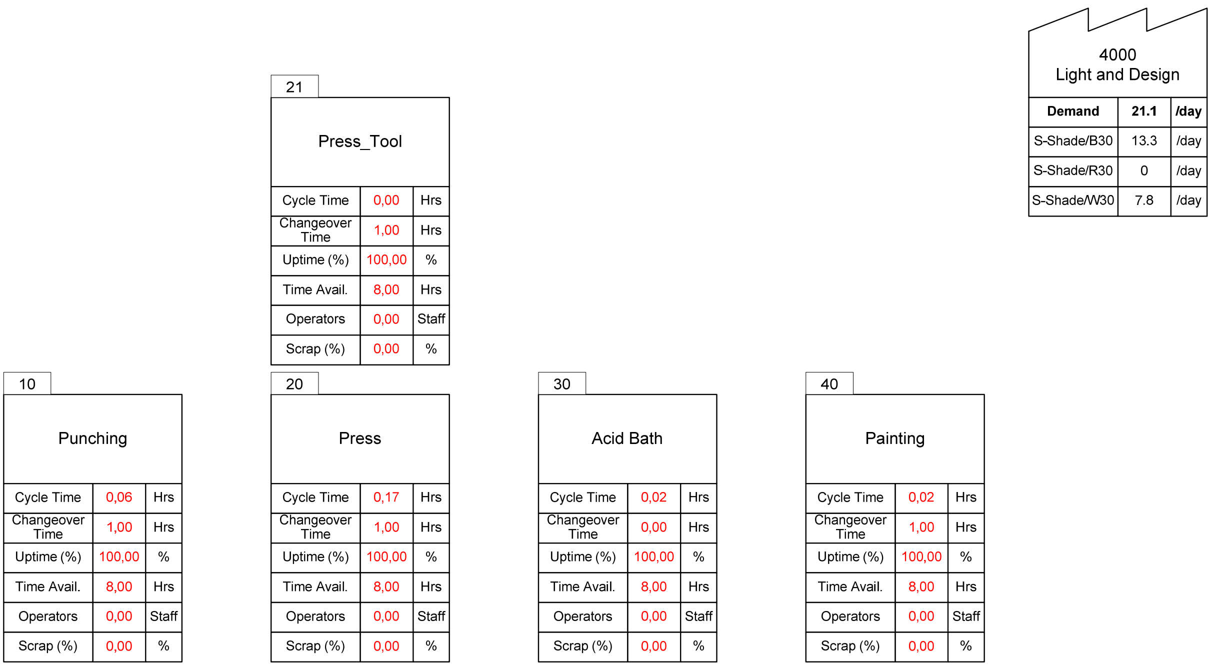

Figure 5.13 *Value stream map with AX and eVSM, 2.*

5.1.5 Inventories

As explained in chapter 4.3.2, all inventory levels must be mapped and expressed as both quantity and time. This includes not only raw material and finished goods inventories, but also work in progress and buffers between operations.

The *Inventory management* module holds information about all items, i.e. raw material, components, and finished goods. In *Bills of materials* in *Inventory management* all ingoing items such as raw materials and components for every product is specified. Figure 5.14 and *Figure 5.15* shows a *BOM Designer*. In this the ingoing items are apparent, and by selecting an item, the arrow in the section to the right indicates in which process this item is processed.

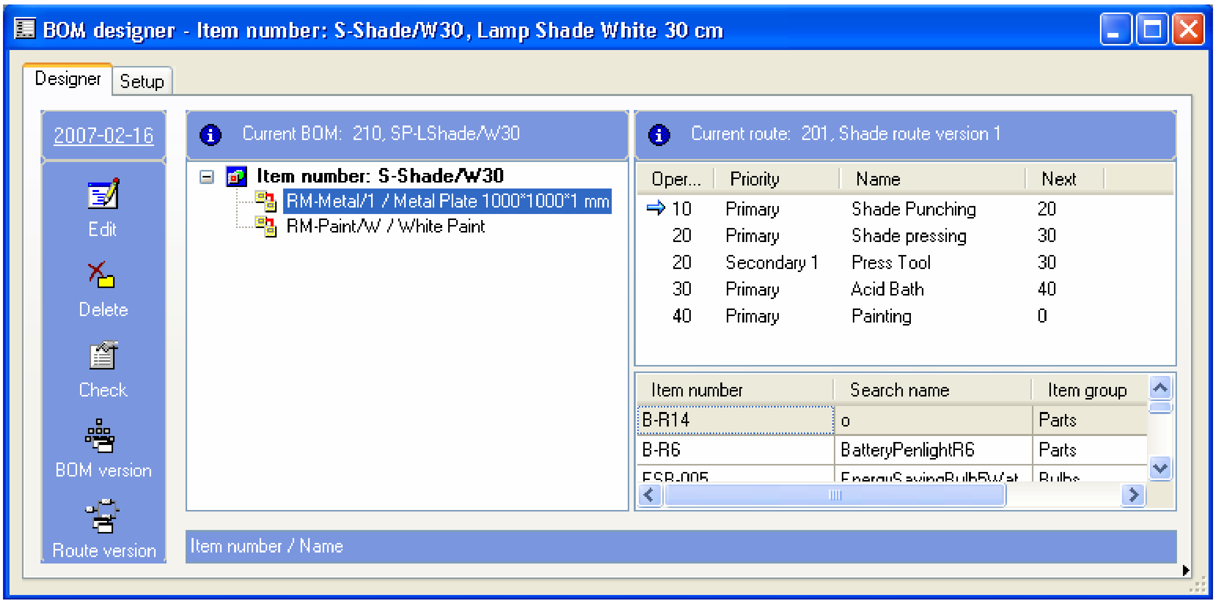

Figure 5.14 *BOM designer, 1.*

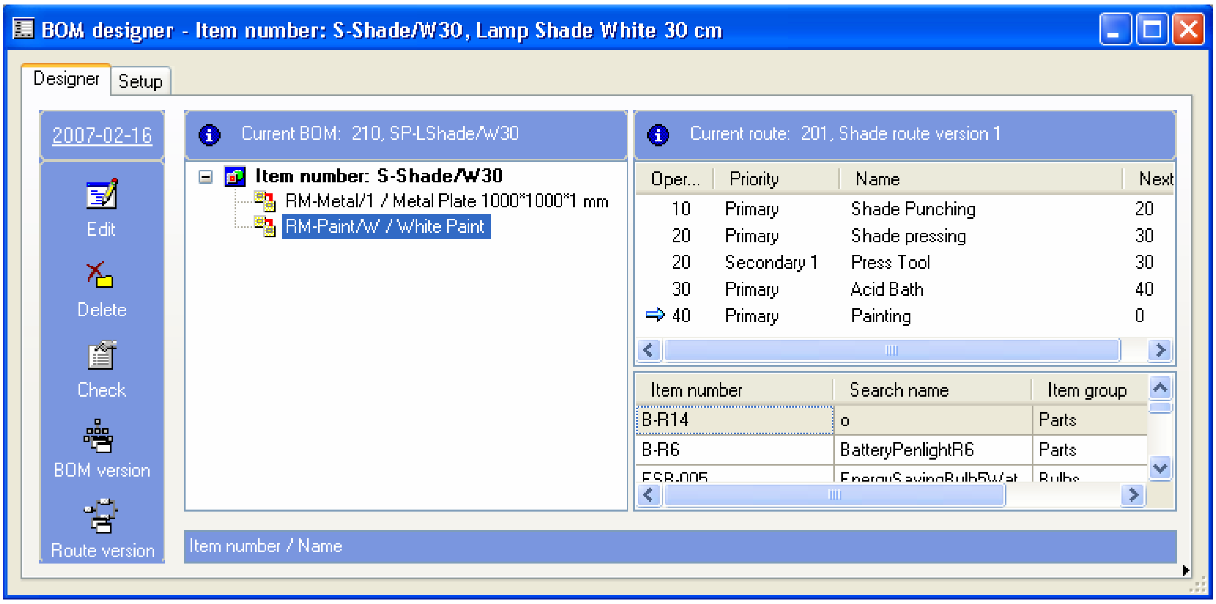

Figure 5.15 *BOM designer, 2.*

The BOM designer is useful when determining the flow of material from warehouses to operations. Under the *Quantity* tab on the *Items* list, it is for every item specified which warehouse is involved in purchase, production and sales transactions. The report *On-hand inventory* displays available quantity for every item, its warehouse, and location. The quantities displayed in this report are the total available quantities, and raw materials are not designated for specific products. So, there is no information about what fraction of the total quantity that is related to a certain product. With the data from this report, it is possible to add inventory levels for raw materials and finished goods to the value stream map in eVSM. Standard inventory shapes are used in eVSM to represent inventories. To facilitate the drawing of material flow, two inventory shapes are used for raw material. An inventory shape typically has a short NVU bar glued to it to specify inventory count and time. According to the *On-hand inventory* report the inventory quantities for the product family are displayed in *Table 5.2*:

Item	On-hand Quantity	Unit
Raw materials:		
RM-Paint/B	99998	Litres
RM-Paint/W	8.20	Litres
RM-Metal/1	99989	Pieces
Finished products:		
S-Shade/B30	45	Pieces
S-Shade/W30	18	Pieces

Table 5.2 *On hand inventories.*

The inventory quantities are manually entered into eVSM, and standard material flow arrows are added, *see Figure* 5.16:

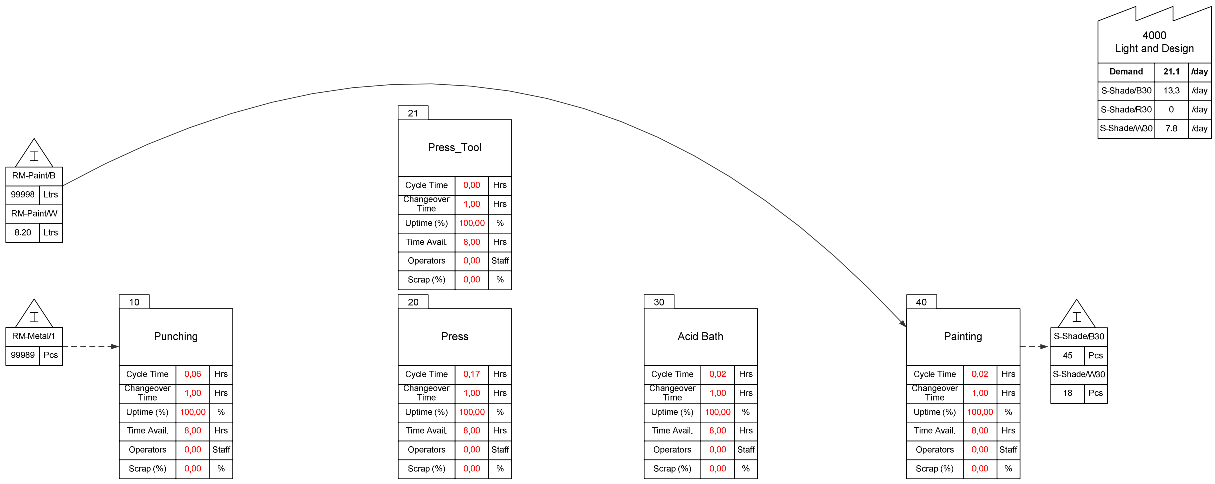

Figure 5.16 *Value stream map with AX and eVSM, 3.*

All items that are not situated in a warehouse at a given time are found in the *Balance* reports in the *Production* module.[96] The *Raw materials in process* report, which is found in the *Balance* reports, shows the quantity and value of all items that are being processed, along with the corresponding production order number. However, there is no information about at which specific process stage the items are currently located in this report. Instead, this information is accessible in the feedback section of the route of the ongoing production orders. By filtering the list of production orders to only include lines with the item number of the product we are mapping and status "started" we get an overview of the relevant production orders. In the feedback section of each of these production routes, it is indicated which operations are finished, and good as well as error quantities are specified for every finished operation. *Figure 5.17* shows the feedback section of a production route:

[96] Vest, T (2007-01-29)

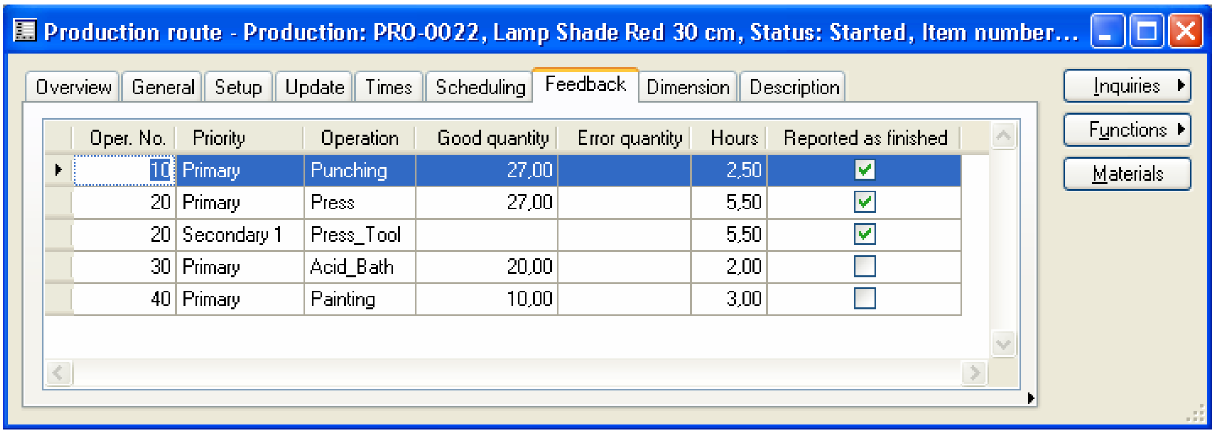

Figure 5.17 *Feed back from a production route.*

This way it is possible to find the levels of material between the different operation stages, by comparing the size of the production order with the good quantity that has come through each operation. If there are several production orders with status "started", the quantities in the feedback section of all orders must be totalled. Inventory shapes are placed between operations and the quantity of work in progress is manually entered in the NVU bars glued to them, *see Figure* 5.18:

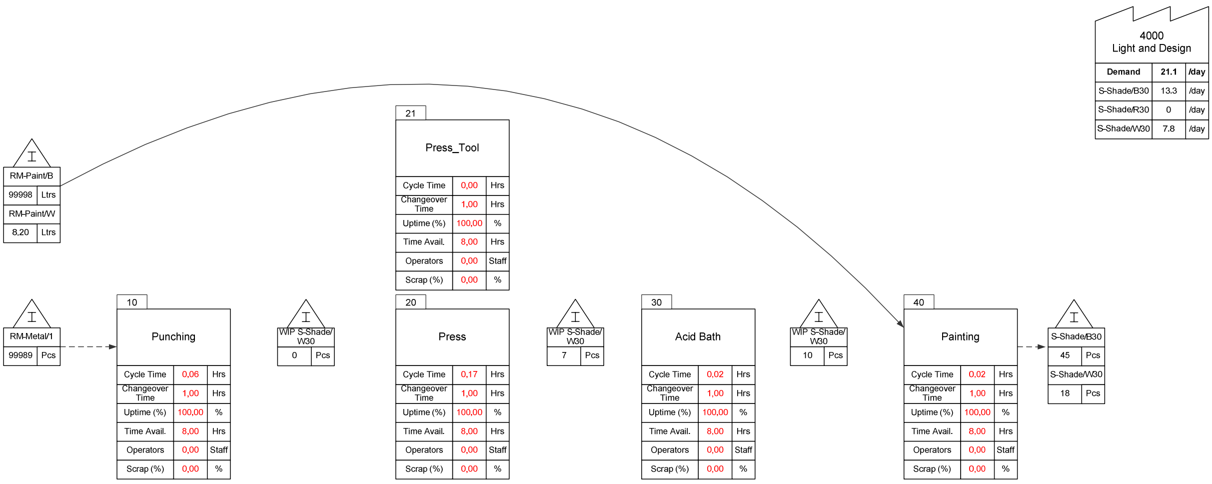

Figure 5.18 *Value stream map with AX and eVSM, 4.*

Inventory levels in quantities divided by the daily customer demand yields the level of inventory expressed as time. In order to find the customer demand of the different items in the BOM for our product, we need to know how many of each item which are needed to produce the final product. This information is found in BOM lines, *see Figure 5.19*:

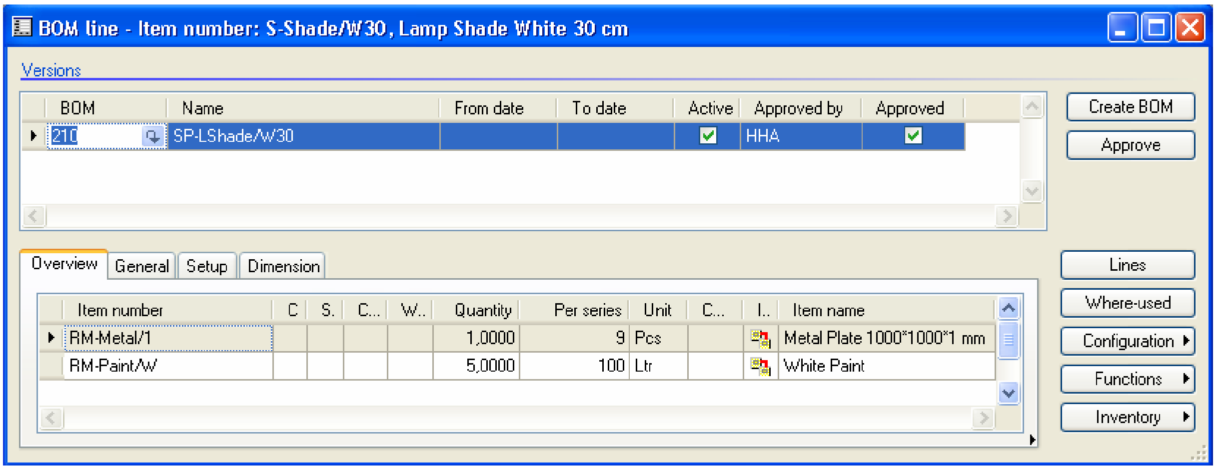

Figure 5.19 *BOM lines.*

As seen above, the required quantity of each item is specified per series. In this case, one piece of RM-Metal/1 is needed to produce nine S-Shade/W30 products. Five litres of RM-Paint/W is needed for 100 finished S-Shade/W30 products. The consumption of materials for one finished product is calculated by dividing the quantity by the series size. The customer demand for the items in the BOM is then calculated by multiplying the consumption for one finished product by the customer demand for the finished product. By copying the BOM lines table into the Excel spreadsheet, these calculations can be done, *see Table 5.3*:

Item number	Quantity	Per series	Per product	Unit	Demand/day
Final product:					
S-Shade/W30			1	Pcs	7,8
Items:					
RM-Metal/1	1	9	0,11	Pcs	0,87
RM-Paint/W	5	100	0,05	Ltr	0,39

Table 5.3 *Demand per raw material.*

Now the timeline line with value adding and non-value adding times can be placed on the map. In eVSM, the standard symbols VA (value adding) and NVA (non-value adding) make up the timeline line. Each segment has a yellow control handle that can be connected to the associated entity. VA segments can this way be connected to operations, and value adding times approximated as the operations' cycle times. Non-value adding times are equal to the inventory level expressed in time. *Table 5.4* summarizes the non-value adding times for the inventories:

Inventory	Item	Quantity	Unit	Demand/day	NVA time
1	RM-Paint/W	8,2	ltrs	0,39	21,03
2	RM-Metal/1	99989	pcs	0,87	114929,89
3	Punched metal	0	pcs	0,87	0,00
4	Pressed metal	7	pcs	0,87	8,05
5	Bathed metal	10	pcs	0,87	11,49
6	S-Shade/W30	18	pcs	7,8	2,31

Table 5.4 *Non value adding time.*

Figure 5.20 displays the eVSM value stream map with value adding and non-value adding times:

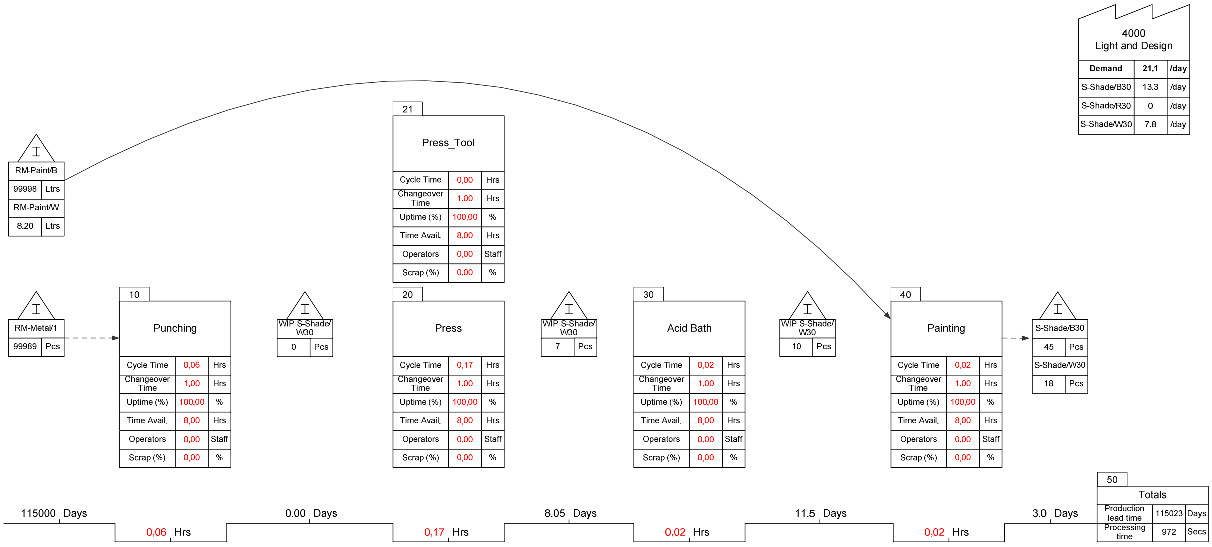

Figure 5.20 *Value stream map with AX and eVSM, 5.*

5.1.6 Inbound Deliveries

On the value stream map, arrows from vendors indicate inbound deliveries. These should be labelled with mode of delivery and delivery frequency. In AX, there is no explicit information about the frequency of deliveries for the different items.

In *Accounts payable*, the report *Purchase lines* lists all purchase orders in the system with ordered and delivered quantities. By looking at the orders that refer to the product in question which have delivered quantities, the frequency of inbound deliveries can be approximated by dividing the number of such orders with the time period between the first and last order. However, for Training Company, there were not enough purchase orders available to calculate the frequency of inbound deliveries this way.

An alternative way to approximate the frequency of inbound deliveries is this: For every item in *Inventory management*, inventory transactions are available. By filtering the transactions list to only include lines with receipt status “purchased” an overview of purchases is acquired. Volumes and physical dates of deliveries of the item are here specified, and a frequency can be estimated. However, there is no information about how many sales orders are delivered in the same delivery, or if several deliveries are required for a single sales order. For Training Company, there were neither enough transactions nor purchase orders available to calculate the frequency of inbound deliveries.

Vendor account numbers are specified for every transaction. In *Accounts payable*, all vendors are listed. Here we find information about vendor names and mode of delivery. Vendors are represented on the eVSM map as outside source shapes with the names identified in the *Accounts payable* module. Standard finished goods arrows indicate deliveries. Transport shapes are glued to the arrows. There is an array of different transport shapes that can be used to represent different delivery modes. Short NVU bars may be connected to the transport shapes for information about delivery frequency and size. The transport shapes can be tagged, so that this data can be transferred from Excel, similar to the operation fact boxes.

5.1.7 Outbound Deliveries

An arrow to the customer indicates outbound deliveries. This should be labelled with mode of delivery and delivery frequency. In AX, there is no explicit information about the frequency of deliveries for the different items.

In the *Accounts receivable* module, information about the company's customers is to be found. Also here, mode of delivery is specified. In *Accounts Receivable – Reports – Transactions – Sales order* a report called *Order lines* is available. This prints the all sales orders available in the system, with information about ordered as well as delivered quantities and dates, which can be used to base the delivery frequency calculations on. The report may be filtered to print orders for a specific item only. By dividing the number of lines which include a delivered quantity by the time period covered by the report, a frequency of deliveries is approximated. However, in Training Company, the number of sales orders available is not sufficient for calculating the delivery frequency.

Transactions for the finished product S-Shade/W30 are also available in *Inventory management*. Every line that refers to a sales order has a customer account specified. This way, we can find the names of the customers that buy the product we are mapping, and label the customer shape on the eVSM map correspondingly. In training company, all sales orders were from the same customer. It is also possible to approximate the frequency of outbound deliveries this way, by filtering the transactions lines to only include sales orders and dividing the number of deliveries by the time period from the first to the last order. The estimated dates for deliveries of the sales orders are available for each transaction under the *General* tab. However, there is no available information about how many deliveries a sales order requires, or how many sales orders that can be delivered at once.

In *Figure 5.21*, the value stream map with inbound and outbound deliveries is presented:

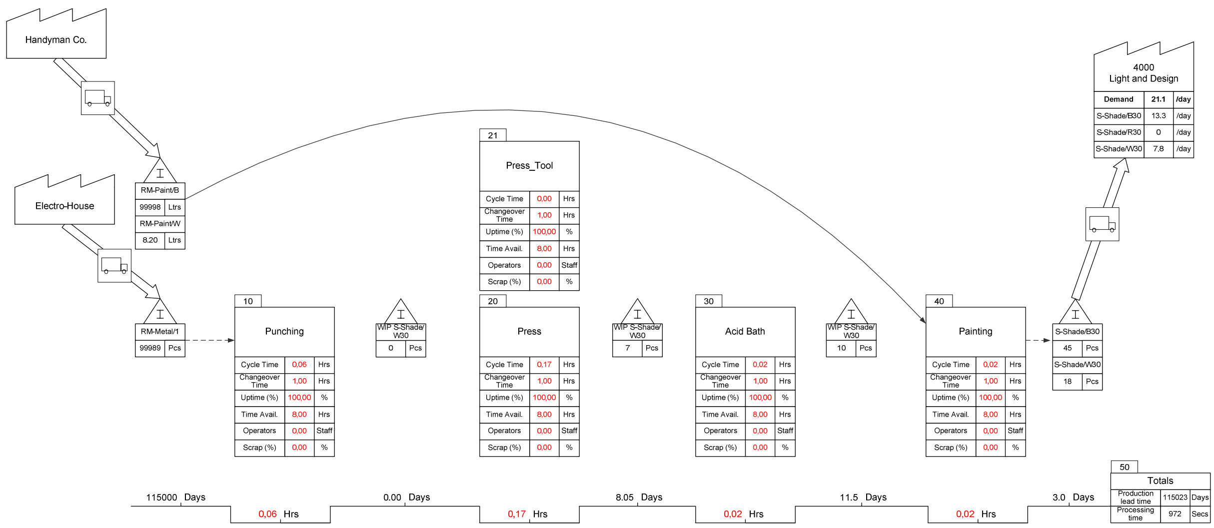

Figure 5.21 *Value stream map with AX and eVSM, 6.*

5.1.8 Information Flow

Next is to add information arrows to the map. Arrows for orders and forecasts from customers and suppliers are added as information flow arrows in eVSM. Depending on how the information is sent, arrows indicating paper or electronic information can be used in eVSM.

In AX, there is no mark indicating the origin of the information.[97] So, it is impossible to tell whether the information is sent electronically or on paper. The arrows should be fitted with a text box indicating order frequency.

In *Accounts receivable*, there is a list of all sales orders with dates and ordered and delivered quantities. By looking at every sales order for a product over a period of time, the frequency of orders for this product can be estimated by dividing the total number of orders (all lines where ordered quantity is specified) by the time period between the first and the last order. In Training Company, only two order lines were available, which is insufficient for a good approximation. Order frequency to the suppliers can be estimated in a similar way. In *Accounts payable*, the report *Purchase lines* prints all purchase orders that has been made. By dividing the number of orders (with ordered quantity specified) by the total time period, an estimate can be calculated. In Training Company though, not enough purchases of the two raw material items were available for this.

In *Inventory management*, it is possible to view historic sales and purchase forecast lines for every item, with dates and quantities of forecasts from customers and to suppliers. The same way order frequency was calculated, forecast frequencies can be calculated from this data. In Training Company, there were no forecasts for any of the items in question.

A standard eVSM process box is used for the representation of production control. AX is used for controlling production, so the process box is labelled accordingly. Since all operation stages are controlled, information arrows go from the production control to all operations. However this can only be seen as an approximation, because it is possible that manual adjustments are made on the shop-floor. Standard push arrows are then placed between operations. These indicate that the material is being pushed forward, as is the case when all operations are controlled by the master planning in AX. *Figure 5.22* shows the current state value stream map for the S-Shade product family in Training Company:

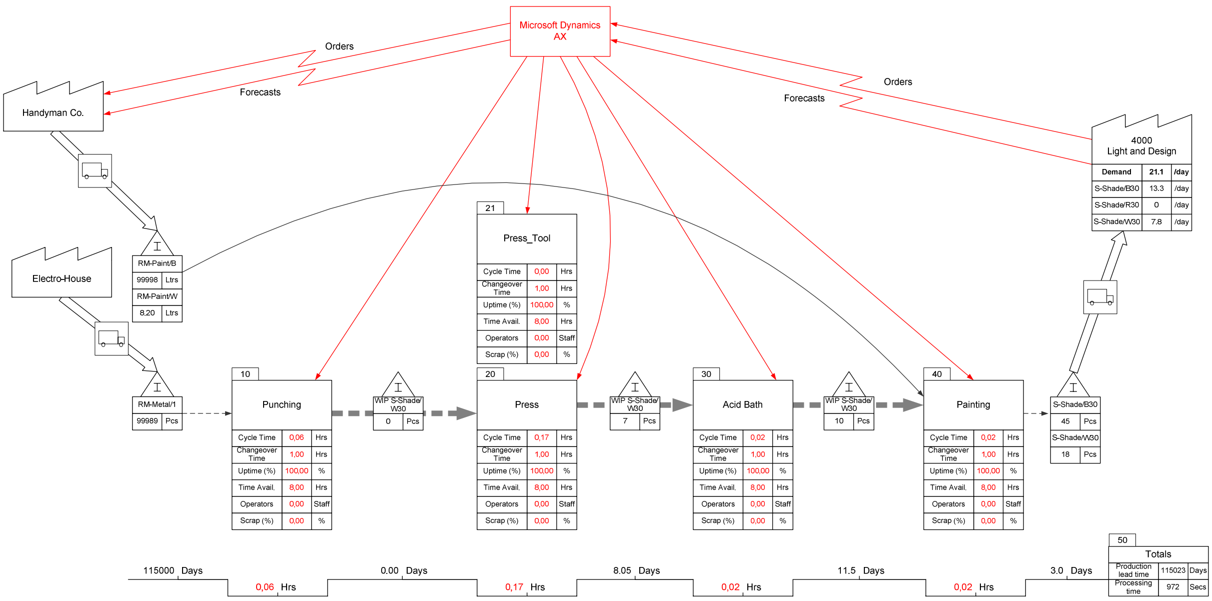

Figure 5.22 *Value stream map with AX and eVSM, 7.*

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Table 5.5 presents a summary of what data, which is necessary for creating a typical current state value stream map and a categorisation of whether this data can be identified in AX or not.

	Has to be entered externally	Exists in AX	Can be calculated	Can be approximated	Can approximately be calculated
Product family					
Strategic product family	X				
Technical product family		X			
Indication of what product family that has the greatest potential for improvements	X				
Customer					
Name of customer		X			
Customer demand					
Quantity/time unit					X
Product variations					X
Packaging demands	X				
Operations					
Sequence of operations		X			
Fact boxes					
Cycle time			X		
Changeover time		X			
Uptime				X	
Available time		X			
EPE Interval	X				
Number of operators		X			
Scrap		X			
Rework	X				
Inventories					
BOM information		X			
Inventory levels (quantity)			X		
Inventory levels (time)					X
Product specific quantity of inventory	X				
Inbound deliveries					
Frequency					X
Mode of Delivery		X			
Outbound deliveries					
Frequency					X
Mode of delivery		X			
Information flow					
Order frequency from customers					X
Forecast frequency from customers					X
Order frequency to vendors					X
Forecast frequency to vendors					X
Type of communication	X				
Communication flow from production control to operations				X	

Table 5.5 *Availability of typical current state value stream mapping data in AX.*

5.1.9 Future State VSM Information

In chapter 4.3.3 a description of how to create a future value stream map is presented. The fact that value stream mapping is a tool for continuous improvements means that a current state eventually might contain elements that in the theory are related to a typical future state. Therefore, typical future state elements are also searched for in AX, in order to visualize all possible current states.

Takt Time

The available time per day in seconds divided by the customer demand per working day in units is the takt time. In the previous chapter available time per day in hours and customer demand per day is identified. In eVSM, a units converter can be used to convert hours to seconds. It is used by the eVSM calculator when moving data to and from Excel. This way, the available time per day in seconds is calculated. It is now possible to find the takt time.

Supermarkets and Kanbans

Microsoft Dynamics AX does not give any information about if operations are linked or communicates with each other by the aid of Supermarkets or kanbans, it is therefore most likely to assume that it is the master planning that links different operations together.

Pacemaker

There is no way for Microsoft Dynamics AX to find out where a possible pacemaker is located. It is reasonable to assume that it is located close to the customer or in connection to a bottleneck operation.

Mixed Model Scheduling

Microsoft dynamics AX offers twelve different ways of job scheduling; these are all varieties of forward or backward scheduling. Forward scheduling gives the earliest possible starting and ending date, while backward scheduling gives the latest possible starting and ending date. This means that there are no options for mixed module scheduling unless you want to schedule manually.

In *Table 5.6* a summery of what typical future state data that is available in AX is presented.

	Has to be entered externally	Exists in AX	Can be calculated	Can be approximated	Can approximately be calculated
Takt time					X
Super markets	X				
Kanbans	X				
Pacemaker	X				
Mixed model scheduling	X				

Table 5.6 *Availability of typical future state value stream mapping data in AX.*

5.1.10 Other Value Stream Mapping Tools

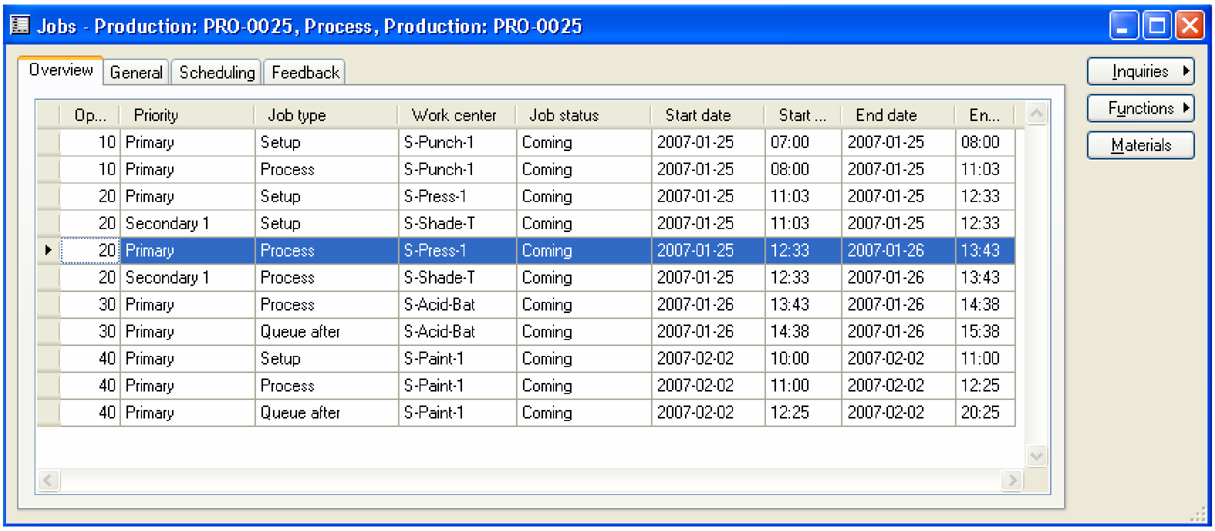
In this section, we examine Dynamics AX in relation to the additional value stream mapping tools presented in chapter four.

Process Activity Map

In order to create a process activity map, detailed information of each process step and a categorization such as operation, transportation, storage and delay for each process step is needed. In the production module the most detailed description of an operation is its jobs. Jobs are found by the production orders in the production module. The actual activity in each process step (such as unload truck) is not specified in jobs, but each job is categorized as one of the following: Queue before, setup, process, transport and queue after. In the process activity map, queue time before and after could represent the delay and store category, setup and process the operation category, and transportation is given, which means the only category in a process activity map that are not represented in jobs is inspection.

In routes information about times for these categories are available. As described in chapter 5.1.4 AX can give information regarding cycle and setup time for a process. In routes times for transportation also is available. The number of people involved in a job is found in the job's work center, as explained in chapter 5.1.4. The area where the job is performed is not indicated in the production route. Instead the work center can be used for an indication of the area. Transportation distances are not available.

In *Figure 5.23*, the job list for a production order of an S-Shade/W30 product is displayed.



Op...	Priority	Job type	Work center	Job status	Start date	Start ...	End date	En...
10	Primary	Setup	S-Punch-1	Coming	2007-01-25	07:00	2007-01-25	08:00
10	Primary	Process	S-Punch-1	Coming	2007-01-25	08:00	2007-01-25	11:03
20	Primary	Setup	S-Press-1	Coming	2007-01-25	11:03	2007-01-25	12:33
20	Secondary 1	Setup	S-Shade-T	Coming	2007-01-25	11:03	2007-01-25	12:33
20	Primary	Process	S-Press-1	Coming	2007-01-25	12:33	2007-01-26	13:43
20	Secondary 1	Process	S-Shade-T	Coming	2007-01-25	12:33	2007-01-26	13:43
30	Primary	Process	S-Acid-Bat	Coming	2007-01-26	13:43	2007-01-26	14:38
30	Primary	Queue after	S-Acid-Bat	Coming	2007-01-26	14:38	2007-01-26	15:38
40	Primary	Setup	S-Paint-1	Coming	2007-02-02	10:00	2007-02-02	11:00
40	Primary	Process	S-Paint-1	Coming	2007-02-02	11:00	2007-02-02	12:25
40	Primary	Queue after	S-Paint-1	Coming	2007-02-02	12:25	2007-02-02	20:25

Figure 5.23 *Jobs.*

For operation number 40 there are three jobs specified. *Table 5.7* is a process activity map for this operation, based on data from AX.

Step	Area	Dist (m)	Time (min)	People	Operation	Transportation	Inspect	Store	Delay	Notes
40	S-Paint-1		0	0	O					Job type: Setup
40	S-Paint-1		85	0	O					Job type: Process
40	S-Paint-1		480	0				S	D	Jobe type: Queue after

Table 5.7 *Process activity map based on data from AX.*

Quality Filter Map
As described in chapter 5.1.5 error quantities are specified in AX. The term “error quantities” is the same as what we describe as “scrap” in our frame of reference chapter. However, there is no way of identifying rework by the aid of AX.[98] This fact makes it impossible to calculate a first time through (FTT) value. Any graphical visualization instrument that shows where error quantities occur for a process route is not available in AX.

Demand Amplification Mapping
To get a periodic report of the demand, information has to be collected during a desired period each day at a specific time. The customer demand for a specific product that day can be found in inventory management at net requirements, by looking at the orders with a requirement date that equals that date. By filtering the production orders by item, information regarding the demand that day for each operation is found, by looking at scheduling times corresponding to the specific day. However, this way of evaluating the customer demand for an operation cannot take in to account whether or not new production orders will be scheduled that day. In accounts payable information regarding received inventories and their arrival is available, but not what BOM:s or production orders they belong to. AX does not provide any graphical instrument that visualizes the in-house demand for a specific period.

Decision Point Analysis
In the master-planning module there are different set up possibilities for the master plan. It is possible to include forecasts and quotations in the production planning and it is also possible to plan production from actual orders. If forecasts and quotations are included the decision point will be set at the end of the production flow, which means products are pushed down stream. By excluding forecasts and quotations the production plan will be based upon real sales orders, which set the decision point at the start of the production flow.

Overall Lead Time Map
Most elements included in an overall lead time map such as; order entry time, schedule assembly time, configuration time, procurement time and delivery time are not to found in AX. An element that can be found is manufacturing time. By localising the production order corresponding to the sales order in question, the start and end times can be noted, and the total manufacturing time calculated.

Spaghetti Diagram
AX cannot provide the detailed information regarding the flow needed in order to create a spaghetti diagram.

In *Table 5.8* a summary of the availability of data in AX that refers to other value stream mapping tools is presented.

[98] Vest, T (2007-02-28)

	Has to be entered externally	Exists in AX	Can be calculated	Can be approximated	Can approximately be calculated
Process activity map					
Process step information	X				
Operation time			X		
Transportation time		X			
Storage time		X			
Delay time		X			
Number of people		X			
Area				X	
Distance	X				
Quality filter map					
Scrap		X			
Rework	X				
Demand amplification mapping					
Customer demand			X		
Operation demand			X		
Product specific demand of raw material	X				
Decision point analysis					
Decision point		X			
Overall lead time map					
Order entry time	X				
Schedule assembly time	X				
Configuration time	X				
Procurement time	X				
Delivery time	X				
Manufacturing time		X			
Spaghetti diagram					
Detailed map of production flow	X				

Table 5.8 *Availability of data in AX, which refer to other value stream mapping tools.*

5.2 Value Stream Mapping with Dynamics AX at Note

In this chapter, a case study is performed. The purpose is to find out whether it is possible to find the data as explained in the previous chapter for mapping a real production situation, where the system is installed and running. The approach is to first find the relevant data from Dynamics AX and draw a value stream map for a chosen product, with no prior knowledge about the production. Next, an inspection of the production facility is undertaken and interviews with Note employees are conducted. This provides a basis for evaluation of the quality of the data explained in the previous chapter, and the overall accuracy of using Dynamics AX for value stream mapping.

5.2.1 Note

Note is an electronics manufacturing service company with production facilities in Scandinavia, Great Britain, the Baltic states and Poland. Close to its customers in Lund, Note offers development, prototypes and industrialisation of electronics components. The company uses Dynamics AX and has the ambition to implement lean production, two factors that motivate a case study at Note in Lund.

5.2.2 Product Family Analysis

A product family analysis may be conducted in order to define an appropriate group of products to map. As explained in chapter 5.1.1, routes define technical product families in Dynamics AX. For this mapping activity, route number K75-K09866004/NL was selected. This route is specific for the product with item number K75-K09866004, which is the product that we want to map.

5.2.3 Customer Demand

In the *Accounts receivable* module, an *Order lines* report with all sales orders available in the system for the product is printed. A total number of 64 sales order lines with specified order quantities and delivery dates ranging from 2005-01-05 to 2007-07-03 are found. These orders are distributed according to *Figure 5.24*:

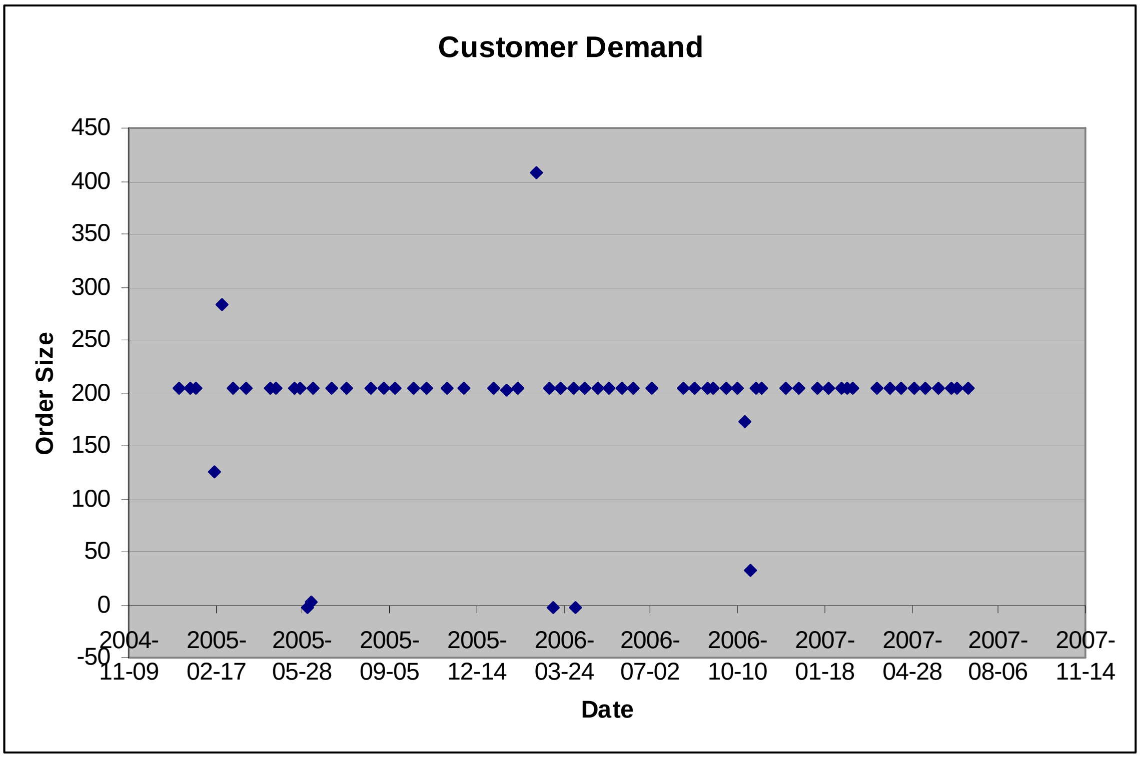


Figure 5.24 *Customer demand*

The majority of orders have the quantity 204 units. The rest are either of a quantity close to zero, a multiple of 204, or two consecutive orders which totals 204 or a multiple of 204. The average order size is 191 and the standard deviation is 62. In total, the customers ordered 12234 products during a period of 910 days. This means that the average demand per day is 13.4 products.

In order to find the customer demand per month, the sales order quantities for every month are summed. Based on all sales orders available, the monthly demand is presented in *Figure 5.25*:

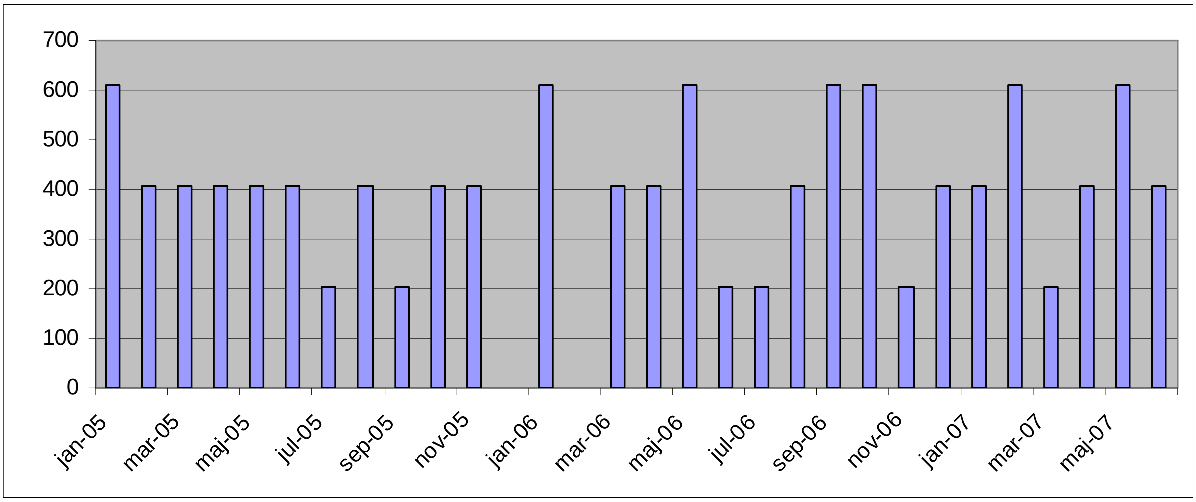


Figure 5.25 *Monthly customer demand*

The customer demand varies from zero to 612 products per month, with an average quantity of 387.5 products. The standard deviation is 172.3.

In order to find an average daily demand that can be used when calculating inventory levels in time or takt time, it must be investigated how many days during this time period that the factory is operating. In the calendar this information is available, but it is a time consuming task to find the working hours for every day in the calendar. Due to time limitations during the case study, this information was instead provided by Note employees. The factory is operating 50 weeks per year, five days per week. The following calculation gives the operating days:

*Number of days in the period / Number of days in a year * Number of operating weeks * Number of operating days in a week = Number of operating days for the period.*

910 / 365 * 50 * 5 = 623

This means that in average, the demand is 12234/623 = 19.6 units per day. This demand can be used when calculating non value adding inventory times and takt time.

In order to obtain the total demand for the past year, the *Item/Customer* report was printed. From this we learned that during the period 2006-02-01 to 2007-02-02, a total number of 4892 units were sold, of which all went to one customer: Gambro Lundia AB. According to this report, the average demand for the past year was 19.5 products per operating day. Also this figure can be used for calculating non-value adding times and takt time, since it is a daily demand based on actual working days.

So far, the customer demand has been based on historical transactions. In order to find the actual current demand, we look at the net requirements for our product in the *Inventory management* module. In *Table 5.9*, the net requirements for item number K75-K09866004, is displayed.

Reference	Number	Requirement date	Req. quantity
On-hand			703
Sales order	SO111235	2007-02-06	-204
Sales order	SO111235	2007-02-13	-204
Production	21270	2007-02-20	440
Sales order	SO111235	2007-02-20	-204

Table 5.9 *Customer demand based on net requirements*

At this moment (12:00 pm 2007-02-02), the current sales orders require a total of 612 products. This quantity will cover the customer demand for the next 18.5 days. This means that the current customer demand is 33 products per day.

This measure may be used to indicate the customer's demand on the value stream map, but it cannot be used for basing takt time and inventory time calculations on, since it does not take actual working days in consideration. Compensating for weekends, there are 12.5 days available for Note to produce this amount. Consequently, the current customer demand rate that can be used for calculating takt time and non value adding inventory time is 49 products per day.

In summary, there are a number of alternative ways to calculate a measure for the customer demand on the value stream map. The pros and cons of the different methods will be discussed further in the analysis chapter. On this value stream map we choose to base the customer demand on the net requirements (33 products per day).

According to the theory presented in chapter 4.3.2, we begin by putting the customer on the value stream map, see *Figure 5.26*:

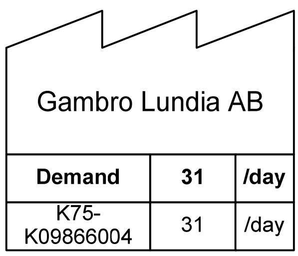


Figure 5.26 *Customer demand for Gambro Lundia AB.*

5.2.4 Operations

The route of item number K75-K09866004 carries the following information:

Oper. No.	Priority	Operation	Work centre	Run time	Setup time	Next	Hours/time	Queue time before	Queue time after	Qty. of work centres	Load	Accumulated	Scrap percentage	Process qty.
10	Primary	Utplock	LAGER GRP		42	11	0,0167			1	100	1	0	1
11	Primary	Prep	MONTERING	0,1		60	0,0167			1	100	1	0	1
60	Primary	THD mont	MONTERING	1,17		130	0,0167			1	100	1	0	1
130	Primary	Lackning	GRUPP 3	1	40	140	0,0167			1	100	1	0	1
140	Primary	Sluttest	GRUPP 3	1		150	0,0167			1	100	1	0	1
150	Primary	Packning	GRUPP 3	0,5		0	0,0167			1	100	1	0	1

Table 5.10 *Process information for product K75-K09866004.*

From this, the sequence of operations is apparent, so they can be drawn on the map as illustrated in *Figure 5.27*. The fact that every operation has its own unique operation number, and that all operations have priority “primary” tells us that there are no parallel operations.

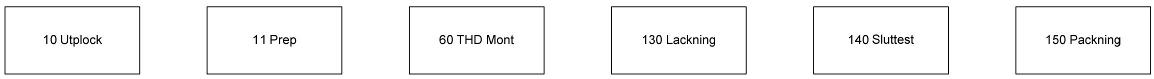


Figure 5.27 *Value stream map with AX and eVSM at Note, 1.*

5.2.5 Fact Boxes

Under each operation, a fact box should be positioned. Set-up times are directly available in the route, while cycle times can be calculated by dividing run times by process quantities. Hours/time = 0.0167 means that all times for this route are indicated in minutes. When applicable, information about queue and transit times is also presented in the route, but in this case there were no such times specified. Expected scrap percentages are also specified for each operation.

The work centers determine the operations’ available time, uptime percentages and number of operators. By following the instructions in chapter 5.1.4, this information was collected. Some work centers had employees working half time. We added the total number of employees in such a way that two half time employees equalled one full time employee.

What we so far know about Note’s production of the product is summarized in *Figure 5.28*:

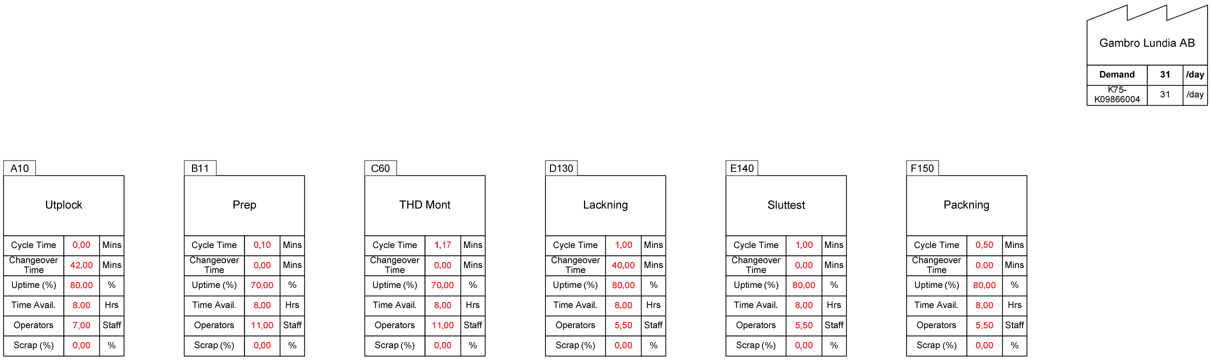


Figure 5.28 *Value stream map with AX and eVSM at Note, 2.*

5.2.6 Inventories

The product we are mapping is of type BOM with the ingoing materials:

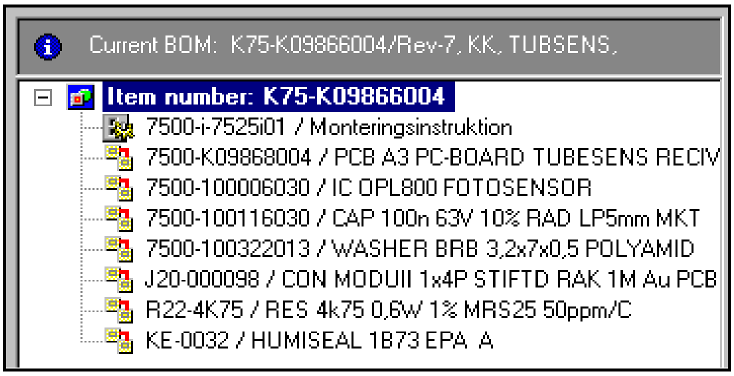


Figure 5.29 *BOM for product K75-K09866004*

Figure 5.29 is part of a screenshot from the BOM Designer for item number K75-K09866004. The BOM Designer also tells at which operation stages the different ingoing items are processed, and the amount of each ingoing material required for the construction of one finished product is specified in *BOM Lines*. This is summarized in *Table 5.11*:

Item number	Quantity	Unit	Operation
7500-i-7525i01	0	service	
7500-k09868004	1	pcs	10
7500-100006030	2	pcs	60
7500-100116030	1	pcs	60
7500-100322013	2	pcs	60
J20-000098	1	pcs	60
R22-4k75	2	pcs	60
KE-0032	3	ml	130

Table 5.11 *BOM design at Note.*

As explained in chapter 5.1.5, the on-hand quantities for the raw materials as well as finished products are available in the *Inventory management* module.

Item number	On-hand	Wharehouse
Raw materials:		
7500-i-7525i01	0	
7500-k09868004	1660	
7500-100006030	880	
7500-100116030	2419	
7500-100322013	12610	
J20-000098	1946	
R22-4k75	1034	
KE-0032	5880	
Finished product:		
K75-K09866004	703	

Table 5.12 *On hand quantities at Note.*

As seen in *Table 5.12*, it is not specified in which warehouse the items are situated. On the value stream map, however, all raw materials are placed on the left side of the operations and all finished items on the right. As illustrated in *Figure 5.30*, the raw materials are separated into different inventory symbols depending on the operations they are being processed in. This way the flow of material to the different operations is depicted. Next is to examine the inventory levels between operations. The report *Raw materials in process* is printed, and it shows no records of the product that we are mapping. When inspecting the production orders with status "started" we find that there are no orders for our product currently in production. This means there is no work in progress, so the inventory quantities between operations are zero.

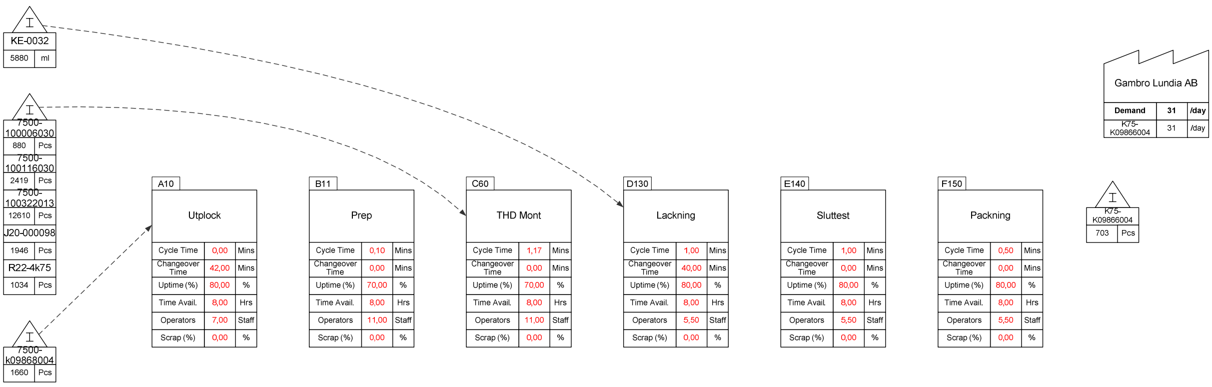


Figure 5.30 *Value stream map with AX and eVSM at Note, 3.*

5.2.7 Inbound Deliveries

All transactions for the all of the items (except for item number 7500-i-7525i01, which is an item of type service) were investigated, in order to find a measure of the frequency of inbound deliveries. It was calculated by dividing the number of transactions with receipt status "purchased" by the time period between the first and last transaction, *see Table 5.13*.

Item number	First	Last	Number of transactions	Deliveries/year
7500-k09868004	2005-03-14	2007-01-10	12	6,57
7500-100006030	2005-01-13	2007-01-25	40	19,68
7500-100116030	2005-03-15	2007-01-05	14	7,73
7500-100322013	2005-03-21	2006-04-05	12	11,53
J20-000098	2005-02-24	2007-01-08	18	9,62
R22-4k75	2005-01-20	2006-09-26	8	4,76
KE-0032	2005-03-15	2007-01-26	29	15,52

Table 5.13 *Inbound deliveries at Note.*

5.2.8 Outbound Deliveries

The frequency and quantities of outbound deliveries is found on the report *Order lines* that we previously used in order to find the customer demand. The report has a column “Delivered”, in which the delivered quantities are presented. The frequency of deliveries is calculated similarly to the frequency of historical orders, as described below in the section about information flow, but it is based on the “Delivered” column instead of the “Ordered” column. Since all lines with ordered quantity and delivered quantity were the same in all lines, the delivery frequency is equal to the order frequency.

5.2.9 Information Flow

There were no records of sales forecasts. The time between all available sales orders in the system is distributed according to *Figure 5.31*:

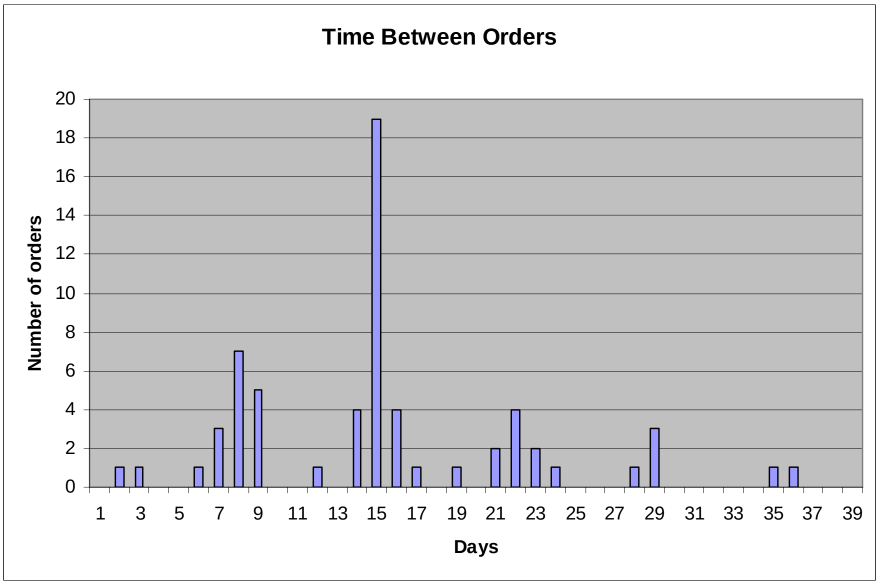


Figure 5.31*Number of orders in relation to time between orders at Note.*

The mean time between sales orders is 14.4 days with a standard deviation of 7.2, which means that in average orders are sent bi-weekly. The time period between order and delivery is not specified.

The frequency of purchase orders is estimated from the purchase transactions for the ingoing items.

We found no information on the frequency or lengths of neither forecasts nor orders sent to vendors. This far we have information sufficient for a value stream map with an appearance as illustrated in *Figure 5.32*:

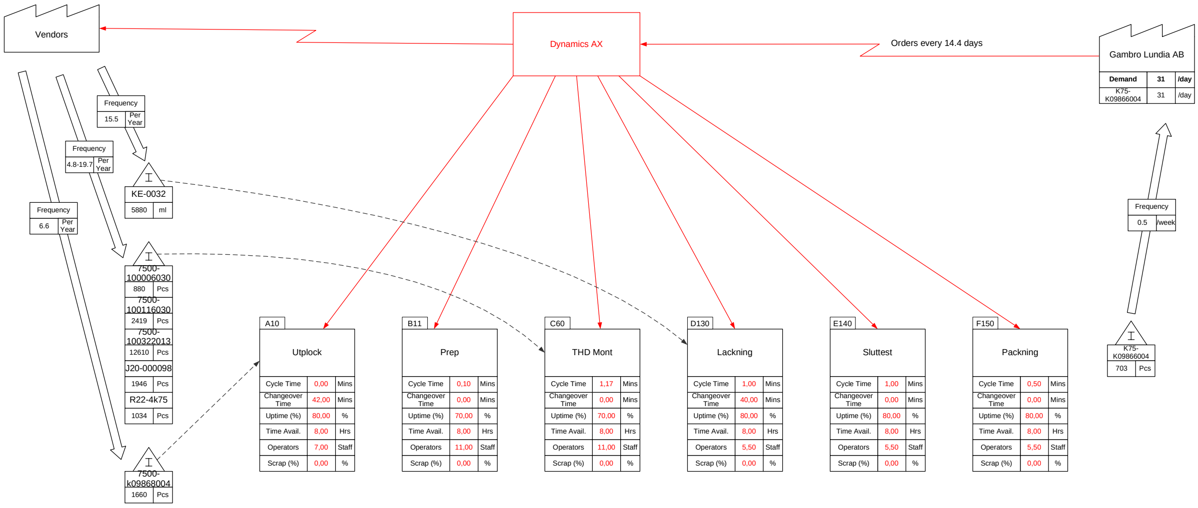


Figure 5.32 *Value stream map with AX and eVSM at Note, 4.*

5.3 Note's Production Layout

Our main purpose for this study originally was to create a value stream map, by walking the flow in the production department at Note, for the product we mapped in the previous chapter. Eventually this would result in two different maps; one based upon data from Microsoft Dynamics AX, and one made the classical way by walking the flow. Unfortunately this was not possible to be performed at Note. Instead we got a brief presentation about how the production for item K75-K09866004 usually is carried out.[99] Even if this did not give us the detailed value stream map we wished for, we still got an understanding of some of the data that would have existed in this map.

5.3.1 Customer demand

The customer demand was regular and set to 204 items every second week, with Gambro Lundia as the only customer. The sales orders with very small or negative quantities did not refer to actual sales; instead they were returns of products with defects or adjustments of order quantities.

5.3.2 Operations

Apart from the operations presented in the previous chapter an additional operation for surface assembling was placed, in-between operations 11 and 60. There were also additional operations for goods in and for warehousing that were not proclaimed in AX.

5.3.3 Fact boxes

Scrap that occurs in production is not entered into AX. The operators make quality controls and wait to report a job as finished until all articles have been processed and are of good quality. Operation number 140 has normally one operator and sometimes two, depending on work load.

5.3.4 Inventories

One safety stock for 204 finished items that was not visible in AX existed after operation 150.

[99] Jepsson, O (2007-02-02)

5.3.5 Information Flow

The customer sends forecasts for the forthcoming six months every month and the orders are sent three weeks before desired delivery date. When orders are placed, planned production orders are created by the MPS. A team leader for work centre “Grupp 3” releases scheduled orders which by the aid of the AX will trigger operation 10 to start production. From this operation the production flow is pushed. A team leader for the operation surface assembling will make daily adjustments of the schedule.

6 Analysis

In this chapter the empirical findings is analyzed in relation to the theoretical reference frame. This analysis serves as basis for the conclusions and the fulfillment of the purpose initially stated in this thesis.

6.1 Current State Value Stream Mapping

From most of the theories there is a clear message that value stream maps should be created by walking the production flow and by the aid of a pencil and a paper. The reason for making value stream maps by walking the flow makes sense. This approach will increase the probability of creating a realistic picture of the flow, and specific problems that cannot be generalized can be visualized. Instead of searching for specific data to use in the value stream map, walking the flow allows an infinite range of different data to use. For example in our method for creating a current state value stream map by the aid of AX and eVSM the cycle time of an operation is, in accordance with our frame of reference estimated as value adding time, but when walking the flow it may become obvious that only a part of this time actually is value adding.

From our frame of reference we also found that a value stream map should be made by the aid of a pencil and a paper and not by a computer, and the only explanation for this is that complicated gadgets that could interfere the mapping should be avoided. This is a sign of anti-computer bias according to us. Our opinion is that flows should be mapped in the least complicated and most reliable way to the person carrying out the mapping. Creating value stream maps by the aid of a pencil and paper, increases the risk of drawing symbols that can be hard to interpret. By using tools like eVSM, standardized symbols that look exactly the same independent of who has drawn the map are used. This will increase the common understanding of the map. If the one that is responsible for drawing the map finds it complicated to use a computer for visualizing flows, then it is probably better to do it manually.

Figure 6.1 represents our method for creating a current state value stream map by the aid of AX and eVSM. Data is transferred from the actual value stream, to AX and from AX to eVSM. The best picture presented is dependant on what data the AX user choose to put in the system. On our case study at Note we discovered that some of the data we looked for, such “error quantities” was not reported. In order to get a reliable picture of the actual flow, the AX users need to put in all relevant information into the system and frequently update this data. The activities for updating could be looked upon as non-value adding activities, from a lean perspective. The fact that data such as “error quantities” was not reported into the system could indicate that there are no routines for acknowledging quality problems. So even when walking the flow, this information could be difficult to collect.

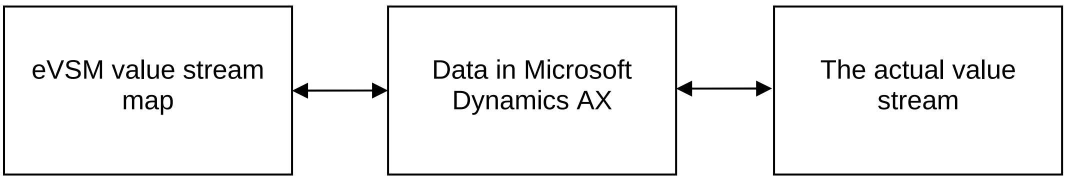


Figure 6.1 *Overview of our method for creating a current state value stream map.*

A value stream map made by AX and eVSM could have time saving potentials compared to making value stream maps by walking the flow, which could be a very time consuming task. Instead of walking the flow and successively collect data, AX offers most of the data from one single source. The time-saving potential could encourage making several current state value stream maps, before planning for the important future state map. Our opinion is that it should be questioned if it is an optimal solution to create a future state map based upon facts that relates to just one specific current state.

6.1.1 Product Families

A negative aspect of using data to organize products into different product families is that in AX strategic issues cannot be considered. Products in a strategic product family share the same characteristics in the sense of order winning and order qualifying criteria from the customers' viewpoint. The fact that AX is restricted of doing this strategic product family classification means that it is limited when it comes to the first lean principle "specify value".

Technical issues on the other hand, are easier to deal with. Products that go through the exact same sequence of operations in the production are organized into the same route, and they thereby belong to the same technical product family. Information regarding product varieties and lists of the operations required to produce every product variety is available, which could be used to organize products with similar routes into the same product family. However how to organize similarities in between different routes has to be done externally.

AX can not decide which product family that has the most to win, when using value stream mapping as a lean tool, like which product family that will have the highest reduction in lead time or inventory. Something though, not discussed in our theories that could be helpful when deciding what product families to start mapping, which is available in dynamics AX, is the ABC-classification of products. It would for example make sense to start mapping the product families containing the most A-classified products, because these products are appraised to be the most important to the company.

6.1.2 Customer Demand

From our frame of reference chapter we cannot identify an exact or general way for calculating the customer demand. This fact makes it hard to get a good value of the customer demand both when walking the flow and when using AX as a data source. An advantage of using AX in this case is that information regarding sales orders and demand is available in the system, when walking the flow this information has to be added from an external source, such as AX.

As explained in chapter 4.3.2, customer demand is a central element in a value stream map. It serves two purposes when value stream mapping. First, it displays the monthly quantity that the customer demands. Secondly, the customer demand per actual working day is used to calculate takt time and inventory levels expressed as time i.e. the non-value adding portions of the total lead time. The fact that customer demand is a deterministic value means that the actual demand has to be smooth in order to get reliable general values for lead time and takt time.

It is hence important with a correct measure of the customer demand and for this reason a number of methods for finding data about the customer demand have been presented. Some does not give the demand per month, as it according to the theory should be expressed. The reason why the demand should be expressed per month and no other time unit has not been clearly stated in the frame of reference. A reasonable assumption would be that demand is normally expressed per month and in order to avoid errors while mapping the traditional way, the same time unit is used.

Order Lines Report

By dividing the totalled ordered quantity in the order lines report with the number of days between the first and the last order, an average demand per day based on historical orders is achieved. The disadvantages of using this method include:

- Demand is not presented per month.
- Demand is based upon historical data and not actual demand.

We mean that the fact that customer demand is presented as daily requirements is of minor importance and the only real disadvantage for this is that it stands in contrast to the theory. This way of calculating customer demand is based on historical data and not upon actual sales orders, which opposes the way of calculating the demand from a lean perspective.

The advantage of using this method is that with direct access to the database, it would be a fast way to approximate the demand. This approximation can be based on a large amount of data which increases its reliability for a general value of the customer demand. When basing customer demand on just one single occasion, there might be a risk that it is not representative for a typical situation.

According to the theoretical reference frame, value stream mapping is a deterministic method which does not take variability into consideration. Also, value stream maps should be based on actual customer demand. This is however most likely a random variable. It could therefore be questioned if it is reliable to use a deterministic method by using the actual demand, which is a random variable, to create a general picture of the situation. In order to get a more general picture of the customer demand it could be useful to take variability data in to account.

Considering the amount of available data regarding the historical customer demand, variations could be acknowledged when basing the customer demand from data in AX. The data from our case study at Note showed that information regarding monthly variations in demand could be taken into account. These variations directly influence the total lead time, and it could be questioned whether variations in the lead time also should be acknowledged when visualizing the current state.

Item/Customer Statistics

At Note, we printed an *Item/Customer statistics* report with a summation of all orders for the product during the past year. When summing the order lines for that same time period in the *Order lines* report, we found that they totalled an equal amount. Consequently, the only new information for the value stream map obtained from the *Item/Customer statistics* is the name and account of the product's customers. This report is thus less appropriate than the *Order lines* report for finding the customer demand, since they are based on the same transactions and the *Order lines* report is more detailed. Still, it is useful for finding the customers that buy the product.

Net Requirements

The only information about the actual current demand for the product is the records in *Net requirements.* The advantage of basing the customer demand from this information is that it is not based on the historical demand. The disadvantage however, is that there is no way we can tell whether the current demand today is coherent with the typical demand for this product. For example, season variations in the demand are not visible this way. At Note, there were only three sales orders and no forecasts in *Net requirements*, which means there is little data for a reliable assessment of the true demand. Also, the demand should be expressed as a rate, and it is not obvious which time period that should be used to calculate this rate.

To sum up, there are different ways of calculating the customer demand. In AX, there is much information available for analysis of customer demand. We suggest further research about how the customer demand should be calculated in relation to value stream mapping in order to get a general and reliable picture of the current customer demand.

6.1.3 Operations

Regardless of the actual layout of the production facility, the operations on a value stream map are drawn from left to right, corresponding to the order in which the product occupies them. When mapping the traditional way, one must walk through the factory and follow the flow of the chosen product in order to get an overview of the sequence of operations. One advantage of using AX when value stream mapping is that the sequence of operations for a product is clearly visible in its respective route. This fact facilitates the drawing of the sequence of operations and saves time.

However, at the case study we identified some limitations with this approach. During the investigation of the production plant, we identified three operations that were not in the route in AX and the map would have had another appearance with these operations in place. These operations added non value adding as well as value adding time to the product.

6.1.4 Fact Boxes

An operation’s fact box should contain any relevant information needed to describe the operation. It is difficult to generalize what information is relevant, a fact that motivates the traditional way of making value stream maps. For instance, when walking the flow, it may be revealed that an operation has a very distinctive characteristic that should be noted in the fact box. When we used AX for value stream mapping, we first decided on a few typical data for each operation, which we later searched for in the system. At Note, we did not identify any operation data that we missed due to this approach, but the risk can still not be ignored.

One problem with using data from AX in order to describe the characteristics of the operations is that we have no knowledge of what these data are based upon. In order to get correct values in AX, a similar procedure for creating value stream maps has to be done when specifying the setup of the production route in the system. The relevance of the existing data in AX is dependant on how it was defined and measured, and its accuracy in relation to the method for creating value stream maps. In order to evaluate the relevance of data we found in AX at Note, external information is needed, such as an interview with the people responsible for setting up the route in AX.

The limitation of using efficiency percentage as an approximation for uptime is obvious. As long as the efficiency percentage is used for increasing the scheduled time (it is set to less than 100%) it is a reasonable approximation. This way the percentage will slow the process down, much like an uptime of less than 100%, and it can be used as uptime in the fact box of the operation. However, uptime can by definition not be greater than 100%, and when the efficiency percentage exceeds 100% it can no longer be used for expressing uptime on the value stream map. Furthermore, efficiency percentages reduce or increase both setup and processing times, while uptime is defined as a percentage of processing time. This limits the appropriateness of the approximation further.

Available time is defined as the working hours per shift minus time for breaks, meetings and tidying. In AX, the work center's calendar gives information about working hours per shift. For the current day at Note, the available time was eight hours. This time was divided into two blocks, with a 30 minute lunch break in between. There is no information about other breaks, meetings and tidying during the eight hours. If no such activities take place during the eight working hours, the working hours in the calendar is equal to the definition of available time.

One illustrating example of how the user habits influence AX's ability to provide ample data for value stream mapping is this: At Note, occurrences of scrap are usually not input in AX. Instead, the operators make quality controls and wait to report a job as finished until all products have been processed and are of good quality. This could explain why the expected scrap percentages in the route are zero. When using the data in AX about scrap for the value stream map, the true occurrences of scrap will not be visible.

According to the theory in chapter 4.3.2, the number of operators needed to run the process should be indicated in the fact box. The operations in the route of the product used work centers with 5.5 to 11 employees. Operation number 140 was assigned work center "Grupp 3" with 5.5 employees. According to Olof Jepsson, this operation normally required one operator, and sometimes two. So in this case, the method for finding out the number of operators needed to run an operation proved wrong.

6.1.5 Inventories

Information about the on-hand inventory quantities of finished goods and raw materials is available in AX. It is also specified in which warehouse the different items are situated, but when value stream mapping, this information is superfluous, since all raw materials are placed on the left side on the map and all finished items on the right side, independent of the actual position of the inventories. One problem with the inventory level of raw materials is this: If the same type of raw material is used in the production of several different products, the product specific fraction is not acknowledged with this method of value stream mapping. This means that the inventory level of raw material for the specific product that is being mapped will be too high, resulting in an error when calculating the total production lead time. However, when mapping the traditional way, this problem may still be an issue if all raw material items are in the same warehouse and not reserved for specific products.

In the empirical investigation of AX, two ways of finding the inventory levels between the operations were investigated. The *Balance* reports in the production module provide a quick overview of the total amount of work in progress, but lack the level of detail needed for a value stream map. Instead, the feedback sections of the production routes are providing the total amount of inventory between each operation.

As stated in the theory, inventory levels expressed as times make up the non value adding portions of the total lead time. Once the customer demand has been approximated, it can be used for expressing the inventory levels as times. Consequently, the total lead time calculation is also an approximation. One advantage of using Excel and eVSM for this purpose, especially for complex products with a large number of ingoing raw materials, is that the calculations of the rate of demand for each raw material can be done in the Excel spreadsheet and are this way facilitated.

6.1.6 Inbound Deliveries

Approximations of the inbound delivery frequency can not give a credible picture of the actual delivery frequency. The first method is based upon delivered sales orders. It is not possible to estimate if several orders are delivered in the same delivery or if one order needs many deliveries. The second method based on purchased orders brings the same problem as the first method, because it does not consider how the orders are delivered. This method is also based upon which orders that are actually purchased and orders delivered but not purchased are not included.

6.1.7 Outbound Deliveries

In the same way as the approximation of the frequency for inbound logistics gives an unreliable picture of the reality, the approximation for outbound logistics is untrustworthy. No information of how the transportations are arranged for the orders is given except for mode of delivery.

6.1.8 Information Flow

One advantage of visualizing the value stream with eVSM is the consistency of symbols which facilitates an overview of the flow. An example is that all red elements in the value stream map indicate information flow.

One advantage of using AX as source of data for value stream mapping is that there is data available for approximating how orders and forecasts are sent from customers and suppliers. The order lines report and the forecast lines carry information about how often orders and forecasts are sent and for what quantities. When mapping the traditional way, an external source of data is needed for this.

The information flow from production control and to operations is illustrated by arrows in eVSM. In AX, production orders are used for scheduling the operations. This means that all operations are centrally controlled and that information flows this way, even though the actual arrows can not be found in AX. At the case study, it showed that even though AX was used for scheduling production, daily adjustments were made manually by the operators. This information was not possible to find in AX.

In AX, it is not possible to see whether information is sent electronically or on paper. According to the theory, different arrows should be used for differentiating the type of information, and this can not be fulfilled when using AX as data source. However, we deem this factor not crucial when evaluating the potential for value stream mapping with AX as data source.

6.1.9 Future State

States that in our theory are related to future state maps could occur in a current state map as well. The fifth lean principle, “pursue perfection”, declares that perfection should be aimed at through continuous improvements. The fact that value stream mapping is a tool for continuous improvements even makes it likely that future conditions eventually will evolve into the current state maps if actions are taken to improve the original current states. This means that AX has to be able to identify conditions that in our frame of reference refer to a typical future state in order to be a useful tool for value stream mapping. However there are pretty few of these future state conditions that can be discovered by just analyzing data in AX. Information regarding supermarket, kanbans, pacemakers, and mixed model scheduling are examples of features that can not be found in AX, while data for calculating takt time is one of the few things related to the theory about a future state that can be found. This makes value stream mapping with AX a limited tool both when it comes to continuous improvements and to identify data that refers to a typical future state map, which means that the lean principles "pursue perfection" and "identify the value stream" can not be fulfilled.

The fact that AX can not identify data related to a typical future state map is due to that AX supports this way of controlling the production flow to a limited extent. This becomes obvious when studying an example of a typical current state map, *see Figure 4.8*, where the MRP controls the flow for each operation compared to a typical future state map where the flows often are controlled by aid of supermarkets and kanbans, etc, *see Figure 4.14.*

Hypothetically a typical current state value stream map could be created by the aid of data from AX and some external information. The question is how a potential user of AX would look upon an ERP system that can give information and support to a typical current state condition, but not much information or support to a future state condition that is desirable. There is a risk that AX offers a current state map, and based on this a future state map which opposes AX's existing way of controlling the flow is created.

These facts make it recommendable to add features that manage supermarkets, kanbans, pacemakers, and mixed model scheduling before considering a tool in AX that can be used for visualizing a value stream.

6.1.10 Other Value Stream Mapping Tools

Process Activity Map

Even though AX can provide different categories for jobs, it would require an unreasonable grade of detailed and updated level of the routes and jobs in AX. Our opinion is therefore that a process activity map should be made manually by detailed studies of processes where there are particular concerns.

Quality Filter Map

In order to get reliable information about good and error quantities, feedback regarding this has to be entered for each production order in AX. At Note no such feedback was entered, which inaccurately made it look like Note did not produce any error qualities. Reworks can not be identified by the aid of AX which means that a tool for quality filter mapping by AX would be limited to manage scrap and that it is not possible to calculate a first time through value. A graphical tool for visualizing the most troublesome quality areas would be a useful tool in AX, which could be used in order to pursue perfection by continuously aiming for further reductions of scrap.

Demand Amplification Mapping

Plant level information regarding the demand is available and can therefore be collected during a specific period in order to be used in a graph that visualizes the amplification. However information about what purchase demand that belongs to a specific product is hard to find out and is therefore difficult to visualize. The existing information could be useful for spotting inappropriate batch sizes and scheduling. Hopefully the master plan in AX administers the best possible and rational scheduling of operations, and will not be an issue. If this is not the case, the scheduling could oppose a lean way of scheduling (regularly and by the aid of small batches) and a demand amplification tool could therefore indicate that AX uses an inappropriate scheduling solution. Once again AX does not have a feature for mixed module scheduling, which would have been a useful element.

Decision Point Analysis

The master planning in AX only gives two possibilities of where to place the decision point. It is either placed at the production start or end point. This means it is not possible to plan the production by the aid of the master planning so that the decision point is placed in between the production start or end point. A decision point analysis by the aid of AX is therefore a limited tool. The theory says that the aim in lean production is to move the decision point as far upstream as possible, and this is feasible by letting the master planning trigger the production by actual sales orders, without considerations of quotations and forecasts. However each operation is planned simultaneously by the aid of the master plan. This means the planning of each operation is not pull oriented in the sense that a subsequent operations production determines the schedule of the former operation as the case is when using kanbans.

Overall Lead Time Map

Much of the information needed for constructing an overall lead time map can not be found in AX. The information that is available and useful for an overall lead time map is considered when constructing a value stream map. The lack of useful information for creating an overall lead time map and the fact that the useful information that can be found is considered when designing a value stream map, makes the overall lead time map a superfluous tool for AX compared to a value stream map.

Spaghetti Diagram

In order to construct a spaghetti diagram AX would need to provide far more detailed information regarding the physical flow. This means that a spaghetti diagram should be made manually in order to design a reliable map.

7 Conclusions

This final chapter is dedicated to present all conclusions drawn in this study. Based on the analyses carried out, the questions arisen with the initial purpose of the study will be answered. Finally, suggestions for further research are presented.

7.1 Value Stream Mapping with AX

It is possible to create some kind of typical current state value stream map by the aid of AX and eVSM. This is ascertained by the fact that during this study actual maps were created by the aid of data from AX and eVSM. Metrics required for value stream mapping were found to the extent that it was possible to create a typical current state value stream map. This means that AX has the potential to provide data for these metrics, but ultimately the existence and quality of the data is dependent on the AX users' habits. Some elements are not available in AX. The most serious data deficiencies are those regarding strategic product family analysis and product-specific inventory quantities. These data have to be added externally in order to achieve a realistic representation of the value stream. Other data have been approximated, and some approximations have been found questionable.

7.2 Advantages in Relation to Conventional Value Stream Mapping

Value stream mapping with AX could have time saving potentials because data is provided from one single source compared to walking the flow where data successively has to be collected manually. This fact could encourage making several current state value stream maps, which will form a better basis for the creation of the future state.

We have found eVSM a good tool for drawing maps, due to the clear pictures and symbols that have been visualized during this research. It is proclaimed that a value stream map should be drawn by the aid of a pencil and pen and not by the aid of a computer. This is according to us an anticomputer bias and we are by the opinion that a value stream map should be created in the least complicated and most reliable way to the one carrying out the mapping.

Walking the flow requires, in contrast to value stream mapping with AX, external sources for information regarding customer demand and order frequencies. Value stream mapping with AX is therefore a more efficient tool than traditional value stream mapping for handling these kinds of data.

7.3 Disadvantages in Relation to Conventional Value Stream Mapping

Our method of creating a value stream map by the aid of AX and eVSM is of a general character, because we are only searching for particular data to describe the value stream. Specific problems and descriptions of the flow risk therefore to be missed out.

Some of the approximations in our method for creating a value stream map with AX have to be questioned. For example the approximation for uptime does not equal the definition of what our frame of reference define as uptime.

The data available in AX is dependent on what the AX user chooses to put in the system. On our case study at Note, data regarding "error quantities" was not reported, which limits the reliability of AX as a tool for value stream mapping. On the other hand, it can not be taken for granted that this would be revealed by walking the flow either, because there might not be routines for such controls.

In order to get a realistic picture of the flow, data in AX has to be updated frequently. These updating activities could be looked upon as non value adding, from a lean perspective.

7.4 Value Stream Mapping with AX in Relation to the Lean Principles

Value stream mapping with AX is limited in relation to the lean principles; “specify value”, “identify the value stream” and “pursue perfection”.

AX is restricted when it comes to classification of products in to strategic product families, which organizes products into groups with the same order winning and order qualifying criteria from the customers view point. This fact means value stream mapping with AX is limited in relation to the first lean principle “specify value”.

AX can not identify data that refers to a typical future state map, such as supermarkets and kanbans, which makes value stream mapping with AX a limited tool when it comes to the second lean principle “identify the value stream”.

A future state can evolve into a current state and the fact that AX can not identify data that refers to a typical future state map means that value stream mapping with AX is restricted when it comes to continuous improvements. The last lean principle “pursue perfection” should be aimed at through continuous improvements and this is limited when creating a value stream map with data from AX.

7.5 AX in Relation to Future State Realization

AX supports the typical future state of controlling the production flow to a limited extent. The fact that AX can not identify data that is related to a typical future state map is due to that AX does not provide solutions for kanbans, supermarkets, pacemakers, mixed model scheduling etc. On the other hand AX can identify most of the data related to a typical current state, and manages this way of controlling the production flow.

7.6 Other Value Stream Mapping Tools with AX

Process activity mapping, decision point analysis, overall lead time map and spaghetti diagram are value stream mapping tools that can not be used properly just by the aid of the information in AX. These tools either need far more detailed or different information than existing in AX today in order to be useful.

A limited tool for creating a quality filter map could be formed by the aid of data in AX. Such a map could only display scrap, and information regarding reworks can not be found. A tool for quality filter mapping could be useful for visualizing troublesome quality areas and to pursue perfection by continuously aiming for scrap reductions in these areas.

A tool for demand amplification could be created from the information available in AX. This tool could be useful for spotting inappropriate batch sizes and scheduling. However such information could indicate that AX, in relation to the lean philosophy, uses an inappropriate scheduling solution. It is therefore recommendable to add a feature for mixed model scheduling, which supports the lean way of scheduling, before considering a tool for demand amplification mapping.

7.7 Suggestions for Further Research

Research regarding how to organize products into strategic product families would be of use to AX. This way AX can identify what is valuable from the customer view point, and thereby better fulfill the first lean principle.

Even though the theory of value stream mapping proposes a deterministic value for customer demand based upon actual sales orders, we suggest further research about how the available data in AX about customer demand can be used in order to calculate a demand that is more detailed and accurate for describing a general picture of a current situation. This could involve variability data which would affect the total lead time.

In order to get a proper value for the total lead time, it is of importance to see how much of the raw materials that is dedicated for a specific product or product family. We therefore suggest research regarding functionality for this in AX.

Before considering AX as a tool for visualizing current state value stream maps, research regarding how features that manage the typical future state flow could function in AX is recommended. These features include: Supermarkets, kanbans, pacemakers, and mixed model scheduling. Otherwise there might be a risk that an AX user designs a future state map, based upon a typical current state map visualized by the aid of AX, which opposes the way AX controls the production flow. Research in these areas could strengthen AX in relation to the lean principles “identify the value stream” and “pursue perfection”.

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