

Production development with the future in sight

-a green field study at Sandvik SRP

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Preface

This report is the result and outcome of our master thesis in the final step to graduate as Masters of Science within Mechanical Engineering at Lund University, Lund. The project was conducted during 20 weeks in the spring 2011, at Sandvik Mining and Construction in Svedala, Skåne.

During this project we have learnt and experienced great things, it has been a tremendous opportunity for us to develop in many ways.

For inputs, time and effort we would like to thank everyone that we have met in connection to this thesis, both employees at Sandvik in Svedala and at other places. All the guidance, feedback and support that Sofia Hedenström and Bertil I Nilsson has given us has been enormous important for us and for that we are sincerely grateful.

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Executive summary

Title:	Production development with the future in sight a green field study at Sandvik SRP
Authors:	Sofia Svensson and Mimmi Hansson
Supervisors:	Bertil I Nilsson, Adjunct professor, Lund University Sofia Hedenström, Process Planning Manager, Sandvik SRP AB
Background:	Sandvik is in the middle of a great investment, the so called Green Field investment, which will imply a new factory for parts of their stone crush production. The facility is, at current situation, in engineering phase and the preparations are in focus and running at high speed.
Purpose:	The aim of this master thesis and final course in the education is to give an insight and valuable experience from the industry. It will also be a preparation of independent work and the first introduction as an engineer within the company world.
Problem definition:	The project should with Green Field in focus, deliver an estimated need of inventory area and evaluate the planning of Parts production. This in aim of finding areas of improvements both related to system and culture.
Method:	This is a study with several different sub-studies which implies that different method has been used. Literature studies, multiple interviews, benchmarking and calculations has been a profound work throughout the project.
Conclusion:	<p>In mission to cope with future changes and challenges that will arise in time for Green Field, Parts is recommended to develop their knowledge and competence within the resources that they have.</p> <p>During this project several areas of improvements are found, most of them can be derived to “soft parameters” such as communication and routines and just a few are derived to “hard parameters” such as system related, e.g. within planning and control systems.</p>

Vocabulary

APS	Advanced Planning System
APP	Advanced Production Planner
BOM, Bill of Material	A hierarchical list of all included parts, raw material, sub-assemblies, components etc. that are needed, and in which quantity, to produce the end product. The top level of the structure represents the finished product.
BOM explosion	Break apart each assembly into its components.
FIFO	First in-first out, an asset method and inventory term that assumes that items purchased first will be sold first.
ERP	Enterprise Resource Planning
GREEN FIELD	Project name for the investment and new facility
M3	The ERP-system that is used within Sandvik Mining and Construction in Svedala.
MRP	Material Requirement Planning
MRP II	Manufacturing Resource Planning
NAUTILUS	The production development concept of Sandvik
QLIKVIEW	A business intelligence system, a tool for analysing ERP data
SMC	Sandvik Mining and Construction

The recommendation for Parts is to establish clear guidelines and routines regarding ways of working and communicate with one and another between different stakeholders.

Parts is recommended to continue their development of inventory layout and evaluate different ways of storing their raw material in aim to reduce inventory area, since this will be a limiting factor in Green Field.

Table of Contents

1 Introduction	1
1.1 Company description	1
1.2 Green Field.....	3
1.3 Problem description	5
1.4 Purpose	5
1.5 Delimitations.....	6
1.5.1 Project objective.....	6
Methodology	7
2.1 Research methodology.....	7
2.1.1 Scientific strategies	7
2.1.2 Strategy in this study.....	8
2.2 Research methods	8
2.2.1 Case	8
2.2.2 Experiment in existing systems.....	9
2.2.3 Action research	9
2.2.4 Benchmarking	10
2.2.5 Research methods for this study.....	11
2.3 Techniques for gathering data	12
2.3.1 Interview.....	12
2.3.2 Observation	12
2.4 Closeness to data sources.....	12
2.4.1 Primary data.....	13
2.4.2 Secondary data.....	13
2.4.3 Quantitative studies.....	13
2.4.4 Qualitative studies.....	13
2.4.5 Research choices	14
2.4.6 Approach for this study.....	14
2.5 How argumentation is built	15
2.5.1 Deduction-testing theory	16
2.5.2 Induction-building theory.....	16
2.5.3 Abduction-combining the two.....	16
2.5.4 Triangulation	16
2.5.5 Approach in this study.....	16
2.6 Credibility.....	17
2.6.1 Validity.....	17
2.6.2 Reliability.....	17
2.6.3 Objectivity	17
2.7 Critics of source	18
2.7.1 Critics of source	18

2.7.2	Self-criticism	19	
	Inventory.....	21	
	3.1 Theory.....	21	
	3.1.1 Warehouse management.....	21	
	3.1.2 Warehouse costs	21	
	3.1.3 Warehouse Design.....	22	
	3.1.4 ABC classification.....	22	
	3.1.5 Material flow	24	
	3.1.6 FIFO, first in first out	25	
	3.1.7 Placing the goods	25	
	3.1.8 Fixed versus floating location	26	
	3.1.9 Warehouse volume	26	
	3.2 Empirics	27	
	3.2.1 Details characteristics.....	27	
	3.2.2 Green Field layout.....	28	
	3.2.3 Model of analysis.....	30	
	3.3 Recommendations.....	33	
	3.3.1 Changes of layout.....	33	
	3.3.2 Inventory goods.....	34	
	3.3.3 Goods placement.....	36	4
	Production planning and control	39	
	4.1 Theory.....	39	
	4.1.1 Planning	39	
	4.1.2 Process choice	40	
	4.1.3 Planning and control systems	42	
	4.1.4 Lean Production	46	
	4.1.5 Tools for production planning	49	
	4.2 Empirics; Planning and production control within Sandvik Parts	53	
	4.2.1 Planning in a larger view.....	53	
	4.2.2 Planning in practice	54	
	4.2.3 Work schedule.....	56	
	4.2.4 Quality.....	57	
	4.2.5 The Green Field machinery	58	
	4.2.6 Benchmarking	60	
	4.3 Recommendations; Production strategies	63	
	4.3.1 Order scheduling.....	63	
	4.3.2 Planning and control improvements	72	
	4.3.3 System evaluation.....	78	
	4.3.4 The final and overall recommendations.....	84	5
	Discussion.....	87	6
	References	91	

Report outline

The report contains several subprojects and chapters where every chapter is introduced with a short and explaining text of its contents. This is in aim of guiding the reader through the chapter.

In mission to assimilate the report and its contents in the best way possible, a vocabulary of certain technical or company related terms is prepared for the reader to follow. Several layouts and calculations are imbedded in the report which makes it more readable, with figures that are explained and referred to in the text.

Since the characteristics of the subprojects are so different, the projects have been presented in their respective chapters with theory, empirics and results.

Chapter 1-Introduction	Provides the reader with an insight of information regarding e.g. the background, purpose and definition of the project.
Chapter 2-Methodology	In this chapter a general explanation in the methodology of building and conducting a project and report is presented.
Chapter 3-Inventory layout	The chapter describes theory of warehouse management together with empirics of Parts situation of inventory. Finally it presents a recommendation regarding how and where Parts should store the raw material.
Chapter 4-Planning and control system	Evaluates and analyse the production within Parts in current situation in mission to develop recommendations for the future production and planning in Green Field.
Chapter 5-Discussion	Reflections regarding the results are discussed together with a brief review.

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1 Introduction

In this introduction chapter the history of Sandvik is briefly presented in mission to give the reader an understanding of the company and its business. Furthermore, a description of the scope and outline of this master thesis is presented.

1.1 Company description

Sandvik was founded as a company by Göran Fredrik Göransson in 1862. In Sandviken he formed the company Sandvikens Jernverk which during the years has developed into a high-technology global enterprise. Sandvikens Jernverk later changed company name into Sandvik which since 1972 has been the corporate name.

Sandvik has today three major segments; Mining and Construction, Tooling and Materials Technology. In 2001 Sandvik AB bought Svedala Industri AB in Svedala, Skåne, and since this acquisition Sandvik Mining and Construction has been one of the largest employer in Svedala, with around 615 employees. The company is a global enterprise with activities in 130 different countries and approximately 47 000 employees' works within the Sandvik AB¹.

SMC produce stone crushers and tools for larger mining industries and have customers all around the world. In Svedala they build entire crushers with all included process steps such as casting the material, process the details and assemble the parts. Within the company site in Svedala there are several greater departments, where of one of them is Parts and where this thesis is conducted. Parts process in an industrial way both purchased material such as shafts and casted details. They process and prepare the details for further operations, turn the details in lathes to get accurate dimensions and surfaces etc., before sending them further on to following steps in the value chain for example to assembly department. The crushers are used in rough environments and are exposed for high friction and pressure, thereby are spare parts also an important service to offer and a significant share of the production volume.

What to come? The scope of this master thesis at SRP in Svedala is founded in reasons of the construction of a new factory. The facility will be an investment of

¹ K. Bergman, 2007, Gjuteriet 125 år

approximately 300 MSEK and this indicates a strong belief in the company future and its development as one of the business leaders within its segment.

The global business idea of Sandvik is to develop, manufacture and provide high technology products and service which improve the customers' productivity and profitability. The core values of Sandvik are:

Open mind, Fair play and Team Spirit

Today, Sandvik SCM is located in the central parts of Svedala. The facility is surrounded of private households and residential areas. During the years, several complaints have been received from the local citizens concerning loud and disturbing noise from the production. The production is today taking place inside the old buildings of Svedala Industry, where the oldest buildings were constructed in 1862. Gradually, several expansions have been made and the factory is today a facility that, in common with many other Swedish manufacturing industries, is not optimised. The flow within the production is not in line with modern philosophy; instead the machines have been placed where the first free space occur. The present factory also has a limited capacity and would have difficulties to support further expansion.



Figure 1: A Sandvik H6800 crusher²

²Mining Technology,
2011-06-27 <http://www.miningtechnology.com/projects/johnsoncampmine/johnsoncampmine8.html>

1.2 Green Field

Sandvik is for the moment preparing for an increasing production volume of their crushers and in the near future they are supposed increase their production volume with approximately 60 %. This is one of the reasons for their new facility and instead of moving their production to foreign low cost countries they have decided to invest in Green Field.

Green Field is an investment of 300 MSEK with an estimated payback time of 2 years of production, estimated to be completed in the beginning of year 2012. The new facility is dimensioned for a production of 600 crushers per year, an increase with 62 % compared to the 370 crusher produced today. The product assortment will be reduced compared to today, from 300 to approximately 200 different parts. While the assortment decreases, the amount in every product group will increase. In the near future Sandvik will introduce new crushers which parts also shall be produced in the new plant.

Since it is important to have goals to know what direction to walk towards, Sandvik SRP's department Parts has established goals for how they want to improve themselves in the Green Field factory.

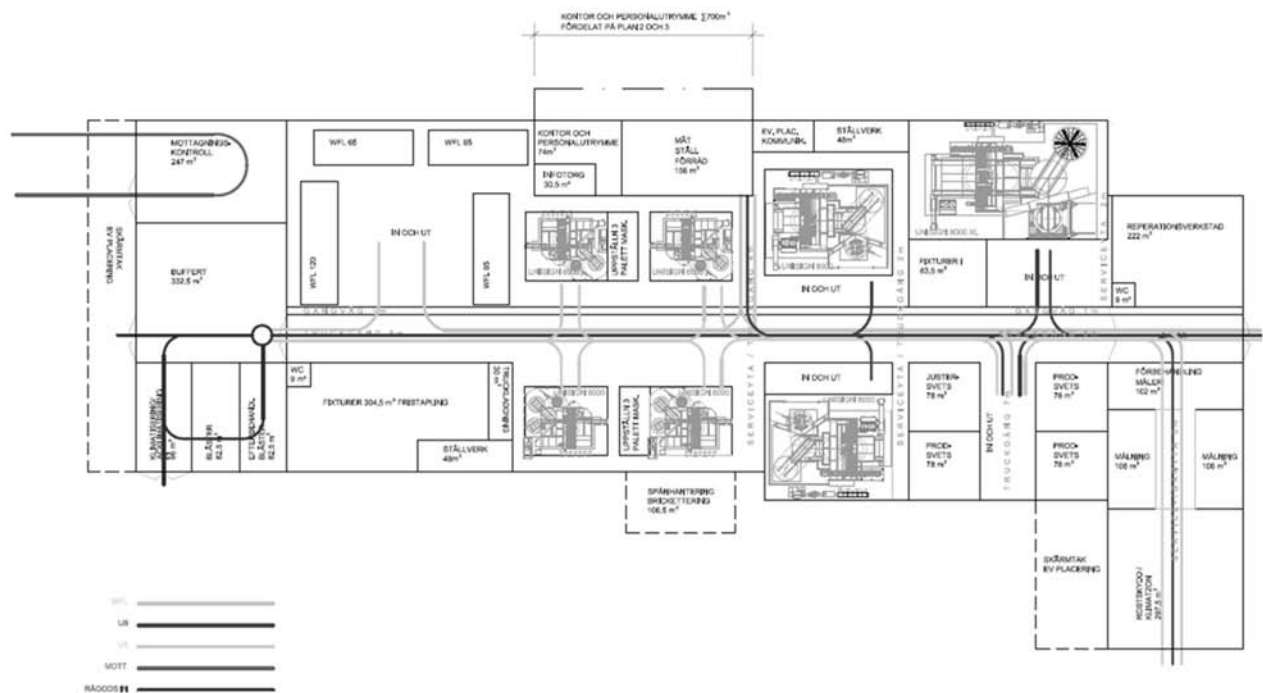
Main goals:

- World class production of crushers
- Stable capacity of 600 crushers
- Global supply of spare parts
- Throughput time less than 10 days

Supportive goals:

- Increase productivity approximately 40 %
- Machine utilization 86 %
- High flexibility
- Straight, stable and visual flows
- High security
- Good working environment
- Fully implemented Nautilus philosophy
- Planned flow
- Strictly key components production

Below, in Figure 2, one of the early developed layouts of the internal flows for Green Field is represented. The flows are made to support and enable the goals of the investment.



GREEN FIELD SANDVIK, SVEDALA LAY OUT 2011-01-19

Figure 2: Internal flows, Green Field

A remarkable objective of the Green Field project is that all current machines will be sold out and eleven new top modern machines are bought to give the production possibilities that are impossible today regarding quality, productivity, lead times, and hopefully only preventive maintenance. Of course, there will be some problems during the first period with introducing the new machines and learning the new ways of working but after an initial period, there will be great achievements to make.

Since the factory is built on a blank sheet, everything has to be thought through and planned to give the best possible start conditions for the production.

A great advantage was given to Sandvik when the opportunity of having one of the new Green Field machines delivered and installed during this spring. This has resulted in that the production staff can learn the new machine at the same time as the ordinary production is running and thereby gain a great start when the future production begins in the new factory.

Unlike the facility today, all needed functions of Parts will be held under the same roof which enables better communication and flow within the factory.

1.3 Problem description

For Sandvik, delivery accuracy to customer is highly important and in mission to secure this a well functional planning and control system is crucial. The current work within the production of Parts is today not working optimal with for example long lead times as a consequence. Are there any solutions to these problems in the way of working and in existing systems or is there a need of new and different methods?

In Green Field, Parts will have a new inventory area for their raw material and they will also change their product assortment which must be taken into consideration when designing and planning. Within conditions of given circumstances, calculations regarding required surfaces and evaluation of different inventory layouts must be prepared.

Sandvik is an old and traditional manufacturing industry and in mission to develop and progress in the future, new philosophies and ideas within manufacturing are interesting. Lean is a philosophy that many companies follow and has implemented with success and Sandvik Parts is interested of improving their production and work with help by Lean and its tools.

1.4 Purpose

The purpose of this master thesis is to conduct several subprojects with goal to improve and facilitate the current and future work within department Parts at Sandvik.

The new facility of Green Field, with increased demand and a new situation, will imply both tactical and practical changes with different ways of planning the production and of storing material.

First; calculations, evaluations and design layouts will be given as suggestions regarding an inventory area in Green Field.

Second, based on the present production within SRP in Svedala, evaluate criteria's for improvements regarding a planning and control system within the production. The improvements should be developed with no consideration of current system, whereof interviews and benchmarking will be a profound input to the work.

1.5 Delimitations

The thesis is conducted within the department of Parts and thereby the investigations and evaluations has not included other departments within SRP even though they are all connected and affect one and another. The studies and research within the production concerns and begins when the raw material leave the buffer zone until the details has been processed in machine.

The inventory layout and placement of the details will be recommended in grouped categories and not item by item.

1.5.1 Project objective

The different subprojects will result in different objectives;

- Recommendations that should be able to work as feedback and guideline for the management of Parts, in a decision-making process regarding change of planning and control system.
- Proposals of inventory layout and placement of the raw material of Parts.

The wish is that this report will be interesting and of importance for both internal and external decision-makers and interested stakeholders at Parts. Hopefully, this thesis may be as good guidance for our fellow students such as others has been for us.

2 Methodology

The importance of a methodology framework within a research is highly graded. The researcher will find support and guidelines within the different techniques and a well founded way of how to proceed with the future work. A well structured methodology approach will also help the reader and audience to follow and understand the work. There are several different methods to apply within a research and the choice of method should be influenced by the nature of the research and its problem.

2.1 Research methodology

When conducting research or studies of this kind it is important to initially reflect of the nature of the problem. The outcome of this reflection will then influence and effect the way of working hence it is an important step in the project. In literature there are four major approaches described in mission to conduct a research; exploratory, explanatory, descriptive and normative studies.

2.1.1 Scientific strategies

The exploratory studies are a method for the cases when no earlier studies, research or models are provided hence the researcher has no earlier knowledge base for his or hers studies. The research and project will initially have no well-defined scope or definition and it is impossible to make a detailed project plan³. Some of the benefits of this method are the flexibility and adaption to changes within the study and the researcher who is approaching this strategy must be willing to eventually change direction as results of data appears⁴. Although, literature points out that the method is not in absence of structure or direction – the focus is initially broad and become progressively narrower during the research⁵.

Explanatory studies emphasis to study situations or problems in order to explain relations between different variables. This research method is commonly used in studies where the cause and effect are interesting factors. It focuses to find the relevant causes, explanations and mechanisms to a specific problem⁶.

“Descriptive studies often represent the first scientific toe in the water in new areas of inquiry”⁷. These studies are as mentioned often very useful for generating

³G. Wallén, 1996, Vetenskapsteori och forskningsmetodik ⁴M. Saunders et al., 2009, Research methods for business students ⁵Ibid. ⁶G. Wallén, 1996, Vetenskapsteori och forskningsmetodik ⁷D. Grimes, 2002, Descriptive studies: what they can and cannot do, The Lancet, Vol. 359, No. 9301, p. 145-149

hypotheses for further research and are conducted with focus is on observational studies⁸. In literature, this method is described as the one giving answer to the five basic W questions: who, what, why, when and where⁹. Those studies, who apply a descriptive approach, are commonly used as pre studies to explanatory research. This is since some notions, regarding the outcome of a descriptive study, points out the desire of evaluations, conclusions or new ideas as a result of the research¹⁰.

In contrast to descriptive studies, normative studies are not supposed to result in only hypothesis but rather an action plan to solve the problem. It is a method used when there is already knowledge within and understanding of the subject area¹¹. With this method, focus throughout a research is not only to gather fact and figures but to establish suggestions and proposals for improvements¹².

2.1.2 Strategy in this study

With the fact that this master thesis will contain several different projects, the authors will approach different scientific strategies throughout the project. In mission to evaluate and set a list of improvements for a planning and control system and calculate inventory areas, the authors will apply the normative studies. The outcome of the study will include a proposal for future improvements or modifications.

2.2 Research methods

It exist several methods of conducting research. Each method are different but may equally be used for explanatory, descriptive or exploratory studies however some of them are more suitable for inductive or deductive research which will be explained in a following chapter. There are several elements or factors that, together with the question and nature of the study, will direct the choice of method. Depending on the amount of time, existing knowledge and other resources the choice will be different.

2.2.1 Case

In mission to test theories and ideas that have been developed during the research, different case studies are commonly conducted. The case study might not answer the questions in total but it enables deep studies of particular situations. It is a useful method for investigations whether how realistic the scientific theories and models that are developed are and if they actually work. Case studies are of flexible

⁸http://www.ehib.org/faq.jsp?faq_key=42, 2011-02-21 ⁹D. Grimes, 2002, Descriptive studies: what they can and cannot do, The Lancet, Vol. 359, No. 9301, p. 145-149 ¹⁰M. Saunders et al., 2009, Research methods for business students ¹¹M. Björklund, U. Paulsson, 2003, Seminarieboken-att skriva, presentera och opponera ¹²<http://www2.uiah.fi/projekti/metodi/178.htm>, 2011-03-01

character and might generate new ideas or concepts and result into new directions for the research. The method may use archival analysis, interviews and observations while gathering data¹³.

The fact that case studies focus on particular situations or narrow fields might generate some negative views regarding the ability to fit an entire problem or question. Case studies have also received critics in cause of insufficient objectivity or precision regarding i.e. quantification¹⁴. A case study is not a statistical method and should therefore be used after these conditions.

During the conduction of case studies it is of importance that the case is prepared thoroughly and that a system for note taking is developed, in purpose to avoid useful information being missed. In contrast with scientific methods there are no strict rules in this method and therefore it is important with focus on the relevant issues for the research¹⁵.

2.2.2 Experiment in existing systems

In mission to analyse cause and effect of variables within a problem, experiment is a method that is commonly applied within research. Experiments will give you the answer to questions like; what happens with B if A...? The classic way of conducting an experiment is based on assumptions of causality, relationships and links, of a hypothesis which includes ideas regarding the relation between some dependent and independent variables. In literature, theories are then explained as being systematically constructed by several hypotheses that has been tested and evaluated through different tests¹⁶.

2.2.3 Action research

Action research is a method preferable in projects where the aim is to improve and find a solution of a problem that is real while at the same time studying it. Hence it is a problem solving research that has direct and immediate effect within the subject area.

Initially, the researcher observes a situation or phenomena in aim to clarify the problem, its nature and causes. The observation will result in suggestions and action proposals to solve the problem. Evaluation of the implemented suggestion through analysis and reflections will be an iterative process and the method is similar to quality improvement processes. To better understand the method and visual show that it is an iterative process, see Figure 3.

¹³M. Höst et al., 2006, Att genomföra ett examensarbete ¹⁴R. Yin, 2002, Design and methods, Case study Research, 3:rd ed

¹⁵<http://www.experiment-resources.com/case-study-research-design.html>,

2011-02-16 ¹⁶G. Wallén, 1996, Vetenskapsteori och forskningsmetodik



Figure 3: Action research method¹⁷

2.2.4 Benchmarking

There are many different ways to look at and define benchmarking. A broad definition which is applicable to many benchmarking projects: “Benchmarking is a method of measuring and improving our organisational performance by comparing ourselves with the best”¹⁸. A benchmarking process consists of two parties; the benchmarker, the organisation carrying out a benchmarking procedure, and the benchmarkee, the organisation being benchmarked. Since different people have different definition they also have various expectations of the outcome from benchmarking. It could be used to compare performance and practices, which could improve the own companies business. Many times benchmarking is used to measure the performance gap between the benchmarking company and the “best in class” with respect to production and consumption within the organization. This is to identify the strengths and weaknesses at the benchmarking company to thereafter develop methods and practices to close the gaps¹⁹. The difficulty with this method is to decide who is “best in class”. Collins et al. claims that a MAUT, a multi-attribute utility theory which is a mathematically driven decision analysis technique, gives a large advantage determine the overall best-inclass performer. This might although not be the best method when conducting benchmarking in each critical metric²⁰.

There are many reasons and benefits with benchmarking because it:

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¹⁷<http://www.llas.ac.uk/projects/2837>, 2011-03-04 ¹⁸T. Stapenhurst, 2009, The benchmarking book
¹⁹M. Kozak, 2004, Destination benchmarking: concepts, practices and operations ²⁰T. Collins et al, 2006, The use of multi-attribute utility theory to determine the overall best-in-class performer in a benchmarking study, Benchmarking: An International Journal, Vol. 13, No. 4, p. 431-446

-Makes organisations realise the “best in class” level; identify the performance to strive for to become market leader and how to improve their competitive advantage.

-Helps to short cut the improvement process²¹.

Benchmarking can be generalised into two parts: internal and external benchmarking. External benchmarking can further be divided into competitive and functional benchmarking. The main difference between the categories is what to be benchmarked and with whom it will be benchmarked²². Internal benchmarking concerns communication and share ideas between different departments within the own organisation. This often includes collection of data of the own performance and compare it to past years and performances Many times, this approach is taken due to difficulties to access external data²³. External benchmarking is when the benchmarker is comparing with an external organisation to discover new ideas of methods, products and services for improvement of the own organisation. External benchmarking is a good opportunity for learning practices and experiences from the companies who are at the leading edge. Competitive benchmarking is the most sensitive type of benchmarking and denotes comparison with competitors only. Functional benchmarking, also called non-competitive benchmarking, compares against not only competitors but also against business within different industries in similar fields, performing similar activities or having problems of the same kind²⁴.

2.2.5 Research methods for this study

Since the master thesis is conducted together with a company the method of case research will most likely be applied. A company is often complex and has its flaws hence it requires case studies to understand the company culture and routines by interviews and observations. When the nature of the project focus on finding the current problems and evaluate improvement proposals with the future factory and organisation in mind an action research method will be partly applied.

At present, the authors see no need of experiments within this research. Eventually, this opinion and stand point may change if new perspectives and demands occur.

Benchmarking will be applied in this study since it is an interesting approach to get new ideas and impressions. Companies which will be visited and benchmarked are Dynapac and Flextronics in Karlskrona. Dynapac is one of the few companies which manufacture products in the same size as Sandvik and Flextronics due to its well

²¹M. Kozak, 2004, Destination benchmarking: concepts, practices and operations ²²Ibid. ²³Ibid. ²⁴Ibid.

known and well-functioning implemented Lean work. Internal benchmarking on chosen departments will also be used.

2.3 Techniques for gathering data

In a research project there is several different ways to gather data. Common sources are books, articles or journals, which the researcher can turn to for information. It is important to question the reliability in gathered information and make a difference between primary and secondary data.

2.3.1 Interview

An interview is a more or less structured questioning of an adequate person with information or opinions desired by the interviewer²⁵. There are three different types of interviews: unstructured, semi-structured and fully-structured. The main goal for the unstructured interview is to explore the experience and knowledge of the person being interviewed within a certain area. Since there is few questions in the interview, it will to a large extent focus on the person interviewed, and his or hers own thoughts and interests in the area. The semi-structured interview contains both open questions and questions with fixed alternatives for answers. To ensure high reliability of the research it is important to keep the same order among the questions to all of the person's interveiwed since the order could affect the answers. The last type, the structured interview, is basically an oral survey where all of the questions have fixed alternatives. The interviewer ask the questions exactly as in the questionnaire and this type of interview is often the easiest to analyse²⁶.

2.3.2 Observation

There is much knowledge to collect by observing a certain phenomena or event. The observer can have different rates of participation in a study and will as a consequence affect the result of an observation. In the same way the choice of being visible will have impact for the observed person and can affect the result. The observed can both perform better and worse than in an ordinary day when he or she knows about the observance, which in both cases will give a skew picture of how the situation actually is²⁷.

2.4 Closeness to data sources

²⁵ M. Höst et al., 2006, Att genomföra ett examensarbete

²⁶ Ibid. ²⁷ M. Höst et al., 2006, Att genomföra ett examensarbete

2.4.1 Primary data

Primary data is information gathered by the researcher which is destined to be used in the research²⁸. This kind of data is sometimes called raw data and it is up to the researcher to interpret the data for its use. The data could be gathered by interviews, experiments and observations, and the advantage of primary data is that it is up to the researcher to decide what data to collect²⁹. A disadvantage is that the data collection often is time consuming and data could be difficult to get access to.

2.4.2 Secondary data

Secondary data is information already interpreted by someone else for another purpose than the specific research³⁰. The secondary data could be used either as a complement to, or as a substitute for primary data³¹. Books and articles is an example of secondary data and with good studies of literature, the researcher can increase knowledge and learn from other researchers learning³². To achieve highest quality of the report it is important to question the credibility of literature.

2.4.3 Quantitative studies

The quantitative studies, the more scientific ones, cover information that is countable and measurable: time (minutes or seconds), number, weight, shares and length etc. It is often sampled through data systems and is frequently treated through statistical analysis. The information is often presented through charts and graphs and enables the researcher to explore present, describe and examine relationships within the data³³. The problem with this approach of gathering data is all the information that is not expressed in numbers; the non-numeric kind³⁴.

2.4.4 Qualitative studies

The qualitative studies are data that are communicated through words and expressions. The method is more subject than the quantitative one and requires another kind of interpretation by the researcher in form of personal understanding and connection with the data source, the interview victims. The risk of interpretation the data incorrect must be known for the researcher and this study technique is used when understanding of a certain problem or situation is of importance. Qualitative studies give the study a richness of expressions and shades³⁵.

²⁸M. Björklund, U. Paulsson, 2003, Seminarieboken-att skriva, presentera och opponera ²⁹Ibid. ³⁰M. Björklund, U. Paulsson, 2003, Seminarieboken-att skriva, presentera och opponera ³¹C. Cowton, 1998, The Use of Secondary Data in Business Ethics Research, Journal of Business Ethics, Vol. 17, No. 4 ³²M. Höst et al., 2006, Att genomföra ett examensarbete ³³M. Saunders et al., 2009, Research methods for business students ³⁴M. Björklund, U. Paulsson, 2003, Seminarieboken-att skriva, presentera och opponera ³⁵Ibid.

Mixing the two sampling methods into a combination is a technique that enables expansion of the scope of the studies. The both methods might contribute with value to the study and therefore it is important with a combination, in purpose to capture both approaches³⁶.

2.4.5 Research choices

Literature describes the way of combining quantitative and qualitative techniques and procedures for gathering of data as research choices. However, note that some other literature refers to it as research design.

Mono method is when the research is conducted with one single technique for data gathering. Multiple methods are divided into multi or mixed methods. Multi method is when combining several data collections techniques, although they must be of the same kind, either quantitative or qualitative.

Mixed method is when both qualitative and quantitative methods. Mixed method research use both quantitative and qualitative research but does not combine them. The data is either analysed quantitatively or qualitatively depending on the data collection technique. Mixed model research combines qualitative and quantitative data. The method can be used to transform qualitative data so it is possible to analyse quantitatively³⁷. For an illustration, see Figure 4.

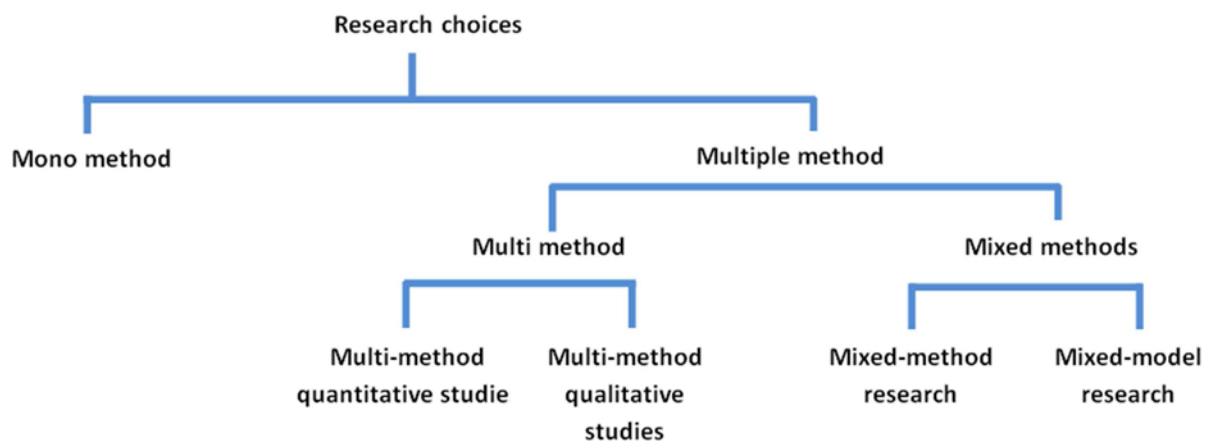


Figure 4: An overview of research choices³⁸

2.4.6 Approach for this study

By both gathering data from primary and secondary sources the authors of the report believes that the studies will get high quality. Secondary data bring

³⁶E.F. Wolstenholme, 1999, Qualitative vs. quantitative modelling: the evolving balance, Research in Nursing & Health, Vol. 50, No. 4 ³⁷M. Saunders et al., 2009, Research methods for business students ³⁸M. Saunders et al., 2009, Research methods for business students

knowledge which may result in ideas and new approaches that, together with primary data, give inputs for the research.

The combination of the two methods, quantitative and qualitative, is important in aim to get the whole picture with all its dimensions hence the authors will use this approach. When investigating the inventory layout a quantitative study will have a higher degree of influence than in the other parts of the project.

During this study a mixed method research will be conducted and applied in the different parts of the project. As mentioned above, when investigating the inventory layout both quantitative and qualitative studies will be conducted. The qualitative data will although, with highest probability, not be transformed into quantitative data.

2.5 How argumentation is built

In conducting research and in writing reports there are different levels of abstract. The emperies, which are the real facts and concrete figures versus the theory which are based on more general ideas, are the two basic concepts. The way of working between the two are divided into three other concepts; deduction, induction and abduction as shown in Figure 5.

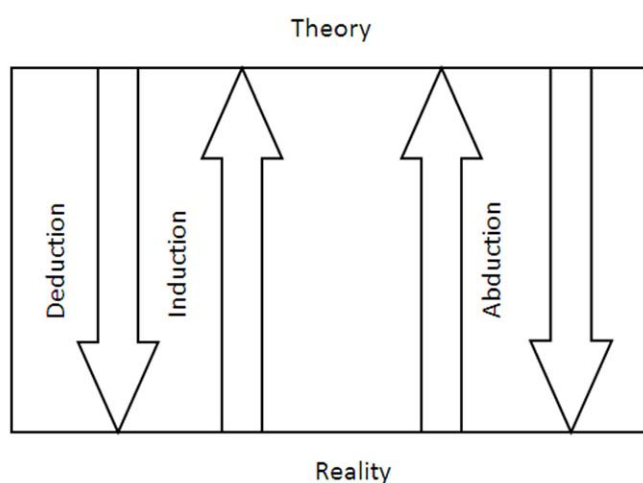


Figure 5: How argumentation is built³⁹

³⁹J. Nilsson, 2007, Alfa Lavals möjligheter till användning av Kanban, MSc. thesis, Lund University, Sweden

2.5.1 Deduction-testing theory

Deduction is the concept that starts in theory and from there proceeds into empiric studies and a clear theoretical position is developed prior to the collection of data⁴⁰. The literature enables the researcher to identify theories and ideas which then will be tested using data and the method will try to explain casual relationships between variables or concepts⁴¹.

2.5.2 Induction-building theory

Induction, in contrast to deduction, is based in empirical studies. By exploring the gathered facts and information; theories are built up after different analysis. There is no need of pre studies, due to the fact that the theory is based on gathered data, and this concept is sometimes criticised. Some literature point out the importance of already competent knowledge within the subject area in mission to absorb the most important and relevant research⁴².

2.5.3 Abduction-combining the two

When walking in theory between the two concepts of induction and deduction, the literature define this as abduction⁴³. It is a method for conclude reasons and present causes for an observation. Abduction cannot be used in a schematic way hence it is a method that requires experience within the problem area or from similar studies⁴⁴.

2.5.4 Triangulation

It is common to use several different methods in a research work in aim to gather comprehensive information. This method of combining different techniques is called triangulation and derives from the geometry⁴⁵. By using geometry when calculating a points' position, by measuring the distance from two different points of reference, it can be and translated into methodology terms in the way of study the problem from different perspectives. Triangulation is a practical method used in mission to cover multiple sources and in aim to get a better understanding of the problem and its nature⁴⁶.

2.5.5 Approach in this study

Triangulation will be used to capture the full view of the scope in this research. Due to the fact that the project is conducted at a company, a pre-study is obliged to understand what sort of information that is possible to gather from different source within the organisation. On the other hand, knowledge and understanding is important and crucial.

⁴⁰M. Saunders et al., 2009, Research methods for business students ⁴¹Ibid. ⁴²M. Saunders et al., 2009, Research methods for business students ⁴³M. Björklund, U. Paulsson, 2003, Seminarieboken-att skriva, presentera och opponera ⁴⁴G. Wallén, 1996, Vetenskapsteori och forskningsmetodik ⁴⁵<http://www.dictometer.com/triangulering>, 2011-02-22 ⁴⁶M. Höst et al., 2006, Att genomföra ett examensarbete

2.6 Credibility

The quality and trustworthiness of a research is often evaluated by its validity, reliability and objectivity. Whether the data collected is qualitative or quantitative; the data should always be both valid and reliable.

2.6.1 Validity

Validity question whether the study measures, process and evaluates what is intended to be measured⁴⁷. Validity can be separated into two areas: internal and external validity. Internal validity is to what extent the study measures what is meant to be measured. External validity concerns the extent to which the results of a study could be generalized and applied for other cases than in the research itself⁴⁸. Would the result be the same if it was conducted in another place, time or group of people? To increase the validity it is a good idea to use triangulation to get different perspectives of the situation⁴⁹.

2.6.2 Reliability

Reliability is to which extent whether another study with the same conditions would provide a consistent result⁵⁰. For example if an instrument would measure the same way and show the same result, under the same conditions, every time it is used. To achieve good reliability it is important to be thorough when collecting and analysing data⁵¹. It is important to keep in mind that reliability is not measured, it is estimated since the true value of a test or a research cannot be calculated⁵².

2.6.3 Objectivity

Objectivity is to what extent the author is able to put his or her personal values aside and give an objective view to the reader. By clarifying the circumstances and make well motivated choices, the reader has the opportunity to personally judge the objectivity of the study⁵³. Scientific studies should always refer to a reality which is independent of any subject and not be affected by any observer⁵⁴.

Figure 6 is an illustration of reliability and validity, which can be illustrated with playing dart. The result is reliable if the darts hit the dartboard closely to each other while the result is valid if they hit the centre of the board. It is first when the dart

⁴⁷C. Handley, 2005, Validity and reliability in research, http://www.natco1.org/research/files/Validity-ReliabilityResearchArticle_000.pdf, 2011-02-22 ⁴⁸<http://www.businessdictionary.com/definition/external-validity.html>, 2011-02-25 ⁴⁹M. Björklund, U. Paulsson, 2003, Seminarieboken-att skriva, presentera och opponera ⁵⁰http://www.natco1.org/research/files/Validity-ReliabilityResearchArticle_000.pdf, 2011-02-15 ⁵¹M. Höst et al., 2006, Att genomföra ett examensarbete ⁵²A. Bruton, J. Conway, S. Holgate, 2000, Reliability: What is it, and how is it measured?, *Physiotherapy*, vol. 86, no 2 ⁵³M. Björklund, U. Paulsson, 2003, Seminarieboken-att skriva, presentera och opponera ⁵⁴<http://www.springerlink.com/ludwig.lub.lu.se/content/q532573240701544/fulltext.pdf>, 2011-02-14

hits in the middle and also gathered together, that the result is both valid and reliable⁵⁵.

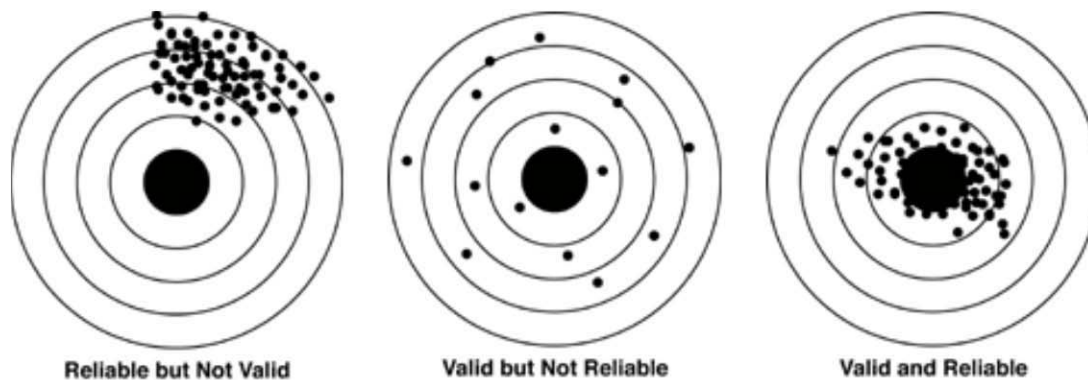


Figure 6: Measurements validity⁵⁶

2.7 Critics of source

In mission to collect data that is correct and without personal reflections and subjectivity several arrangements and precaution are planned to influence this master thesis.

2.7.1 Critics of source

While collecting data through interviews there is always a risk that the gathered information, from staff within the company, is not objective. Interview requires an interpretation by the authors and in order to avoid misinterpretations and misunderstandings, a revision control will be written. This content will then be approved by the person being interviewed and first after this approval the information will be used in the research. The personnel are of course affected by their operation area and company and therefore it may sometimes be difficult, for both them and the authors, to see the reality and true picture. When conducting the master thesis at a company and especially when most of the project time will be spent at the company location, there is a risk of being dazzled of the culture and spirit within the organisation. Possible problems may be reflected by the values and importance for the specific individual and the person will allocate more or less focus to the problem. By carefully selecting interview persons within and outside the

⁵⁵ M. Björklund, U. Paulsson, 2003, Seminarieboken-att skriva, presentera och opponera

⁵⁶ http://ccnmtl.columbia.edu/projects/qmss/measurement/validity_and_reliability.html, 2011-0301

company, with high reliability, expertise within its area and with adequacy for this master thesis, the authors will try to validate and ensure standard on the information and data. Information from sources on Internet will be inspected and thoroughly controlled, since Internet is an open medium where publications of text and information are not always trustworthy and reliable. In aim to avoid this risk in largest extent possible, utilisation of multiple and independent sources for the same information and theory will be used.

2.7.2 Self-criticism

The authors have no earlier experience that could be compared to this project. In contrast to these studies, most courses and tasks in university has a fix solution and key answer. These factors may have an influence on the result of the thesis and it is possible that the project would be conducted in a different way if it was performed by more experienced researchers.

3 Inventory

In this chapter; theory, empirics and results for Parts future inventory area of raw material in Green Field is presented. The inventory strategy is an important question since it might have large impact on the production.

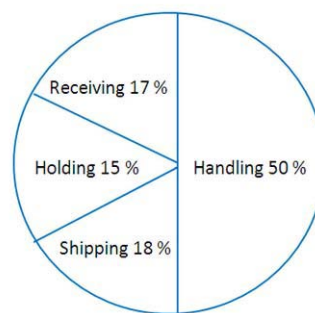
3.1 Theory

3.1.1 Warehouse management

There is often a big variety of details within a company and warehouse, many of them with different requirements regarding volume, weight, volume value, turnover rate, frequency etc. It is important that the design and construction of the warehouse is thoroughly elaborated since it has effects on the efficiency and storage of the company's articles⁵⁷. Manufactured products may also have other characteristics than unmanufactured and therefore require a different kind of storage.

3.1.2 Warehouse costs

Figure 7 represents how the costs within a warehouse are commonly shared between four main areas; receiving, holding, shipping and handling of the goods. Receiving the incoming products is operations that are often difficult to automate hence the work labour are intensive and expensive. The cost of holding the goods is highly depending on the requirements of the products, its physical characteristics and the number of items. Picking operations varies between fully automated systems with devices that move the inventory under control of a centralized computer, to manual operations where human pickers transport by foot or on



trucks⁵⁸.

Figure 7: Common warehouse costs⁵⁹

⁵⁷K. Lumsden, 2006, Logistikens grunder, 2: nd edition ⁵⁸R. Musmanno et al, 2003, Introduction to logistics systems Planning and control

In mission to decrease the costs of warehousing the handling of the goods should be minimised to the largest extent. Hence; planning and organisation of a warehouse together with how to place the different products are of importance.

3.1.3 Warehouse Design

When designing a warehouse there are three major aspects to consider and strive against in aim to optimise its functionality; high utilisation rate, minimisation of transportation and structure but also flexibility and safety. The utilisation rate should be as high as possible. Although it must be in relation to the costs since a too high filing rate may have a negative effect regarding handling and transportation cost of the articles. Unnecessary movements and transportation can be avoided by a smart design of the layout, taking the frequency or turnover rate of the articles into consideration when placing them in the warehouse. Articles with high turnover rate should be placed where they are accessible with a short transportation distance while articles that are not as frequently at the least accessible locations⁶⁰. By transporting goods, resources are unnecessary consumed which also consequence in increased risks of damaging or losing the inventory. An unstructured warehouse will consequently lead to increased costs, inefficient handling and problems with a FIFO, first in first out, approach.

The mission of designing a warehouse layout is to create as rational flows as possible together with high utilisation rate. A rule of thumb when designing is that the handling efficiency is prior to space utilisation⁶¹.

3.1.4 ABC classification

As mentioned in the pretext; all articles within a company do not have the same requirements regarding handling and warehousing. The volume value is an interesting factor when focusing on the material flow and there are one well known strategy regarding this, the ABC classification. Through analysis of all the articles in the range or assortment it is often showed that a small number of articles stand for a greater part of the turnover. This is referred to as the 80/20 rule which implies that 20 % of the articles answer to approximately 80% of the volume value and vice versa; 80% of the articles stands for 20% of the volume value. In practice the classification is conducted by analysing all the products and then ranking them in decreasing order after chosen criteria. Calculate the percentage and the cumulative percentage for each product and then assign them categories A, B or C. Depending on the category different policies are determined, see Figure 8⁶².

⁵⁹ R. Musmanno et al, 2003, Introduction to logistics systems Planning and control

⁶⁰ S-A. Mattson et al., 2005, Logistik-läran om effektiva materialflöden ⁶¹Ibid. ⁶²

Supply Chain and Maintenance Management

Newsletter, <http://www.managementsupport.com/nl/abc-pareto.htm>, 2011-05-26

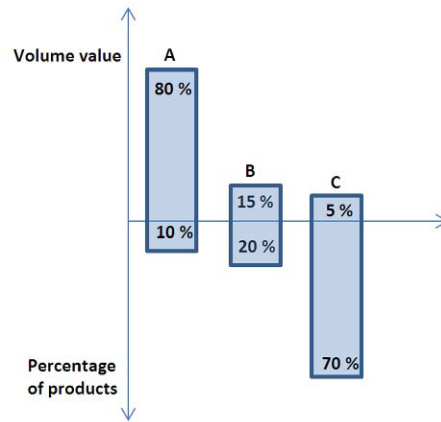


Figure 8: The 80/20-rule⁶³

Although, this single dimension analyse has some restraints in function since it is only based on volume value, inventory value or similar and it does not take the frequency, such as picking or sale frequency, of the products into consideration. A product with high frequency has other capabilities of an effective control than the ones with lower, even if they have the same volume value. In mission to avoid problems that this issue may cause, a two dimension analyse is preferable where the combination of volume value classification and frequency grouping creates a more nuanced analyse that is also more flexible in the choice of dimensions.

Figure 8, visualise that the result will be nine different classes of products where AA is the class with highest volume value and the highest picking frequency (or whatever frequency being used) while the CC class is contains the products with low volume value and low picking frequency which is also often irregular.

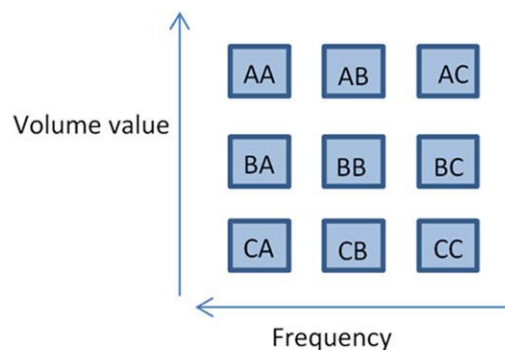


Figure 9: ABC-analyse in two dimensions⁶⁴

Grouping of items is a general way to easier and more practical control and distinguish the big variety of articles within a company⁶⁵. By classifying articles by

⁶³M. Rudberg, 2007, Artikelklassificering, http://www.optilon.se/Global/Dokument/Artikel_Artikelklassificering.pdf, 2011-05-26 ⁶⁴M. Rudberg, 2007, Artikelklassificering, http://www.optilon.se/Global/Dokument/Artikel_Artikelklassificering.pdf, 2011-05-26

the frequency that they are being moved, both received and picked during a certain period of time, an aid for managing and designing the warehouse is developed.

Classification are utilised in mission to design and dimension the warehouse layout and enable a smart placement of the articles in a rational way, from at picking point of view. It also guide lines the inventory control in the sense that articles with high frequency are being more often controlled than others⁶⁶.

3.1.5 Material flow

Four basic concepts concerning material flow within a warehouse will be presented and they are all developed for different kinds of organisations.

A circulating material flow results in cost savings since the receiving and shipping area are combined with no need of separate docks. The U-shaped layout benefits the same savings regarding receiving and shipping, the concept also enables placement of articles following ABC-classification, a way of classify articles that will be explained in following chapter. The combination of U-shaped warehouse and ABCclassification reduce the transportation cost since a greater part of the volume is transported a shorter distance. Approaching a triangular material flow enables development of functional areas. In the linear concept of material flow the goods will be transported all the way through the warehouse, from goods receiving to shipping. This results in increased transportations and concept is appropriate for facilities with high volumes and fairly few different articles with the advantage of a clearer flow⁶⁷. See Figure 10 for a visualised presentation. **Figure 10: Different concept of material flow within a warehouse⁶⁸**

⁶⁵S. Axsäter, 2006, Inventory control, 2:nd edition ⁶⁶S-A. Mattson et al., 2005, Logistik-läran om effektiva materialflöden ⁶⁷K. Lumsden, 2006, Logistikens grunder, 2nd edition

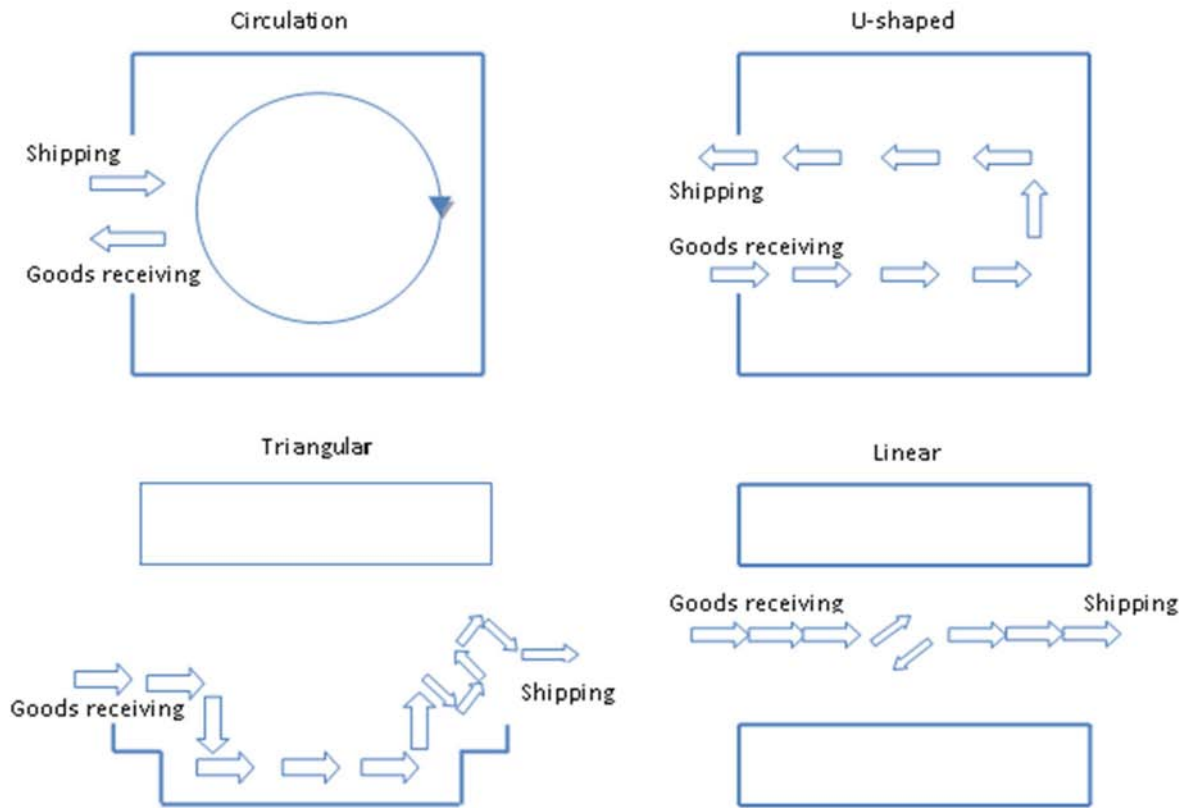


Figure 10: Different concept of material flow within a warehouse⁶⁸

3.1.6 FIFO, first in first out

FIFO is one of the simplest queuing policies in warehousing strategies and it is a principle that is highly usable when the quality of the product diminishes over time⁶⁹. It is a method used in inventory or production meaning that the first product that enters the inventory or production should also be the first one to leave⁷⁰. Strictly followed will imply that no customer is more important than another one. By using the FIFO method, the company will ensure that the oldest stock is used first and will reduce the cost of spoiled and obsolete inventory.

3.1.7 Placing the goods

When placing the goods within the warehouse, several factors are to be considered. The location will of course depend on which type of goods being stored, e.g. restraints regarding refrigeration or barriers to protect the goods from humidity. Even physical dimensions, as weight and height, and throughput of the articles will influence the placement. By basically categorise the goods and articles into groups, after physically dimensions, throughput ore similar functionalities, different systems

⁶⁸K. Lumsden, 2006, Logistakens grunder, 2nd edition ⁶⁹A. Muhammed et al., 2007, Optimum Packet Size of Voice Packet in the FIFO Adversarial Queuing

Model, Asia-Pacific Conference on Applied Electromagnetics ⁷⁰Accounting tools, <http://www.accountingtools.com/fifo-method>, 2011-06-09

might be utilised. Fast moving items with high picking frequency can preferably be placed closed to receiving or shipping areas in mission to reduce transportation and travel time⁷¹. Normally, a small amount of the articles stands for a greater part of the handling activities. If grouping the articles by the frequency that they are picked out of storage, these figures are common: 5 % of the articles stand for 50 % of the picking frequency, 20 % of the articles stand for 80 % of the picking activities and the remaining per cent of the articles are picked less frequent and represent approximately 20 % of the picking activities.

3.1.8 Fixed versus floating location

A fixed location, "A place for everything and everything in its place", the system where articles have their special and dedicated storage location within the warehouse or storage area reduces the amount or need of record keeping. On other hand, this system usually leads to poor utilisation since space must be available for the replenishment order quantity and the number of storage locations is the sum of the maximum inventory level for each article⁷². Floating location is a system commonly used for reserve stock where the goods are placed wherever an appropriate place is available hence the utilisation rate is high. This system requires, in contrast to a fixed location system, a well-structured record keeping⁷³.

3.1.9 Warehouse volume

Average inventory level⁷⁴;

$$\text{Average inventory level} = SS + Q/2$$

is the combination between safety stock, SS, and the order quantity delivered to the warehouse, Q. The sum for multiple products;

$$\text{Average inventory level} = SS_i + \sum_{i=1}^n \frac{Q_i}{2} \text{ where } i=1,2,3\dots n$$

This equation and method of describing the average inventory level within the warehouse are more applicable in organisations with an even or cyclic demand.

The dimensions of safety stock are chosen to cover the fluctuations in demand and the size depends on the risk and level of delivery security. Safety stock is a strategic decision however it is built on facts and figures⁷⁵.

⁷¹D. Notman, January 2009, Material Handling, Lund University, lecture 2 ⁷²

Ibid. lecture 5 ⁷³Ibid. ⁷⁴B. Oskarsson et al., 2006, Modern Logistik-för

ökad lönsamhet ⁷⁵S. Axsäter, 1991, Lagerstyrning

3.2 Empirics

3.2.1 Details characteristics

Figure 11 shows that Parts have today approximately 6000 m² of storage area spread on different areas around the present factory area. One area is dedicated to pallet racks and holds ten pallet racks with the measurements 10 m wide and 4 shelves high.

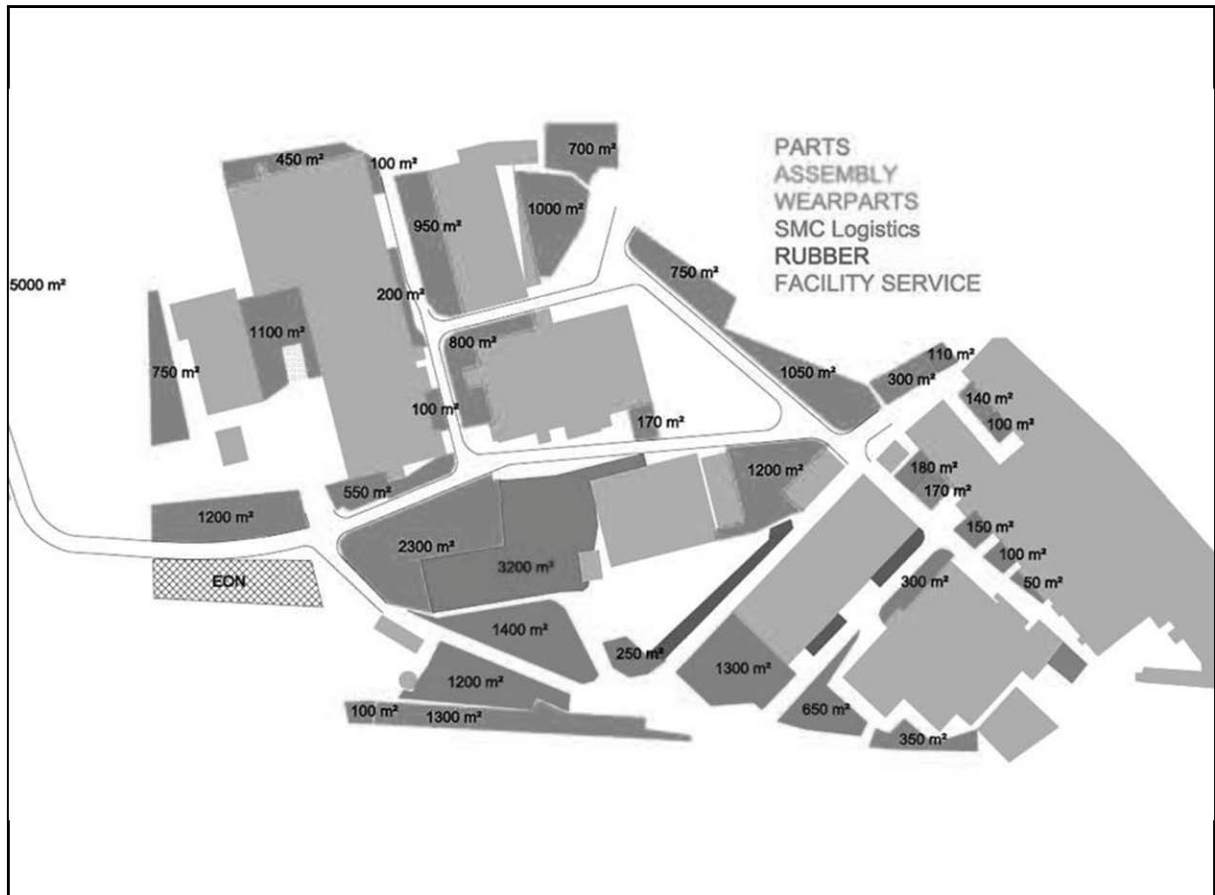


Figure 11: Goods storage areas today

The material characteristics of the different parts is generally the same, however the size and shape of the parts have large variety and thereby also the weight which can vary between a couple of kilos up to thousands of kilos. This result in that the different parts need to be stored on different places, either in pallet racks or free stacked on the ground.

3.2.1.1 Pallet rack goods

Today there are 400 pallet positions available in the pallet racks which according to the transport personnel is too few since a lot of goods which is possible to place in a rack today is stored on the ground. When the forklift drivers are placing the goods in racks they receive an area from the ERP system where the pallet should be placed

within. The driver then afterwards reports the specific position into the system. An observation is that the pallet racks are not filled to their highest capacity and without strategy or order; the articles within the rackets are not placed according to ABC-classification or any other system such as sorted by category. One benefit with the pallet racks is gained during the winter season since it prevents pallets and details to break or get stuck in the ground due to ice. With the pallet racks the details will be protected from this even though there is no ceiling. It is, on the other hand, harder to view the content of the top shelf pallet when it is covered by snow. The pallet racks can be placed on detritus area as long as the rack foundation is placed on concrete groundwork which can hold the weight of the goods. Between the pallets racks is today 7 m of distance, although a wish from a forklift driver is to increase this to 8 m to have enough space of handling the vehicle safely.

3.2.1.2 Free stacked goods

A part which fits on a European pallet, 800*1200 mm, is generally able to put in the pallet racks. Sandvik also uses 1200*1200, 1450*1450, 1750*1750 and 2100*2100 mm pallets and although these pallets are free stacked on the ground the pallets facilitates the handling of the material. Goods free stacked on the ground need reinforced asphalt due to its size and weight, to not sink in the asphalt or detritus. The goods are today placed in groups with similar characteristics; shafts with shafts and top parts with other top parts. The parts are stacked from in to out, and minimum FIFO is applied. The parts are marked with chalk the date of arrival and the oldest one is innermost, and therefore most inaccessible, and the newest one is furthest out. Since the parts are not very sensitive regarding time and conditions, the parts are not damaged by being stored outside although; after a while the parts will get rusty.

Transporting goods is entirely handled by forklifts due to the weight. The goods arrive from the supplier with truck or container. The transport personnel unload and place the goods on a pallet, which will be placed on the ground or in a pallet rack, or free stacked on the ground. Forklifts are also used moving goods into the factory for production. An issue today with the forklifts and the detritus areas is that the road is damaged throughout the seasons and thereby jeopardise the safe handling of heavy goods.

In the new plant, the material handling will, to and from the inventory, be handled by forklifts. The factory will have several entrances and exits which have to be considered when constructing the layout.

3.2.2 Green Field layout

Since the project of Green Field is a continuously on-going process the work has been affected by parallel projects. One of it is the layout of external areas of the

future factory which naturally affect this thesis outcome. The original layout, when this thesis started, is shown in Figure 12.

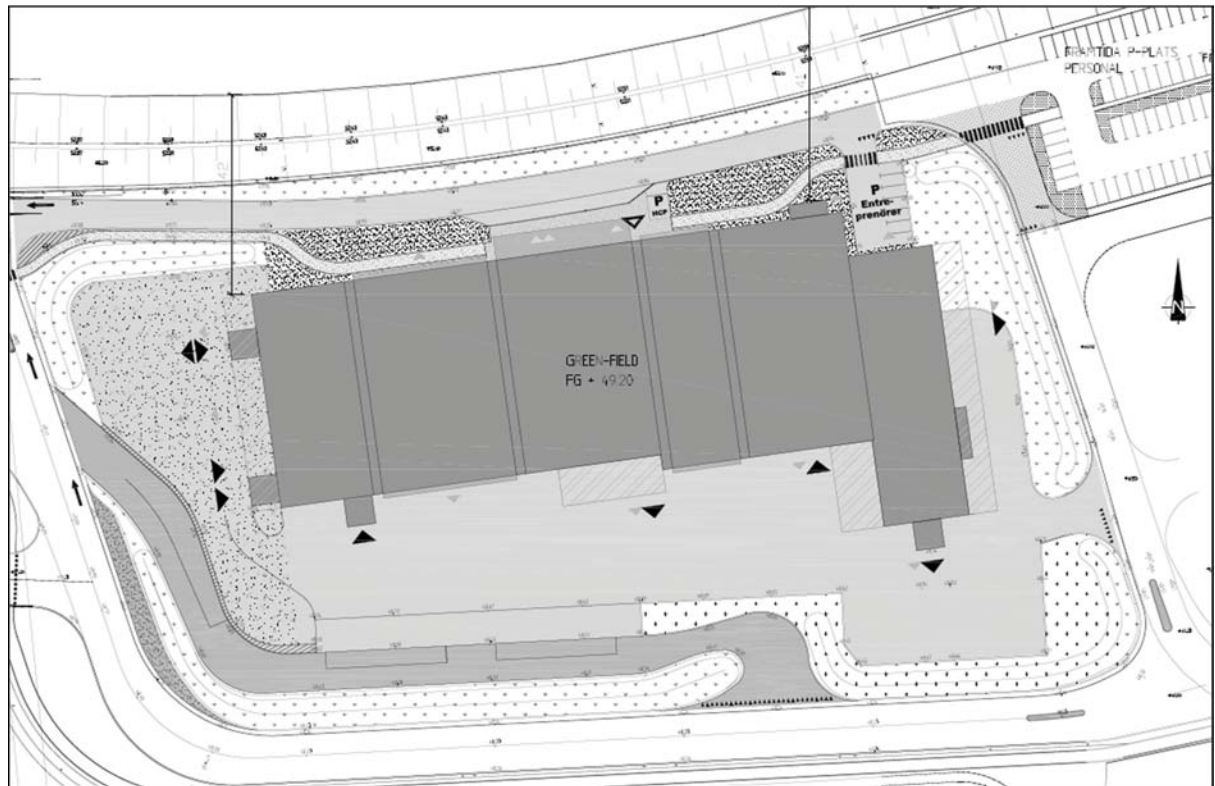


Figure 12: Original layout of Green Field

As shown in Figure 12 the Green Field factory is situated in the northern part of the area. Within the factory, as straight flows as possible is sought for why incoming raw material will enter in the west end of the building and finished goods leave in the east. There are also several gates along the building which limit the usage of the area in front of them. At the east end where the material will leave the building, there is an idea of having transport wagons where finished material can be placed and then transported to storage or the next step in the process. The road in south of the area contains surfaces which are intended to work as unloading areas where the trucks will unload both material and containers with raw material. The trucks will enter the road in west and exit in south. Since the traffic is occasionally dense, there is a truck waiting area if the two unloading squares are occupied. At the lower left there is a parking area for a finished truck before it will continue its drive. The white fields around the area are ditches needed to take care of surface water and slow up the damage if a substance harmful for the environment would leak into the drain.

The layout has been developed through several sessions and the drawing above was the current drawing when this project started. During the process opinions about the layout has occurred and the authors had the possibility to express these opinions

and together with the persons present contribute to the development of a new plan proposal which together with the findings will be presented in the next chapter.

3.2.2.1 Layout flaws

The original layout had flaws regarding the surfaces surrounding the factory. To maximize the utilisation there were several points to improve:

- The ditches and green areas surrounding the area was unnecessary large.
- Since the upper left corner was rounded, it was hard to maximize the use of it.
- The entrance for the unloading area steals a lot of surface which could be used for storage area.
- The area would benefit if the road in south was located even more south to increase the possible storage area.
- By moving the roads turn in south to the right, the area would be easier to utilise.
- The transport wagon area would benefit a lot of an extra exit road to facilitate the turning of the wagons.

The result of the inputs and changes will be presented in the result chapter.

3.2.3 Model of analysis

In the beginning of the Green Field project, Sandvik hired a consultant firm to investigate the required factory area for a production for 600 crushers a year. The report has contributed with data and information, see closer description of which below.

Assumptions:

- Daily demand of material is calculated on a 365 days a year production.
- The Green Field factor, GF-factor = $370/600 = 1.62$, linear increase of production from 370 crushers to 600 crushers. The same factor is applied for spare parts.
- Cover time and safety stock equal as today.
- Clearance between goods = 20 %

Since the production in Green Field not will be equal today, regarding quantity and product range, some assumptions had to be made to get an opinion of the amount of raw material needed to be stored in Green Field.

The parts for crushers and also spare parts are assumed to increase linear up to production of 600 crushers, which is an increase by 62 %. This factor, the GF-factor of 1.62 is applied on the daily demand when calculating the requirements.

To be able to dimension the inventory level, the amount of goods expected to be stored needs to be calculated. Due to lack of sufficient data in the ERP system concerning order quantity and safety stock to calculate average inventory level, the equation for calculation presented in the theory chapter could not be used. A calculation with the data possessed had therefore had to be made. In the ERP systems there are two types of cover time and safety stock, forecasted and current, and the authors have chosen to calculate two ways to get a bigger picture of the possible amount of goods. A requirement for the inventory is that it should manage three months of production to be able to handle increase of production. This will result in three parallel solutions for the problem.

Data concerning the daily demand of goods is calculated on 365 days of production basis and gathered from Qlikview which is a business intelligence system that Parts use. The daily demand is based on the production volumes today; hence a Green Field factor has been developed to describe the relationship between the volume today and the future produced volume. The GF-factor will further on describe the increase of volume of future daily demand. Data concerning cover time and safety stock is also gathered from Qlikview.

By adding the parts demand during its cover time and also the safety stock level, an average stock level has been calculated. The cover time and safety stock is not within this thesis frames and will therefore not be analysed and is considered to be equal to today. Data about the relationship for the part and its required pallet size is withdrawn from the consultant report mentioned earlier. The amount of pallets required for each part is rounded up to next integer since there is by nature only full size pallets in the storage.

The future holds a number of new crushers why some of the parts which will be manufactured in Green Field are not manufactured today. Therefore have the demand, safety stock and cover time been estimated with the same data as similar parts.

Pallets larger than a normal European pallet is accounted as free stacked goods. Free stacked goods need clearance to enable the forklift to pick up the goods without damaging other parts. To achieve the clearance 20 % has been added to the required surface and will secure safe goods handling.

Shafts characteristics, length and weight, is based on data from the finished detail drawings.

When the three months of production alternative was calculated, the daily demand was simply multiplied with the daily demand to get the amount of goods. The safety stock is not added since it is considered be included in the three month demand.

In addition to the raw material, an area of 100 m² for adjustment goods is needed. The goods are details which need to be adjusted before they can be put in stock. Today the area is about 50 % larger, but with a faster handling time the surface is possible to increase. A smaller surface also forces the responsible to take quicker actions against quality issues.

3.3 Recommendations

3.3.1 Changes of layout

When starting up the project for designing a raw material inventory for Green Field, the first mission was to decide the amount of reinforced asphalt needed for the area around the factory. During the project the conditions have been changed, why this chapter begins with a declaration of the changed conditions.

The inventory layout requires optimal surfaces to store the goods on. By taking part of a meeting with a consultant firm regarding the layout, the authors contributed to a change off the external layout. The new layout and its changes are presented below in Figure 13:

- Decreased ditches and green areas around the area.
- Upper left corner is now phased and creates an area which is easier to use.
- An entrance/exit road for the transport wagons is added which will simplify the drive, the driver only need to drive forward and never backwards.
- The unloading road in south has been moved to the east and more south. The truck turn is maintained to enable the truck to turn and be right to the exit road.
- The truck entrance road has been transferred from west to south. The road is still safe from a traffic perspective with good view of the opposing traffic.

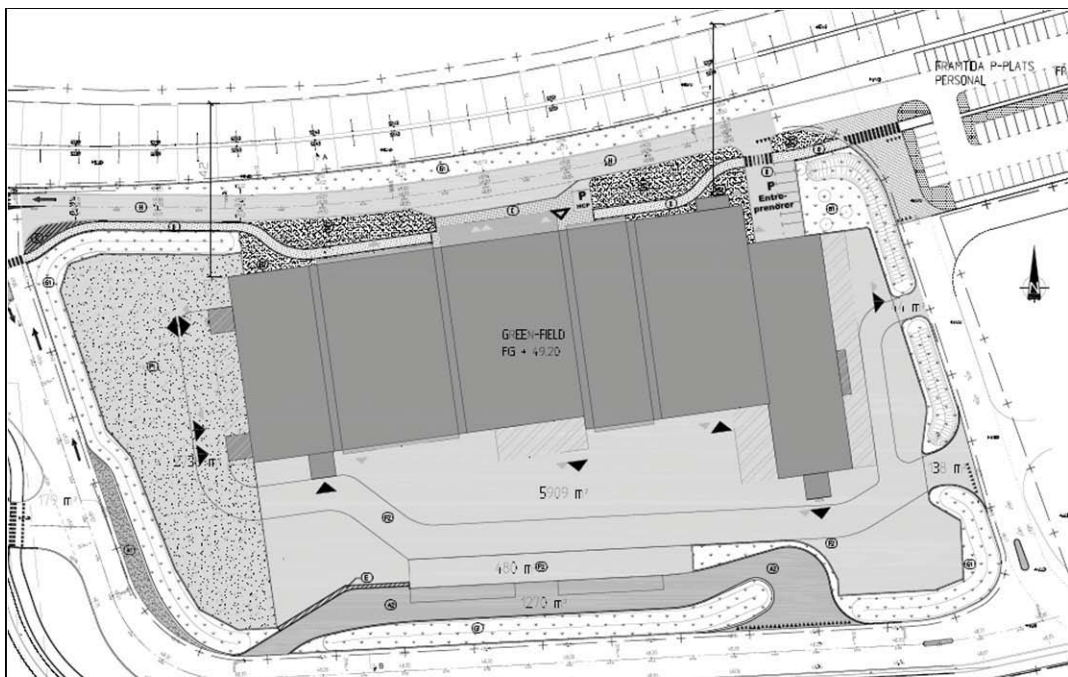


Figure 13: New layout of Green Field

These changes that have been made are certainly not the last but have contributed to improvements regarding the usable areas for the Parts raw material inventory. Before the change, the area available for storage was circa 2600 m² and after the changes 3300 m², an increase of 27 %.

To maintain the flexibility of the storage area, reinforced asphalt is recommended of the whole area, which would result in a total amount of asphalt, with the unloading road not included, of circa 7400 m². To increase the available areas for storing goods further, the truck path should be audited. To gain even more available surfaces, the truck path could be placed where it is difficult to store goods viz. along the fabric walls.

3.3.2 Inventory goods

The different goods needed to be stored at the Green Field inventory is divided into three separate groups of details after their way of being stored: pallet rack goods, shafts in pallet racks and free stacked goods. With three different types of data, three different areas are calculated for each group. As seen in the tables below, the 90 days cover time demands significant more space than the other alternatives, but since this is the amount of goods the inventory should be able to store, the future layout will be based on those calculations.

3.3.2.1 Pallet rack goods

The pallet rack goods are details which in today's inventory is stored in pallet racks. The number of pallet position needed is calculated, with data from the consultant report and M3, the ERP-system, depending on daily demand, cover time, safety stock and also amount of details per pallet. To sustain flexibility and avoid over filled pallet racks, a flexibility factor of 20 % has been added. The aisle of the pallets is included in the calculation, a pallet rack and a half of an aisle per rack, why the total area is the total amount of space needed for the group. The pallet rack goods are smaller parts with often a high frequency of usage, why it is advantageously placed close to the fabric entrance.

Table 1: Estimated area for pallet rack goods

Pallet position	Flexibility with available pallet positions 20 %	Number of pallet racks 10 m, 4 floors	Area per pallet rack (including truck aisle) Total area
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Current cover time 146 175,2 5 53 265 **Prog cover time** 141 169,2 5 53 265 **Cover time 90 d** 373
447,6 12 53 636

3.3.2.2 Shafts in pallet racks

Today, the majority of the shafts are stored free stacked on the ground. This is a very ineffective usage of space, why it is recommended to store the shafts possible in pallet racks. Since the area for inventory at Green Field already is less than the area available today, this is a high prioritised issue. The qualification for a shaft to fit in a standard pallet rack, with some reinforcements, is a weight of maximum 3000 kg and the length under 2 m. With these requirements over 50 % of the former free stacked shafts was possible to store in pallet racks. Regarding shafts with a length exceeding 1 m, the shaft needs two pallet positions next to each other to be able to fit. As in the pallet racks goods, a flexibility factor of 20 % is added to ensure that there always will be free positions. Since the shafts might be hard to handle with a truck due to the length, it is preferred that the racks are placed with no opposite pallet rack. Therefore the area required is calculated as the pallet rack and 8 meters aisle.

Table 2: Estimated area for shafts in pallet racks

Pallet position	Pallet position pallet positions	Flexibility with available pallet racks 10 positions 20 %	Number of pallet racks 10 (including truck aisle)	Area pallet (inc. truck)
20 %	Current cover time	127 152,4	6,0 93 558	Prog
Total				
cover time	104 124,8	5,0 93 465		
Cover time	90 d 264 316,8	11,0 93 1023		

3.3.2.3 Free stacked goods (including large shafts)

The free stacked goods area is based on what kind of pallet size it would fit on. Since the different parts have different shapes, this is an estimation of the area for the goods. The goods should not be placed too tight on each other; a 20 % clearance is therefore added. The sum of the area does not include truck aisles since this is a strategic question for the management to handle. Of course, in the perfect world, FIFO is applied throughout the entire inventory where the oldest detail is picked first, but this would require huge areas and be inefficient space usage. The management need to make a decision if FIFO is as important as the cost of it. If an expansion will be made, will there be additional areas to use or is the purpose to use and compress the current ones? In this scenario, FIFO probably would be ignored to fit the material in the inventory. To use the same material placement as today, the material tracking needs to be improved to be able to always know where each product is.

Table 3: Estimated area for shafts in pallet racks

	Theoretical area for goods	Clearance 20 %	Sum theoretical area
Current cover time	268,8	1,2	323
Prog cover time	297,4	1,2	357
Cover time 90 d	1075,3	1,2	1290

3.3.3 Goods placement

As earlier mentioned, goods frequently used should be placed close to the entrance of the factory building. This is why it is recommended for pallet goods to be stored in pallet racks at the area closest to the factory entrance. The forklift traffic will be quite heavy, why the transport distances should be lowerd as much as possible. This will result in increased safety and also lower the amount of noise and exhaust which is positive in a matter of surrounding environment. The inventory area will be limited, why some of the layouts presented in the theory chapter will be hard to apply. Since shafts are possible to store in pallet racks and are not always the easiest to manouver, they should therefore posses the pallet racks in close connection to the factory walls. This to facilitate for the fork lift driver who can use the whole truck path to turn the vehicle with load. The pallet racks along the wall will not be sufficient, why the end of the outer racks at the other area will function as storage for shafts. If the inventory would be brimming, i.e. keeping inventory for three months production, the pallet racks would not be enough. The marked area for pallet racks is estimated to hold 21 racks which would almost be enough according to the estimations for alxes and pallet goods. See Figure 14 for illustration of the goods placement.

Since the exact amount of area needed for the free stacked goods is hard to estimate, 2300 m² is reserved for this type of goods. If the stock would be filled with three months of production, this area would be very scarce dimensioned and visual FIFO would be almost impossible.

Within the type of goods areas, the order is preferrably influenced by their doubled ABC-classification since this takes both frequency and volume value in consideration. This classification of details is already in the ERP-system and every detail is classified.

The inventory should also include a adjustment area, which is recommended to be placed at the west end of the factory as the adjustment weld is located in this region.

By having the area close to the details' next stop, the transportation is minimised and it is also easier to keep track of the details stored in the inventory area.

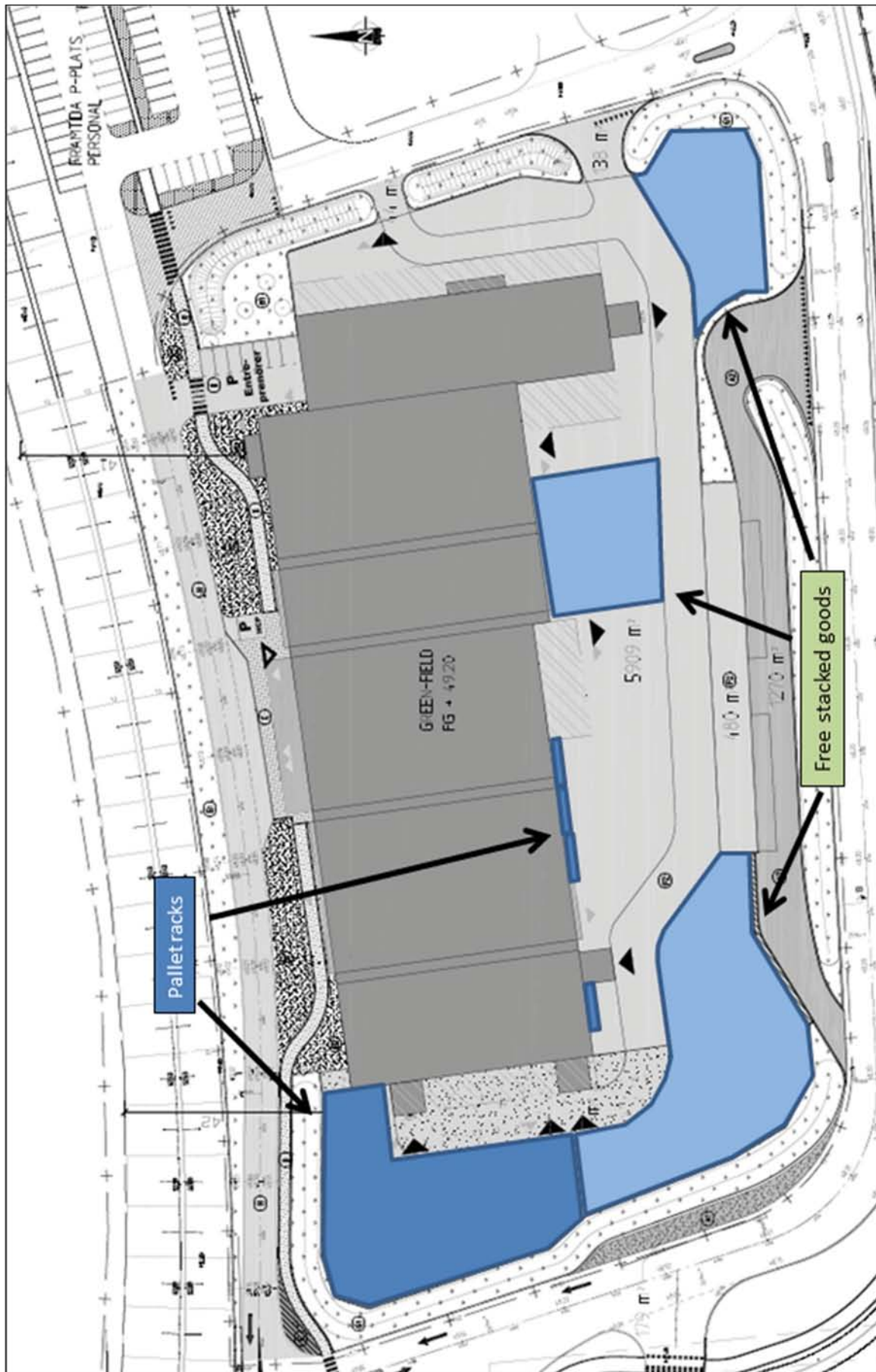


Figure 14: Goods placement

4 Production planning and control

This chapter will give the reader an insight of the importance of production planning, since different processes require different planning and control systems. The present situation of Parts has been analysed in mission to develop recommendations for the production planning in future Green Field.

4.1 Theory

4.1.1 Planning

Planning mean making decisions about future activities and events⁷⁶. The decisions might have time frames from the closest hours or days e.g. planning what order to make, and is called operative planning. Decisions concerning events that will not have affect until six months from now e.g. decisions concerning investments and hiring, is called long term planning. Naturally, different levels of decision require different levels of details for the decision basis^{77,78}.

In a manufacturing company it is common to use the planning functions: sales and organisation planning, head planning, order planning and detail planning⁷⁹. Capacity is a measurement of certain resources abilities to perform. Manufacturing company usually measure different production resources abilities to refine material. The most common units for capacity is man-hours or machine hours per period but other units as number, kilograms and money per period occurs⁸⁰.

Production planning involves material requirements planning, capacity planning and process scheduling. Delays of material delivery and machine break-down are just a few of the things that can decrease capacity and interrupt the production plan⁸¹. According to Patig there is three ways to cope with these uncertainties; ensuring proper safety stock, make sure the production plan is obsolete else re-do and make it right and finally; make the production plan flexible enough to cope with disruptions⁸². In the ideal world, a company should have large safety stock and top quality machines to be able to satisfy all of its customers. However, as often, the problem is money. The customer is not willing to pay the

⁷⁶ www.ne.se/planering, 2011-03-11 ⁷⁷P. Jonsson, S-A. Mattsson, 2005, Logistik ⁷⁸ www.ne.se/planering, 2011-03-11 ⁷⁹P. Jonsson, S-A. Mattsson, 2005, Logistik ⁸⁰ Ibid. ⁸¹S. Patig, 2001, Using planning steps for productive planning ⁸² Ibid.

price that would be necessary to charge for the product. To know where to invest money, the company have to look at the company strategy, whether it is for example high delivery reliability or quality and then strategically place the money.

One of the major problems in planning is that it rarely coherent with the reality, and as literature describes it; “forecasts are never correct”. There are often restraints in available capacity or in material resource and the challenge is how to deal with these problems, either by longer lead times or more flexible capacity⁸³.

4.1.2 Process choice

Different types of products are appropriate to manufacture in different types of processes. Products can be split into three different categories; special products, standard products and mass products. Which category a product belongs to is depending on the product variety and also the volume⁸⁴. For example; a yacht is manufactured in low volumes but is probably offered with a high variety of options on motor, seats, colour etc. Compare this to medicine which is produced in high volumes and with few options to change for the product. The later alternative often has a low cost per item but a production process which is inflexible. According to Hill, there are five generic types of manufacturing process: project, jobbing, batch, line and continuous processing⁸⁵.

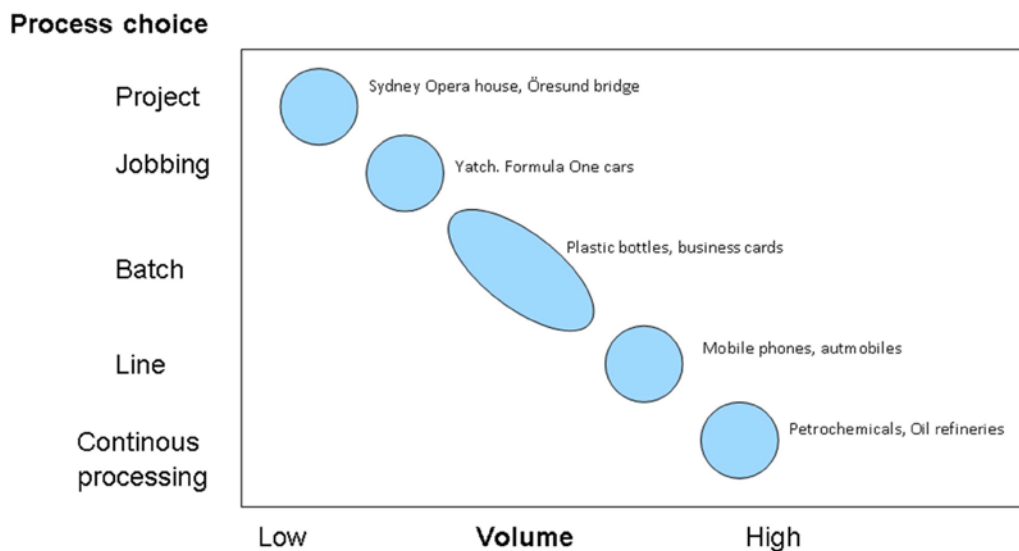


Figure 15: Process Choice⁸⁶

⁸³Oskarsson et al., 2006, Modern logistik-för ökad verksamhet ⁸⁴

T. Hill, A. Hill, 2009, Manufacturing Operations Strategy ⁸⁵Ibid.

⁸⁶T. Hill, A. Hill, 2009, Manufacturing Operations Strategy

The project process is often used for one-off and complex products which normally are built on place at the customer, since the product often is large and difficult or even impossible to move when it is finished. Also the resources are moved to the building site which is necessary but costly. Therefore the company often tries to prepare and produce as much as possible of site and then move parts of it to the site for assembly. Examples of this kind of products are buildings, roads and bridges.

Once the products are possible to transport, companies tend to use the jobbing process. The jobbing process is applicable to unique, one-off complex products that are possible to move, and therefore possible to manufacture elsewhere than it is purposed to be once finished. The products require the supplier to interpret the customer needs and expectations to be able to satisfy. The group working with the product is skilled and responsible for making the process as best possible.

When the volume increase and the products are manufactured on a more common basis the company can use the batch process. This process type covers a wide range of volumes as seen in Figure 15: Process Choice and can therefore be the process choice for both low to mass volumes. When producing in batch process, the manufacturing is divided into a number of different steps, which will depend on the product complexity. The entire batch size will be completed in one step before entering the next one. Since batch is between jobbing and line, it links the differences between the two businesses process together. For example the strategies of low/high-volume, special/standard-products and make-toorder/make-to-stock are combined.

Line process is suitable for high volume products where investments are made to suite a single product or group of products. The production equipment is dedicated to the product or product group and a change of manufacturing will be wide and costly. In almost every case; the higher flexibility that the equipment is developed for, the higher equipment costs. In contrast to batch process, the line process never needs to stop, even when changing products.

The last process alternative is continuous processing which is well suitable for high volume products, which easily is moved from one part of the process to another. Usually the narrow product range contains of liquid or gas which will be transported through pipe lines. The start-and stop-cost is very high so it is important to maintain continuous processing.

To satisfy the customers at a specific market, many companies have developed hybrid processes. Some are mixes between two of the generic processes and others are developments of an existing process type⁸⁷. An example is NC-machines, numerical control

⁸⁷T. Hill, A. Hill, 2009, Manufacturing Operations Strategy

machines, which in reality is a batch process since the machine stops after the current job ends, but is striving towards the jobbing process and can do complex one-off products.

4.1.3 Planning and control systems

In many occasions the challenge for manufacturing companies is the creation of robust systems and processes that can handle the disorder and problems that occurs within the production. In this chapter a comparison between different planning and control systems will be conducted. Initially, a brief introduction, history and development of today's system in general are presented. To easier follow the discussion or its contents, Figure 16 visually describes the interaction of the systems that is being represented.

4.1.3.1 Planning and control system

The demand of functional planning and control systems within a manufacturing company is of highly importance and the performance and reliability are crucial for the organisation. The system must be able to schedule production, plan demand material and control shop floor activities. Control and planning of the shop floor activities ensures that the production fulfils the customer demands regarding delivery. The industries can choose to either push, towards a forecast, or pull the manufacturing orders through the production towards a customer order⁸⁸. The production schedule, either the demand is based on forecast or it is known, determine the products that are to be made and at what time. The questions whether make-to-order, assemble-to-order or make-to-stock is important and decisions are taken on strategic level within the company⁸⁹.

4.1.3.2 History

Before the enormous industrial growth within the 1950's, manufacturing companies utilised punch cards, tape equipment or various kinds of office equipment to control and manage their business processes⁹⁰. The calculation of required amount of material in an assembly, the demand of BOM explosion, could and was often made manually. Although, the planning process could take days or weeks to perform for a large assembly which resulted in a disability to quick cope with changes within orders or plans. For these calculations to be meaningful, the required quantity needed to be netted in each level, in a sense that determine the net requirements considering stock on hand, open purchase orders etc.⁹¹.

⁸⁸Hill et al, 2009, Manufacturing operations strategy, 3rd edition, ⁸⁹Ibid. ⁹⁰J. Peeters, Early MRP systems at Royal Philips Electronics in the 1960s and 1970s, History of Technology Foundation, Vol. 31, No. 2, 2009 ⁹¹Ibid.

These two demands can be explained to constitute the heart of MRP. MRP is an integrated system for production planning control that level by level manage a BOM explosion and calculate the net demand⁹².

4.1.3.3 Development

During development within production planning and material control, new methods and philosophies has been introduced. Every step in the development has satisfied requirements demand but also created new expectations and demands. Increased desires of new features and functionalities has progressed the development forward, from MRP to MRP II and further to ERP⁹³.

The traditional production planning methodologies has received notions of being inventory intense and also insufficient regarding time to market in contrast to new and alternative methodologies like JIT and OPT/TOC, two methodologies which will be explained further on⁹⁴. As the competitive environment of market becomes more and more uncertain, time has become the most powerful resource⁹⁵. However, in literature the MRP methodology is still described as the planning production tool that remains most effective in non-repetitive production⁹⁶.

4.1.3.4 Material Requirements Planning, MRP

Material Requirements Planning, MRP, is a management system that is based on the fundamental principle that planned delivery time for incoming material is determined from the time when demand of material arises. MRP is commonly referred to as a push system⁹⁷. The demand of material is built on forecasts and in mission to cover uncertainty regarding this, safety stocks or safety lead time is applied⁹⁸. In purpose to determine time of production start the approach of MRP is to plan backwards in time. Hence, it initially starts in date for delivery of the end product and counts backward for every assembled detail⁹⁹.

For products containing underlying components and sub-assemblies, MRP also consider the demand of degeneration of resources with help from a list of material. This list, the bill of material or BOM, is a list that is hierarchical structured with all included information

⁹²J. Peeters, E., 2009, MRP systems at Royal Philips Electronics in the 1960s and 1970s, History of Technology Foundation, Vol. 31, No. 2 ⁹³Ibid. ⁹⁴G. Plenert, 1999, Bottleneck allocation methodology (BAM): an algorithm, Logistics Information Management, Vol. 12, No. 5 ⁹⁵W. Jiang et al, 2009, The methods of improving the manufacturing resource planning (MRP II) in ERP, International conference of computer engineering and technology ⁹⁶G. Plenert, 1999, Bottleneck allocation methodology (BAM): an algorithm, Logistics Information Management, Vol. 12, No. 5 ⁹⁷K. Nagedra et al., 1999, MRP/sfx: a kanban-oriented shop floor extension to MRP, Production planning and control, Vol. 10, No. 3 ⁹⁸S-A. Mattson et al, 2005, Logistikk-läran om effektiva materialflöden ⁹⁹K. Lumsden, 2006, Logistikens grunder

regarding sub components to an end product. For example; the raw materials, subassemblies, intermediate assemblies, sub-components, components, parts and the quantities of each needed. From planned orders the MRP system breaks down the BOM in a structured way, all the levels down to the raw material or purchased items and for each level the articles are planned regarding the net based demand¹⁰⁰.

4.1.3.5 Manufacturing Resource Planning, MRP II

The Manufacturing Resource Planning, MRP II, is an extended concept from the MRP and was developed during the 80's¹⁰¹. The ability of the software program to integrate production function with other functions within a company, e.g. purchasing, engineering, marketing and accounting is one of the main reasons of its popularity and the system is applicable to a wide range of manufacturing companies¹⁰². Although, the MRP II system has in literature received negative opinions regarding, among other things, its defections and it is criticised for its use of fix lead time. The fact that MRP II use fixed lead time as parameter in planning limit the possibility to satisfy the requirements of flexible and adaptable manufacturing systems.

Safety stocks are set in order to cover the uncertainty within production, fluctuated demand and machine break down, and the level of security or the quantity is initially set to be a fix parameter although even the degree of fluctuant demand varies. In an international conference article, it is described that the system should set bigger safety stock when the degree of fluctuation was higher and small safety stock when the degree was low¹⁰³. One of the primary drawbacks with both MRP and MRP II systems is the ineffective shop floor control. The shop floor control, SFC, is the performance of scheduling the day-to-day production and roughly the SFC involves some major tasks. E.g. assigning jobs to limited resources, sequencing job at each machine, department or process group and conduct detailed scheduling of start and end times¹⁰⁴.

4.1.3.6 Advanced Planning System – APS

Every day, Enterprise Resource Systems (ERP) and Material Requirements Planning Systems (MRP) are used in manufacturing companies all over the world. For some of them, the company would benefit a lot from implementing an APS, Advanced Planning and Scheduling System, as a complement to the ERP system. APS systems are used to help

¹⁰⁰S-A. Mattson et al, 2005, Logistik-läran om effektiva materialflöden ¹⁰¹P. Kraemmergaard et al., 2009, A research framework for studying the implementation of Enterprise Resource Planning (ERP) systems, Centre for Industrial Production, ¹⁰²K. Nagedra et al., 1999, MRP/sfx: a kanban-oriented shop floor extension to MRP, Production planning and control, Vol. 10, No. 3 ¹⁰³W. Jiang et al, 2009, The methods of improving the manufacturing resource planning (MRP II) in ERP, International conference of computer engineering and technology ¹⁰⁴K. Nagedra et al., 1999, MRP/sfx: a kanban-oriented shop floor extension to MRP, Production planning and control, Vol. 10, No. 3

manufacturers to optimize their schedules for production and warehouses¹⁰⁵. When generating the production schedule, APS has the availability to, in contrast to MRP systems; simultaneously take in to account material and capacity constraints which are a valuable asset in planning production. This is to overcome unrealistic assumptions in mission to get the actual picture rather than pretend to live in the ideal world, where capacity limits or material replenishment issues does not exist. The key feature of the APS is Finite Capacity Scheduling, FCS, which plan the jobs so that the capacity availability for each and every machine is not exceeded¹⁰⁶. To work properly, the APS system have to have access to up-to-date and sufficient data from the ERP system. The techniques behind a APS system to create the best manufacturing schedule is linear programming, advanced mathematical formulas, rules and heuristics¹⁰⁷.

4.1.3.7 Enterprise Resource Planning, ERP

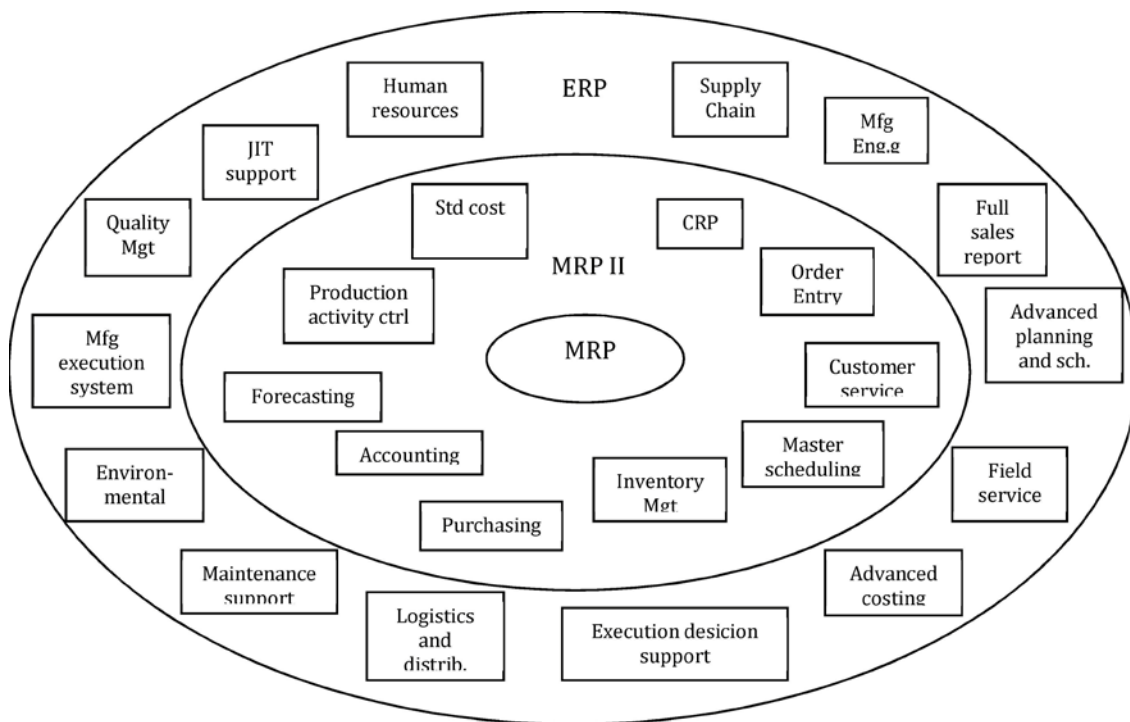


Figure 16: Relationship between ERP, MRP II and MRP¹⁰⁸

Figure 16 gives a visual explanation of how different planning and control systems interact and relate.

¹⁰⁵B. Wagoner, 2007, Plant floor scheduling systems in a lean environment, North Carolina State University ¹⁰⁶W. Liu et al., 2002, APS, ERP and MES systems integration for Semiconductor, Backend Assembly, Singapore Institute of Manufacturing Technology ¹⁰⁷B. Wagoner, 2007, Plant floor scheduling systems in a lean environment, North Carolina State University ¹⁰⁸B. Wagoner, 2007, Plant Floor Scheduling Systems in a Lean Environment, North Carolina State University

MRP II is the core within the Enterprise Resource Planning, ERP, which has been widely used within manufacturing industries¹⁰⁹. MRP and MRP II may be seen as the predecessors to ERP but in contrast to MRP II, ERP systems also include suppliers and customers – it is a system for the total business enterprise¹¹⁰. The thesis will not treat this subject in depth. The target group for the thesis presumes to have the sufficient knowledge of ERP, since the reader only needs an overall understanding for ERP to benefit from the thesis.

4.1.4 Lean Production

“Lean manufacturing is the identification and application of best manufacturing practice to eliminate waste and variation”¹¹¹.

This is one of several definitions of the Lean philosophy, a philosophy which during the years have gained attention in the industry world. Both opinions from researcher and information from literature have several different and conflicting definitions of what the Lean philosophy really means. Continuously production development is crucial and a condition for a competitive manufacturing company and the Lean philosophy has enable manufactures all over the world to improve and gain good results in costs and quality¹¹². The transformation from classic production into Lean philosophy has for many companies been seen as a paradigm change, a total new way of thinking and control the production¹¹³. Normally the philosophy is applied in production processes within manufacturing companies where physical products exist. However; literature also describes that it with enough amount of creativity can be applied within other service processes such as problem solving and information management¹¹⁴.

Lean production as a concept was founded by Womack and Jones when conducting a study of the global car industry and has its history in the Japanese car manufacturer Toyota and are also known as the Toyota Production System^{115 116}.

¹⁰⁹W. Jiang et al, 2009, The methods of improving the manufacturing resource planning (MRP II) in ERP, International conference of computer engineering and technology ¹¹⁰K. Nagedra et al., 1999, MRP/sfx: a kanban-oriented shop floor extension to MRP, Production planning and control, Vol. 10, No. 3

¹¹¹M. A. Lewis, 2000, Lean production and sustainable competitive advantage. International Journal of Operations and Production Management, Volume, 20, number 8, p 959-987 ¹¹²N. Piercy, N. Rich, 2009, Lean transformation in the pure service environment: the case of the call service centre, , International Journal of Operations & Production Management, Vol. 29 No. 1 ¹¹³J.-E. Ståhl, 2009, Industriella tillverkningssystem-länken mellan teknik och ekonomi ¹¹⁴B. Keyte et al., 2004, Lean-handboken ¹¹⁵J.-E. Ståhl, 2009, Industriella tillverkningssystem-länken mellan teknik och ekonomi ¹¹⁶M. Holweg, 2007, The genealogy of lean production, Journal of Operations Management, vol 25

Within the Lean philosophy there are several tool, for example 5S, VSM, Kanban, OEE and SMED¹¹⁷.

5S A tool focusing on five different S within the production: Sorting, Straightening, Systematic cleaning, Standardizing, Sustaining. The workplace should be clean and organised with everything at its place so that minimal time is dedicated for unnecessary searching.

VSM Value stream mapping, a way of analysing and clarify the flow of both information and material all the way from customer order to the products are delivered at customer. It is used in mission to decrease the non-value adding activities and eliminate waste activities to create an improved flow where every activity has its purpose.

Kanban The Japanese word means card and are one of the most recognised Lean tools. It is a sort of a two bin system that is often used within industries with a stable demand and flow and in practice the tool controls the supply of material and information between different stations within the production. It creates a pulling system since the card works as a material order and is sent backwards in the chain when the demand arises at a station.

OEE OEE is short for Overall Equipment Effectiveness and is measurements which reduce complex production into a relatively easy way to measure the production efficiency. It enables finding bottle necks and putting goals to achieve within production to get high utilisation. The measure consists of three parts; availability, performance and quality.¹¹⁸

SMED Singe Minute Exchange of Die, a tool that focus on minimising the required time for changing die within the production should not exceed ten minutes. By separating external and internal set up-time, preparations can be made in mission to reduce the time that the machine is not operating.

Literature describes that there are often a certain degree of misunderstanding of the Lean tools and their purpose. The risks of misunderstanding the tools are the use of wrong tool to solve a problem or the use of a single tool to solve all problems etc.

4.1.4.1 Lean thinking

The Lean philosophy has it origin in the Toyota Production System, TPS, and the philosophy is concluded in 14 fundamental principles which can be grouped into sections.

¹¹⁷J-E. Ståhl, 2009, Industriella tillverkningsystem-länken mellan teknik och ekonomi ¹¹⁸
<http://www.oee.com>

Realise the role of the employees and their competence and since it is the people that add value to the organisation, it is important that they continuously develop. In Lean philosophy the employee has an important role; it is the people who bring the system to life. The workers are expected to be active in improving the both processes and their own work and it is supposed to not be seen just as a system but also a culture¹¹⁹. The human resources should in teams develop and help each other to grow within the philosophy of the company. By finding the roots to problems the organisation will continuously learn and improve by reflection. Decisions should be slowly and thoroughly analysed before execution, while the implementation should be made rapidly¹²⁰.

The management should be based on long term decisions prior short term financial gain. Develop the right processes with focus on value adding activities that will create value for the customer. Minimise overproduction by creating a pull system, even out the work load and continuously bring up problems to the surface in mission to improve the process. Quality is highly prioritised and it is important to build up a culture where "quality right at the first time" is general hence it is accepted to stop or slow down the production to improve the process and enhance the quality in the long run. The processes should be standardised, with visual controls and well adapted technology to facilitate for the employees. Realise the role of the employees and their competence and since it is the people that add value to the organisation, it is important that they continuously develop. In Lean philosophy the employee has an important role; it is the people who bring the system to life. The workers are expected to be active in improving the both processes and their own work and it is supposed to not be seen just as a system but also a culture¹²¹. The human resources should in teams develop and help each other to grow within the philosophy of the company. By finding the roots to problems the organisation will continuously learn and improve by reflection. Decisions should be slowly and thoroughly analysed before execution, while the implementation should be made rapidly¹²².

Five Lean principles are described in a famous book, of James Womack and Dan Jones, Lean Thinking (1996) in mission to guide managers through a transformation into Leanmanufacturing:

- 1 Value, the customer value is the most important and it is also crucial to determine what that really is.
- 2 Value stream, determine the process that leads to customer value and eliminate the areas that does not add any value.

¹¹⁹J. Liker, 2003, The Toyota Way

¹²⁰J. Liker, 2003, The Toyota Way

¹²¹Ibid. ¹²²Ibid.

- 1 Flow, analyse and improve the value stream both of products and information. Remove buffers and apply instead cellular work and multi-skilled employees.
- 2 Pull, meaning the creation of a production where the actual demand are the driving factor.
- 3 Perfection, in continuously improving processes and systems regarding the above principles.

To summarise; Lean is: “right product at the right time at the right place in the right quantity at the right price and at the right quality”.¹²³

4.1.5 Tools for production planning

4.1.5.1 Just in Time, JIT

The famous and well recognized concept of Just in Time, JIT, is applied in many companies. The strong characteristics of the method and philosophy, is the idea of elimination of all waste, by having a pull based production, reducing manufacturing lead time, transportation and inventory levels^{124 125}. JIT also have three other overall principles; developed systems that are meant to discover and determine problem, attack and solve the problems and strive towards simplicity within all processes¹²⁶. JIT is commonly applied within manufacturing industries and the demands of short lead time has shown to be an increasingly trend¹²⁷. JIT has proven to be extremely effective in high repetitive and fixed productions environment and it is developed and adapted to production processes where the product variations are limited¹²⁸. The variations should be limited within such a narrow range that the production will not be distinctly affected by eventual change of product. Within JIT, the production orders are all in the same size. These factors characterise JIT as a method that are non-effective and inflexible in productions that are non-repetitive or with varied demands operations¹²⁹.

¹²³ <http://expertscolumn.com/content/introduction-lean-manufacturing-principles>, 2011-06-08 ¹²⁴ S-A. Mattson et al, 2005, Logistik-läran om effektiva materialflöden ¹²⁵ G. Plenert, 1999, Focusing material requirements planning (MRP) towards performance, European Journal of Operational Research, Vol. 119, No.1 ¹²⁶ K. Lumsden, 2006, Logistikens grunder ¹²⁷ S-A. Mattson et al, 2005, Logistik-läran om effektiva materialflöden ¹²⁸ G. Plenert, 1999, Bottleneck allocation methodology (BAM): an algorithm, Logistics Information Management, Vol. 12, No. 5 ¹²⁹ G. Plenert, 1999, Bottleneck allocation methodology (BAM): an algorithm, Logistics Information Management, Vol. 12, No. 5

4.1.5.2 Optimized Production Technology, OPT/TOC

Several companies experience that the organisation and dimensioning of resources as a complex problem. The main reason is the almost constant presence of capacity restraints in form of bottlenecks which is the factor that controls the throughput of the production system¹³⁰. When there is capacity restraints in a production resource, the system will build up stock of products within the system or work in progress, WIP, since the company strive to maximise the utilisation of every resource. This will have an effect in long lead times, high inventory costs, frozen capital and decreased capability to ensure the request from customer¹³¹.

OPT has during development been renamed, expanded and repacked as Theory of Constraints, TOC, hence OPT/TOC, which aims to decrease the frequency of disturbing factors, increase the productivity and create an even flow in each part of the supply chain. OPT is a planning-and material management system that is based on the assumption that there is always a restraint resource¹³². The method has proven to be effective where the bottle neck exist but has on the other hand, when applied to situations where a bottle neck did not exist been less successful¹³³. The idea is to allocate the critic bottle neck and then utilise them to a maximum in aim to create a balanced system. The production planning focuses on the critical resource, the bottle neck and not the other resources. Hence the method simplifies the complexity and production schedule is only needed at the points where material are released, where the bottle necks are and where the flow converges or diverges¹³⁴.

4.1.5.3 Bottle-neck Allocation Methodology, BAM

BAM, is also a method or a system that in comparison with OPT is built on the assumption that there is always a certain restrained or limited capacity, a bottle neck, within the production and it is a “critical resource based capacity planning production scheduler”¹³⁵

136BAM initially starts with the production capacity and then try to adapt the planning after these conditions and determines the production scheduling after available recourses.

¹³⁰ K. Lumsden, 2006, Logistikens grunder ¹³¹ K. Lumsden, 2006, Logistikens grunder ¹³² Ibid. ¹³³ G. Plenert, 1999, Bottleneck allocation methodology (BAM): an algorithm, Logistics Information Management, Vol. 12, No. 5 ¹³⁴ K. Lumsden, 2006, Logistikens grunder ¹³⁵ G. Plenert, 1999, Focusing material requirements planning (MRP) towards performance, European Journal of Operational Research, Vol. 119, No.1 ¹³⁶ G. Plenert, 1999, Bottleneck allocation methodology (BAM): an algorithm, Logistics Information Management, Vol. 12, No. 5

4.1.5.4 Comparison

In mission to get an overview of the different systems, two tables are presented. The first one focuses, Table 4: Design comparison on the characteristic differences in design and the second one, Table 5: Usage comparison on the usage of the systems.

Table 4: Design comparison¹³⁷

Title:	Production development with the future in sight a green field study at Sandvik SRP
Authors:	Sofia Svensson and Mimmi Hansson
Supervisors:	Bertil I Nilsson, Adjunct professor, Lund University Sofia Hedenström, Process Planning Manager, Sandvik SRP AB
Background:	Sandvik is in the middle of a great investment, the so called Green Field investment, which will imply a new factory for parts of their stone crush production. The facility is, at current situation, in engineering phase and the preparations are in focus and running at high speed.
Purpose:	The aim of this master thesis and final course in the education is to give an insight and valuable experience from the industry. It

Table 5: Usage comparison¹³⁸

Title:	Production development with the future in sight a green field study at Sandvik SRP
Authors:	Sofia Svensson and Mimmi Hansson
Supervisors:	Bertil I Nilsson, Adjunct professor, Lund University Sofia Hedenström, Process Planning Manager, Sandvik SRP AB
Background:	Sandvik is in the middle of a great investment, the so called Green Field investment, which will imply a new factory for parts of their stone crush production. The facility is, at current situation, in engineering phase and the preparations are in focus and running at high speed.

In comparison between MRP and JIT, considering both strengths and weaknesses, JIT is ideal for shop floor execution while MRP is the winner as a production planning tool. The objectives between the two systems are similar but the processes in which they are applicable are different¹³⁹.

4.1.5.5 Combining Kanban and MRP

In mission to combine the traditional pull-and push systems of MRP and the Lean tool Kanban several benefits may be gained. The desire is to pick “the cherries” from both

¹³⁷G. Plenert, 1999, Bottleneck allocation methodology (BAM): an algorithm, Logistics Information Management, Vol. 12, No. 5 ¹³⁸Ibid. ¹³⁹K. Nagedra et al., 1999, MRP/sfx: a kanban-oriented shop floor extension to MRP, Production planning and control, Vol. 10, No. 3

methodologies; the planning capability of MRP and the superior shop floor control of Kanban. The combination enables companies to effectively control the production flow, organise the flow in sections with shorter lead times, reduce inventory of finished goods and at the same time have small inventory between each operation station in the production flow¹⁴⁰. Researchers have evaluated several hybrid systems to draw the benefits from both systems but there is no general method of the combination. There are examples of both successful implementations and not so successful ones since the two methods are developed for two different processes¹⁴¹. In practice the combination of the two methods works as follows; the MRP system receives information regarding future demand and calculates the netted need of material and in turn sends out information and resulting calculations to previous stations in the production flow. The stations thus get information, regarding material demand, both from following stations in the flow and from the MRP system and this in an early stage. See Figure 17.

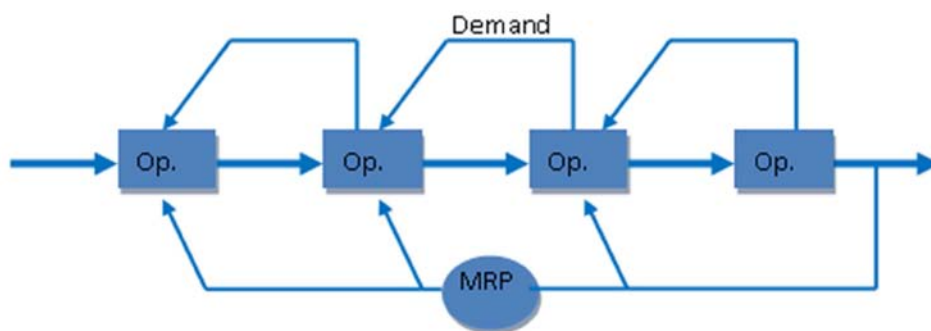


Figure 17: Combined push and pull system¹⁴²

¹⁴⁰ K. Lumsden, 2006, Logistikkens grunder ¹⁴¹ K. Nagedra et al., 1999, MRP/sfx: a kanban-oriented shop floor extension to MRP, Production planning and control, Vol. 10, No. 3 ¹⁴² K. Lumsden, 2006, Logistikkens grunder

4.2 Empirics; Planning and production control within Sandvik Parts

To get an overview and overall understanding, the planning will be explained from a larger view and then be degraded into everyday planning both systematically and practical. In the end of the chapter, the characteristics of the new machines are presented.

4.2.1 Planning in a larger view

Capacity Management has its base at the Sandvik Svedala site and is responsible for developing the Global Production Plan (GPP) each month for every one of the five Sandvik Mining and Construction sites around the world that produce stone crushers. The GPP is a rough made plan of how many hydraulic tanks and crushers that every site should manufacture for the next 12 months. Each site receives the GPP for their particular production which shall evaluate if the site can manage to produce the number of crushers that is forecasted in the plan.

The GPP is based on several different aspects which need to be considered when developing an as well-reasoned plan as possible to avoid unexpected demands. The business group is divided into different regions in which Sandvik has their market companies and salespersons which once a month reports the expected sales types and amount of crushers, for 12 months ahead to Capacity Management. The forecast is not calculated but an assessment made by the salesperson which requires good and qualified personnel on these positions. The inventory level at the different regions is considered when developing the GPP and also the material in the factories, productions units and assembly centres. The different sites may have material which has been left over due to lost customers and customer orders.

When the GPP is set by the Capacity Management and distributed to the local site the process planning manager, site sourcing manager and the plant manager sit together for a couple of days to decide if the site can and will accomplish the plan. The departments of purchasing and production planning are also involved to evaluate if the prognosis is possible to meet. If the GPP is approved, the prognosis will be mirrored into M3, the enterprise resource planning system that Sandvik in Svedala uses.

A crusher is to the degree of 97-98 % standardised where the remaining percent is the customisation. For the last percent is either no prognosis made or the prognosis is based on how often parts occur in the crushers. For example if a custom part figure in 30 % of the crushers, the prognosis is 30 % multiplied with the amount of crushers' forecasted which thereafter will be sent as an order to the supplier.

A target for Sandvik Svedala is to realise 90 % of the prognosis to customer orders, today the value is 85 %. The remaining percentage will result in inventory levels used for spare parts sales by the spare parts company, SMC Logistics, or in temporary stock for nonforecasted parts.

4.2.2 Planning in practice

Parts use an enterprise resource planning system that is called M3 or Movex, which is provided by Lawson, an American company that has been developing software since the 1970's. The system was however developed by a Swedish company called Intenia. APP, Advanced Production Planner, an APS system that also is developed by Lawson was implemented within Parts in the fall of 2010 and has thereby not been in function a very long time. APP is developed especially for M3 and this system follows in the "package". Thereby Parts already had the license of the program for no extra charge and this was one of the contributing reasons of APPs implementation. There is several other planning and control system on the market, whereof iPlanner is a prominent one. iPlanner is distributed by a company called InSync and several other big industries, both Swedish and international, use the system in their daily work¹⁴³.

Earlier there were three employees at Parts that each planned one type of machine separately, this routine has however changed and in current situation there is one planner that is responsible for the production. In practice, responsible at planning department starts the daily work by importing updated data; manufacturing orders, inventory level, time of operation etc. from M3 into the planning tool APP. Simulations are then run through in the system; in the beginning with no consideration to capacity constraints in mission get a view of bottle necks and other critical areas within the production. By doing these simulations the planner detects the operations with high and low cover. First after this, simulations with restraint of machine capacity, material status and priority etc. are conducted which will give the realistic operation schedule.

Before, when planning the daily production, Sandvik used M3. Although; the program had limited capacity keeping track on the availability in machines hence, the systems also had problems in rescheduling work in other machines. If there was a breakdown in one machine, the system could not see the status and availability in others which then put the work on a planner to manual reschedule the orders. One of the major drawbacks with M3 as planning and control system was that the program could neither do simulations nor keep track of material status and capacity restraints in the machines. The work of planning the production has therefore, since the change of system, improved and become more accurate with a higher utilisation rate.

¹⁴³ <http://www.insyncservices.com/>, 2011-06-13

APP plan after the prioritised date of delivery and optimise thereafter. The system then allocates material to highest prioritised orders regarding delivery date, with no consideration to material need or demand of following. Priority is often a strategic standpoint for companies and so also for Sandvik where different orders have different priority within the production. Orders to customer are prior orders to safety stock and details for complete crushers are prior spare parts. Although, APP does not consider priority automatically in its calculations and planning, since Parts has made a choice to plan the orders by delivery date. This issue has been a discussed question for the department, but since the production is suffering from back log and is not in line with time there is a risk that orders to safety stock always would be down prioritised and never enter the production if the system where prioritising in another way. This inconsequent way of prioritise result in manual work from the planning department since the intension to follow the outlined strategy is in conflict with producing towards delivery date. This requires information and investigations of the order customer; this is not something that is done by routine but rather occasionally.

In case that orders with particular high priority arise, simulations are run through to see consequences of certain choices, so called "what if"-analysis. E.g. 40 orders may be delayed because of one particular express order that have been rescheduled and placed in the close future and effects regarding inventory, work-in-progress and lead times can be analysed and taken into consideration. These operations was not possible to do earlier in the M3 program and the consequences for the production and lead time for certain details in situations like this was therefore not as clear as in APP.

Reporting of executed operations and updating of order scheduling in M3 are set to be done by the operators after each working shift. Although; the routines regarding this seems to be not fully implemented according to planning department and the reports are sometimes sent in as seldom as once a week. The operator does not have a personal, but a shared login username, when they report into the systems.

One of Parts resource groups is called Component workshop and contains of three similar machines with some features separating them apart. Earlier, the machines were grouped into one resource with one common work order list. This was however changed when APP was implemented and at current situation the three machines have separate lists with dedicated orders in the system. In practice the machines could still be seen as one common resource with one planning point for all orders. This since team leaders together with operators in this group change the work order list and dedicates work to the most suitable machines for that moment. This way of manual planning is working well and according to the team leader this is much thanks to the experienced and competent team of operators within this resource.

4.2.3 Work schedule

Even if material is not available, APP allocates material to an order and then reschedules these orders as soon as all required material becomes available. This consequence is that the work order list suffers from continuously changes. Depending on what kind of order and the operating hours of the machine that will process it, the work order list changes different rapidly. AC25-a machine similar to the Unisign palette machine which will be used in Green Field is one of the biggest machines and has long operating times, sometimes up to 24 hours. The fact that APP allocate material like this leads to a work order list that change and is irregular which consequence in problems for preparations in the workshop. Great parts of the details that are supposed to be turned in laths are big and heavy and require truck or overhead cranes to transport. There are time consuming preparations regarding fixtures and tools for the machine that has to be made by the operators. The raw material is stored outside and for casted material, due to temperature differences; there is a need of acclimatisation for approximately 24 hours during cold seasons before processing. Otherwise tensions within the material may be too high and damage the detail during processing. This puts demands on a long time planning and when the work order list then changes and is not consistent the work of the operators becomes affected, with uncertainty and small or no chances to plan their work as a result. The authority of planning and changing work orders after current conditions in the workshop has been taken away from the operators and they have today no influence on the planning in the system. Although, with their experience and knowledge they sometimes make their own work schedule which are modified to suit their way of working regarding tools, fixtures, set up times and machine programs but also available material at the machine.

The work order list is partly grouped by the planning department into batches of similar products and details in mission to minimise set up times, both fixtures and machine programs. Although, when sometimes express orders occur and arise on the work order list, the operators still finish their current batch, even though the process time for an entire batch size can vary from a couple of hours up to days. This since a preparation and change of fixture and program are in relation quite costly both in time and resources.

It is important to merge the expertise and knowledge of the operators in the workshop together with the ability of an overall view from the planning department. The planners have possibility to analyse consequences of certain actions as well as they have communication with other functions and stake holders within the company that may have impact on the production.

One problem in the production is that the order lines are not enough and that operators have to contact planning department to note this. If the work schedule does not contain enough orders or not are planned in time, there is a risk that raw material is not acclimatised and in right temperature for operation which puts the machine on hold just

waiting. Although, in Green Field a special acclimatisation hall is planned, this will both store and acclimatise details as a preparation for process.

Every other week team leaders, production manager and other stake holders have so called capacity meetings where they analyse and go through the current status within the production but also plan and make strategic decisions for future production. Production manager sees no concerns in future development and production, even though planning will be different and be influenced by other factors than today, such as material planning and sourcing in contrast to today when planning are highly determined by machine capacity and reliability. In aim to focus on their core competence, Parts has decided to outsource some of the details to other companies to handle the processing. Thereby will the number of different details decrease in Green Field, from around 300 details to 200 key components which will change the way of working and ease the planning and its complexity.

4.2.4 Quality

One of the problems within the production at Parts is the quality of delivered material. Problems regarding insufficient quality of delivered material, e.g. dimensional errors or casting defects such as cracks or air cavities, contributes to disorder within the production and time scheduling that cannot be held which requires re-planning. The problems contribute to disorders in the production with delayed orders, more work in progress and increased handling cost.

In case of quality problems within the production, the operator sends e-mail with information to planning department which reschedules the order three months ahead. The orders are placed in the future by reasons of not interfering with other orders while quality department then handles them further and investigate required actions, either reparation, sending it back to supplier or other arrangement. Although, sending material back to supplier is an action that does not happen often since it is costly, the details need special transportation and the suppliers are not local.

As much as 70 % of certain processed details requires repair welding which results in high work load on the quality department. This is a department with five employees, three process experts who handle manufacturing problems and two process technicians who handle all the quality problems in casted material. Quality department has their own work order list in M3 which they follow. They write a report document with information regarding required actions, a report which will follow the detail through the production and for traceability they also register all the information for this specific detail in M3. Traceability of all included parts within a product is important in case of eventual defects or problems later on when the product is delivered at customer.

Every time a quality problem or a defect occur the details are supposed to be brought out of the machine and its fixture, wait for a control and decision to be made by quality or construction department, a procedure that are highly time and resource consuming and therefor also costly. From the moment a suspected defect is found, the detail can be put out of production for between one week up to a year and along the process the detail is just waiting and being stored which consequence in locked up capital and high rate of products in process.

4.2.5 The Green Field machinery

One of the great benefits with the new machines in Green Field will be the flexibility and possibilities of high utilisation rate due to the pallets system and the machines multiple operations functionality.

There will be three types of multi operational Unisign machines in Green Field that will process details such as eccentrics, top-and bottom shells; Unisign 6000 (U6), Unisign 8000 (U8) and Unisign 8000 XL (U8XL). The U6 is the smallest one regarding capacity restraints of processing large details although it has higher rpm capacity, which is preferable when processing smaller details. The U8 is a bigger machine and can process larger details just as the U8XL which is the largest one of Parts, former described as the "big as a housemachine".

The WFL machines treat the details with lathing, for example shafts. The question about how to plan the pallettes are not concerning the WFL machines, since shafts not are fixed in the same way as other details. They are fixed in both ends along the rotating centre axis with different fixtures than in the Unisign machines, so called chuck jaws. In the former machines some preparation could be done, like installing counterweights when processing eccentric shafts, but in the WFL machines the technology is so advanced that the machine itself adjusts support legs to counter the weight. That implies that no specific preparations can be done except ensuring that material and fixtures are accessible. Also within this category of machines there are different sizes; WFL120 is the largest one with WFL65 following hence they have different restraints.

The machines are restricted by several factors but the ones that separate them from one and another is the planned and purchased pallettes and their dimensions for each machine. The pallettes enable the operators to prepare and fixate details external while another detail is processed in the machine. The pallettes have different dimensions and thereby possibilities or impossibilities to bare and fixate certain details-this will affect the planning of the pallettes and details in the machines. Due to the different sizes of the Unisign machines, all pallettes cannot be used in all machines. Within the different machine groups the different pallettes can be shared and used in every machine, however the pallettes does not function in other machine groups due to the different dimensions of fixating systems.

In Table 6, the number of planned and purchased palettes for each and every Unisign machine is presented following given information base.

Table 6: Number of palettes in each Unisign machine in Green Field

Machine Nbr of palettes Diameter

UNISIGN 8000 U8.1 21×2000 mm, 1×1250 mm **U8.2** 21×2000
mm, 1×1250 mm **U8.3 XL UNISIGN 6000 U61** 21×1800 mm,
1×1250 mm **U62** 21×1800 mm, 1×1250 mm **U63** 33×1250 mm
U64 33×1250 mm

4.2.6 Benchmarking

To get inspiration of how planning and controlling at other companies is conducted; benchmarking has been made at two companies in Karlskrona, Sweden. Dynapac is chosen due to that they manufacture large products like Sandvik, and Flextronics due to its prominent Lean work and philosophies.

4.2.6.1 Dynapac

Dynapac is a global company with manufacturing sites in Sweden, China, USA, France, Germany and Brazil. At the Karlskrona site, they manufacture millers and rollers that are customised or standardised, and have the largest manufacturing range of products among the sites. Dynapac recently changed their ERP system from a quite unknown one to M3. At the same time the selection between the production planning systems, APP and iPlanner, was a question and the choice at last fell on iPlanner since "it is a more modern system and was more suitable for Dynapac".

Initially, Dynapac plans their production based on 70 % prognosis and 30 % customer order but as the time goes by the percentage changes and when production starts, it is normally based on 100 % customer order. The demand changes with season and has its peak during springtime.

Between internal customers there is a set lead time where the orders are put. This means that within these lead times, the production personnel themselves plan and organise the work order list to get the best mix and variation for the actual process.

Quality issues are not a big problem at Dynapac as in the production of Parts. The purchased material from the suppliers have few flaws and during production, few deviations occur which are not possible to correct directly. To derive problems occurring on the finished product, Dynapac splits the problems into two categories, problems occurring before-and after 200 hours of usage. The first category relate to manufacturing mistakes while the second is assessed as abrasion.

Once a week the production has scheduled preventative maintenance, where they after a predetermined matrix clean, control and service for the upcoming week. Dynapac have at multiple times tried to implement the Lean philosophy with mixed results. Now they practice 5S and feels that the mind-set is clear among the personnel. "Right from me" is an implemented expression at Dynapac, which means that every single person is responsible for his/her work and its consequences. Personal follow-up is used, and the general opinion is that if the problems are not shown, it is not possible for improvements. This mind-set has

only had positive effects, where the staff feels pride over their profession and uses constructive criticism as a possibility to improve.

4.2.6.2 Flextronics

Flextronics site in Karlskrona manufactures circuit boards used in electrical products such as TVs, computers etc. and has approximately 350 employees. Flextronics is prominent within the Lean philosophy which is implemented through the entire company. It has been implemented for four years and now they use many of the classic Lean tools e.g. Kaizen projects, TIMWOOD, Lean Maturity Tracker (LMT), Small group activities (SGA), PDCA, 5 Why etc.

Kaizen project is very dominant within the improvement work at Flextronics. Every month the management choose five Kaizen projects to conduct, which including the thoroughly preparation takes four weeks each whereof one week of full time work. The projects concern around 40 employees from different parts of the organisation and is estimated to a cost of 250 000 SEK per Kaizen. This sum includes salaries, lunches etc. and the payback time of a project is two months.

To keep up the motivation among the workers, the management puts a great effort into making them understand that the improvements are not made to save on job opportunities, but rather to work smarter and increase capacity.

Important is, which Flextronics has discovered is not their strength; to make sure that the improvements are sustainable. To prevent this, they now always have an evaluation of the Kaizen result eight weeks after the project to make sure that the result will last.

At the end of every production line there is an information board which tells the personnel of how the status of the line is, its goals and problems. If the line is suffering from a bottle neck, the machine sign about this with a red alarming light and the working staff is all responsible of keeping it running.

When assessing the production, it is important for Flextronics to set measurable goals to know if they are achieved. When quality problems occur different time frames exist of when a short-term solution, "cause found" and a long-term solution should be performed.

4.2.6.3 Comparison

To compare Sandvik and the two benchmarked companies, they are placed in Hills Process Choice, see Figure 18. Sandvik produce about 300 crushers a year, they are highly costly and with high quality and there is a high rate of customisation. In the beginning of a new contract or customer deal, Sandvik sends representatives to the customer in mission to find their needs and requirements. This place Sandvik and their products within the jobbing category in Hills process choice map.

Flextronics marked F in the figure, the company that produce high technology circuit cards in high volume and with a line production should be placed in the line category. Dynapac, marked D in the figure, produces their rollers towards customer order also with high customisation and a smaller amount of units per year. These factors place them in the same category as the stone crushers of Sandvik.

Process choice

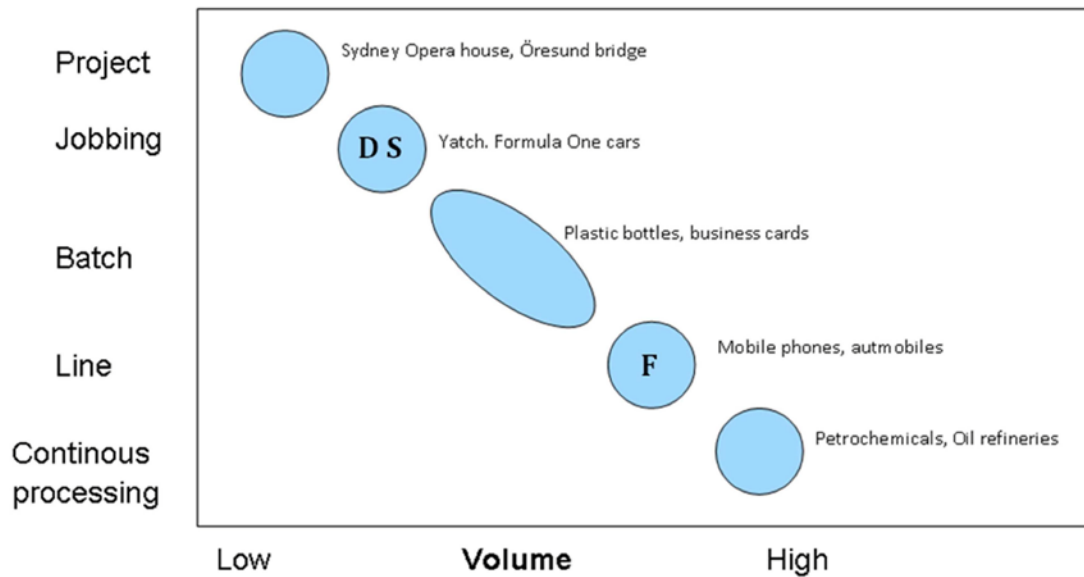


Figure 18: Process choice

4.3 Recommendations

This chapter will present the findings and developments to make for production improvements by choosing the appropriate production strategy. Ways of working in the production regarding resource planning methods and machine utilisation is shown and a recommendation for both is presented. A planning system evaluation is also performed where the current system and an alternative system is compared, and results in a recommendation of future work.

4.3.1 Order scheduling

4.3.1.1 Planning points

The completely new machinery at Green Field will force the production to settle new routines of how to work. Several alternatives regarding planning points have been developed. These have been evaluated, with individual benefits and drawbacks, together with process leaders and operators to get input. In addition; their experience and expertise within the subject have been an important feedback. In these suggestions the two different types of machines, the WFL and Unisign that is meant to operate in Green Field, are separated and should be seen as two totally individually resource groups. The overall ideas of the suggestions are although developed to custom them both.

The illustration idea is that machines marked 3 are larger, such as WFL120 or Unisign 8000 XL, than the ones marked 1. Details in manufacturing orders marked C follows the same principle, they are larger than the ones marked A. Hence, A detail can be processed in machine 3 but C details cannot be processed in machine 1. Then, not all A details may be preferred to process in a machine 3 due to rotation speed and other features as one comment described it “it would be like peeling a carrot with a band saw” and even if this metaphor may be exaggerated it gives an idea of the sentence.

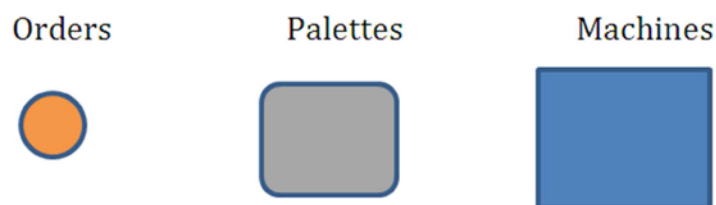


Figure 19: Figure explanation

1. The details are allocated to one specific machine The machines are predetermined to process one specific groups of details, details that are as most suitable for that machine.

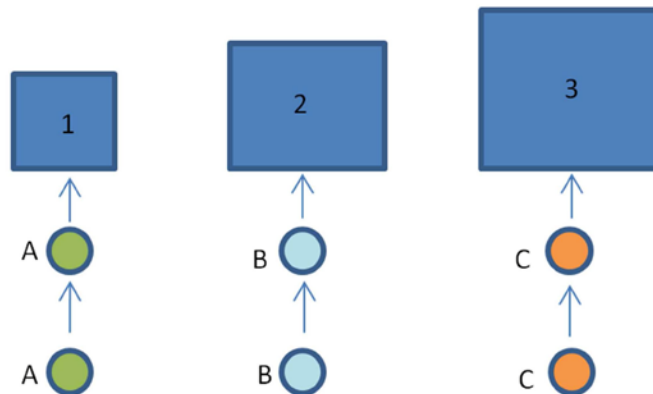


Figure 20: Illustration of "The details are allocated to one specific machine".

Benefits:

- The machines and area around it becomes customised for the specific groups of details, with fixtures and tools etc.
- The knowledge and experience from the operators will be high if it is divided with one operator/machine. In this way, it will be easier to emphasise the method of SMED and strive against efficient and less time consuming rigs.
- A less complex planning.

Drawbacks:

- Uneven or fluctuating utilisation of the machines.
- Inflexible.

2. The details are allocated to one specific machine group

The details are always processed in one specific machine group due to its properties and the machines within the same group have one common planning point. This is comparable with the situation in the Component work shop, where several equal machines are grouped into one resource and planned thereafter.

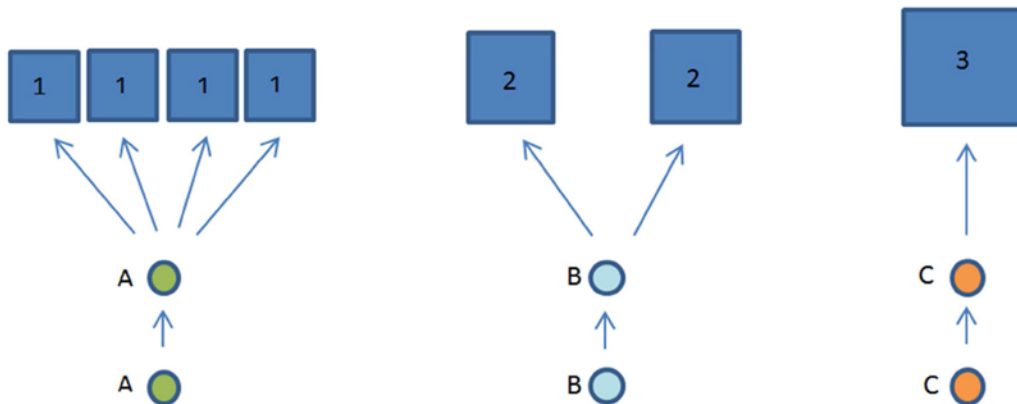


Figure 21: Illustration of "The details are allocated to one specific machine group"

Benefits:

- A less complex planning since there are less conflicts in prioritising between orders.
- Special knowledge and skills of the operators.
- Higher flexibility than in suggestion 1 since the machines is divided into groups and not individual.

Drawbacks:

- Lower flexibility than in suggestion 3.
- May result in low machine utilisation, if details in category C are less frequent than others the machines sometimes risk to just wait for orders.

3. One common planning point One common planning point and queue for all orders and the orders are allocated to the first available machine. The first machine with free capacity, regardless machine 1 or 3, takes the first work in the work order list, regardless type of detail A or C.

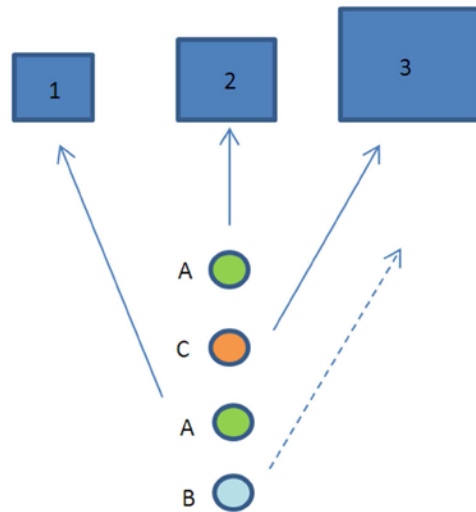


Figure 22: Illustration of "One common planning point"

Benefits:

- The work order list will be followed and the planned orders will be processed in the way that they are prioritised.
- High flexibility due to the fact that the details are not allocated to a certain machine group.
- No empty machines since they will always have orders standing in queue waiting.

Drawbacks:

- ⑩ Decreased machine utilisation due to rigs and change of fixtures after, usually, every detail that's being processed. It will also require operational work and work with production efficiency tools such as SMED will be suffering.
- ⑩ Will require greater amount of identical fixtures if the gain should be as high as possible. If there is only A details standing first in line the required amount of A fixtures will be the same as details in mission to be able to follow the work order list.
- ⑩ Certain B or C details may be standing in line and need rescheduling because of A details that's being processed in a 2 or 3 machine.

⑩ A Complex planning if the statement above, regarding consequences for following orders is to be avoided. This requires programming such as; “ if a detail B is calculated to reach the first in line-spot before an A detail is finished in machine 2, then detail A should not even start in machine 2 but rather wait for next free machine 1” .

⑩ Suffering details if by chance that there is a breakdown in machine 3 and C details has been down prioritised due to that A details has been first in line the supply of C details will be suffering.

Questions to be answered:

- Is the machine utilisation more important than FIFO?
- Should an A detail that have the highest probability to a short queue-time and the most alternative machines to be processed in, be processed in a machine 3?

4.3.1.2 Palette planning

Pallet system offers several possibilities to plan and control the production in mission to optimise the utilisation rate and minimise the through put time. For the most part, all details are in need of being processed in different tempos. This implies that the detail require to be re-set or fixed a number of times during the whole process chain to be able to access certain areas or surfaces. Palettes enable the operators to rig and prepare multiple orders and tempos while the machine is processing other details. With multiple numbers of fixtures of each detail a higher flexibility may be gained. Thereby a higher machine utilisation, shorter throughput time and decreased number of work in progress with less fixed capital. Although, the fixtures are expensive and space demanding.

It is only the Unisign machines that are equipped with palettes and thereby this chapter only concerns that group of machines.

It is recommended that the palettes should be dedicated the machines in another way than planned. Instead of planning palettes with the same dimensions to different machines, we suggest that they are dedicated to one and the same machine-this would enable a more flexible planning. Thereby the palette dedication to the machines will change according to Table 7.

Table 7: Change of palettes

Machine	Nbr of palettes	Diameter
U8.1	21×2000 mm, 1×2000 mm	U8.2 21×1250 mm, 1×1250 mm
U61	21×1800 mm, 1×1800 mm	U62 21×1250 mm, 1×1250 mm

4. Different tempos -different machines

Idea; the machines is set to process the details divided after tempos.

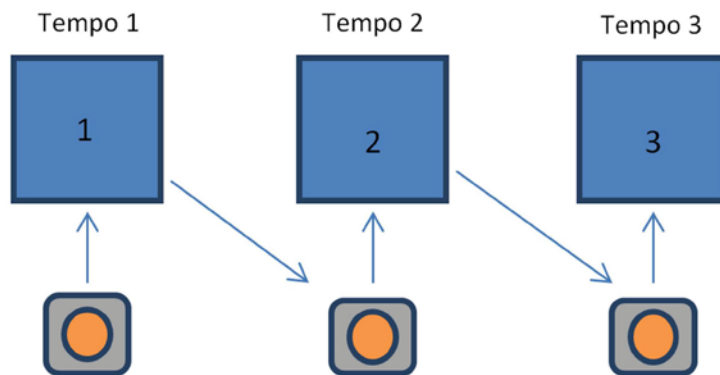


Figure 23: Illustration of "Different tempo - different machine"

Benefits:

- ⑩ Could be beneficial when processing large batches with tempos that are equally long.

Drawbacks:

- Unbalanced flow. The big variety of details and the fact all tempos requires different operations hours will consequence in an unbalanced flow with machines that stand in line just waiting.
- Security risks. Transportation of details between the machines which is time consuming and result in increased security risks which is one of the highest prioritised factors within the production of Parts.

5. Single unit production

Idea; the fixtures are set and prepared in mission to reduce set up time for the detail.

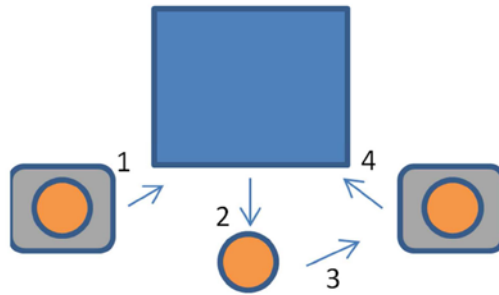


Figure 24: Illustration of "Single unit production" 1

Benefits:

Figure 25: Illustration of "Multiple work in progress"

- Single unit production.
- Less work in progress.
- Short through put time for the specific detail.

Drawbacks:

- ⑩ Utilisation rate. The machine is waiting unused while the detail is being moved and rigged for the next coming tempo.

6. Multiple work in progress The details are processed for one tempo in the machine and meanwhile it is being set and fixed on another palette for the next coming tempo, an already prepared detail is entering the machine and being processed.

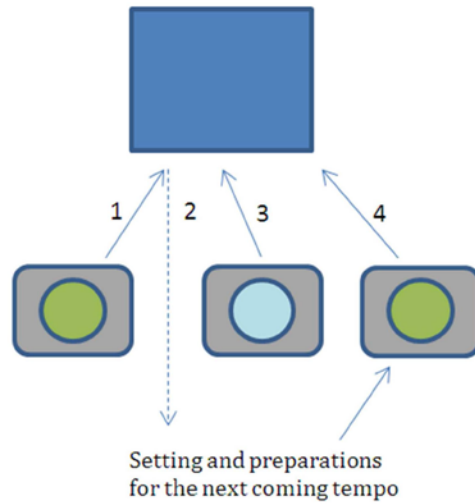


Figure 25: Illustration of "Multiple work in progress"

Benefits:

- ⑩ High machine utilisation since the following jobs is prepared and entering the machine directly after the previous job is finished.
- ⑩ Flexible in handling both small and large batches.

Drawbacks:

- ⑩ Longer through put time in relation to previous suggestion number 5.

4.3.1.3 Recommendations and other findings

The first recommendation regarding how to plan the orders is to follow suggestion 2, where the details are allocated to one specific machine group. This since it picks “the cherries” out of the two other suggestions while it avoids some of their drawbacks. This way of planning has a high rate of flexibility, it enables the operators to build up a detail-and machine specific experience, the machine utilisation is high at the same time as the area and fixtures within the machine group are customised.

In specific cases there will be possibilities to reschedule details in other machine groups, in mission to increase the machine utilisation or get a short through put time for the detail, although this should be avoided.

The second recommendation is that the planning of palettes and tempos follows strategy in suggestion 3: Multiple works in progress. With the high machine utilisation and possibility to prepare and set following details this is considered to be the best option. A suggestion is that alternative 5: Single unit production, will be a possible way of working in case of important orders that is highly prioritised to be finished within a certain time frame.

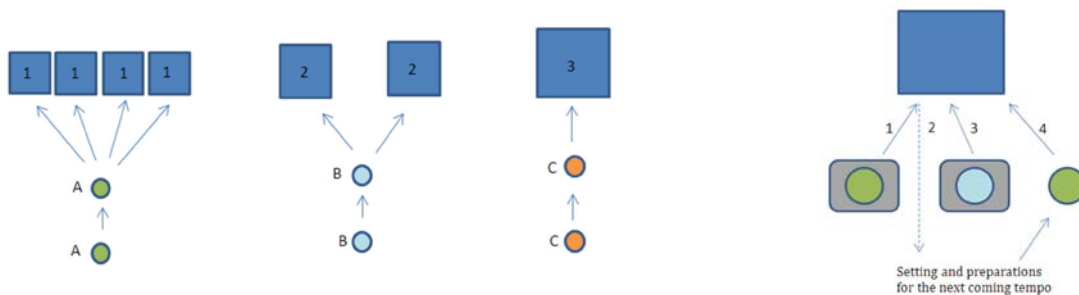


Figure 26: Recommendations of planning points and palette planning

Another and important recommendation concerning the work within the workshop will be a service, so called a Resource. This Resource will be an ambulating service-person that facilitate and ease the work of rigging and setting of the details, with reduced set up time and increased machine utilisation as result.

The recommendation is a rotating schedule where the operators take turn in being Resource, with one Resource serving three operators. In this way it becomes relevant for everyone that is involved, to develop this into a good and successful service which is important and that fulfils its purpose. The Resource moves between the different machines and operates where the help and assistance is needed and since the machines are placed in close connection to one another the communication will not be a problem.

Responsibilities of the Resource;

- Assist and support the operator in set up and rig of a machine.
- Supply the machine with material in time before following operation.
- Ensure that fixtures, tools, drawings and other requirements are available in time for operation.
- Maintenance and service of the area around the machine.

It is of highly importance that the guidelines and responsibilities are clearly defined and communicated to the operators so that no misunderstandings regarding the scope of the Resource working tasks occur. The group dynamic and the operators' ways of working and feeling responsibilities towards each other are crucial. As it seems today, Sandvik has the fortune to have a good working environment where the employee works together. Although, the situation may change and there should be an awareness of this. High security is one of the supportive goals for the Green Field projects and in an industry and production as the one of Parts this is outermost relevant. Thereby, the Resource is required to be skilled and experienced-the operators need to be able to trust one another and rely on that the work of the Resource is accurate done and safe.

4.3.2 Planning and control improvements

In this chapter, findings and issues of an improved production control, is presented. The presentation is divided in the same way as the study has been conducted, separating the production in the work shop/production, the planning and then question concerning quality. The statements are not listed in priority order.

4.3.2.1 Basic functions

Since the production and control system depends on the information within the ERP system it is a basic requirement that the systems can interact. The systems must also take restraint of capacity and material resource, both in short and long sight, into consideration when planning the production. This since the organisation of Parts with all its employees and processes is complex. Due to this it is also important that the system can simulate different scenarios and consequences of changed schedule. As Sandvik is a global company with English as corporate group language the systems should either handle English or Swedish but preferable both. To ensure that the system is sustainable and reliable it must be provided by a well-established and secure company. The service degree should also be high and have capacity to ensure that it cope future changes or development. In mission to utilise the system optimal, the supplier should also offer education for users.

4.3.2.2 Improved production control

Work shop/production

Measurement of the machine utilisation and allocation of time spent

By allocating how machine time is spent, measurements can be made and in time also statistics over the actual utilisation of the machine. Examples of activities could be staff breaks, machine breakdowns or exchange of fixture and detail in machine. Measurements are a tool in finding areas or processes in need of improvements and also be an input data to KPIs'. OEE is a measure the production would benefit from using to increase production efficiency. Although, risks when measuring exist and it is important to fully understand why and what to measure and that it is conducted consequently and in the same way everywhere. In this case, it is also of importance to mediate to the operators that it is the machine utilisation that is measured and not their efficiency or way of working. When analysing gathered data, the knowledge of how to interpret information is crucial to avoid making false conclusions. With too many measurements there is a risk that the most important factors disappear among others and that goals are in conflict with each other.

At current situation, measurements in the production of Parts are inadequate. In Green Field, high pressure and expectations will be put on the new machines which are supposed to pay back the investment in terms of high efficiency and productivity where measurements is a way in ensure this.

Measurement on a personal level is in several occasions a sensitive topic for many people since they experience it as stressful with to high personal responsibility which could be held against them. Although; study visits and benchmarking has shown good examples of when measuring on a personal or group level is working well. At the visited companies it is used for the right purpose and creates motivation, not stress. This since the management of the companies has thoroughly explained the purpose of measuring as a way to improve through smarter processes and with increased productivity as result. The companies have understood the importance of clarifying that the measurements are not supposed to decrease the number of employees but instead focus is on company growth and prosperity. The information should, and will, never be used in negative terms as in negotiating salaries etc. The study visits has shown team spirit and pride over profession which results in a better work environment.

In Parts organisation there is today no follow up of operators, since the general opinion is that it will bring negative stress into the situation. Although, as mentioned above, with a straight and well communicated purpose of the measurement this eventual negative stress would be minimised and also worth the risk. It might be an idea to develop a system where bonuses or other benefits may be gained as a pay back of good results.

Routines regarding reporting and communication with other functions

With clear routines regarding reporting order status and finished operations into the system, more up to date and actual information is obtained. This will enable more accurate control and planning of the production. As it looks today routines exist but the importance of continuous reporting is not transmitted to everyone concerned.

On account of transportation and acclimatisation of raw material, the material is ordered from stock two days ahead of its operation which requires a reliable and stable dispatch list. This proactive work lead to decreased time of waiting and today it is in practice but not working optimal with occasions of lack of material that disturbs the production. Clear and standardised routines that are easy to follow have to be made, which ensure right information flow between work shop and truck drivers. This is to ensure a reliable delivery of material, especially during the winter season when the acclimatisation of raw material is necessary.

Clear communication routines at machine breakdown

As mentioned earlier, information that is up to date and actual is important for accurate control and planning of the production. In occasions of machine break down there are, at current situation, no clear and established guidelines regarding information flow between the work shop and the planning department. Instead of rescheduling orders and operations in other machines, the lack of communication consequence in that orders just waits in queue and not getting served. In Green Field this high rate of unexpected scenarios such as machine break down, will hopefully be less frequent due to new and fewer machines. The production will also involve fewer operation steps, and with the machines physically placed close to each other the communication between operators will be simplified.

Planning

A sufficient dispatch list regarding amount of orders.

An issue that has been identified is that the dispatch list is not updated and does not contain enough orders to make sure that work and preparations in work shop can be optimised. This consequence in extra and non-value adding work for the staff within production since they need to contact planning department. An updated dispatch list in real time should prevent this problem since new orders are then automatic available for the operators. Alternative, create routines regarding this-either through communication via mail or phone call from operator to planning.

If this problem could be prevented in time for Green Field, better conditions to prepare and plan the production in the work shop are created.

Increase participation from team leaders and operators in work order planning.

One opinion that has been expressed in several interviews and meetings is the desire from operators or team leaders to have greater influence on work order planning. An involvement like this requires high competence, experience and insight both regarding their process and consequences of changes. This could be difficult to obtain from all of the operators whereby involvement from primarily the team leaders is to prefer. By involving the team leaders in planning, a better cooperation and understanding about the entire process will be created. This collaboration will result in more suitable workflow achieved by optimising and sequencing change of tools, set up times etc. By all means, it is then important to clarify the roles with degrees of authorisation and restraint of planning.

Through benchmarking at Dynapac a high involvement from operators, through their team leader, in planning has been studied which seems to work very well. The operators have influence in planning the sequences before the actual production begins and they can therefore share their knowledge with planning department in mission to create an optimal workflow. Although; between operations, changes in dispatch list made by operators is not allowed since the next coming stations and also the delivery accuracy towards internal customer will be affected. In practice it is the first station in the chain that receives the work order list from the planning department and is then responsible for passing it on forward. Thus previous operation is responsible to ensure that the next coming station follow the work order by placing the goods in predetermined order, so that FIFO is applied.

Visualise express orders in work order list

By declare and show delivery dates, both to external and internal customer, the work order list will reflect how well the production is in time. This would not change anything of how the production works, but would give the operators direct feed-back on current status and increased possibilities of preparation. Express orders are not visually separated from ordinary orders in the work order list; it is announced by other media from planning department to operators. By marking them in the system a higher awareness of order priority is achieved in the work shop.

Today is the visualisation of express orders, orders that of some reason are prioritised to have short through put time, not made through the system but rather through personal contact with planning department. In Green Field and future situation, a visual mark of these orders would be a desirable service for the operators.

Documentation of the planning process

Today, the planning of Parts basically relies on one person with high knowledge, experience and competence of the production. This is however risk full since the work of planning department is fundamental for how the production will work – and would be strongly

affected if this person would not be able to work. The work and competence should be thoroughly documented to easier adapt to eventual future changes.

A recommendation for Green Field is to update manuals and documentations to ensure that information and competence is available to the concerned as easy as possible. Manuals should be developed, to either work as a guideline for new co-workers or for others in situations where the decision making is unclear. All of this in aim to secure that planning competence is not based on only personal knowledge.

Quality

Increased resources to handle quality problems

Quicker decision making from process experts regarding quality problems would, among other things, result in savings in form of less work in progress and more free space in the work shop. Education in quality judgment for team leaders would enable quicker decisions regarding further actions. A quick process would also enable the detail to stay in the machine, waiting for decision and this would save time and work of set up.

In the layout for Green Field there is not planned a single square metre area for deviation details with quality problems. In relation to current situation where Parts holds a total area of approximately 600 m² for these details, this puts a high pressure on quality work. Either if the details could be controlled and approved, while it is still rigged in the machine, to be continuous processed in machine or if the detail could be decided of require further arrangements such as repair welding.

The recommendation for Green Field will thereby be extended resources among the process experts in terms of an expert that is always at place, all the hours that there is production going on in mission to cope with the situation and high production speed.

4.3.2.3 Over all improvements

During this project, through interviews and studies, several issues have arisen as problems or things to improve about the way to control the production. Some of them could not be derivative to the list of improvements regarding planning and production control but they are still important to bring up.

Communication between departments is lacking today and has to be defined and improved. The communication seems to be without routines and everyone has their own view of the "right way". Knowledge about other departments and their functions is important in a way to understand their needs. This could be accomplished through the Lean tool value stream mapping, where all the material and information flows are determined to identify unnecessary activities. This would also clarify how the departments link to one and another

hence the best and most important communication routines can be defined. Value stream mapping is a good start on the way to a mutual and overall understanding of the company. The map gives a good view regarding consequence of an action for concerned stations. Understanding is a fundamental cornerstone in a prosperous company – both on a detail and overall level. This concerns understanding of a wide range of functions such as the systems, delivery accuracy-both for internal and external customers, suppliers etc. Improved relationship with suppliers is recommended since one of the problems within Parts is the quality on delivered material. With a better relationship the communication will also be better and this might be a way to manage these problems. It is important for Sandvik and its suppliers to share interests; monitoring of quality problems enables proactive work of creating agreements to secure delivered quality and reduce amount of defects. Clear goals within production are important since without any aims it is difficult to know what to strive for. The goals should be set on both daily and weekly basis as well as in long term.

4.3.2.4 Conclusions of results and recommendations

The problems that during this project have been detected are not mainly within the system but rather a question of culture and way of working with better communication and routines. For a smart company it is important to grow and develop with the competence and resource that is within the company, in terms of both human and physical resources. Since Sandvik is one of the leading companies within its segments there is a risk that they are not constantly striving to improve.

Table 8 should be seen as a brief summary of the above presented statements. The statements which are derived to the “planning system” column have worked as inputs to the further work regarding system evaluation. “Ways of working”, is the statements that have been derived to “soft” or culture factors which imply that they could be avoided or improved with other routines and ways of communicate between employees within the organisation. Education may also be a way to improve the situation, such as education in quality judgement or process documentation.

Table 8: Summary of improvements

Requirements	Planning system	Ways of working
Measurement of machine utilisation	√	√
Routines regarding reporting		√
Routines at machine breakdown		√
Sufficient work order list		√
Participation from team leaders in planning	√	√
Visualisation of express orders	√	√
Frozen work order list	√	
Handling of quality problems		√
Process documentation		√

4.3.3 System evaluation

This evaluation of APP has been conducted in mission to analyse if APP is adequate for planning Parts production. APP has only been implemented and executive less than a year, now there are wishes to evaluate the degree of its functionality. Changes will always imply an uncertainty and a bit of “chaotic” period before routines and benefits of the change may be seen. Parts have a unique opportunity at this stake to a possible change of system in time of the big and transformative change of Green Field. Several areas of interest are extra focused on and others are put aside. This since the later ones are considered to not be of such great importance to Parts and are valued to perform adequate no rather what system that is being used, such as visualisation in the system or user interface.

Initially, APP is evaluated and declared within following areas-how does it work and what are its features. The choice has then been made to evaluate the system in comparison with another planning and control system, iPlanner, which Parts has been interested of before in earlier stages.

iPlanner has been declared in a similar way as APP and within the same areas of interest. The criteria’s that are brought up in the comparison between APP and iPlanner are the ones that are judged to have impact on the production of Parts and at the same time separates the two systems apart.

The financial aspect has not been a significant aspect in the evaluation. In investments like Green Field, the gain of having a well-functioning planning system in relation to the cost of implementing it is considerable high, especially over time.

Table 9: System evaluation APP

Title:	Production development with the future in sight a green field study at Sandvik SRP
Authors:	Sofia Svensson and Mimmi Hansson
Supervisors:	Bertil I Nilsson, Adjunct professor, Lund University Sofia Hedenström, Process Planning Manager, Sandvik SRP AB
Background:	Sandvik is in the middle of a great investment, the so called Green Field investment, which will imply a new factory for parts of their stone crush production. The facility is, at current situation, in engineering phase and the preparations are in focus and running at high speed.
Purpose:	The aim of this master thesis and final course in the education is to give an insight and valuable experience from the industry. It will also be a preparation of independent work and the first introduction as an engineer within the company world.
Problem definition:	The project should with Green Field in focus, deliver an estimated need of inventory area and evaluate the planning of Parts production. This in aim of finding areas of improvements both related to system and culture.
Method:	This is a study with several different sub-studies which implies that different method has been used. Literature studies, multiple interviews, benchmarking and calculations has been a profound work throughout the project.
Conclusion:	In mission to cope with future changes and challenges that will arise in time for Green Field, Parts is recommended to develop their knowledge and competence within the resources that they have. During this project several areas of improvements are found, most of them can be derived to "soft parameters" such as communication and routines and just a few are derived to "hard parameters" such as system related, e.g. within planning and control systems.

Vocabulary

APS

APP

BOM, Bill of Material

Advanced Planning System

Advanced Production Planner

A hierarchical list of all included parts, raw material, sub assemblies, components etc

Table 10: System Evaluation iPlanner

Title:	Production development with the future in sight a green field study at Sandvik SRP
Authors:	Sofia Svensson and Mimmi Hansson
Supervisors:	Bertil I Nilsson, Adjunct professor, Lund University Sofia Hedenström, Process Planning Manager, Sandvik SRP AB
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Vocabulary

APS

Advanced Planning System

APP

Advanced Production Planner

BOM, Bill of Material

A hierarchical list of all included parts, raw material, sub assemblies, components etc

As a way to summarise and get an overview, Table 11 is created. In this table the most important factors of the systematic planning features are compiled and evaluated towards one and another. The factors are not equally important and are not presented in a certain order since they are difficult to grade towards one and another. They have neither equally impact on the production of Parts. The fields marked in grey distinguish the system that is considered to be the most suitable for Parts production with a related motivation. Where both systems are marked in grey, they are evaluated to fulfil the statement equal.

Table 11: Comparison between APP and iPlanner

Assessments criteria's	APP	iPlanner	Motivation
System compatibility	Developed for M3, but compatible with other ERP.	Compatible with all major ERP.	Since M3 is the current ERP system, APP is the most compatible system.
Modification possibilities	Limited	Unlimited	Since Green Field will result in straight flows and easier planning, APPs modification possibilities is adequate.
Planning methodology	Heuristic planning "Seconds planning"	Meta heuristic planning "Bucket planning"	Since the manufacturing at Parts is a shaky process, bucket planning is preferable in combination with the machine operators influences.
Tempo-planning abilities	Limited abilities	Cope well with re-entrant flows	Depending on whether the tempos should be controlled through the system or by operators.
Material shortage	Need all material in inventory before production starts	Custom start of production when lack of material	Preferable to get as high trough put time as possible.
Optimal solution	One solution	Tries multiple ways for solutions and picks the best	Of course, the best solution is the one to prefer.

4.3.3.1 Results and recommendations

Even though that iPlanner has more statement marked grey in the table above, the recommendation will not follow this strict since the choice is more complex than that. The statements are not seen as equal important and through discussions and analysis of different scenarios the recommendation is to continue with APP as executing APS system within Parts.

APP is developed for M3 and there are no indications at current situation that Sandvik in Svedala is in any state of changing ERP-system within the closest future. M3 is the

system that should contain and provide all information regarding articles, BOMs and operation hours etc., APP is only set to gather the required information from the ERP-system and then to execute the planning built on this information. Thereby there are no remarkably drawbacks that APP only gathers information from one source. According to the main goals, the flow is set to be straight and easy in Green Field, with less complex processes. iPlanner might be unnecessary advanced for the production of Parts, although the future is uncertain regarding development and its requirements. Hence, we consider the Green Field-future as a period of time where at the moment given circumstances will apply. Regarding the planning methodology, where iPlanner keeps track of the “current optimum” and thereafter plans after this, iPlanner is considered to be the best one. Although, APP has done a decent job before and with more stable flows, APP will have better conditions than earlier to perform well. If the production should be completely system controlled, iPlanner probably has better software to control tempo-planning. It is as earlier mentioned a management decision but since it would imply complex programming, it would be better to control with operators experience and knowledge. The work list should be frozen to receive a stable work situation for the operators, without frustration over constantly changed order of orders. The work will also be easier to prepare with tools and fixtures. A setback of this action would be when APP reschedules orders due to lack of material, but the frozen period should not be too long, so that it results in a problem such as delivery delays. Since the Green Field strategy heads towards single-unit production with short throughput time, this will not be a big problem and the system evaluation should not be too assessed on this point.

4.3.4 The final and overall recommendations

The evaluation of production and control within Parts consists of two different parts, whereof two individual recommendations have been given. In the final recommendation, the most important issues are collected and the two parts will be integrated. The issues are improvements and recommendations which the management of Parts, according to the authors, should adapt in Green Field.

- **Keep APP**
- **Plan the details with allocation to one specific machine group**
- **Use palette planning with multiple work in progress**
- **Adapt the Resource concept**
- **Measure machine utilization**
- **Freeze the work order list**
- **Increase participation from team leaders within planning**
- **Break down the operations on tempo level**
- **Document the planning process**
- **Increase resources to handle quality problems quicker**

As in the recommendations made earlier, planning details with allocation to one specific machine group is to prefer in combination with using palette planning with multiple work in progress.

If the Resource position is well defined and used right, this service will accomplish great benefits in the work shop. It will create conditions for flow improvement and machine utilization which is crucial for Green Field.

With a supportive goal for Green Field of 85 % utilisation rate of the machines, the pressure will be high and measurement should be conducted. Initially, the situation will be unstable but over time it should stabilise and create conditions for accurate and important measurements. The recommendation is thereby that the management of Parts should analyse the production and develop measurements that fulfil the strategic goals.

The recommendation is that the work order list should be frozen within a certain time period, how long this period should be is difficult to decide at the current state. This since it is depending on operating hours and knowledge about the production. The production buffer zone of material is dimensioned for six days, and as long as the frozen

list does not exceed this amount of days the production should not be affected by lack of material due to acclimatisation.

Possible problems regarding express orders that will be affected by this frozen work order list is not seen as a major factor since these orders should not arise in such high rate, and if it does it will be taken into production as an exception.

The planner should develop a continuously meeting routine together with team leaders and operators and these should be held in the work shop. These meetings should be held at least at every new frozen period but preferably once a day. This will be less time consuming than today since there will be less resource groups which are located closer to each other. At these meetings eventual problems, wanted changes in the work order list or expected express orders should be brought up.

In time for Green Field, where all operation information is in need of a systematic update regarding operating times etc., the operations should be broken down and analysed on tempo level. At current situation, the operations are today "large", with all including tempos and set up times connected into one which decrease the flexibility. By breaking down the operations into tempo level, a higher degree of tracking the status of orders is enabled. It will be possible for the management or planning department to, in a system based way, easier follow up and analyse the required amount of time and resource that the order will need. This could also be seen as a proactive work for future changes of systematic planning.

5 Discussion

Green Field will result in multiple questions, both tactical and practical, that needs to be answered, questions that affect the possibilities to follow the given recommendations of this master thesis. Without straight decisions in these factors, the results should be seen as recommendations that might change with changing circumstances.

One of the biggest challenges has been to separate the current and future situation within Parts. How will the future look like and how will it affect Parts and its organisation? Which issues or problems will follow to the new facility and which will Parts be able to leave behind? Since no one within the department has any experience from a similar situation there have been several questions and issues that has not been answered to and that we have found no guidelines within.

Will the production emphasis batch or single unit production? Stake holders in different resources have of course various opinions about this-batches facilitate the operators work in the production while single unit production decreases the number of work in progress and thereby also frozen capital.

What is the strategy regarding number of pallets and fixtures for the new machines? Depending on the answer different ways of how to plan and prepare the work in the production, regarding optimisation of utilisation, flexibility and efficiency may be conducted. Number of pallets and fixtures is, as everything within a company, a question about costs but where does the line go between the burden of a cost and the gain of flexibility and a high utilisation rate? Without straight guidelines regarding number of fixtures to each detail or pallets in the different machines it is not possible to deliver a clear and distinct recommendation of how to plan in mission to optimise the work in these machines.

Will the different departments or functions in Green Field look as is does today at current situation? Will they have the same functionality and responsibilities and will the work and responsibilities of team leaders and production leaders remain the same? Or is there a gain of increasing the knowledge and flexibility within the staff by widen the borders of areas of responsibility? New functions, responsibilities or departments might create foundations to better understanding and also an environment where personal experience from different departments can be combined into new ways of working.

The overall view about how to control the production is not fully common within the organisation; however on a strategic level there is a will to strive against single-unit production and the Lean production-philosophy. The resources and departments have various demands and thereby different requirements regarding how to control the work. Parts, that handles details with weights up to 20 tons, has other conditions for

visual control and e.g. Kanban than the Assembly shop for hydraulic tanks, that uses smaller parts such as bolts and screws and therefore easier can utilise Kanban-systems. The planning of Parts has been complex with details that re-enter in the same resources and flows that are crossing each other, so the need of a systematic planning tool has so far been predominant.

Mildly speaking, Sandvik is heading towards a challenging and exciting future.

Contribution to science

The study is an example of the difficulty and importance of taking strategic decisions when starting up a project. Starting up a project with the size of Green Field demands thoroughly preparations and an expressed strategic direction from the management to follow. To be able to make all decisions towards a mutual goal to achieve an as profitable investment as possible, this is an essential issue which needs to be handled early in the project. Naturally it is difficult decisions, but the management needs to show the way to enable the employees to have the best possible conditions to perform in best possible way.

Earlier, the critics of source are brought up, and it could also be added that it is not only the researchers of this thesis that is inexperienced of a project like this but rather the whole industry. In terms of constructing a totally new factory from scratch Sandvik is quite unique in Sweden and a project like Green Field is exceptional. By combining the culture of a heavy and old industry with all its experience and knowledge, together with two students with little practical experience and few barriers of different thinking – new ideas have good possibilities to be created. Throughout this master thesis, the researcher's contribution to science is just this-to process and deal with the uniqueness of Green Field.

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