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Mapping of relations and dependencies using DSM/DMM-analysis

Casting mold manufacturing at Husqvarna

Bachelor's thesis within Management

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Abstract

Background Husqvarna is a Swedish company producing products for forestry, park and gardens. Due to harder competition they wish to increase efficacy in production. This can be achieved by shorter lead-times in the complex process of making casting molds. Activities within this process have certain relations and dependencies between each other that can be analyzed by using a Dependence Structure Matrix. The Dependence Structure Matrix is a tool that can improve efficiency by rearranging activities according to how they are dependent of each other.

Purpose: The purpose is to make a Dependence Structure Matrix of activities that Husqvarna can use to analyze dependencies within the process of cast molding. The DSM Matrix will propose restructured activities of the process which can be evaluated to determine if greater efficacy can be reached.

Method: To determine the activities within the process of making cast molds a workshop at Husqvarna for the people involved was conducted. A matrix has been constructed based on the information of activities and their dependencies. This information has then been analyzed by the software Multiplan.

Conclusion: The process of making casting molds could be analyzed by the DSM/DMM approach. A new order of how to carry out activities is the outcome of the analysis. The result can be analyzed by Husqvarna in order to determine if greater efficacy can be reached.

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1 Introduction

This chapter presents the background and gives a problem discussion that ends in the purpose of the thesis.

1.1 Background

Development of components or parts for outdoor products is often a complicated task carried out in complex projects. The traditional way to product development projects have been to organize tasks sequentially and to corresponding corporate function. This way of organizing does not always correspond to the efficacy that companies are seeking when handling complex projects (Engwall, 1995). Sahlin-Andersson and Söderholm (2002) adds another dimension of difficulties by pointing out that that projects are often described when the context is stable and resources readily available. In the real life however, resources are commonly scarce and the context or environment of the project can be everything but stable. Ideal conditions for management are seldom found in practice and the "whole picture" needs to be understood in a complex project rather than isolating elements of a single project.

Engwall (1995) and Kreiner (1995) points out that projects are not isolated islands, independent of outside events. The situation with projects being dependent on outside events and interdependencies over project boarders can be described as a multi-project environment (Danilovic, 1999) which calls for information sharing efforts among projects (Sahlin-Andersson & Söderholm, 2002). Working in a multi-project environment is common for companies nowadays, especially in product development. Payne (1995) estimates that up to 90 percent of all projects are carried out in a multi-project context. Grey (1997) sees the multi-project environment as a nominal umbrella grouping mainly of projects by reason of interdependencies among projects. Danilovic & Sandkull (2005) describes the multi-project situation as projects that runs concurrently, sequenced, or overlapped, which creates a vast demand for information exchange between people, customers and suppliers due to complexity and lack of resources. The activities conducted in such an environment must be coordinated between individuals, organizations and the projects since information and cooperation needs to be carried out over the project boarders.

Danilovic and Börjesson (2001a) state that an enhanced approach to meet changing demands and environments is desirable to gain competitive advantages in terms of shorter lead-time, better quality and lower cost. An enhanced approach different from the traditional way of product development according to them is one handling the different dimensions in a multi-project environment; the *Design Structure Matrix* (DSM) and *Domain Mapping Matrix* (DMM). The DSM and DMM can handle the dynamics a multi-project environment.

The approach is used in order to represent and analyze dependencies and relations between elements in multi-projects (Danilovic & Sandkull, 2005). DSM and DMM are similar approaches but handles different dimensions of the multi-project environment. The difference between them is that DMM can handle more types of elements at the same time, while DSM handles a single type of element in the multi-project environment. An element can be explained as the people within a project or the activities that need to be completed in a project as an example. This means that the DSM can analyze dependencies and relations between a single element like *people* while the DMM can analyze dependencies and relations between *people* and *activities* giving the DMM two dimensions. Several authors and researchers including Browning (2001), Danilovic (2005), McCormick, Schweitzer & White (1970) and Merwe (1997) motivates that the DSM and DMM approach is one of the better ways to increase efficacy in a multi-project environment. The original research within Design Structure Matrix was introduced by Don Steward in 1967 while the Domain Mapping Matrix was first introduced by Mike Danilovic (2001).

1.2 Problem

Husqvarna is a Swedish company working actively with product development. One part of the product development work at Husqvarna is the making of molds that later will be used to cast light metal parts of the final product. Due to harder competition from low-wage countries they need to raise the efficacy in present production if they want to keep it locally in Huskvarna which is of interest since the location is where the company was founded and has its deepest roots.

The work of making casting molds is time consuming and there is a whish to shorten lead times. Husqvarna estimates that they will have a substantial competitive advantage on the global market if they can shorten the lead time for the mold from 14 to 10 weeks.

The casting mold department works in a multi-project environment. By examine the multi-project environment, dependencies and relations can be discovered and analyzed, providing a visualization of the casting mold process. With the visualization a greater understanding of the process can be obtained and help managers reach higher efficacy and shorter lead times.

1.3 Purpose

The purpose is to examine dependencies within the process of cast molding at Husqvarna and by a DSM analysis propose a restructuring of the process which can be evaluated by Husqvarna to determine if greater efficacy can be reached.

1.4 Disposition

Chapter	Headline	Content
1	Introduction	*This chapter describes the background, the problem statement, the purpose and meaning of the thesis, and the disposition of this paper.*
2	Husqvarna	*Gives a short description about the company Husqvarna, the company were the survey is being conducted.*
3	Frame of Reference	*Since this particular area of science is rather unexploited the purpose of this chapter is to explain what a DSM and DMM are. The chapter also provides the history of the two matrices and the benefits with using them in a multi-project environment. The last part is a description of the software program Multiplan.*
4	Method	*The method chapter explains the methodology used and the way that the study was preformed. It also describes the selected approach.*
5	Empirical Findings	*This chapter is mainly information given in the group interview and in-depth interviews by the respondents on Husqvarna.*
6	Analysis	*In the analysis chapter the focus is on the results of the workshop and the analysis of the information. The results are connected with the frame of reference.*
7	Conclusions	*This chapter examines if the purpose of the thesis is fulfilled and presents the result of using the matrices. The last part gives a suggestion to how Husqvarna can change the production to be more efficient.*
8	Discussion	*This chapter presents the benefit of this thesis and some methodological criticism. The chapter ends with recommendations on continuing studies on this subject.*

2 Husqvarna

Chapter 2 gives a historical description of the company Husqvarna and how they make their products.

2.1 The Company

Husqvarna was founded in Sweden as a weapon factory in 1689 and is now one of the world's oldest industrial companies. Today they are a world leader in forestry, park and garden products commonly referred to as outdoor products. Other products produced by the company today or in the past are guns, sewing machines and motorcycles. The outdoor product range is extensive and contains professional machines to products for demanding consumers as chain saws, brush and grass cutters, hedge trimmers, lawn mowers, special products for lawn care, ride-on mowers, garden tractors as well as accessories and protective equipment. Husqvarna's product development has been conducted in close cooperation with professional users. Therefore the products are designed based on strict professional demands for reliability, performance and user-friendliness. The products are manufactured in many different locations (Husqvarna, 2005a).

The company is working in a multi-project environment where activities, people and resources overlap and are shared over project boarders (K. Holmqvist, Personal communication, 2005-04-12).

The head office is located in Huskvarna, Sweden, where approximately 1,800 of a total of 2,200 employees work in the areas of high-technology research, product development, production and marketing. They are represented in more than 100 countries with around 18 000 dealers around the world. Husqvarna is a member of the Electrolux group since 1977. Sales in total are approximately five billion Swedish Crowns, with 95% of the products exported (Husqvarna, 2005a).

2.2 Casting molds

At the factory in Huskvarna chain saws and trimmers are assembled from parts produced both locally and from external factories. The parts that are manufactured locally in Huskvarna are made out of light metal, a process of casting the metal into the right shape by pouring it into molds. The majority of those parts are cylinders, flywheels and crankcases for chains saws and brush/grass cutters. Making the molds is a time consuming activity and often demands the hand of a skilled worker even though most of the work is done by computers and unmanned machines. The casting molds are made by a special tool making division, which will refer to the creation of the casting molds whenever mentioned through out the rest of this paper. The casting mold itself consists of several pieces that need to be assembled or made in several steps. At the factory in Huskvarna there are around 20 people actively working with the creation of casting molds in a multi-project environment (K. Holmqvist, Personal communication, 2005-04-12). Figure 2-1 illustrates the different components of the casting mold.

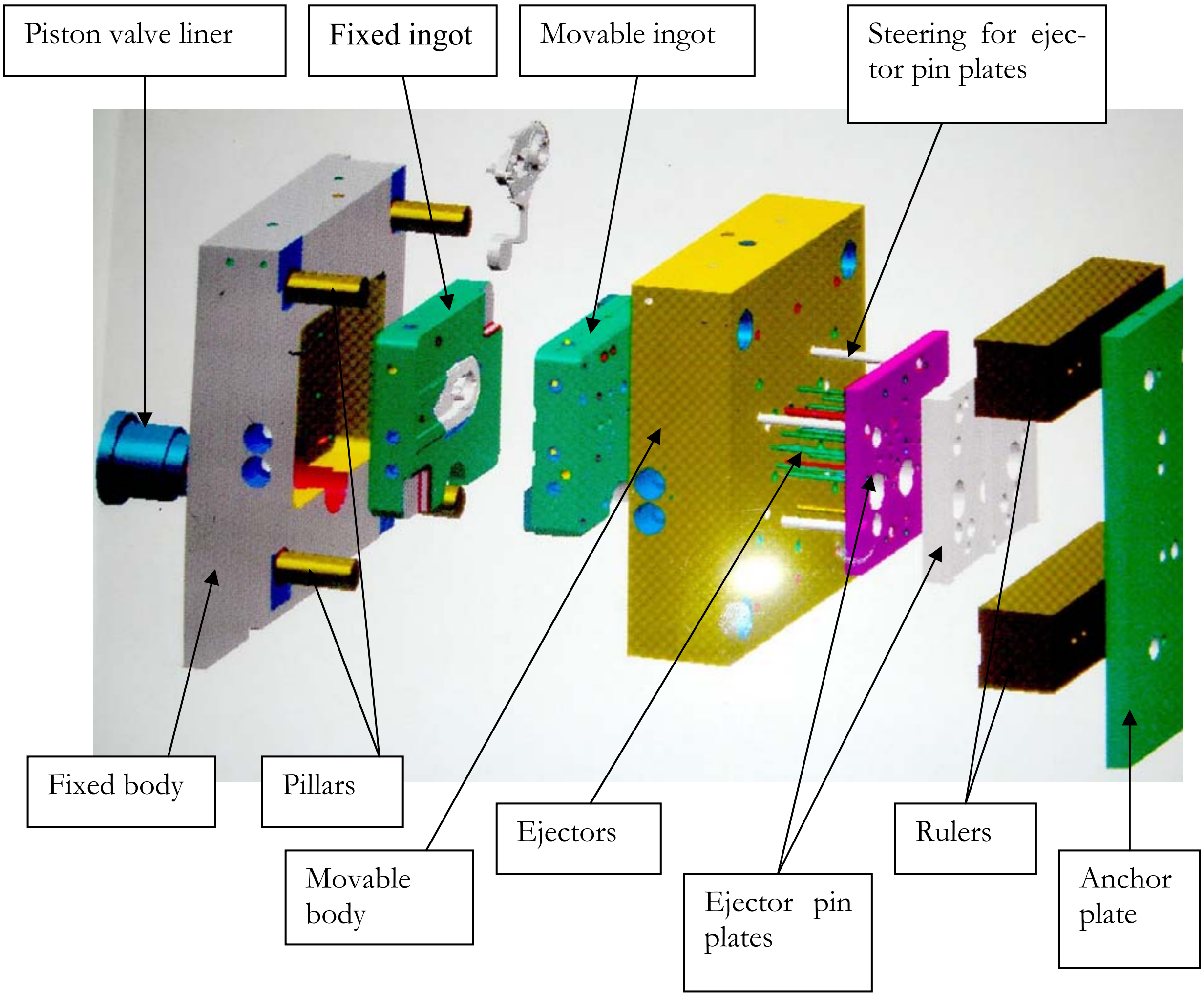

Figure 2-1 *The components of the casting mold*

3 Frame of reference

The theoretical framework clarifies how the two matrices DSM and DMM work. The last part explains the software program used.

3.1 Design Structure Matrix

There are many types of matrices but they all share the basic structure of a rectangular scheme of elements set out by rows and columns. The Design Structure Matrix, (DSM), (also known as The Dependency Structure Matrix, The Problem Solving Matrix (PSM) or the Design Precedence Matrix (www.dsmweb.org)) is a tool for visualizing relations and dependencies within a certain activity (Danilovic & Börjesson, 2001). The matrix is useful in almost any kind of project whether it involves tasks and activities, components and sub-systems or people in teams. Tasks, activities, product architectures and people are all examples of domains and a DSM examines domains by determining the relationships among the elements within that domain (Danilovic & Sigemyr, 2003). The visualization of relationships among the elements (components, activities, people etc.) in a project can easily determine iterations in the design of the process. **Iteration** is a loop of information (or material), a form of feed-back that works upstream forcing refinement in a previous activity. Consider the following: A certain component is created by going through three processes, A, B and C. These are carried out in sequence. However the extent of detail in A can only be roughly estimated without a more specific agenda which can be realized once the component has reached C. The process in A is despite this carried out in its simplest form before it continues on to B. Once the component has reached C the component will be sent back to process A along with the changes that must be made. The entire process starts over but this time with the "correct" agenda. As a result, work will be performed twice in the activities flanked by the nodes of the "loop" (in this example all of the activities) (figure 3-3). Depending on the use of it, the DSM matrix will minimize the number of these iterations by a restructuring of the process design or more correctly provide a new process design with fewer and faster iterations (Browning, 1998). This is essential for cycle time reduction, a major barrier in improving the efficacy for many manufacturing corporations. The effects of iterations dominate activities concerning the development of semiconductors at Intel for example. 13% to 70% of the total development time corresponds to iterations in different processes (Browning, 1998).

In order to visualize the dependencies the matrix must first be constructed. Briefly explained the elements in a project are plotted along the x-axis and again along the y-axis (both by rows and columns) the matrix will as a result always be represented in the form of a square (NxN) with each row intersecting its corresponding column along the diagonal of the matrix. A relationship is indicated by manually marking the intersection of a row with the column (www.dsmweb.org). A quick scan down a column or across a row will determine the nature of the relationships whether they are parallel relationships (concurrent), sequential relationships (dependent) and coupled relationships (interdependent) (www.dsmweb.org). Sequential relationships imply that activities must be carried out in sequence, that the output of one activity is required for the next. A must come before B, or B is dependent of A, see figure 3-1.

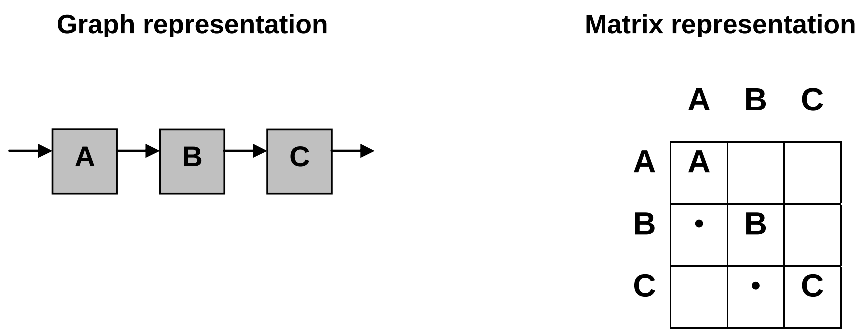

Figure 3-1 *Sequential relationship (Dependent)*

If activities are not dependent of each other they are independent and can be carried out parallel to each other. In a matrix there would not be any marks to indicate dependencies. See figure 3-2.

Figure 3-2 *Parallel relationships (Concurrent)*

The complexity in a process transpires when activities become interdependent. C is dependent on the output of B and B is dependent on the output of A but A requires information from C. This is a clear example of iteration from C to A. See figure 3-3.

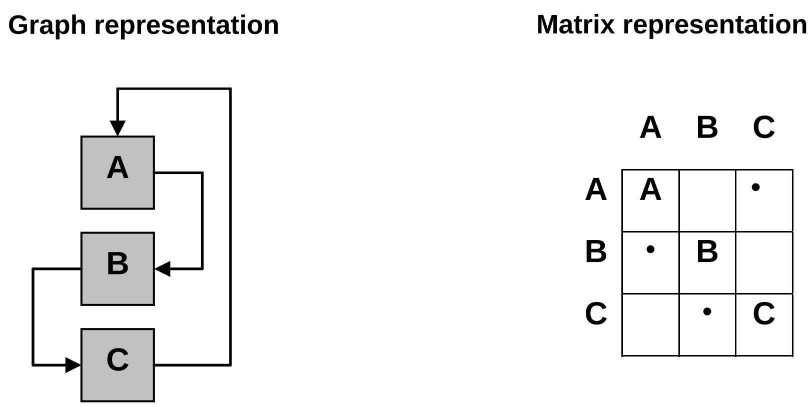

Figure 3-3 *Coupled relationships (Interdependent)*

Since a DSM use manual input it is essential that the information is relevant and correctly represented. Incorrect information will render the matrix obsolete. The quality of the result provided by the matrix is to a large extent dependent on the information provided by individuals involved in a project (Danilovic & Börjesson, 2001b). The common approach to making a DSM analysis is firstly to define the system that will be analyzed in the matrix. All elements related to the system must be recognized and listed. The flow of information between them must also be determined. This is accomplished by examining or studying the process or system but also by conducting interviews with managers and engineers with experience or insight in the system or process. The components, tasks, parameters or people that are relevant to the analysis must be sorted out and listed. Further interviews are conducted to attain more precise information about the information flow. The matrix can be constructed and marks representing interactions is entered. The managers and engineers verify the representation before it is processed and can be used (Danilovic & Börjesson, 2001b).

After having constructed the matrix it has to be analyzed. There are two different types of algorithms that perform the analysis, namely a partitioning algorithm and a clustering algorithm. There are also different kinds of DSMs that suits different needs. Activity- and parameter-based DSMs use the partitioning algorithm while component- and people-based DSMs use the clustering algorithm to conduct the analysis.

3.1.1 Partitioning

The removal of iterations is referred to as sequencing or partitioning. The matrix is divided in two sections by a diagonal line (each element intersecting itself). Every mark in the upper triangle symbolizes iterations (See figure 3-4). The DSM rearranges the order in which tasks are carried out to move these marks to the lower triangle (www.dsmweb.org). In figure 3-4 the left matrix illustrate a fabricated process with its dependencies. It also gives the order of when the tasks are issued. A is the first task in the process, G is the last. This arrangement of activities has six iterations, the largest spanning from G to B. The right matrix provides the optimal solution obtained through a partitioning algorithm. By rearranging the order of tasks (F-B-D-G-C-A-E) only two minor iterations remain.

	A	**B**	**C**	**D**	**E**	**F**	**G**
A	A		•	•			
B		B					•
C	•	•	C			•	•
D		•		D			
E			•		E	•	
F						F	
G				•		•	G

	F	**B**	**D**	**G**	**C**	**A**	**E**
F	F						
B		B		•			
D		•	D				
G	•		•	G			
C	•	•		•	C	•	
A			•		•	A	
E	•				•		E

Figure 3-4 *Example of partitioning (www.dsmweb.org)*

Partitioning a DSM aims at finding the optimal order of activities. To do so the first thing is to understand what components the project consists of. After this you list all of the activities that make up each component. When this is done one can start looking on who does what and what time the activity takes (duration). The time each worker spends on an activity must also be anticipated i.e. the workload (Danilovic, personal communication: 2005-04-05).

3.1.1.1 Activity-based DSM

Sequencing or partitioning is a method used mainly for task based (activity-based) and parameter based DSMs. These are two different uses of the DSM but they are similar in nature. They both aim at reducing process duration and are therefore said to be time-based (Browning, 2001).

The activity-based DSM provides a brief visual format for understanding and analyzes issues regarding rework in a project. Because activity-based DSM is time-based it is particularly useful to point out iteration and coupled activities in the design process. An input/output relationship between activities is firstly described showing the dependency structure of a process. In the next step a remodeled DSM can give guidance to an improved process architecture where unintentional iterations can be minimized (Browning, 2001).

3.1.1.2 Parameter-based DSM

The parameter-based DSM is very similar to the activity-based DSM. Instead of minimizing unintentional iterations it focus on reduced process duration. To increase performance they provide a brief and visual description of interactions between low-level design activities or tools. The description can be used to point out interface improvement opportunities and to structure integrated contextual activities (Browning, 2001).

3.1.2 Clustering

A different method of analysis is by grouping elements that have the most interaction into modules along the diagonal. These modules consist of both sequential relationships and iterations. Tasks that share the most information should be carried out in close proximity; this method is known as clustering (figure 3-3) (www.dsmweb.org). The aim of clustering is significantly different from partitioning, the objective is to increase iterations within the modules but remove any iteration between the modules (Browning, 2001). Clustering is useful when dealing with representation of design components or in shaping project development teams (www.dsmweb.org). Areas between clusters may also contain dependencies. These areas are referred to as the interface between clusters. Dependencies in the interface share information to at least two clusters and must be carefully coordinated. They are the links between the modules (Danilovic, 2001).

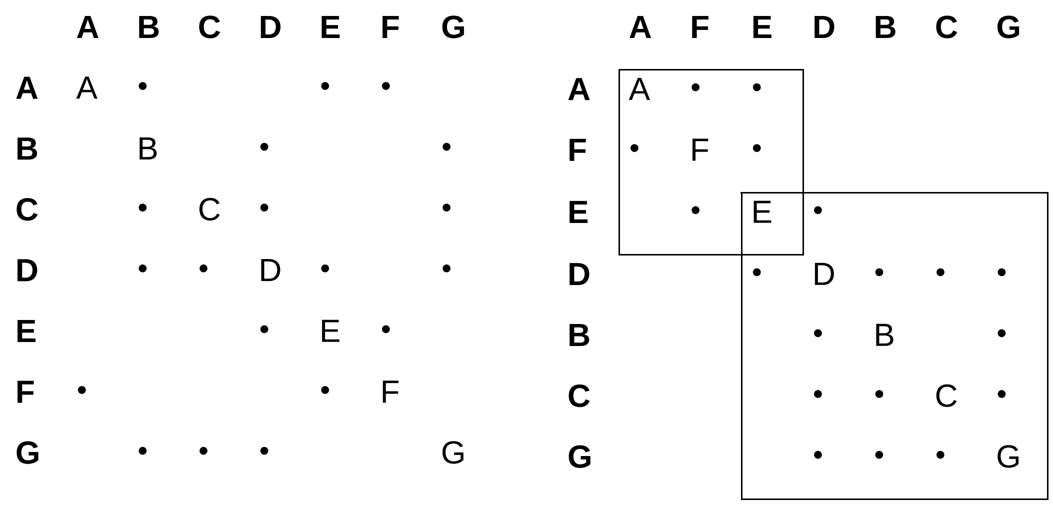

Figure 3-5 *Example of clustering (www.dsmweb.org)*

3.1.2.1 Component-based DSM

When analyzing system- or product-architectures component-based DSM can be used. The method defines interactions between the different components and subsystems within the architecture and processes the information with a clustering algorithm (Yassine, unknown). Browning (2001) point out that the type of interactions can vary in a component-based DSM and classifies four different types of interactions described in Table 1 (Pimmler and Eppinger in Browning, 2001). Different types of relationships can be represented in a single matrix by marking the type of interaction; the matrix is then referred to a three-dimensional matrix. A binary representation then requires the matrix to be divided into several matrices, one for each type of interaction (Browning, 2001). The analysis becomes more complex when dealing with a three dimensional matrix. It is therefore essential that one recognize the relative importance of the different types of interactions.

Table 1 *Different types of interactions in component based DSM (www.dsmweb.org)*

Spatial	Identifies needs for adjacency between two elements. Associations of physical space and alignment
Energy	Identifies needs for energy exchange between two elements
Information	Needs for data or signal exchange between two elements
Material	Needs for material exchange between two elements

3.1.2.2 People-based DSM

Similarly the People based or team based DSM use different types of interactions. The focus on this type of matrix is to determine which individuals or groups of people should be working together. All individuals are plotted in the rows and columns and the type of connection or communication is set (Yassine, unknown). Table 2 presents possible characteristics of information flows or interactions among people. The people based DSM aims at finding clusters of individuals that are highly interacting by forecasting the communication need of the participating individuals, and again reducing the interactions between clusters (Yassine, unknown).

Table 2 *Different types of interaction among people (www.dsmweb.org)*

Level of Detail	Sparse (Documents, e-mail) to rich (models, face-to-face)
Frequency	Low (batch, on-time) to high (on-line, real)
Direction	One-way to two-way
Timing	Early (preliminary, incomplete, partial) to late (final)

3.2 Domain Mapping Matrix

The Domain Mapping Matrix (DMM) is similarly as the Design Structure Matrix (DSM) and was introduced by Danilovic (2001). The DMM-analysis focuses more on the dynamics in product development and represents dependencies between dual domains in product development and not a single domain as in DSM. In a DMM-analysis information can be transformed into another domain. Enabling the information captured in one domain to be used in the other. The DSM/DMM approaches are complementary to each other with the difference that DSM focuses on one domain while DMM focuses on the interaction between domains. In other words two different sets of elements are plotted on the x-axis and y-axis, NxN when using DSM and NxP when using DMM. Since the DMM has the structure of NxP it is most likely that it will be rectangular and not squared as the NxN in the DSM (Danilovic & Sandkull, 2005).

Danilovic has introduced several types of DMMs in publications since 2001. "Product architecture vs. Organization" was the first introduced matrix (Danilovic, 2001). Other matrices showing how to compare different elements of product development are Systems vs. Organization, Product requirements vs. Functional requirement, Functional requirement vs. Product architecture, Product requirement vs. Product specifications, and Functional requirement vs. Product specifications, and Product specifications vs. Product architecture (Danilovic & Sandkull, 2005).

Danilovic and Browning (2004) argue that other examples of what the DMM-analysis can perform or deal with are transformation of information between domains, traceability of information between domains and system elements, synchronization of information and activities between domains, verification of system models and project assumptions, integration of the individual systems into a cohesive project/program system and improved quality of decision making.

As an example DMM can aid in visualizing dependencies between teams within one project towards other projects i.e. how other projects affect or relate to teams that are carried out in the project of interest. Clusters in the matrix can identify the level of interdependencies between teams and the other projects (Danilovic & Sandkull, 2005).

According to Danilovic & Sandkull (2005) the DSMs and DMMs can be combined to provide engineers a situational visibility, in which individuals can understand the need for information exchange, interdependencies and the context of the project. This will lead to transparency within and between domains in a project, between a project and the basic organization and between projects. This reduces the risk and uncertainty, as individuals understand the whole situation and have a better insight in their responsibility.

3.3 Multiplan – Software for DSM

Danilovic and Sigemyr (2003) point out that Multiplan is a multi-dimensional DSM-tool. It differs from earlier DSM-tools due to the ability to handle two dimensional domains. Handling means in this case the ability to represent matrices or domains and then to analyze the dependencies and restructure activities according to the analysis. The analysis is made by a built-in algorithm based on DSM research.

The features of the two dimensional domains is earlier described as rectangular domains, meaning it can combine two different dimensions of data. Multiplan is an Excel-based tool, which also can make connections between DSM analysis and resource database, risk analysis, GANT-schemes, and multi-project analysis possible. To make a GANT-scheme with Multiplan the workload and duration of all activities in a project must be known. Workload is the number of hours spent on the activity or process, while duration is for how many hours the activity has been running. To exemplify the meaning of workload and duration one can say that the activity of playing a soccer game has duration of 90 minutes, but the workload is 1980 (22*90) minutes since there are 22 soccer players on the field. Many traditional project management tools and software like MS Project do not handle all problems that are caused by complexity. The creators of Multiplan argue further that these tools can handle modeling of sequential and parallel tasks, but not interdependent tasks. The idea behind Multiplan is to offer an extensive tool that will easily and understandable present DSM data to project managers or other people of concern for a project. One of the advantages with Multiplan is that changes can be made easily. If something in the matrix proved to be wrong it can be deleted or changed and the matrix will instantly be restructured. This cannot be done in MS Project, where everything has to be manually updated if such a change needs to be done (Danilovic & Sigemyr, 2003).

4 Method

The method chapter gives an understanding of how the interviews were conducted. It also explains the selected approach and if the approach has reliability and validity.

4.1 Methodological considerations

Our purpose is to examine dependencies within the process of cast molding and we shall analyze these dependencies with the help of a matrix. To do this we need to use some kind of method. According to Williamson (2002) the research method is what gives a design for undertaking research, which is supported with theoretical clarification of its value and use. Different methods for data gathering and sample collection are frequently integrated as part of the design. In order to write a good thesis one has to consider the choice of method. Carlsson (1990) states that one has to start by looking at the problem and the purpose of the research and what type of new knowledge that can be found. There are many different research methods but with two main approaches, the qualitative and the quantitative (Backman, 1998).

On one hand Williamson (2002) stresses that the quantitative school tries to relate scientific methods to social sciences. The central theme of a quantitative research is that it seeks to link the cause and effect and the goal is a unification of all sciences, it considers the possibility that data can merely be based on things that may be impartially observed and experienced. The quantitative view has a more objective approach and often is about observing, registering and measuring in a more or less given reality (Backman, 1998).

The qualitative school on the other hand is trying to measure the reality and the collecting of data often takes place in a more natural setting (Williamson, 2002). The central theme is that people are always involved in interpretations of their own constantly changing environment. According to Backman (1998) one of the qualitative approach distinguish feature is that it does not use numbers or numerals but results in verbal formulations, written or spoken. The statement occurs verbally and the used instrument is the traditional word. The author argue further that when performing a qualitative study one sees the surrounding reality as subjective, which means that the reality is an individual, social and cultural construction (figure 4-1). The interest is dislocated towards the studying of how a human being is interpreting the surrounding environment (Backman, 1998). In the qualitative research the interest is aimed at the individual and questions are asked concerning how the participant is interpreting and forming its reality. The human is the mainly instrument used and the researcher is around the studied object (Backman, 1998).

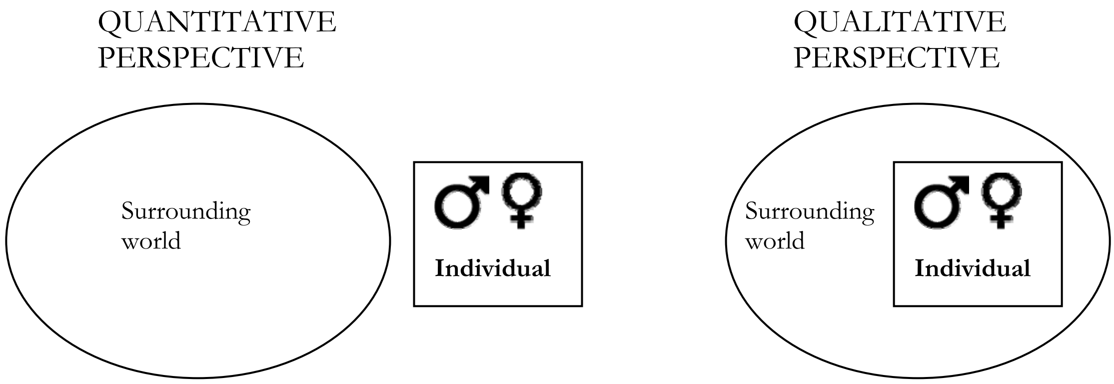

Figure 4-1 *The Quantitative and the Qualitative perspective (Backman, 1998, p.47)*

In our research we decided to use the qualitative approach with different kind of interviews since it is our opinion that this approach is best suited to fulfill our purpose. To use a quantitative approach in order to get the relevant and needed information to build up the different matrices would have been almost impossible since the information we needed was qualitative and not quantitative. There are many different ways to perform a qualitative research such as observation or an analysis of already existing data but we choose to make a workshop containing a group interview with complementary in-depth interviews. It would have been hard to make an observation about how to implement the matrices and very time consuming and there were not sufficient existing data for us to examine so the choice of doing an unstructured workshop and unstructured in-depth interviews came very natural for us.

When we use the term focus group and group interviews we refer to the workshop conducted.

4.1.1 In-depth interviews

According to Williamson (2002) all types of interviews are supposed to be impartial and dispassionate, but also personal and enthusiastic so that partaking is encouraged. Body language is another important matter and the interviewer must be acceptable to the interviewee and a touch of humor may release some of the initial tensions between the parties (Williamson, 2002).According to Darlington and Scott (2002) in-depth interview is the most used technique for data collecting in the qualitative approach and takes the belief that people are specialists in there own experience. Just like every different method commonly used, the in-depth interview has its relative strengths and weaknesses and the choice of using the “right” method will best be made in relation to the data wanted and the different limitations of the context (Darlington & Scott, 2002). The best approach for any research is the one that yield data that meet up with the problem and the purpose of the study. We believe that group interviews (in our case a workshop), and in-depth interviews will best serve our purpose.

The relative strength of in-depth interviews is that it has a benefit with the face-to-face interviewing regarding the intimacy with the person being interviewed (Darlington & Scott, 2002). If the personal chemistry does not match you will probably get some bad results but we believe that the people we will be interviewing has everything to gain by being honest and nothing to gain by being dishonest since their jobs may depend on getting shorter lead-times. In-depth interviews are especially practical when there is problem with a direct observation (Taylor & Bogdan in Darlington & Scott, 2002).

Williamson (2002) point out that there are several advantages of using in-depth interviews; one is that the interviewers can organize the context of the interview and try to make sure that the interviewee focus on the issues at hand. The author argues further that in-depth interviews may provide much richer data than questionnaires and gives the interviewer a chance to quote the actual words. Another advantage is that unstructured in-depth interviews have flexibility in asking questions and follow–up questions if needed.

There are also some disadvantages with in-depth interviewing. It cost both money and time and limits the geographical locations of interviewees (Williamson, 2002). Un-structured interviews may be hard to analyze and record and there is always a risk that the interviewer emphasizes some questions more than others and changes the tone of the voice so it is not a consistency in the way questions are asked (Williamson, 2002).

4.1.2 Focus groups, group interviews and workshop

A focus group is a well planned dialogue for receiving thoughts about a specific area of interest in a non-threatening environment performed with approximately 7-12 people (Krueger in Williamson, 2002). The **first step** is to set up the focus group and this can be done by looking at who is best suited for answering the research question. A good way to determine which participants to include in a group interview is to use an already existing contact.

The **second step** is according to Bernard (2002) that if a focus group is to small it may be dominated by just one or two persons opinions and if it is to large its very hard to manage. Little smaller groups can be more effective if you really want to go into in-depth discussions. It is very important that a small group is lead by a skilled moderator with experience of this kind of interviews.

The **third step** is the choice of a moderator. The moderator is a skilled person who makes the focus group talk about the topic that is to be discussed (Bernard, 2002). Often there are one or more participants that are shy and the trick is to draw them out without scaring them. The moderator must also think about closing down the participants that like to brag and show off without offending them. People are more likely to open up and tell what they really think about the topic if the environment is non-judgmental and supportive. Bernard (2002) also states the importance of explaining that there is no right or wrong answers, and that the moderator is not supposed to lead too much or put words in the participants mouths.

The **fourth step** is to decide what type of questions that will be asked. Williamson (2002) argues the importance of carefully selecting the questions that is to be asked and to find participants that are likely to have an opinion regarding the given topic.

Williamson (2002) argues that the advantages of focus groups are that people often listen to others to get more than one perspective on the matter prior to forming their own personal opinions. Focus groups can also create concentrated quantities of data on exactly the topic of concern. Another advantage is that these groups are very easy to organize, cheap and makes it easy to gather large amounts of information. It is also much uncomplicated to clarify the questions if needed and to give follow up questions.

The disadvantages of focus groups, according to Williamson (2002), are that some partakers may be dominated by others and afraid of saying what they really think. There is a risk that the moderator's driven interest may manipulate the group's reactions and answers. Even if focus groups are cheap there are limitation concerning how the result can be applied on the larger population. Since the nature of these groups is open-ended responses, the analysis of the interview may be difficult to conduct.

4.1.3 How to conduct an interview

According to Darlington and Scott (2002) the interview process consists of six different stages:

- Finding and selecting participants
- Making a connection (establishing rapport)
- The initial contact
- The Interview
- Recording
- Ending

The senior manager and former head of the tool making division at Husqvarna Kjell Holmqvist (further referred to as only Holmqvist) was assigned as a contact person. Holmqvist was contacted and a date set for our first meeting in order to learn more about the process of making casting molds and to plan a schedule for the continuing work of the thesis.

Since Holmqvist has experience and knowledge about the tool making division he was consulted when finding and selecting participants for the workshop according to the first stage in Darlington and Scott's stages. The next stage is about establishing trust between us and the participant's of the interview (Darlington & Scott, 2002). The authors argue further that the one performing the interview must respect if the participant's does not want to answer a question. Stage three concerns the participant's questions and thoughts regarding the study and if the interview is to be recorded this is the stage when the question is asked about consent. If it is possible a group or an in-depth interview should be taped because continuously taking notes during an interview can be disturbing for the interviewees and it is not very likely that taking notes takes the same time as for the participant's to answer the questions so there will be some waiting. The last stage is the ending and it is vital that the interviewees get some type of feedback. It could be that the final report is send to them. Darlington and Scott (2002) further stresses that when every mutual agreement is fulfilled every part should be satisfied.

4.1.4 Our approach

We started out by doing in-depth interviews with Holmqvist. These 4 interviews were all recorded based on the model of how to conduct an interview by Darlington and Scotts (2002). The first two interviews helped defining a purpose of this thesis by focusing on the dilemmas of the tool making division and the wish for reduced lead-times in comparison to the resources.

In order to decide on how to collect empirical data Professor Mike Danilovic of Jönköping International Business School was asked for feedback since he is one of the leading researchers within the field of DSM/DMM and one of the creators behind the software Multiplan. Professor Danilovic presented the idea to carry out a workshop with some of the employees at Husqvarna. According to Bernard (2002) it is very important that a moderator is skilled. Since our own knowledge in the field is rather limited Professor Danilovic was asked to function as a moderator. Professor Danilovic used his experience from workshops at companies such as SAAB and Scania in planning and performing the workshop in which we assisted by observing and taking notes. Our belief was that the outcome and result of the workshop could be improved with the help of Professor Danilovic due to his former experience of workshops and his experience of DSM and DMM. Moreover it is likely that an increased legitimacy due to age and title enables trustworthiness that would be hard to achieve for students due to lack of experience. The last interview with Holmqvist helped to get an understanding of how the tool making division currently operates. It was important for us to gain as much knowledge as possible about the molding process before conducting the workshop, in order to increase or possibility to estimate the validity of the collected data.

We decided to do the workshop at Husqvarna with complementary unstructured in-depth interviews with people involved in the process of making casting molds, i.e. our focus of interest. Those participating at the workshop were chosen by Holmqvist, together with Maria Wallin who is the present manager of the tool making department at Husqvarna.

The workshop was conducted on Friday the 29th of April in a conference room located in the Husqvarna facility in Huskvarna. The focus group of the workshop consisted of 8 people, which corresponds well to the 7-12 people that Williamson (2002) proposes. The people in the workshop were selected from different expertise areas needed to make a complete casting mold in order to get a wide perspective and a good mix of competences. The workshop started with an initial discussion describing how to work during the day. The interviews with Holmqvist had given us enough information to put up a preliminary list of all components. The first stage for the participants was to catalog the different components involved in the process. Then instructions were given to the focus group that their task was to list all activities on paper that needs to be done in order to make a complete casting mold. The first half hour of listing activities was a bit unstructured but after the initial stage of tensions and finding roles the participants performed their task. During the lunch for the participants a matrix with the paper-listed activities was created by us. The activities were plotted along the y-axis and x-axis and the finished matrix had the dimensions 248x248, which was printed and put up on a wall. When the participants came back, Professor Danilovic explained that they now had to list all the dependencies between the different activities in the matrix. Because of time restrictions the workshop was not fully finalized on the 29th of April. The remaining work of listing dependencies in the matrix was finalized during two sessions with participants of the workshop on Tuesday the 3rd and Wednesday the 4th of May. During the later part of the Friday workshop we noticed a problem with some participants being influenced by others which can lead to misleading data, described by Bernard (2002), and to get around this problem we divided them into smaller groups of 3-4 persons when having the second and third sessions. The action seemed to have a good effect since all the members of the group had a chance to say their opinion. Considering the form of the workshop it was not possible to be recorded. The final report will be sent to all the participants that are interested in reading it.

4.2 Reliability and Validity

Reliability concerns if you will get the same results if you perform the same test over and over again (Bernard, 2002). According to Carlsson (1990) reliability is the accuracy and security one can achieve with the type of gauge that is used. If the reliability is poor it has a negative affects on the validity. Williamson (2002) states that reliability refers to the consistency of results produced by a calculating tool when it is used more than once in a comparable situation. Many experiments occupy a sequence of tests, and it is very vital to make sure reliability in following direction of the experimental treatment (Williamson, 2002). In order to make sure that our interviews have reliability we have recorded the in-depth interviews used in this report and we have the matrix for showing reliability on the workshop.

Validity refers to the trustworthiness and accuracy of the findings and collected data (Bernard, 2002). Carlsson (1990) argue that validity is how good the variable that is supposed to be measured actually is measured. According to Williamson (2002) validity is the ability of the instrument measuring what is supposed to be measured or be able to foresee what it was meant to foresee or the actions of observations. To get validity for this thesis we have conducted a workshop and if any of the participants gave untruthful information there were others in the group who was able to correct the wrongly given information. We used smaller groups when finishing the matrix so all participants should get to say their opinion.

The relationship between reliability and validity is illustrated in figure 4-2. Here the task could be to test shoot a rifle. The first shooting shows that the there is good reliability since the shoots gathered at the same place, but the validity is poor since they are not even near the centre of the target. The second shooting has good reliability and good validity since all the shoots are where they are supposed to be. The third shooting has poor reliability since the shoots are spread around the target and it is very easy to see that even validity is poor.

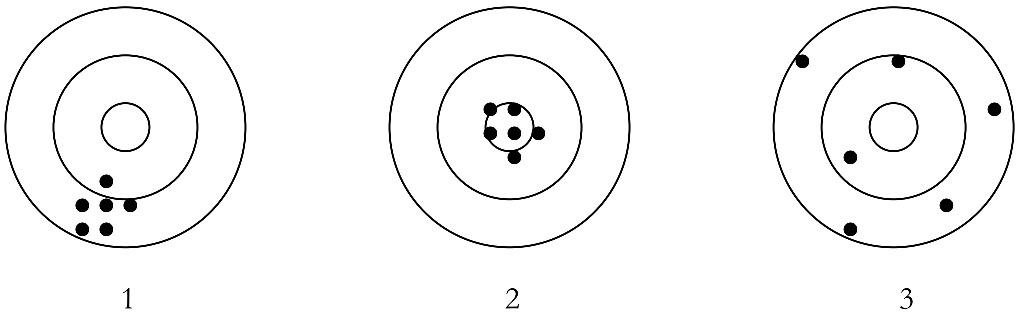

Figure 4-2 *Relationship between reliability and validity (Carlsson, 1990, p.152)*

5 Empirical findings

The empirical findings are based on the workshop and complementing interviews conducted at Husqvarna.

We started our search for empirical data by doing in-depth interviews with Holmqvist. These interviews gave us deeper knowledge and a clarification on what all the different activities in the casting mold process mean since none of the authors of this thesis had any previous understanding regarding that. These interviews with Holmqvist were the underlying base for identifying the structure of main components involved in making a casting mold. He also explained the process more deeply and showed us around in the facility, giving detailed information of when and where the components are being manufactured. In addition Holmqvist also provided documents containing information about the tool making division. These documents were used to figure out all of the components involved in cast molding at Husqvarna. The document also contained more detailed information about the components and some of the activities. The list was not a complete list of all different components but contained the most important ones. By important we mean the components that take the most hours to complete for the employees.

The workshop at Husqvarna resulted in a decomposition of all activities carried out by the tool making division to make a casting mold. In the **initial stage** the participants listed the components of the mold. A preliminary list of components was after a brief discussion reorganized into a more logical arrangement.

In the **second stage** of the workshop the participants listed all activities involved in the creation of a complete casting mold. This part was organized by identifying activities for of each component in the list of the 16 components. In the continuing discussion some of the suggestions of activities were questioned, either for being too vague or too imprecise. Some activities could on the other hand be divided into more activities. One issue of concern is that many of the activities have been poorly defined. Some activities have been given the name of items impeding the understanding of these particular processes for the authors. The reorganized list of components of the tool and their activities include:

1. **Construction**: Contains 24 different activities such as foundry simulation and layout of tool.

2. **Purchased components**: Contains 4 different activities examples of these are component list from construction and control of purchased material.

3. **Piston valve liner**: Contains 5 different activities for instance buying piston valve liner and milling.

4. **Fixed body**: Contains 10 different activities such as preparation and programming.

5. **Core**: Contains 11 different activities for instance sawing/pressure turning and grinding.

6. **Fixed ingot**: Contains 37 different activities such as drilling of lift holes and break out of electrodes.

7. **Piston pin**: Contains 13 different activities examples of these are heat manipulation and assembling.

8. **Movable ingot**: Contains 44 different activities for instance curing and etching.

9. **Movable body**: Contains 8 different activities examples of these are construction and milling.

10. **Slide + Bracket**: Contains 15 different activities such as electro-erosion and polishing.

11. **Ejector pin plates**: Contains 11 different activities for instance component list from construction and delivery of material.

12. **Ejector**: Contains 8 different activities examples of these are operating list and mantling.

13. **Steering for ejector pin plates**: Contains 9 different activities such as preparation and sawing.

14. **Ruler**: Contains 6 different activities examples of these are routing and drilling.

15. **Anchor plate**: Contains 9 different activities for instance construction and delivery of anchor plate.

16. **Final assemble**: Contains 8 different activities such as assembling and fitting at bench and final inspection.

In total there are 222 activities divided over 16 components giving a complete matrix with the dimension of 238*238. We have deliberately chosen not to list more than two activities under each component partially because of large number of activities but also because they are not likely to provide the reader with any indispensable information. Two components can be considered more essential than the others, namely the **fixed** and the **movable ingot**. These two are the most complex components of the casting mold and are linked to most of the activities in the process of making a complete casting mold. It is these two parts that under pressure will hold the liquid metal that will become the outcome of the process.

The components *Construction*, *Purchased components* and *Final Assemble* are different from the others since they are not physical components or parts of the cast mold. Purchased components correspond to the actual activity of buying rather than the physical part bought. Construction and Final Assemble speaks for them selves. There are however activities within these components which make them interesting to include in the matrix.

In the **third stage** of the workshop when the participants had listed the components and activities and begun to plot the dependencies they noticed that some activities were missing and some were unnecessary. This behavior of constantly upgrading the matrix kept on going during the entire process of the workshop. When the first session had ended and we were to expand the matrix with new input we had got, we were not able to perform this action since there is a limitation in Excel in the x-axis of 256 columns and we had more columns than that. We had to erase some of the activities that were connected with the Purchase components. As a result the matrix is limited to activities carried out at Husqvarna no further attention has been paid to external activities. The matrix consist of the same activities in both the x-axis and the y-axis and the diagonal is where the same activities intersects itself and in that cell there is no value because one activity can not be dependent of itself. To enlighten this we have marked the diagonal with gray. There is also horizontal and vertical lines throughout the matrix which shows the headlines of each component, and shall neither not have a value in the cell. There were also some components that were bought, but there were still some work for the employees to do such as drilling and milling. Another thing that deviated from the rest of the process was that some components were sent away for external work.

If looking at the matrix one can see that the most of the plotted dependencies are grouped along or below the diagonal from the left upper corner to the right down corner with only a few exceptions. Unfortunately there is not any possibility for us to include the whole matrix in its actual size in this thesis as an appendix; since the size of the reworked matrix has the dimensions of 238*238 and is approximately 2*2 meters giving a total of 84 A4 documents. Figure 5.1 shows the entire matrix in 7% of its actual size. Each color is representing one component.

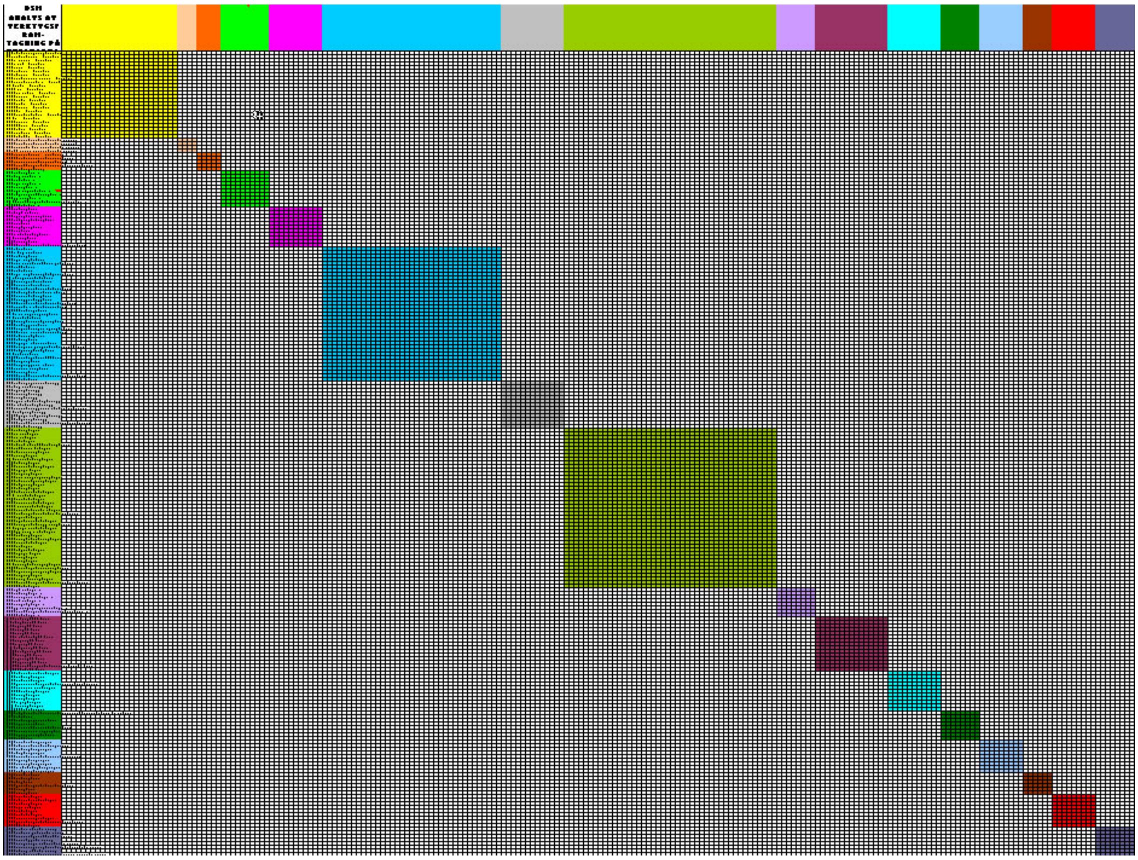

Figure 5-1 *The matrix in 7% of actual size*

The big colored squares along the diagonal of figure 5-1 displays where one component meets itself. The dependencies where more or less concentrated within these squares.

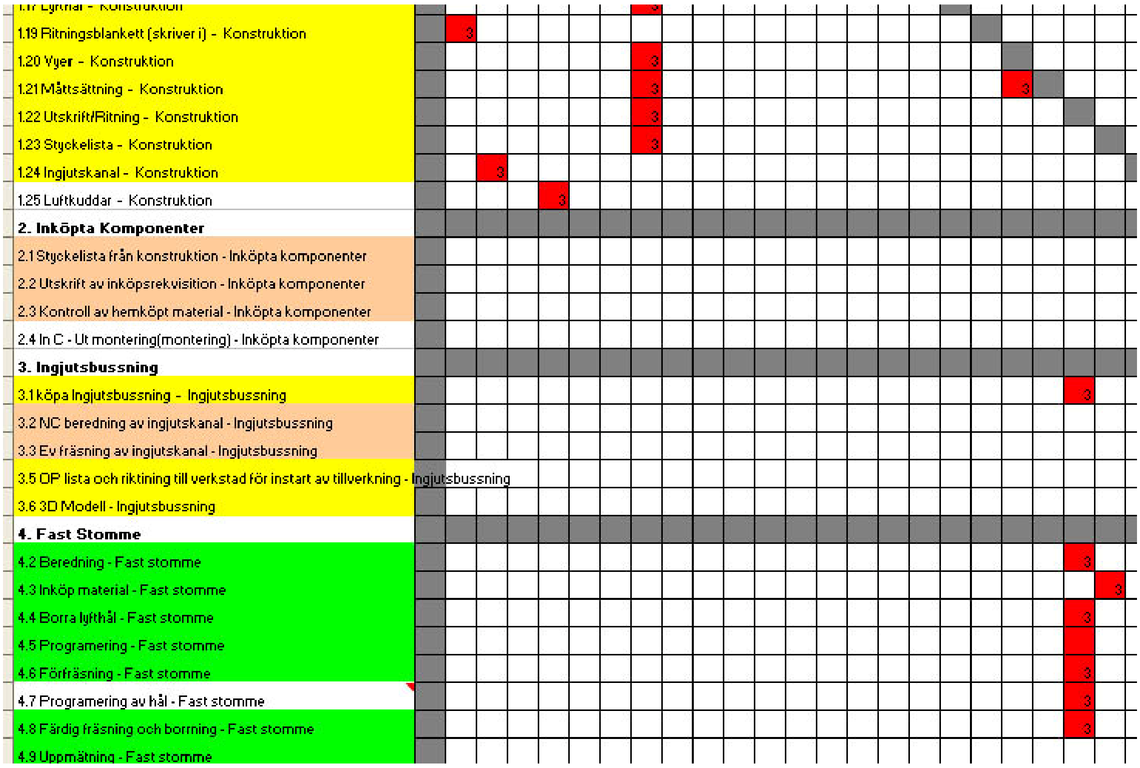

Figure 5-2 *The matrix in 75% of actual size*

Figure 5.2 shows a small part of the matrix in 75% of the actual size and here it is shown that the most of the dependencies is listed below the diagonal. This pattern is typical for the whole matrix. The red square markings in the matrix are where the partakers of the workshop found dependencies between two activities. If the dependency were very important they should mark it with the number 3, if the dependency were important the mark should be a 2, and finally a 1 if there was a dependency but not really important. All the cells with not marking in them are where there are no dependencies between activities. The different activities and components written to the left in the figure have different colors depending on which of the participants who wrote them. This was done to be able to differentiate between which one had put what information into the matrix.

6 Analysis

The focal point of the analysis is on the results from the workshop and the outcome is linked with the theoretical framework.

6.1 Circumstances of the analysis

Husqvarna wish to reduce the lead-times in the tool making department. Identifying and removing iterations in the process of making cast molds would reduce the lead-time for the entire process. An activity based DSM has been used in the analysis since it is most suitable for removing iterations among activities. Activity based DSM use partitioning algorithms for conducting analysis. A DMM analysis can also be used to complement the DSM analysis and to make a deeper analysis. However given the collected data and time limitation focus has been put solely on conducting a DSM analysis. The choice of matrix has also been influenced by the fact that we wish to remove iterations between activities within the process which is not possible with a DMM analysis. Therefore the activities will be listed on both axis and produce an NxN matrix.

The empirical data have been analyzed in Multiplan which uses a mathematic algorithm to restructure activities into a more efficient order at the push of a button. The outcome of the analysis made by Multiplan will then be interpreted by Husqvarna to see if a higher degree of efficacy can be reached.

The matrix holding all activities from the tool making division at Husqvarna turned out to be very large. A large matrix can be complex to analyze and is often more time consuming to interpret than a smaller one. Because of the size we made a choice to focus the analysis on the fixed and movable ingot part of the matrix. These are the only two parts that will be presented and discussed in the analysis part of the thesis. The fixed and movable ingot includes more than a third of all activities and are considered to be the most important ones by Holmqvist. The smaller focus does not affect any other considerations of the analysis, since all aspects of the matrix will be taken into thought. One thing to notice is that the whole matrix has been analyzed in Multiplan but no interpretation has been made. The result will however be presented to Husqvarna.

6.2 Before partitioning analysis

For the partitioning analysis we mapped the activities concerning the fixed ingot in the order listed by the participants in the workshop followed by the activities of the movable ingot (also in the order listed by the workshop participants). Figure 6-1 shows a part of the matrix before doing a sequential analysis with Multiplan. Every activity in the matrix is given a number which is represented along the diagonal. In the matrix there are 15 iterations, two of which are visible in figure 6-1. The iterations are those dependencies located above the diagonal and are more thoroughly described in part 3.1. The first of the two iterations has the coordinates 3,2 and the second has the coordinates 18,9. By examining the matrix before partitioning one can notice that many activities are dependent of the previous activity. The preferred method when reducing lead-times is to perform as many activities as possible concurrently. In figure 6-1 one can see that only a few activities can be performed concurrently for example activity 11 and 12. Both figure 6-1 and figure 6-2 displays the exact same area in the matrix. Still, the activities differ since they have been rearranged in a larger context.

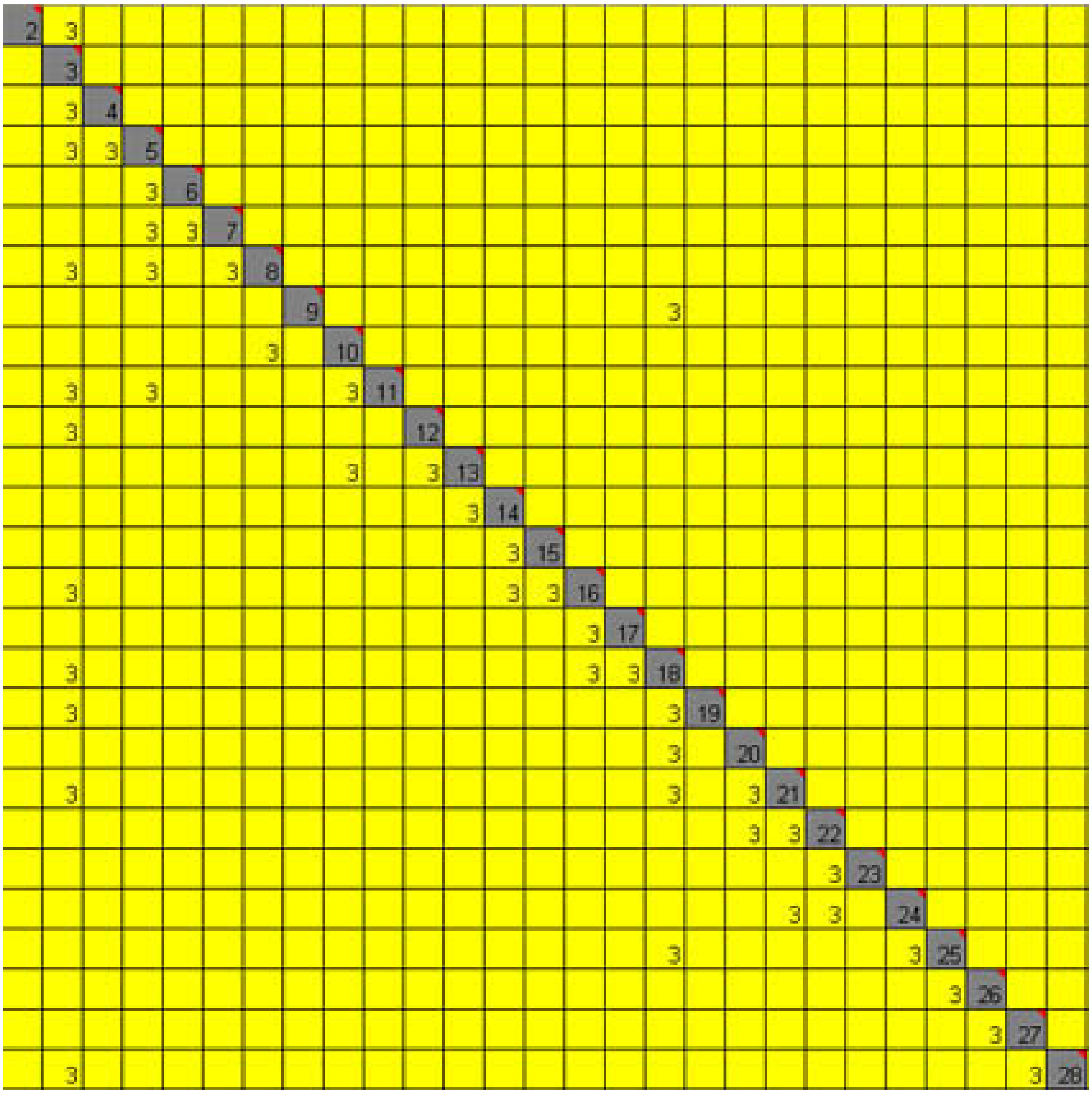

Figure 6-1 *A part of the matrix before partitioning*

6.3 After partitioning analysis

The DSM analysis performed by Multiplan suggests a new order of how the activities should be arranged. The DSM output shows that eight of the tasks lack dependencies entirely or are not the predecessors of any other activities. They can therefore theoretically be performed concurrently. The term theoretically is used since there may be other factors for example a requirement for additional machine time or an insufficient work force that might prevent these activities from running concurrently. These eight activities are:

- “Items list” for fixed and movable ingot.
- “Preparation” for fixed and movable ingot.
- “Operations list” for fixed and movable ingot.
- “3D-model” for fixed and movable ingot.

Please note that no explanation to these activities is given because they are only of interest for the people at Husqvarna, not for the reader or the authors. The actual meaning of the activities or how they are performed is only known by the participants of the workshop and has not been questioned by the authors.

Figure 6-2 shows a part of the matrix after the partitioning. By looking closely at the figure 6-2 one can now see that the numbers corresponding to an activity in the grey squares have changed. This is because only a minor part of the matrix is visible in figure 6-1 and 6-2.

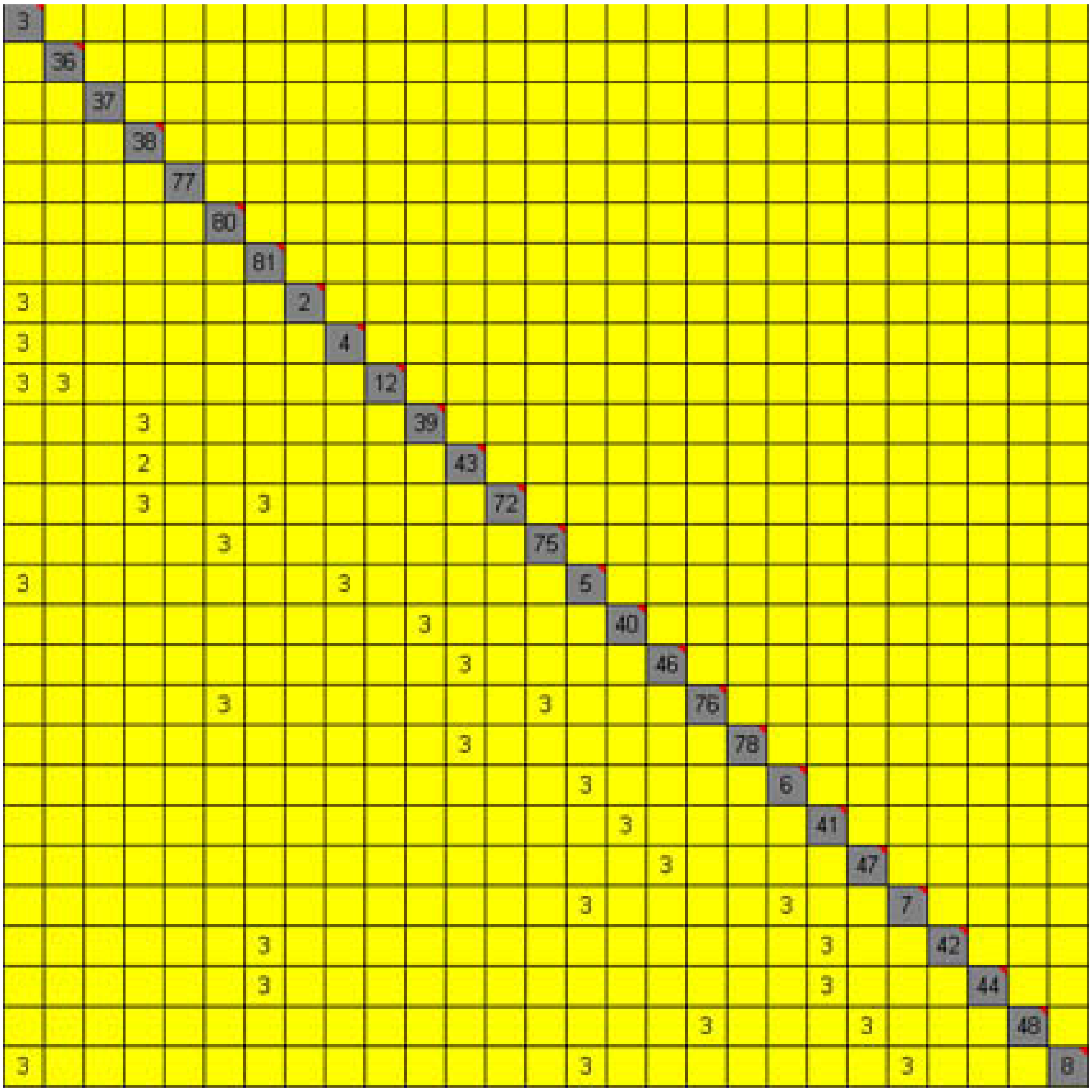

Figure 6-2 *A part of the matrix after partitioning*

A quick glance at the entire matrix will show that Multiplan also has rendered a new matrix completely without iterations as there are no dependencies above the diagonal. The large iteration in figure 6-1 with the coordinates 18,9 has been removed by performing activity 18 prior to performing activity 9. The new coordinate is 58,60 and is not visible in figure 6-2. All of the 15 iterations are gone and all dependencies are now situated below the diagonal. The elimination of the iterations is precisely the result that was wanted and the reorganized matrix is hopefully representing a more effective way of working. Note that the word hopefully is used since the 15 iterations listed before being analyzed in Multiplan are a product of the order in which the activities was listed on the workshop.

Figure 6-2 displays that the activities 2, 4 and 12 can be preformed concurrently. The activities 39, 43 and 72 are located underneath each other and can also be preformed concurrently.

To analyze if greater efficacy can be reached at the tool making division at Husqvarna the DSM output needs to be analyzed by Husqvarna and compared to their current configuration of activities. As written earlier the participants listed activities but was not told during the workshop to list them in the specific order of how they are done in reality. However, most activities were written in the order of how they are done in reality since it was easier for them to remember all the activities i.e. “first I do this then I do that” and so on. Basically this means that it is not certain that there really are 15 iterations in the process when comparing to how the work is done in reality. To point out that 15 iterations have been eliminated we would have needed to ask the participants at the workshop to list all activities in the exact order in which things are done for the entire process. The result of the analysis can however be used and evaluated by Husqvarna to see if the output of Multiplan is a more efficient way of working. The people at Husqvarna have the required knowledge and understanding to make a fair comparison. Only they can draw the conclusion if 15 iterations have been eliminated or if they never actually existed.

6.4 Source of error

Given that some of the activities have been formulated as being items rather than using a verb to describe an activity, a possibility of inaccurate results has been noted. Maybe the empirical data collected is not as accurate as it first seemed to be. By using terms only understandable to people with explicit knowledge of the process, it is difficult for others to question if these “activities” belong in the matrix. One example of this is the activity “3D-model” which is listed as an activity under several components. Common sense tells you that a 3D-model is likely to be drawn under Construction. The activity should preferably be named “draw 3D-model” and placed under Construction. If this activity actually is misplaced there are several cases where a dependency has been marked within a component when it should be placed in the interface between components. This would affect the outcome of the DSM analysis negatively. Multiplan would not be able to provide an optimal arrangement of activities. As mentioned in the frame of reference it is very important that all information entered into the matrix is true and accurate.

Ill defined activities are not the only thing that can affect the result in a negative way. According to Danilovic (Personal communication, 2005-05-16) a common mistake that people make when they try to list dependencies between activities is that they think sequentially. Rather than thinking on what they actually need to perform an activity they tend to focus on what is done before they perform their activity. One thing that suggests that this might have happened in this case is that many dependencies have been marked just below and along the diagonal. This means that one activity is needed for next. This might be true but the frequent occurrence implies that there is a small possibility that at least a few of the dependencies have been marked by sequential thinking.

All of the activities and dependencies should be verified by the people at Husqvarna once again to confirm if the input is accurate. Lack of time has prevented the input from verification at time.

7 Conclusions

The conclusions look at how well the purpose was fulfilled and explains the consequences with using the result given by the matrices.

The use of the DSM/DMM approach has provided a suggestion to how the activities within the tool making division can be arranged. Prior to the analysis 15 iterations were identified, some larger than other. The analysis conducted by Multiplan has restructured the activities within the process and provided a new matrix completely without iterations. The analysis also shows that many of the tasks can in theory be performed concurrently. There might however be other restrictions that prevent parallelization of tasks. One example can be limited resources. Whether or not Husqvarna have the required resources to carry out these tasks concurrently is left unsaid.

Activities in the analyzed DSM are listed in a different order than in the original DSM made at the workshop. The activities are rearranged according to the most efficient order Multiplan and the DSM algorithm can calculate. This gives Husqvarna a good overview of how activities can be carried out when making cast molds.

8 Discussion

The last chapter is a discussion of what could have been done better, criticism of the selected approach, and finally a suggestion on how further studies within this area may be conducted.

8.1 Self criticism

After having completed the study a few things that have impacted negatively on the results and that could have been done differently have come to mind. First and foremost the workshop which normally is conducted over at least two days was reduced to only one day due to lack of time. If additional time had been available, more time could have been set aside on explaining how the information would be processed something that in our minds could have improved the results. This could have facilitated both the listing of activities as well as the determination of dependencies. Some activities could be left aside or reformulated and dependencies could be settled on with greater accuracy. It feels like many of the dependencies have been plotted according to how the work is done at present rather than how it could be done. Possibly the routines of the workers are so deeply rooted that thinking "out of the box" is difficult. Instead of marking a specific activity essential for a worker's needs, a series of activities or the last activity in a series of activities has been marked. This does not provide us with precise information and if this is the case it would affect the results negatively. If this is the actual case is not however certain. It is more of an intuitive reaction after examining the matrix input. More time could have improved the communication giving us more confidence in the accuracy of the results.

The size of the matrix was greatly under estimated. A delimitation of what we were supposed to investigate would have been a good idea. This was suggested by Kjell Holmqvist when we first contacted him. Although the workload was underestimated we do not regret examining the entire process because we now have a more complete overview of the cast molding process.

8.2 Our approach

The selected approach of our study worked satisfactory. It may be possible to conduct this type of research using a different approach but it is doubtful that a different result will be reached. The recording of the in-depth interviews and the matrix that shows what we came up with during the workshop gives this thesis reliability. Concerning the validity of the thesis there is no way of determine exactly how valid it is since there are many factors that may have an impact on the result, for example our own inexperience of this kind of work and maybe the participants of the workshop had trouble thinking in this new way. When looking at figure 4-2 we hope that this paper is very close to the first target but it may be more like the second target.

8.3 Further studies

For further studies we recommend that a similar work is conducted but within another kind of area than the tool manufacturing process. We know that some of the largest organizations in the world such as Boeing and Airbus uses this technology and have been developing their own software programs.

8.3.1 Wider range

Given that the DSM approach has proven to be an efficient tool in complex environments it would be interesting to apply the DSM in a larger context. Not just focusing on the tool making department but every department concerned with a certain product. This would provide information across boarders within the organization, to a higher extent than simply in the tool making division.

8.3.2 Using DMM

It would also be interesting to apply the DMM approach, comparing the components or activities to the organizational structure. The workers could be compared with the activities in this approach revealing another dimension of the work. This information can provide managers with useful information about key interactions between people and their corresponding activities.

At the workshop we used eight different colors in the matrix that were supposed to represent what each participant is doing in the cast molding process. This information could however not be used because all of the participants of the workshop knew what their co-workers activities were and many of the activities in the matrix were put there by the "wrong" participant, i.e. not by the employee that actually performed the activity. This gave us a problem when we should use this information in the DMM-analyze given that one uses this information to create a new matrix in which one can plot the dependencies between the various activities and the employee that performed them. After doing this the software program Multiplan can analyze and come up with a new matrix explaining what departments that perhaps should have a closer cooperation between each other.

8.3.3 Workload and Duration

One of the features in Multiplan is that it can be used as a planning tool and produce GANT schemes. This was initially thought of as being part of this thesis but was later rejected due to difficulties in collecting the empirical data needed. The data needed concerned the workload and duration of all activities in the process of making a cast mold. Documents provided by Holmqvist illustrated at what percentage of the capacity some of the machines had been running at and at what dates. They also showed how many minutes this corresponded to. The idea was to generalize the duration of the activities involving machines by using time measurements from an already completed tool (an old project). The workload would later be determined by the participants at the workshop. However after examining these documents more thoroughly it came clear that most of the data on the machine time concerned the wrong dates and a lot of data on many of the machines was missing.

Concerning the collection of data on the workload also proved to be very hard. When asking the workers at the tool making division how long time each activity took they could not present an answer since the time differs with several hundred percents from one casting mold to another. This was not true for all of the activities, but rather many of them. One explanation to the great time difference in activities is that each mold is unique in design. Depending on the details and design of the casting mold different levels of action and work is done to finalize each activity resulting in various workloads and durations. An additional reason for the great time differences is the dimension of craftsmanship. The craftsmanship makes it hard to benchmark the activities since some irrational decisions can be made depending on how the work of the casting molds progress. An example of that can be the reduction of material from the fixed body. Depending on how much material the workers decide to reduce from the fixed body, the activity varies in time. If a small amount of material is carved of from the fixed body the activity will be take short time, but this will most likely mean that more material needs to be carved off in a later stage of the process. The later activity that involves carving of material will consequently take longer time. Following this reasoning it is clear that the duration and workload for one activity can differ depending on a decision made by the workers. The decision of how much material that should be carved of is taken on the basis of craftsmanship and situational factors, like the availability of machines.

Workload and duration of the activities is needed to enable the GANT-scheme feature of Multiplan. Knowing the workload and duration could easily provide information on when a project to start at its latest to finish before certain date.

For further studies it is recommended that how to find information on the workload and duration is investigated further. This would certainly be of value for Husqvarna when planning for a new casting mold.

References

Backman, J. (1998). *Rapporter och uppsatser*. Lund: Studentlitteratur.

Bernard, H. R. (2002). *Research Methods in Anthropology: Qualitative and Quantitative approaches* (3rd ed.). Boston: Rowman & Littlefield Publishers, Inc.

Browning, T. (1998). *Use of Dependency Structure Matrices for Product Development Cycle Time Reduction*. The Fifth ISPE International Conference on Concurrent Engineering: Research and Applications, Proceedings, July 15 – 17, 1998, Tokyo, Japan.

Browning, T. (2001). *Applying the Design Structure Matrix to System Decomposition and Integration Problems: A Review and New Directions*. IEEE Transactions on Engineering Management, Vol. 48, No. 3, Aug. 2001. pp. 292-306.

Carlsson, B. (1990). *Grundläggande forskningsmetodik för medicin och beteendevetenskap*. Göteborg: Graphic Systems AB.

Danilovic, M. (1999). LOOP: *Leadership and Organization of Integration in Product Development.* Institute of Technology, Linköping University.

Danilovic, M. (2001). *Supplier Integration in Product Development.* 10th International Annual IPSERA Conference, Proceedings, pp. 253-265, April 8-11, 2001, Jönköping University, Jönköping International Business School, Sweden.

Danilovic, M. & Börjesson, H. (2001a). *Managing Multiproject Environment*. The 3rd International Dependence Structure Matrix (DSM) Workshop, Proceedings, October 29-30, 2001, Massachusetts Institute of Technology (MIT), Massachusetts, Boston, Cambridge, USA.

Danilovic, M. & Börjesson, H. (2001b). *Participatory Dependence Structure Matrix Approach*. The 3rd International Dependence Structure Matrix (DSM) Workshop, Proceedings, October 29-30, 2001, Massachusetts Institute of Technology (MIT), Massachusetts, Boston, Cambridge, USA.

Danilovic, M. & Browning, T. (2004). *A Formal Approach for Domain Mapping Matrices (DMM) to Complement Design Structure Matrices (DSM)*. The Sixth Design Structure Matrix (DSM) International Workshop, Proceedings, September 12th – 14th, 2004, Trinity Hall College, University of Cambridge, Cambridge Engineering Design Centre, Cambridge, United Kingdom.

Danilovic, M. & Sigemyr, T. (2003). *Multiplan – A new multi-dimensional DSM-tool*. The 5th Dependence Structure Matrix (DSM) International Workshop, Proceedings, October 22-23, 2003, University of Cambridge, Cambridge Engineering Design Centre, Cambridge, United Kingdom.

Danilovic, M. & Sandkull, B. (2005). *The use of Dependence Structure Matrix and Domain Mapping Matrix in managing uncertainty in multiple project situations.* Forthcoming in International Journal of Project Management.

Darlington, Y. & Scott, D. (2002). *Qualitative research in practice: Stories from the field.* Philadelphia: Open University Press.

Engwall, M. (1995). *No project is an island: linking projects to history and context.* Research Policy, Amsterdam.

Field, M. & Keller, L. (1998). *Project Management.* London: International Thomson Business Press.

Grey, R, J. (1997). *Alternative Approach to Programme Management.* International Journal of Project Management, Vol. 15, No. 1, pp. 5-19, Elsevier Science Ltd and IPMA, UK.

Kreiner, K. (1995). *In search of relevance: Project management in drifting environments.* Scandinavian Journal of Management, 11(4), 335-346.

McCormick, W., Schweitzer. P, & White. T (1970). *Problem decomposition and data reorganization by clustering technique.* The Urban Institute, Washington, D.C.

Payne, J, H. (1995). *Management of Multiple Simultaneous Projects: A State-of-the-Art Review.* International Journal of Project Management, Vol. 13, No. 3, pp. 163-168, Elsevier Science Ltd and IPMA, UK.

Sabbaghian, N., Eppinger, S. & Murman, E. (1998). *Product Development Process Capture & Display Using Web-Based Technologies.* The IEEE International Conference on Systems, Man, and Cybernetics, Proceedings, pp. 2664-2669, Oct. 11-14, 1998, San Diego, CA, USA.

Sahlin-Andersson, K., & Söderholm, A. (2002). *Beyond Project Management.* Liber. Copenhagen Business School Press.

Steward, D. (1967). *The Design Structure Systems.* General Electric report no. 67APE6, San Jose, California, USA.

Van Der Merwe, A, P. (1997). International Journal of Project Management, Vol. 15, No. 4, pp. 223-233, Elsevier Science Ltd and IPMA, UK.

Williamson, K. (2002). *Research methods for students, academics and professionals.* Wagga Wagga: Quick print.

Yassine, A. A. (Unknown). *An Introduction to Modeling and Analyzing Complex Product Development Processes Using the Design Structure Matrix (DSM) Method.* Product Development Research Laboratory, University of Illinois at Urbana-Champaign

Internet sources

International.Husqvarna.Com, (2005). *Welcome to Husqvarna!* Retrieved 2005-04-07, from http://international.husqvarna.com/

Dsmweb.org, (2005). *The Design Structure Matrix Web Site.* Retrieved 2005-03-15, from http://www.dsmweb.org/