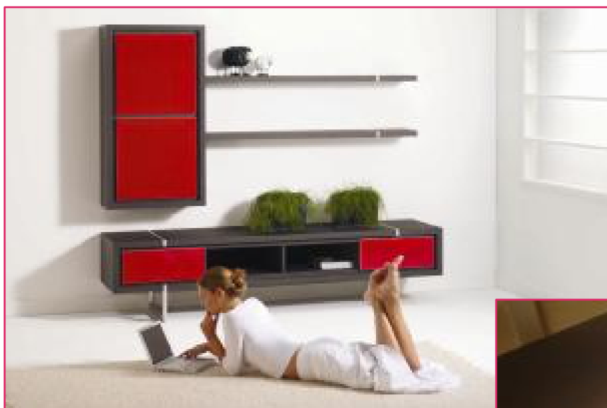
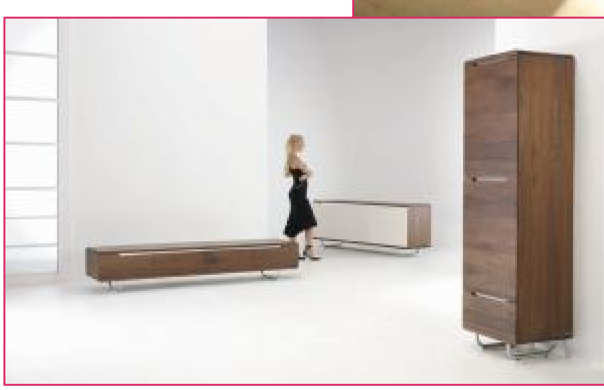
“OPERATIONAL PROCESS INNOVATION”

‘IMPROVING THE FIT BETWEEN OPERATIONAL PROCESS AND COMPETITIVE FLEXIBILITY AT GM THE FURNITURE FACTORY’





“Operational Process Innovation”

‘Improving the fit between operational process and competitive flexibility at GM the Furniture Factory’

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…For my father who I still miss dearly…

PREFACE

As a student of the School of Management and Governance, on the University of Twente, I was given the opportunity to perform my gradation assignment at GM 'the Furniture Factory'. From the first with meeting with the management of GM, it was clear that its production methods did not fit the current market demands. During the following meetings, we refined the different symptoms into an overall problem, namely not enough competitive flexibility.

This document is meant for those that are interested in the concept of competitive flexibility, competitive objectives, and the changes that are needed to give a company a higher competitive flexibility. Within this research project, these changes are focussed on operations planning & control. For GM, additional recommendations will be made for future development

This research project would not have been possible without the help of several people:

- The counselling of Mr. Löwik and Mr. Schutten from the University of Twente.
- Mr. Kleis for giving me this opportunity, and his counselling during the project.
- The employees of GM for their ideas, thoughts, and cooperation.
- Ilonka Maathuis for reviewing this document and her support.
- My dear mother Coby Aalders for her support.
- Jan Joost Stock for reviewing this document and the discussion evenings.

Yours truly,
Ron Peeks

Enschede, December 2007

SUMMARY

GM 'the Furniture Factory' is a manufacturer producing both cabinets and tables for living rooms. The company has about 50 employees, and an annual turnover of around 3.5 to 4 million euros. In order to stay competitive inside the higher segment of the market, GM wants to focus more on flexibility. Therefore the overall goal of this research project is:

The goal of the research is to advice GM on how to improve its operation process design and operation planning & control in order to fit with the strategic focus on competitive flexibility.

Competitive flexibility is defined as the ability for a company to produce non-standard orders, to introduce new products, and to accelerate and decelerate production quickly. It is also directly related to three other competitive objectives, specifically cost, quality, and delivery. Because they are directly related, all four objectives are measured during this research project.

In order to improve competitive flexibility it is important to create an intermittent operation. This means that a company has to choose between a project, jobbing, or batch process, in combination with a design-to-order, buy-to-order, or make-to-order strategy. The order penetration point (OPP) is than placed upstream as much as possible.

Within GM's current situation there are several problems; Competitive flexibility is too low, inventory value is too high, and delivery reliability too low. The OPP is placed at an inventory for semi-finished-products, after which the parts are assembled, varnished or painted, and shipped to the customer. The production is controlled using a MRP like system.

For the desired situation, levels are set for each competitive objective. In order to achieve these levels, the OPP is replaced further upstream, creating a buy-to-order strategy. The option for design-to-order is therefore also possible if a customer wants to customise its products. To plan and control the process, Conwip is used with a slight alteration. Only using a maximum WIP, instead of keeping it constant makes it possible to solely produce customer orders. It will however require a more flexible workforce. Next to Conwip, implementation of different lean principles is needed to reduce the chance for errors, and further improve performance. However, these are not implemented within the experimental situation.

For the experiment, two concessions are made concerning the process design. The experimental flow is not a complete buy-to-order strategy, and a small inventory was created near the assembly activity. These concessions are needed, to implement the experimental situation into the current situation. Next to Conwip, Kanban is being used to plan and control two different process flows. The results of the experiment on all of the competitive objectives are promising. The indicators direct costs, error free production, and volume flexibility are already within the level of the desired situation. The other indicators show improvement towards the current situation, but have not reached the desired state.

Concluding the research, there are a two mayor points for GM to improve its fit with competitive flexibility. GM needs to move the OPP more upstream, and change its method for planning & control. The results of the experiment show that by changing these two points, improvement is possible on almost all of the competitive objectives. Also we advice that GM should perform further research into the possible effects of implementing the lean principles.

CONTENTS

1 INTRODUCTION

Within this first chapter we give an introduction into the research project that is performed for GM 'the Furniture Factory'. Section 1.1, gives a view on the research background clarifying the problems at GM, which are the starting points of the research project. Within Section 1.2, we present the research goal and problem statement, after which we describe the different research questions. Finally, the research model will give an overview of the research questions in how they relate to each other. Also here we describe which strategy we will use to answer the research questions.

1.1 ORGANISATIONAL INFORMATION

1.1.1 BRANCHE DESCRIPTION

The Netherlands has over 8.300 retailers selling different kinds of furniture, divided over several branches. GM only serves the 'hard furniture' market by manufacturing both cabinets and tables for living rooms. With their cabinets and tables, GM aims for the higher quality and price segment of this market. This means that GM's direct competitors are within the higher quality price segment, and are therefore competing within a same range of cost/quality ratio. This is largely the result of the manufacturers using the same kind of raw material, because the high prices for hardwood cover a large part of the production costs. This means that the use of different quality in raw materials is responsible for the large gap between the lower and higher price segment within the market.

During the year of 2001, sales within the furniture market dropped, resulting in a decline over the years 2002 until 2005 (see Appendix A). Due to the higher competition and a lower turnover, many furniture manufactures where forced to close down. Within the years 2006 and 2007, there is an increase in sales, although, on average, the turnover within the branch is still lower than prior to 2001.

The competition on cost and quality has dominated the market for many years, however, with the arrival of more competitors from low-wage countries, this focus shifted away from cost to other competitive priorities.

1.1.2 GM 'THE FURNITURE FACTORY'

GM 'the Furniture Factory' was founded in 1966 under the name of Ganzeboom. GM is a private company owned and managed by R. Kleis, with a single factory located in the city of Almelo, the Netherlands. The company had an annual turnover of around 3.5 million euros over the year 2006. Within the year 2002, annual turnover was about 4.2 million euros. This is a decrease of 16.7% over 5 years, which is higher than the branch average (-12%).

The company has about 50 employees divided over 9 manufacturing departments, 2 commercial departments, and 3 staff functions. The manufacturing departments are managed by the production manager, who is responsible for planning and controlling the production. Recently, a new commercial manager was hired to manage both the internal and external commercial departments. Appendix B gives an overview of the company structure. GM can employ more than 50 people with the current machine capacity, but due to the loss of turnover within the year 2001, a reorganisation was needed.

The lower turnover since the year 2002 has resulted into a negative financial result over the past few years. Although the financial position of GM has improved due to the reorganisation, a higher turnover will be needed to ensure future viability.

1.1.3 PROBLEM BACKGROUND

In order to stay competitive inside the higher segment of the market, GM wants to focus more on flexibility. To achieve this, GM has already extended their assortment a few times over the last couple of years. Combined with an 'assemble-to-order' strategy, this resulted in a high inventory value (1.6 million euros in 2006), with most of the products in stock having a turnover of more then 4 months. Next to this, GM wants to offer customers the possibility to customise the standard designs of the assortment.

This research will focus on the following points:

- Competitive flexibility in general is not high enough.
- High variety in assortment has resulted into a high inventory value.
- Customers should be able to customise the standard products from the assortment.

To achieve a higher flexibility at GM, changes will have to be made in its operations management and in particular its operations process, and planning & control. These changes should be focused to create a better fit with GM's competitive objectives and operations management.

1.2 RESEARCH OBJECTIVE

1.2.1 GOAL AND PROBLEM STATEMENT

From the organisational information above, we summarised the overall research goal in the following statement:

> *The goal of the research is to advice GM on how to improve its operation process design and operation planning & control in order to fit the strategic focus on competitive flexibility.*

This results in the following central research question:

> *What are the changes needed regarding GM's operation process design, and operation planning & control, in order to improve the fit between the GM's operations management and strategic focus on competitive flexibility?*

In order to answer this question, several subjects or sub questions have to be clarified. For instance, what do we exactly mean with competitive flexibility, operation process design, and operation planning & control? With these concepts clarified, it is possible to describe GM's current situation, and desired situation. Based upon the desired situation an experiment will be conducted on a single collection from GM's assortment. Both the current situation and the results of the experiment will be clarified using measures for the competitive objectives. With this knowledge, it is possible to describe an implementation plan for GM to reach the desired state.

1.2.2 RESEARCH QUESTIONS

In order to achieve the goal and address the problem stated above, we divide the central question into several research questions. Each of these questions contributes to the fulfilment of the research goal without broadening it:

1) How can flexibility as a competitive objective be measured at GM?
   - 1.1) What is competitive flexibility?
   - 1.2) What is the relationship between competitive objectives and market demand?
   - 1.3) What are the measures for competitive objectives?

2) What does the theory explain on operations process design regarding flexibility?
   - 2.1) What is the relationship between flexibility and operations process design?
   - 2.2) Which type of operations design fits a flexible operation?
   - 2.3) Which methods for planning & control fit a flexible organisation?

3) In what way is GM currently managing its operations regarding a single collection?
   - 3.1) Which collection is a good representation of GM's current assortment?
   - 3.2) What is the design of the current process?
   - 3.3) Which method is being used for planning & control?
   - 3.4) What are the measures of the current situation regarding the competitive objectives?

4) What would be a desired method to manage GM's operations in order to become more flexible?
   - 4.1) What are the desired levels for the competitive objectives?
   - 4.2) What is the desired operational process design for GM?
   - 4.3) Which method should GM use for planning & controlling its operation?

5) What are the effects on the competitive objectives of the single collection after changing the operation design, and operation planning & control?
   - 5.1) What is the new operation process design for the collection?
   - 5.2) Which method for planning & control is used for the collection?
   - 5.3) What are the measures of the experimental situation regarding the competitive objectives?

6) Which changes does GM have to implement in order to reach the desired situation?
   - 6.1) Which of GM's collections should be included within the implementation?
   - 6.2) In what way do the collections relate to the experimental one?
   - 6.3) What are the steps needed to change all the desired collections?

1.2.3 RESEARCH MODEL

To create a schematic visualisation of the purpose of the research and the global steps that will have to be taken to reach the goal(s), we will use the research-model of Verschuren & Doorewaard (2000). The model is part of a progressive scheme intended to support the start of a research project.

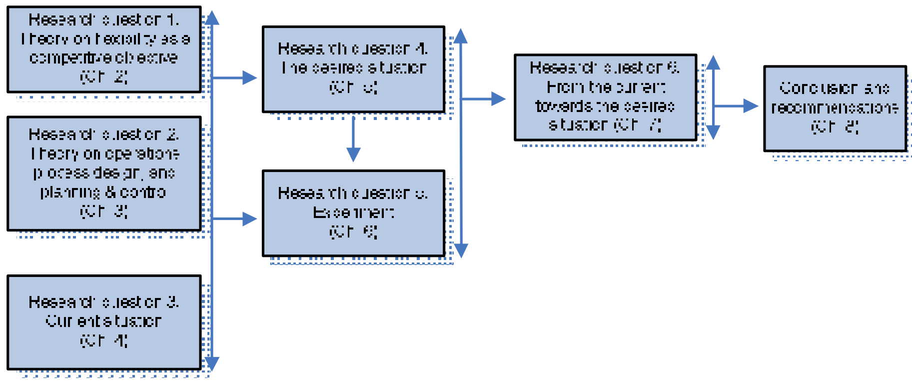


Figure 1-1: Research Model (A vertical arrow resembles confrontation between the objects, from which the horizontal lines represent a conclusion)

1) GM strategically wants to focus more on flexibility as a competitive objective. Flexibility is a broad concept and can be explained in many different ways. Therefore, the answer to this research question will give a description of flexibility within the concept of competitive objectives. Each of the competitive objectives will be made operational for measurements throughout this research. To answer this research question we will use literature research on the theory of competitive objectives.

2) In order to increase the competitive flexibility, a fit has to be created with GM's operations process. For explanation of the fit with flexibility, this question will give a description of both operation process design, and operation planning & control. In order to focus this question, it will be answered using literature research on the theory of operations management regarding flexibility.

3) An analysis of the current situation regarding GM's operation process design, and operation planning & control is necessary in order to describe the needed changes in this research. This part of the research will be focussed on a single collection of GM's assortment, in order to create a more profound and practical result for GM. The analysis will be based upon observation of the current operation.

4) From both the theory on flexibility, operations management, and the current situation, a desired state can be described for GM regarding its operation process design, and operation planning & control. We answer this question with the literature research conducted for the first two questions.

5) The focus on a single collection gives the opportunity to experiment on its operational process design, and operational planning & control. The experiment is conducted in order to analyse the effects of the changes on the competitive objective.

6) From the experiment we will describe an implementation plan including the steps that can be taken by GM in order to reach the desired situation. This question will include an analysis of GM's collections regarding their fit with the experimental collection, and live cycle so that 'old' collections can be left out of the implementation plan. Also the results of the experiment will be analysed in relation to the desired situation. These two steps will be the basis to describe the steps that GM has to take towards the desired situation.

7) In the final chapter the conclusions of this research will be presented. We will also make recommendations for GM on how to proceed, or any additional actions that should be taken that are outside the scope of this project.

1.3 READING GUIDE

The goal of this research project is to advice GM on how to improve its operation process design and operation planning & control in order to fit the strategic focus on competitive flexibility. This document is therefore divided into 9 chapters, each describing a single step of our research project. After reading this introduction, the reason, goal, problem statement, research questions, and working method should be clear. The chapters 2 to 7 will each concern one of the research questions.

Within the Chapters 2 and 3, a theoretical framework will be formed. Chapter 2 describes four competitive objectives and their relation to both the market and each other. Also, each competitive objective is made operational for measurement during this research project. Chapter 3 describes the theory on Operations Management relevant to this research project, including operations designs, and methods for planning and control.

Chapter 4 describes the current situation within GM, focussing on a single collection. The process design for the chosen collection is described, including a description of the factory layout and production flows. Also, the current method for planning and control is described, and the four competitive objectives are measured.

The desired situation is described in Chapter 5, based upon the desired levels for each competitive objective. Based upon the desired levels, a desired process design and method for planning and control is described, including several Lean Manufacturing principles.

Within Chapter 6, the experiment is described and analysed. The experiment is defined, and the steps that are taken for implementation are given. The alterations made to the desired process flow are explained, and the experimental method for planning and control is described. At the end of the chapter, the four competitive objectives are measured and analysed.

Chapter 7 describes an implementation plan including an analysis of GM's assortment and the steps taken during the experiment. The assortment of GM is described and each collection is compared to the experimental collection. After which, a possible implementation plan is presented to reach the desired situation.

The conclusion of our research project is presented in Chapter 8, along with our recommendations to GM. An abbreviated view on the answers for each research question is given, and several recommendations towards GM are described.

2 COMPETITIVE OBJECTIVES THEORY

This chapter provides an insight into the theory on competitive objectives, focussing on what is relevant to this research. First, a definition of flexibility as a competitive objective will be given. This definition will be used throughout the project. Due to the fact that competitive flexibility is one of several competitive objectives, we will describe all of the objectives in relation to the market demand. Finally, Section 2.3, presents measures for each of the objectives, which will be used throughout this research project.

2.1 COMPETITIVE FLEXIBILITY

2.1.1 COMPETITIVE PRIORITIES TRADE-OFFS

Companies have to choose on which of the competitive objectives (or priorities) they want to focus. This does not mean that they should forget others competitive objectives, but prioritising means that when creating an operations strategy, trade-offs will have to be made (Skinner, 1978). When a company is using a higher quality and therefore more costly resources, it will lower their chance of having the lowest price on the market. The same holds for companies that are focussing on flexibility, as they tend to have more general-purpose equipment that can be used to make many different kinds of products. Making a customised product will take more time, as it is impossible to sell directly from stock, and machine setup time will be longer per product. Both price and delivery time are still important to minimize, although in this example a higher quality and flexibility is preferred.

2.2 COMPETITIVE OBJECTIVES AND MARKET DEMAND

2.2.1 MARKET EVOLUTION

The world is constantly changing, as are consumers and therefore product markets. Bolwijn & Kumpe (1998) describe a theory in which the market demands develop in a logical order. For each of the different market demands, they describe an ideal type of firm. Figure 2-1, presents the relation between market demands, performance criteria, and ideal firm types.

Year	Market demand	Performance criteria	Company (ideal firm type)
1960's	Price	Efficiency	The efficient firm
1970's	Price, quality	Efficiency + quality	The quality firm
1980's	Price, quality, choice/delivery time	Efficiency + quality + flexibility/speed	The flexible firm
1990's	Price, quality, choice/delivery time, uniqueness	Efficiency + quality + flexibility/speed + innovativeness	The innovative firm

Figure 2-1: Market demands, performance, and ideal firm types (Bolwijn & Kumpe, 1998, p.95)

- Price - Up to the 1960's, the only important market demand was the product price. To meet this demand, companies were competing only on efficiency trying to produce as cheap as possible. The ideal type is therefore an efficient firm.
- Quality - Around 1970, product quality as a market demand is getting more and more important. Consumers are starting to pay more attention to the reliability, repair, and maintenance costs of products. Producing error-free is saving companies money due

to less money being spent on defects, repairs, malfunctions in the production process, and service costs. Mastering both efficiency and quality are the traits for a quality firm.

- Flexibility - In the 1980's, leading companies that have mastered both quality and price are seeking new ways in order to gain competitive advantage. Strategic choices are made to speed up introduction of new products. The product life-cycle diminishes, the amount of product types rises, and delivery time is being reduced. The demand from the market for a wider assortment and shortening of the delivery time are manifesting themselves into a demand for a more flexibility firm.
- Innovation - Entering the 1990's, again there are several companies that have implemented the changes needed to suit the new market demands. By then these companies are already trying to use technological innovations as their competitive advantage. The ability to quickly embed new technology into products and processes is getting more important. An innovative firm is therefore demanded.

2.2.2 COMPETITIVE OBJECTIVES AND THE MARKET EVOLUTION

Companies are trying to meet the demands of the customer through their competitive objectives. The competitive objectives from Wheelwright cannot directly be related to the theory of Bolwijn and Kumpe. For each concept that is within both theories, different definitions are being used. Figure 2-2 presents several common market demands demonstrating the differences between the two theories. These market demands are; (a) low price, (b) high quality, (c) fast delivery, (d) reliable delivery, (e) the ability to change the quantity of products and services, (f) wide range of products and services, and (g) innovative products and services. Both theories include all of these market demands and use the same demands for their concepts for cost and quality. Bolwijn and Kumpe see flexibility as the market demands (c), (d), (e), and (f), and use a separate definition for innovation (g). Wheelwright sees the market demands (c) and (d) as delivery, and the demands (e), (f), and (g) as flexibility.

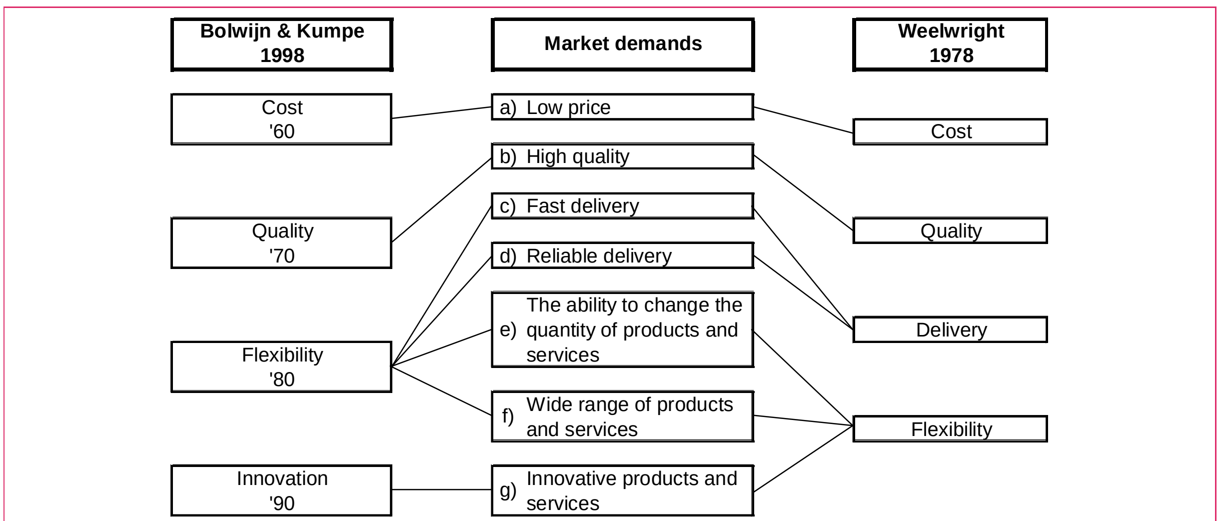


Figure 2-2: Market demands related to the theory of both Wheelwright, and Bolwijn and Kumpe

Besides the use of concepts, there is another large difference between both theories. As described above Wheelwright sees the competitive objectives as priorities in which a company has to make trade-offs. In order to increase performance on a competitive objective, a company will have to trade in some performance on another. Bolwijn & Kumpe see the development of competitive objectives as an evolutionary process, in which a company constantly needs to adopt new objectives into its strategy. Although both theories do not consider the competitive objectives as mutually exclusive, Bolwijn & Kumpe recognise that adding a new objective can even improve performance on previous objectives.

2.2.3 DEFINING COMPETITIVE FLEXIBILITY

The concept of flexibility has been a popular topic for researchers in the past few years and several theories have been developed. For this research project, the focus is on flexibility as a competitive objective, or flexibility offered to the customer. For GM flexibility is important in order to offer customers a wider range of choices within their assortment and their individual products. Also being able to offer products to different customers is important, for instance not only producing housing furniture but also interior furniture for businesses.

Many different authors have used competitive objectives as a basis for their research throughout the past 40 years (Skinner, 1978; Wheelwright, 1978; Van Dierdonck and Miller, 1980). Although many authors use different definitions for the competitive objectives, the overall theory remains the same. Within this research, four different competitive objectives are being used, specifically price, quality, delivery (or dependability), and flexibility. Competitive flexibility consists of product and volume flexibility. Volume flexibility is the ability for a company to accelerate and decelerate production very quickly. Companies that compete on the basis of product flexibility emphasise their ability to handle more non-standard or customised orders and lead in new product introductions. From this description we defined the following definition for flexibility:

> *Competitive flexibility is the ability for a company to produce non-standard orders, to introduce new products, and to accelerate and decelerate production quickly.*

2.3 MEASURING COMPETITIVES OBJECTIVES

Within this section, the four competitive objectives (cost, quality, delivery, and flexibility) are made operational. For each of the objectives several indicators are described, which we will use for measurement throughout this research project.

2.3.1 COST

The ability of a company to manufacture and distribute a product at low costs gives it a competitive advantage. This can be achieved by reducing production costs, reducing inventory, and increasing equipment utilization. Since so many variables have an effect on costs, often measures as return on sales, inventory turnover, and return on assets are being used (Wheelwright, 1978). Because this research project is focussed on a single collection, the direct and indirect costs of the production will be used as a measure.

Direct Cost

Direct costs are expenses that change in proportion to the output and which are directly accountable towards a particular product. At GM the direct costs are calculated by a sum of the resource, machine, and labour costs. The amount of resources needed for a particular product, are calculated in the designing phase. The actual resource costs may alter over time due to inflation, change of suppliers, or usage of new machines. The machine and labour costs are calculated by multiplying the total production time with the corresponding cost per hour.

Indirect Costs

Indirect costs represent expenses that are not directly accountable towards a particular product or collection. The indirect costs include taxes, administration, indirect personnel, and etcetera. At GM the overall direct costs are calculated and divided over the different collection according to sales. For this research project, the only indirect costs that are eligible for change are the inventory holding costs. These holding (inventory) costs can be determined by adding up three cost components (Reid & Sanders, 2005): capital costs, storage costs, and risk costs.

In order to measure the holding costs for a single collection, we will calculate the percentage for holding costs over the total inventory value. For the capital costs, GM currently calculates 5% over the total inventory value, which is the interest rate the company has to pay over borrowed money. The storage costs include the warehouse and employee costs. For the total storage costs, GM calculates € 90.000 a year which is about 7.5% of the total inventory value. The risk costs are measured at GM by the costs that are lost due to products not being sold, or being sold below the cost price. The total cost of risks over 2006 was € 140.000, which is equal to 11.7% of the total inventory value. For further measurement of the inventory cost, 24.2% (5% interest + 7.5% storage + 11.7% risk costs) over the calculated inventory value will be used, to measure the inventory cost per year.

2.3.2 QUALITY

Product quality itself is a broad concept, and it is therefore important to differentiate between actual quality and perceived quality, as well as high performance and error free production (Wheelwright 1978). Perceived quality refers to the way a customer sees a particular product, and is therefore very difficult to measure.

Performance Quality

The performance of a product is decided at the designing phase of product development, where the choices for the actual design and materials are made. Since the design phase of product development is outside the scope of this project, this criterion will not be used within this research.

Error Free Production

As soon as a product is developed, error free production is important to keep every product that is being produced consistent with the original design. The consistency with the design can be checked on several points within the operations flow. When errors occur it often costs extra money to correct them. To get an overview of the total cost of internal errors, we calculate it in relation to the direct costs.

2.3.3 DELIVERY

The criteria for delivery can be related both to the speed of the product delivery (delivery time), and the ability to consistently meet delivery standards or promises (delivery reliability) (Van Dierdonck and Miller, 1980). If delivery time is an important competitive priority, the company will have to critically analyze its operations system and improve, combine, or even eliminate processes in order to save time. This can for instance be done by using technology to speed up processes, and relying on a flexible workforce to meet peak demand periods. For on-time delivery, it is important that realistic delivery times are being communicated towards customers.

Delivery Time

The delivery speed depends on the throughput time of the production and order intake. The delivery time is measured in days from the moment an order arrives until the finished product is delivered at the customer.

Delivery Reliability

The reliability of delivery is calculated by dividing the amount of on time orders by the total order sum within a particular time period. Each order is planned by GM based either upon the standard delivery time or the requested delivery time by the customer. This planned delivery time is then communicated with the customer and is the basis for the delivery reliability.

2.3.4 FLEXIBILITY

This criterion refers to the ability to respond quickly to changes in demand or new product opportunities. It covers three important aspects, namely product flexibility, volume flexibility, and change-over flexibility (Wheelwright, 1978). Competing on the basis of product flexibility means that a company is able to quickly introduce new products into the market (Change-over flexibility), and handle a wide variety of products or customized orders (Mix flexibility). Volume flexibility stands for the ability to accelerate or decelerate the production of goods, in order to accommodate market changes.

Volume Flexibility

For an organization it is important to quickly adept to market changes, it can therefore be necessary to accelerate or decelerate the production. Because we are unable to measure the exact acceleration and deceleration rate for GM, we will measure the volume range GM can produce. This will show us the range in which GM can either accelerate or decelerate.

Mix Flexibility

Mix flexibility measures the variety of the collections or width of the assortment. It can be measured by the total of choices a customer can make within the assortment or a particular collection.

Change-Over Flexibility

Change-over flexibility stands for the ability to quickly introduce new products into the market. It can therefore be measured by calculating the time that is needed to develop and produce new products. As explained before, the design phase of product development is not within the scope of this project and will therefore not be measured as such. Because the throughput time is part of the time to market and within the scope of this project, we will measure it as indicator for the change-over flexibility.

2.4 CONCLUSIONS

From the literature study, we can make several conclusions regarding the first research question, which are both interesting and relevant for this research:

- What is competitive flexibility?

  Based upon several different insights on competitive objectives, we have given a single definition for competitive flexibility, namely: *Competitive flexibility is the ability for a company to produce non-standard orders, to introduce new products, and to accelerate and decelerate production quickly*. The definition is related towards the focus of this research and the situation of GM. According to the theory of trade-offs it is important to measure all competitive objectives when changing the focus towards flexibility.
- What is the relationship between competitive objectives and market demand?

  There is a direct relation between competitive objectives and the market demand. Bolwijn and Kumpe explain that the market is constantly evolving in a logical way, and that with each step another objective has become important for a company.

Weelwright explains that trade-offs have to be made by a company between the several competitive objectives.

- <u>What are the measures for competitive objectives?</u>

  For each competitive objective at least one measure is given so that all objectives can be analysed during this research project. The four competitive objectives we explained within this chapter are presented in Figure 2-3 together with their indicators and measures.

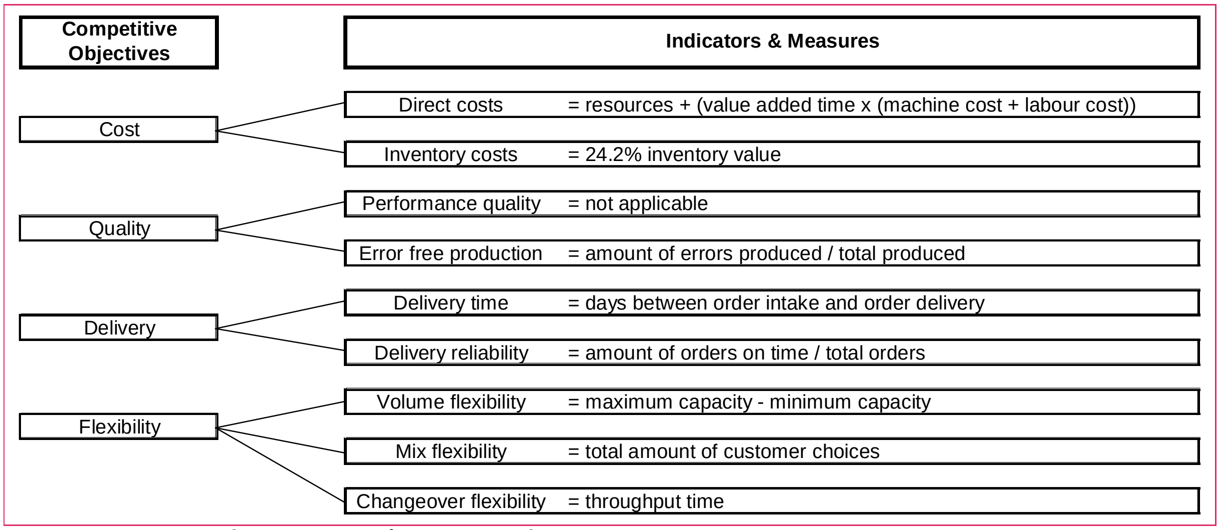


Figure 2-3: Objective measures for competitive objectives

3 OPERATIONS MANAGEMENT THEORY

This chapter describes the theory on operations process design and planning & control in relation to competitive flexibility. Section 3.1, explains the term operations management (OM) in order to clarify the relationship between the concepts; process design, and planning & control. Also, this section describes the relationship between OM and competitive objectives. Section 3.2, explains several types of operations design and product strategies. These designs and strategies are analysed for their fit with competitive flexibility. And finally, Section 3.3, describes different methods for planning and control that are relevant to this research project, and analyse their fit with competitive flexibility.

3.1 RELATIONSHIP BETWEEN FLEXIBILITY AND OPERATIONS MANAGEMENT

3.1.1 OPERATIONS MANAGEMENT

Operations management (OM) is defined as the design, operation, and improvement of the systems that create and deliver the organisations primary products and services (Chase et al., 2001). It is therefore a functional field of business with clear line management responsibilities. OM is concerned with the management of the entire system for the production of goods, involving all manufacturing resources like people, technology, information, and equipment as input, and sold company goods or services as output.

3.1.2 OPERATIONS MANAGEMENT AND COMPETITIVE OBJECTIVES

Operations Management is influenced by many different factors, as it is linked to customers and other parts of the enterprise. Figure 3-1 presents these vertical and horizontal links. The needs of the customer can be related to either existing products or new products. As explained in the previous chapter, the different customer demands can be related to four competitive objectives. The strategic operations choices that are made are partly based upon these competitive objectives. Also the operations strategy is connected to other business functions like for instance finance, R&D, and human resource management. The customer needs are also influenced by newly developed products, order fulfilment, and after sales service.

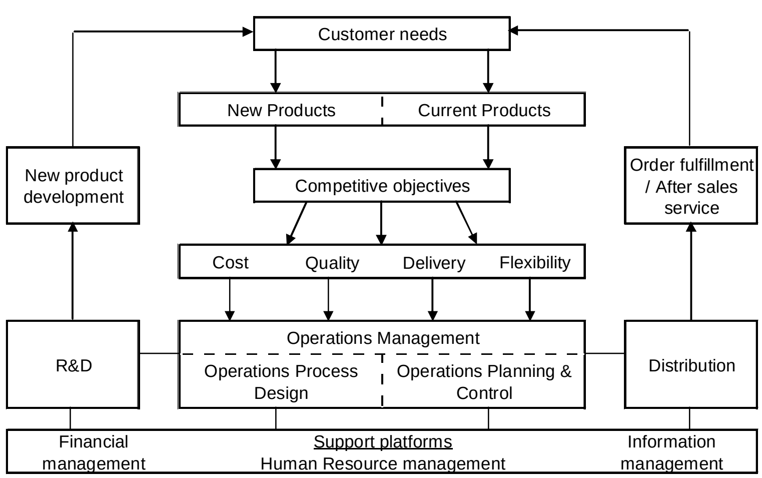


Figure 3-1: From market demands to Operations Strategy (Chase et al., 2001, p.29)

3.2 OPERATIONS DESIGN AND COMPETITIVE FLEXIBILITY

3.2.1 OPERATIONS PROCESS TYPE CONTINUUM

Process types are used to describe a particular general approach to managing processes. In manufacturing, these are project, jobbing, batch, mass, and continuous processes. Although several authors describe different types of processes, they can all be sorted using the four different dimensions of process tasks, process flow, variety, and volume (Slack et al., 2007). Figure 3-2 represents the five process types against the four dimensions. The dimension process task can range from diverse/complex to repeated/divided. Variety stands for the level of standardisation within products, in which a high variety is equal to a low level of standardisation. Volume describes the amount of products being created at once, ranging from a single product towards large numbers or even a continuous production. The type of process flow is a continuum between intermittent and repetitive operations:

Repetitive Operations

The repetitive operations are used to produce a high volume of products with a low variety. The resources within repetitive operations are organized into a line flow so that the production is highly efficient. The operations often rely heavily on technology and automation instead of labour skill, to increase output and thus improve efficiency. Repetitive operations are therefore more capital intensive than labour intensive.

Intermittent Operations

These operations are used to produce a high variety of products using a low volume. Production is often based directly on customer orders, creating the possibility for customised products. Because different products have a different way of manufacturing, there is hardly a standard route that all products follow through the facility. This means that workers need to be flexible and able to perform different tasks. As explained before, due to the high variety the available equipment has a more general purpose. Also automation is less common, because it is typically product specific and not cost efficient to invest in. Intermittent operations are therefore often labour intensive rather than capital intensive. Due to the low volume and high variety, intermittent operations can compete better on flexibility.

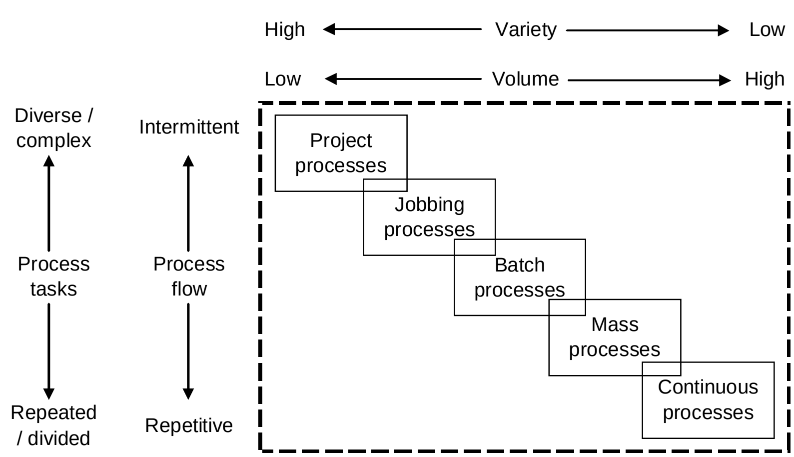


Figure 3-2: Process types within four dimensions (Slack et al., 2007, p.94)

3.2.2 PRODUCT STRATEGIES

The product and service strategy is directly related to the type of operation a company has in place (Reid and Sanders, 2005). For instance, due to their labour intensive nature, intermittent operations are less competitive on cost than repetitive operations. As the repetitive operation is able to mass produce a large volume of a single product, it is able to spread its design and equipment setup costs over a larger quantity. For the same reason, repetitive operations are less able to compete on flexibility. The competitive priorities as described above should therefore be ranked so that it fits the operations process. On the other hand, if a company wants to enter a market where most competitors are already flexible or even innovative firms, then a repetitive operation will not be basis for a good competitive position. A careful evaluation for the right production strategy is therefore required.

Product strategies differ both by the delivery lead time and by the degree of product customisation they offer. Delivery lead time stands for the amount of time needed from receiving an order to when the product is actually delivered. Several product strategies exist from designing the product based upon the customer's requirements to selling finished products from stock. The change where an internal order becomes a customer order is called the Order Penetration Point (OPP) (Olhager, 2003). Figure 3-3 presents the different strategies.

A make-to-stock strategy produces finished products in anticipation of demand, making sure it is ready for immediate sale or delivery. It is largely used by companies producing large volumes of a standardized product, and is therefore typically seen in repetitive operations. Delivery lead time is the shortest, but the customer does not have any influence in the product design.

Assemble-to-order (or build-to-order) uses an in-between stock with standard product components that can be combined to customer specifications. This strategy results in a longer delivery lead time, but it leaves room for some customization.

To include customer influences even further, a *make-to-order* strategy can be used. Production starts as soon as a customer order has been received, resulting in an even longer delivery time, although more customisation is possible. The strategy is characterised by lower volumes and higher variety, and is therefore an example of an intermittent operation.

The *buy-to-order* strategy differs not much from the make-to-order, as it only includes the purchasing of the raw materials needed for the ordered products. It does, however, add a dimension towards the delivery reliability, as the production time is not only depending on the company itself but also its suppliers.

To fully include the customer influences in the product design, a *design-to-order* strategy is used. It is often used by companies that create complete custom specific products, and where standardisation is not possible. Delivery time is longer because it also includes the product development.

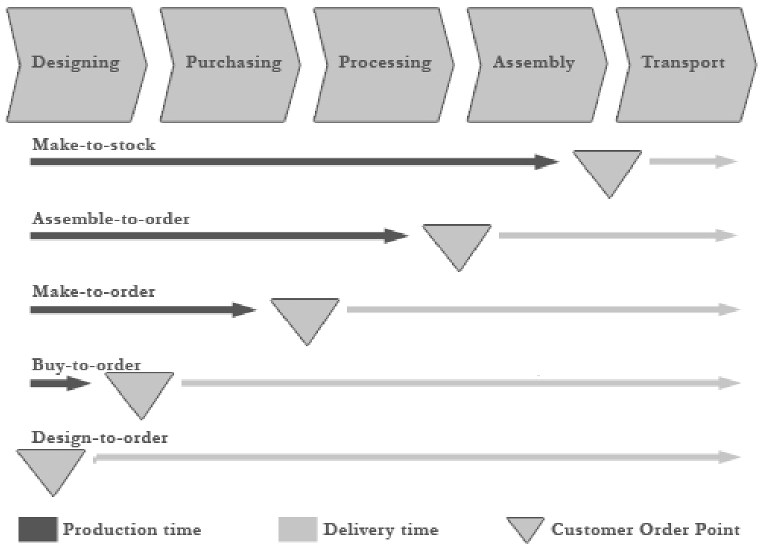


Figure 3-3: Product strategies (Olhager, 2003, p.320)

3.2.3 PUSH AND PULL STRATEGIES

The terms push and pull refer to the way the products are directed through a supply chain. The supply chain, logistics network, or supply network of a company is a coordinated system of information, resources, activities, people, and organizations involved in moving a product or service from supplier to customer. It therefore expands beyond the company itself. The difference between push and pull is the mechanism that triggers the movement of work within a system (Hopp and Spearman, 2000). Within push systems the demand (or forecast) for a particular product is recalculated towards an overall production planning. There is a signal that indicates that the materials have to be sent through the operations system. Each sub-process therefore receives a signal from the planning that certain materials have to be moved towards the next sub-process on a particular time. In a pull system each sub-process controls its own demand and sends requests towards its preceding (upstream) sub-process. Planning & control within a push system is therefore more centralised, and in pull systems more decentralised. Figure 3-4 presents an example of a push and pull system.

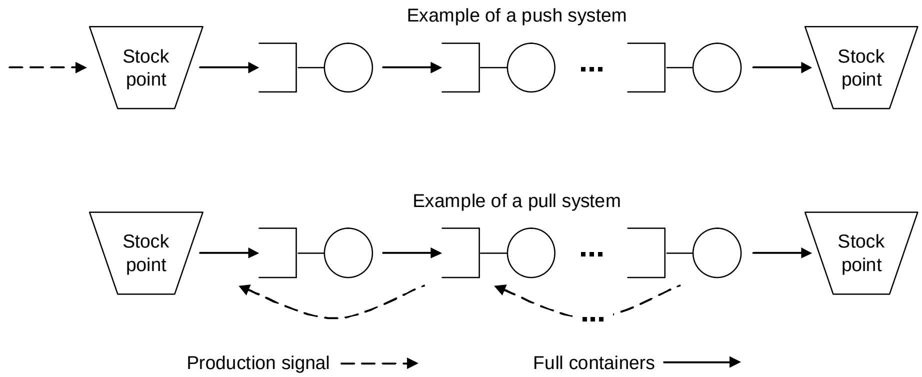


Figure 3-4: Push and Pull system (Spearman and Zazanis, 1992, p.523)

Pull systems are often used in repetitive operations with an exception of true continuous processes (Schmidt and Ploos van Amstel, 2000). Although, as long as it is batch production, it is possible to use elements of pull systems inside intermittent operations. It is also possible to use both systems within the same factory, either by using a hybrid system of both, or the use of a push-pull interface (Hopp and Spearman, 2000). The push-pull interface acts like the OPP, dividing a production process into push and pull segments. In front of the push-pull interface, products are produced based upon stock level. In order to keep inventory as low as possible a pull system should be used for this flow. Behind the push-pull interface, the movement of products is triggered by customer orders pushing it through the remaining processes. Olhager and Östlund (1990) also describe, that pull systems are applicable on the upstream side of the OPP and push systems are necessary for downstream flows.

3.2.4 THEORY OF CONTRAINTS (TOC)

The Theory of Constraints (TOC) or constraint management is originally developed by E.M. Goldratt (Goldratt and Cox, 2004). An important presumption of TOC is that 'generating more money' is often the most important part of a company's goal. The bottleneck is the sub-process that has the lowest capacity of the company and is therefore limiting the total output. Goldratt explains that an hour lost on a bottleneck resource is equal to an hour lost for the whole production process. It is therefore important to constantly monitor the bottleneck. Also because the bottleneck defines the total output, it is important to balance the flow in order to reduce rising inventories at the bottleneck.

The concept on itself is a simplified model, although many planning & control methods recognise the existence of bottlenecks. Recognition of the bottleneck is also important while designing the operations process. As it sets the maximum capacity, it influences volume flexibility. When the change-over time is increased due to a higher mix-flexibility, capacity may be diminished. This could lower the throughput time and the total output of a factory. Controlling the bottleneck may therefore be an important precondition for the focus on competitive delivery and flexibility.

3.3 FLEXIBILITY IN OPERATIONS PLANNING & CONTROL

Within the literature, many different methods for planning & control are being developed and described by several authors. Some are merely variations on others or have evolved out of older methods. This section describes methods for operations planning & control, related to this research project. Section 3.3.1, describes methods such as Kanban, MRP, and Conwip, which control the WIP or throughput of a production flow. Section 3.3.2, describes the philosophy Lean Manufacturing and some of its methods. Although the goal of this research project is not to create a Lean environment, we feel that the individual methods can improve the competitive objectives. The methods described at Section 3.3.1 do not focus on all four of the competitive objectives. Lean methods can be used to control for instance the quality, or to improve the throughput time.

3.3.1 METHODS FOR PLANNING & CONTROL

Many different methods for planning and control have been developed, because of the great importance of these systems for companies to reach their competitive objectives. The methods can be classified regarding their characteristics. Figure 3-5 classifies the methods based upon their primary control variable, level of aggregation, flow complexity, and variety.

The level of aggregation is divided into centralized and decentralised. A planning and control method is classified as centralized if the WIP level, lead times, or work centre utilization are determined on a centralised control level. Decentralised methods will typically set these parameters by means of control loops between the manufacturing work centres (Lödding et al., 2003).

Throughput is the primary control variable if the method controls throughput and observes WIP, whereas WIP is the method's primary control variable if it controls the WIP level and observes throughput (Hopp and Spearman, 2000).

The variety (or variability) of products a method can handle is classified in either high or low. The complexity of the flow also ranges from low to high, where a low complexity can be compared to mass and continuous processes, and high complexity to project and jobbing processes. However, the classification of methods for both complexity and variety depend differs between authors.

		Level of aggregation	
		Centralized	Decentralized
Primary control variable	Throughput	MRP II BS	
	WIP	LOOR Conwip	Kanban Polca DEWIP

		Variety	
		Low	High
Flow complexity	Low	Kanban BS	Conwip
	High		MRP II LOOR Polca DEWIP

Figure 3-5: Classification of planning and control methods (Lödding et al., 2003, p.44)

BaseStock (BS)

Within the BS method, the base amount of inventory is maintained continuously. The inventory is replenished one unit at a time as random demands occur (Hopp and Spearman, 2000). Depending on the throughput time for delivery of products, the base stock level is set.

Resource Planning (MRP & MRP-II)

The Material Resource Planning (MRP) approach is one of the oldest methods, and uses a time-based materials planning for manufacturing process. Within MRP, the need for resources within the operations process is often calculated from a sales forecast. Based upon fixed throughput times, MRP calculates when particular resources need to be available (Bertrand et al., 1998). The management of production and materials purchasing is therefore centralised, pushing the production orders through the operations process.

Due to the disadvantages of MRP, new concepts were developed in the 1970's based upon the techniques of MRP-I. Manufacturing Resource Planning (MRP-II) grew from these concepts and was further standardised over the years. Unlike MRP, it creates an overview of the available machine capacity, capital, and labour (Bertrand et al., 1998). Several parts of the company's management system are combined into one planning and controlling system, with emphasis on passing through the planning and giving feedback on the feasibility of those plans. A large disadvantage of MRP-II is the needed calculative power for the planning and forecasting. Often, large and expensive ERP (Enterprise Resource Planning) software solutions are bought to resolve these issues.

Kanban

Kanban is a system that implements the JIT philosophy, which we will describe in Section 3.3.2. It was developed by the Japanese car manufacturer Toyota in order to eliminate the inventory from the operations process. The Japanese word Kanban stands for a physical card, which is used to communicate the need for parts from a sub-process to the previous sub-process. Goods may therefore not be transferred through the manufacturing process without a Kanban-card, reducing the need for large inventory buffers. There are two types of Kanban systems, the single Kanban and dual Kanbal system. The single Kanban system uses a single card to block production at each stage based on the total queue size. The dual Kanban or two card system uses both Production-ordering cards and Withdrawal cards, making it more appropriate for manufacturers who are not prepared to adopt strict control rules to the buffer inventory (Huang and Kusiak, 1996). A Withdrawal Kanban specifies the kind and quantity of products which a manufacturing process should withdraw from a preceding process. This means that the required products are taken from a buffer inventory. A Production-ordering Kanban specifies the kind and quantity of products which the preceding process must produce.

The amount of Kanban-cards per part depends on the demand per day or week, and on the steadiness of the demand. Every Kanban-card represents a defined amount of parts to be produced each time. By passing on Kanban-cards upstream through the operations process, the product is actually pulled through the system. It therefore requires a steady demand on a particular item to give a satisfactory result. Effectively it can only handle a very limited number of variants efficiently, since the total WIP increases with the number of variants (Lödding et al., 2003).

Constant Work in Progress (Conwip)

Conwip is developed as a system with the benefits of a pull system to be used in a wide variety of manufacturing environments (Spearman et al., 1990). Conwip is a generalised form of Kanban, and like Kanban it relies on signals. The difference with Kanban is that when a card needs to be filled, it is sent directly to the beginning of the flow where it waits in a queue, instead of moving one process upstream. It is therefore a hybrid system of both push and pull, as the trigger is the demand pulling parts into the system, pushing it downstream through the system. To control the WIP, Conwip complies with the view of TOC to balance the flow. The operation of a Conwip line is regulated by the bottleneck resource (Spearman et al., 1990). In the best case scenario with a sufficient demand and a correct number of cards, a Conwip system will maintain just enough WIP to keep the bottleneck busy.

Conwip as a pull system, shares the advantages of a pull system with respect to WIP control, while it is more robust, flexible, and easier to implement than other pull systems (Framinan et al., 2003). Since the WIP is kept at a constant level making use of backlog lists, it is a centralized method. Also Conwip can handle a higher variation than Kanban, as the Conwip cards are not part specific, and relies less on inventory buffers. These are important characteristics for manufacturing companies that try to control inventory levels and at the same time, face uncertain and dynamic environments where Kanban does not perform well.

Load oriented order release (LOOR)

The LOOR system is developed by Bechte in the year 1980 (Bechte, 1988). It is a combination of a centralized WIP control, and a load balancing algorithm based on load limits of the work. The algorithm makes it possible to get a higher performance, than only controlling the WIP. The system holds back selected orders, until the current activity level indicates that resources required for it are actually available. Bechte (1988) presents empirical evidence for reduction of both WIP inventory and throughput time, compared to the situation before the LOOR implementation. There are, however, also simulations performed on job-shop environments that did not show consistent improvement (Newman and Maffei, 1999). In most of these cases, the WIP and process lead times were decreased, but the overall reliability was reduced.

Paired-cell overlapping loops of cards with authorization (Polca)

Polca is a material control system that focuses on throughput time control in production situations with high variety and customization. It is part of the overall concept Quick Response Manufacturing, and developed by Suri in 1998 (Riezebos, 2006). Within the Polca system, WIP control loops are implemented between pairs of manufacturing cells. The system uses a release mechanism based on route-specific capacity signals (Polca cards) and product-specific release signals (ERP system) (Riezebos, 2006). The Polca cards level the maximum amount of WIP within a specific loop. The product-specific signal is based on the list of customer orders and their release date, and therefore decides which products are being produced. Besides the loop on pairs of cells, another important difference between Polca and Kanban is that Kanban uses cards to replenish inventory, and Polca cards to fill up available capacity. Polca can therefore better handle a more complex production flow and higher variability.

Decentralised WIP (Dewip)

Dewip is a manufacturing control system aimed at achieving short and reliable throughput times. The system designs decentralised control loops between the manufacturing work centers. The urgent and available customer orders enter a pool, from which the manufacturing work centres draw if the state of manufacturing allows. Lödding et al. (2003) present empirical evidence that Dewip achieves roughly the same performance lead times as Conwip, and worse performance than LOOR due to the missing load balancing algorithm. However, unlike Conwip, Dewip can function well within a more complex flow and has a decentralised level of aggregation unlike both LOOR and Conwip.

3.3.2 LEAN MANUFACTURING

Lean manufacturing is a generic process management philosophy that evolved from the Toyota Production System (TPS) (Womack et al., 2007). The philosophy encompasses several other methods that include the 'lean' idea, for instance: Just-In-Time, Kanban, Single Minute Exchange of Die, and Six Sigma. Womack and Jones define a set of five basic principles that characterize a lean enterprise (Womack and Jones, 2003):

- A very important part of lean thinking is 'value', and product value can only be defined by the customer.
- Identify the steps within the value stream, eliminating every step and action that does not create value.
- Make the remaining value-creating steps occur in a tight and integrated sequence, so that products will flow smoothly towards the customer.
- Let the customer pull the product from you as needed rather than pushing products, often unwanted, onto the customer.
- Pursue perfection through continuous improvement.

A lean technique that is often used to analyse the flow of materials and information to bring a product to a customer is Value Stream Mapping (Rother and Shook, 2003). It is commonly used in lean environments to identify opportunities for improvement in lead time. Within a value stream map the non-value adding steps are divided from the value-adding steps within a single representation, in which 'waste' is visualised.

Just-In-Time (JIT)

Throughout the literature, several different definitions of JIT are being used, although in many cases it is seen as a general philosophy of reducing waste and improving product quality (Brown and Mitchell, 1991). Companies following the JIT philosophy or a JIT based method, often work with small multifunctional groups. For the creation of these groups, the functional layout of the factory is redesigned into several cells. These cells exist from several dissimilar but sequentially complementary machines, each processing the needs of a particular family of parts. Also JIT manufacturing is following a pull rather than a push strategy.

The JIT philosophy is especially important within the operations process itself. Work in Progress (WIP) inventory can be eliminated when every sub-process is delivering exactly on time to the next sub-process. Due to the elimination of inventory, costs can be lowered. Also the throughput time is reduced, improving both the competitive objectives delivery and flexibility (Sakakibara et al., 1997). The JIT philosophy is often implemented with the Kanban method. Like Kanban, in order for JIT to work, a stable demand of products is required. Also a large disadvantage is that successful implementation of JIT, depends on the reliability of the suppliers. The reliability will have to manifest itself into the internal reliability of the quality and reliability of the equipment, thus the total reliability of the operations process.

Single Minute Exchange of Die (SMED)

The concept for Single Minute Exchange of Die (SMED) arose around the 1960s at the company Toyota. The main concept of SMED is the calculation of the economic lot size of the ratio of actual production and the change-over time (McIntosh et al., 2000). Change-over time stands for the time needed to switch a machine in order to work on a different product. When change-over time is high, valuable production time may be lost. The goal of SMED is to provide a rapid and efficient way of converting a manufacturing process from running the current product to running the next product. It is therefore also often called Quick Change-over (QCO). Several authors describe different implementation stages of SMED, although two very important steps are:

1) Separate the internal and external activities. Internal activities refer to those activities that can only be performed when the process is stopped, and external activities can already be done when the process is still running.

1) Convert internal activities into external where possible.

A rapid change-over capability is an essential enabling tool for competitive flexibility time (McIntosh et al., 2000). When the mix-flexibility is increased a higher variety of products will have to be produced. Reduction of change-over time is therefore important to lower throughput time and inventory, improving cost, delivery, and flexibility.

5S Method

The 5S method gets its name from five different Japanese words that start with the letter S. Its key targets are workplace morale and efficiency. The benefits from the methodology come from deciding which resources should be kept, where it should be kept, and how it should be kept. This decision making process should include employees and build a clear understanding of how work should be done. It thereby also creates employee ownership inside the process. The 5S's are:

- *Seiri (Sort)*; sort all the resources within the work area and eliminate everything that is not essential.
- *Seiton (Straighten)*; keep an orderly workplace by arranging the resources in an order that promotes work flow.
- *Seiso (Shine)*; keep a workplace clean and neat.
- *Seiketsu (Systemize)*; standardize work practices.
- *Shitsuke (Sustain)*; sustain discipline, referring to the previous S's. Ensure that there is not a fall back into the previous ways of working.

There are several similar methods with their own alternative acronyms, for example the 5C's (Clearout, Configure, Clean, Conformity, and Custom), CANDO (Cleaning, Arranging, Neatness, Discipline, and Ongoing improvement). Also there are several additions made to the 5S method, adding concepts as Safety and Security.

Six Sigma

The term Six Sigma refers the ability to create products within specification by a highly capable process. Six Sigma means, that when there are six standard deviations between the mean of a process and the nearest specification limit, there will be practically no products or components that fail to meet the specifications. The goal of Six Sigma processes is to produce products with a defect level below 3.4 Defects Per one Million Opportunities (DPMO). For a normally distributed process, 3.4 defects per million is actually equal to 4.5 standard deviations above or below the mean (one-sided Capability Study). This implies that 3.4 DPMO corresponds to 4.5 sigma, and not 6 sigma as the name would imply. DPMO is calculated with the following formula:

DPMO = (1.000.000 x number of defects) / (number of units x number of opportunities per unit)

Defects are defined as a non-conformance of a quality characteristic to its specification. The opportunity for defects (and therefore how to count and categorize defects) can be difficult, but generally organizations consider the following when defining the number of opportunities per unit:

- Knowledge of the process under study.
- Industry standards.
- When studying multiple types of defects, knowledge of the relative importance of each defect type in determining customer satisfaction.
- The time, effort, and cost to count and categorize defects in process output.

Six Sigma consists of a set of practices originally developed by the company Motorola, in order to systematically improve processes by eliminating defects. The practices were inspired by quality improvement methods such as Total Quality Management (TQM) and Zero Defects. Like its predecessors, Six Sigma asserts the following:

- The key to business success is a continuous effort to reduce variation in the process output.
- In order to succeed at achieving a sustained quality improvement, commitment from the entire organisation is required, particularly from the top-level management.
- Operations processes can be measured, analysed, controlled, and improved.

3.4 CONCLUSIONS

Summing up this chapter we make the following conclusions regarding the second research question:

- What is the relationship between flexibility and operations process?

  Operations Process Design and Planning & Control are in two ways connected with the competitive objectives. First, customer needs in new and current products are being translated into competitive objectives which are embedded within the operations strategy. Second, the fulfilled orders, after sales service, and new product development influence the customers' needs.
- Which type of operations design fits a flexible operation?

  Intermittent operations have a better fit with competitive flexibility, due to higher variety and lower product volume. For production, a make-to-order, buy-to-order, or design-to-order strategy is the best option when a higher mix-flexibility or even change-over flexibility is desired. The OPP should be placed upstream as much as possible. When a full make-to-order strategy is not possible a push strategy can be used for the downstream flow, combined with a pull strategy for the upstream flow. Finally, when designing the operations process it is important to keep in mind the influence of a possible bottleneck.
- Which methods for planning & control fit a flexible organisation?

  If a higher variety is desired, methods like BS and Kanban are less efficient. Methods that have a better fit with a flexible organisation are Conwip, MRP-II, Loor, Polca, and Dewip. However, this does not mean that BS and Kanban cannot be used at all within a flexible organisation, as more than one method can be used at the same time, each controlling different flows.

  The philosophy of Lean Manufacturing is a generic process management philosophy encompassing several other methods that include the 'lean' idea. Although the goal of this research project is not to create a Lean environment, the individual methods can improve the competitive objectives. For instance, Six sigma which goal is to minimise product defects, SMED for the reduction of change-over times, and 5S method to improve the overall workplace morale and efficiency.

4 THE CURRENT SITUATION

Within Section 4.1, a collection is chosen which will be used to describe the current situation. This collection is also used within the experiment in Chapter 6. Section 4.2, describes the current process design of the chosen collection. Within the process design we present and clarify the several flows with their OPP. Section 4.3, describes the method for planning and control of the chosen collection. Finally, Section 4.4, will include a measurement of the competitive objectives within the current situation.

4.1 COLLECTIONS WITHIN GM'S ASSORTMENT

4.1.1 GM'S CURRENT ASSORTMENT

GM's assortment consists of three different brands namely: Times, Motto, and Delato. All products are sold through a retailer network, in which GM is responsible for the development, production, and marketing of the brands. The *Times* brand holds classical collections and is the oldest brand that GM's produces. Recently the brand has been updated to combine both a classical look with a modern touch. *Delato* was the second brand that GM introduced, and it was born from the idea to create more modern collections. At this moment it is the bestselling brand from GM. In order to expand GM's retailer network beyond the Dutch borders, GM launched a new Brand named *Motto* in the year 2006.

GM tries to design one new collection per brand each year; with an average of four different collections per brand, this means that most collections have a life cycle of four years. Figure 4-1 describes the current chest collections from GM. Per collection, the start-up date is given, the average turnover per month (from Januari-2007 to September-2007), and an overview of the different parts within the design.

For the experiment, it is important that the chosen collection is not too old, as the collections life cycle is not very long. Also the average turnover has to be substantial so that the order intake will provide a steady demand for production. A turnover of € 10.000 per month equals an average of 10 chests sold per month. Next to the collections age and turnover, the different parts on the chests within the collection are important. There has to be a good mix between fibre plating and solid wooden panels to make it a good representation of the whole assortment. With these considerations in mind, we choose the collection Riverwood for the experiment.

	Artimo	**Rosso**	**Seaside**	**Quarto / Linea**	**Riverwood**	**Artimo Color**	**One**	**Two**	**Three**	**Desert**
Brand	Delato	Delato	Times	Delato	Times	Delato	Motto	Motto	Motto	Times
Collection startup	June-2003	Sept-2004	Sept-2004	Sept-2005	Febr-2006	Apr-2006	May-2006	May-2006	May-2006	Feb-2007
Average turnover per month	€ 15.390	€ 30.330	€ 23.612	€ 4.504	€ 35.579	€ 4.504	€ 5.517	€ 4.528	€ 3.382	€ 5.259
Top	P	P	S	S	S	P	P	P	P	S
Sides	P	P	S	P	S	P	P	P	P	S
Bottom	P	P	P	S	P	P	P	P	P	P
Dividing boards	P	P	P	P	P	P	P	P	P	P
Front	S	P/Glas	S	P	S	P	S	Glas	P	S
Legs	P	X	S	X	X	P	X	X	X	X
Side tops	S	X	S	X	S	S	X	X	X	X

S = Solid wooden panels P = FibrePlate X = Not part of the design

Figure 4-1: GM's assortment with the current running collections

4.2 CURRENT PROCESS DESIGN

4.2.1 FACTORY LAYOUT

The layout of GM's factory can be seen as a combination of 3 separate parts (see Appendix C). The first part consists of the first 7 sub-processes (shortening, slicing, sorting, gluing, sand grinding, CNC & traditional, and assembly). At GM this part is called the 'Machinale', and it is where most of the actual woodworking takes place. The second part (number 8 in the layout) is a large inventory for semi-finished components. From the inventory the components are set out towards the final part which is called 'Expeditie', and it includes sub-processes 9 to 13 (finishing, varnishing, sand grinding, drying, and shipping). Each of these subparts used to have its own manager, since the large reorganisation in 2006 both the first and third part are controlled by a single manager.

Within the separate parts of the factory several departments can be defined, with each department having their own machines. For the readability in flows we will use only the names of the departments. These departments with their sub processes are:

'Machinale' (first 7 sub-processes)	'Expeditie' (sub-process 9 to 13)
▪ Raw wood o Shortening o Slicing ▪ Panel production o Sorting o Gluing o Sand grinding ▪ CNC & Traditional o 3 CNC machines o Several traditional machines ▪ Assembly o Assembly (for semi-finished components)	▪ Finishing & assembly o Finishing (sand grinding) o Assembly (for varnish and paint process) ▪ Varnishing & painting o Varnishing & painting o Sand grinding ▪ Assembly & shipping o Assembly (for shipping)

4.2.2 CURRENT RIVERWOOD FLOWS

As described before, every chest collection can be divided into several subparts. These parts naturally differ between the several chests within a single collection, although they are produced in the same way. Some of these parts follow the same flow through the factory. If these are combined, there are five different flows visible for the Riverwood collection, which are stored at an inventory for semi-finished products. All of these five flows currently form a separate production request, belonging to a production project that represents a final product. The products that result from flows one to five are stored within the semi-finished products inventory, waiting for a customer order. The sixth flow represents the activities that are needed based on customer orders. A full schematic view of the process flow is given in Appendix D.

1) Top, sides, and side-tops (solid wood)
2) Bottom, and dividing boards (fibre plates)
3) Front (solid wood)
4) Drawers (solid wood)
5) Plinth (solid wood)
6) Customer Order production flow

The first flow (top, sides, and side-tops) is started from raw wood inventory and directed through the raw wood department, panel production, CND & traditional, and finally assembly. The second flow (bottom, and dividing boards) contains an outsourced activity for sawing the fibre plate to minimise waste. After the sawing process, the fibre plates are directed through the CNC & traditional department and combined with the first flow at the assembly into the body of the chest. The assembled chest body is then stored at the inventory for semi-finished products. Figure 4-2 presents these two flows.

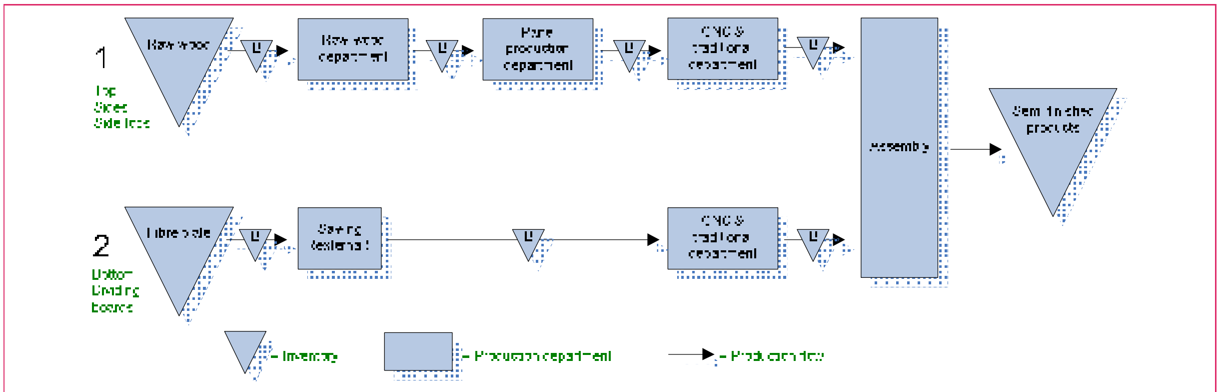


Figure 4-2: Flows one and two (top, sides, side-tops, bottom, and dividing boards) of the current situation

GM altered the production of chest fronts in 2006, when the OPP for tables was replaced from the semi-finished products inventory towards a solid wood panel inventory. The advantage of this change was that there was far less inventory needed as only the panel size was fixed. This means that for every customer order, the panels still have to go through the CNC & traditional department where it is altered into a defined tabletop. Due to satisfactory results with the solid wood panel inventory, the chest fronts are also produced out of this inventory. Figure 4-3 presents the flow for panel production.

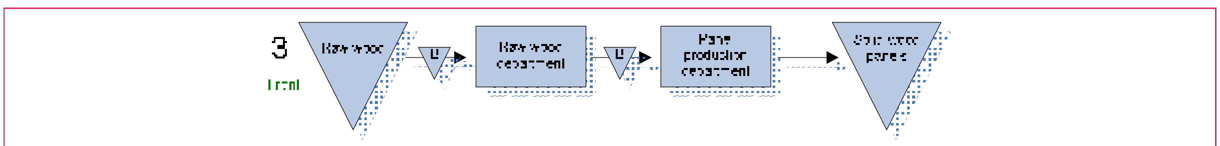


Figure 4-3: Flow three (front) of the current situation

The fourth flow (drawers) is almost equal to the first, although it is separated because the drawers can be used in different sizes and types of chests within the same collection. They are therefore produced in larger quantities than the different chest bodies. Figure 4-4 presents the flow for the production of drawers.

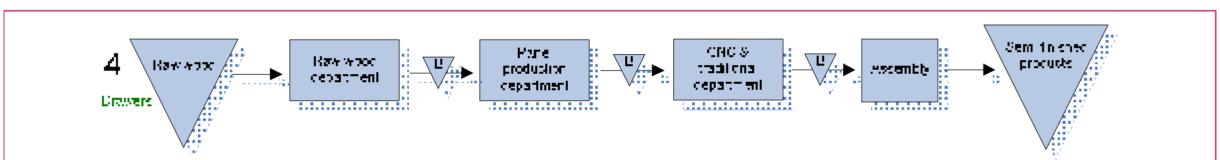


Figure 4-4: Flow four (drawers) of the current situation

The fifth flow (plinth) is less easy to define, as the initial inventory is variable. The plinths are made from waste that is created by the production process. The most common input for plinths are wooden boards that are not suited for a panel. This form of waste is created at the sorting activity, but will suffice for small parts like plinth. When the waste inventory is depleted, regular raw wood will be used for the production. After production the plinths are stored in the inventory for semi-finished products. The flow for plinth production is represented in Figure 4-5.

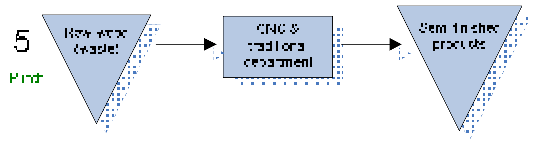


Figure 4-5: Flow five (plinth) of the current situation

Each customer order is planned for a 'finishing & assembly' week. Within this week all the parts that are needed are delivered by the semi-finished products inventory to the finishing & assembly department. As we described, since the year 2006 chest fronts are not stored in the semi-finished products inventory anymore. These are therefore made by the CNC & traditional department and delivered in the first week at finishing & assembly. The products are then made ready for varnishing & painting. Within this first, week a clustering is made on colour to reduce production time and waste for varnishing & painting. After the products are varnished or painted, the assembly & shipping department will fully assemble the chests adding the details as metalwork and hinges. This whole process takes three weeks, from which the actual shipping to the customer uses one week. A representation of the customer order production flow is given in Figure 4-6.

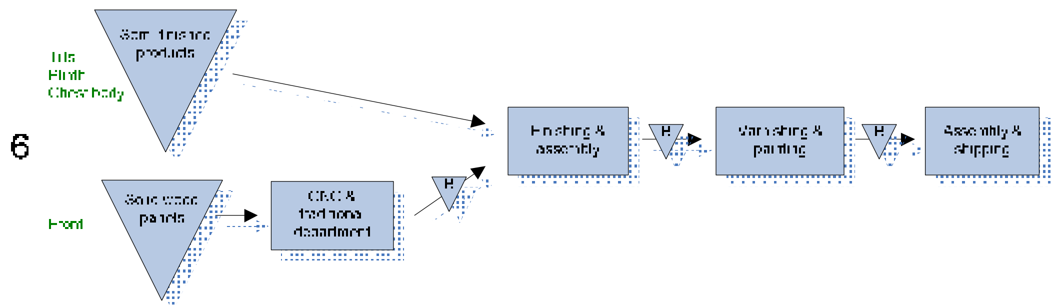


Figure 4-6: Customer order flow of the current situation

4.2.3 ANALYSIS OF THE CURRENT PROCESS DESIGN

The current process design of GM can be related to a batch process, in which the production sizes per product range from 10 to 25 for a single production order. It is therefore neither a true intermittent nor repetitive operation. Machines are set up in a flow and placed together within departments based upon its characteristics. The Order Penetration Point is placed at the inventory for semi-finished products. An assemble-to-order strategy is being used to offer some variety to the customer, which is in most cases restricted to the choice of varnish or paint. Also, within some collections the choice between glass and wooden doors are possible, although this is not the case for Riverwood.

4.3 CURRENT METHOD FOR PLANNING AND CONTROL

4.3.1 STANDARD METHOD FOR PLANNING AND CONTROL

For the description of the current method for planning and control, we simplified the current process design. Figure 4-7 presents the signals from and towards the production. The simplified model includes flow 1 (top, sides, and side tops), flow 2 (bottom, and dividing boards), flow 4 (drawers), flow 5 (plinth), and flow 6 (customer order flow). Within Section 4.3, we will describe the planning and control method for flow 3 (fronts).

The inventory levels of semi-finished products are registered within a software package that is created by GM itself. This software package called GP2002 is an ERP like program that connects the inventory levels with production planning. The production processes upstream of the OPP are planned and controlled based upon the inventory levels of semi-finished products and a sales forecast. After the release signal is given, the products are pushed through the flow towards the OPP. It is therefore an MRP like method for planning and control. Because throughput times are difficult to predict, causing products to arrive later than expected at the inventory for semi-finished products, GM created required and available capacity overviews. Based upon these overviews, a maximum amount of WIP was set. This Conwip like method has slightly improved the throughput times, although required products still arrive at the semi-finished products inventory too late.

Downstream of the OPP, the processes are planned and controlled based upon individual customer orders. A list is made of the customer orders per week in which a clustering is made based upon the product colour. This list is sent to the semi-finished products inventory, so that the requested products are released. When the department of finishing & assembly has received all the parts that are needed for a single order row, it is made ready for varnishing or painting. The order status is then changed in GP2002 so that it can be traced. The different products are then pushed anonymously (clustered on colour) through the process towards the final assembly where it is made ready for shipping. Because the products are anonymous, controlling the flow is very difficult. Because there is just a single flow with a maximum throughput time of one week, this has never been changed.

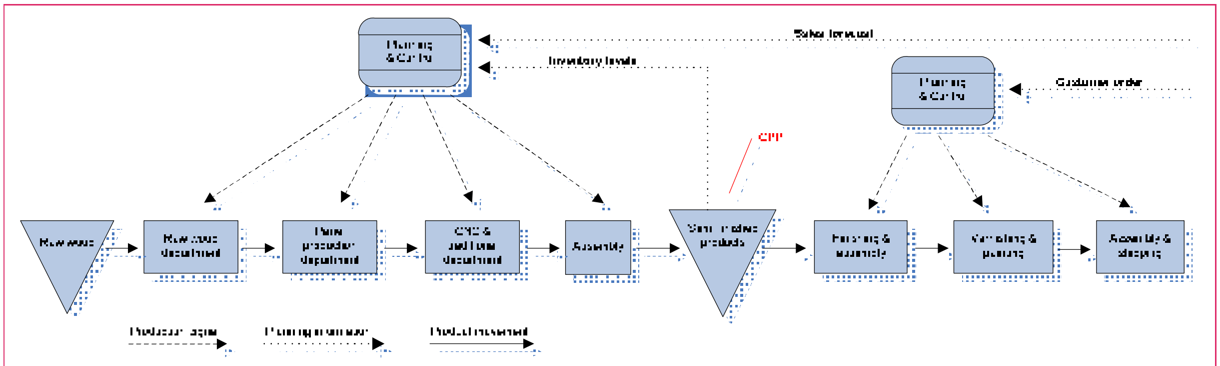


Figure 4-7: Current method for planning & Control (simplified production flow)

4.3.2 INTRODUCTION OF KANBAN

The managing of the inventory and production planning has shown to be rather difficult for GM. During the expansion of GM's assortment in the years 1995, 2003, and 2005, desired inventory levels where never re-evaluated. This resulted in both too many production orders (clogging up the factory) and a very high inventory value. In the year 2006, a project was started to lower the inventory value for tables. It included an introduction of a Kanban like system to manage a new inventory of solid wooden panels as described in flow 3 (fronts) of the current situation. This inventory made it possible to create more different tables out of the same wooden panels, thus reducing the required inventory. Because the project gave satisfactory results regarding the inventory levels, GM decided to expand it to the production of chest fronts. It does not effect the method for planning and control, but it pushed the OPP for chest fronts upstream in front of the CNC & Traditional department. However, the inventory for solid wooden panels has some disadvantages. Because the measures of the panels are fixed, inventory is already growing larger than expected, and the panels tend to bend when they are stored too long.

4.4 MEASURING THE COMPETITIVE OBJECTIVES

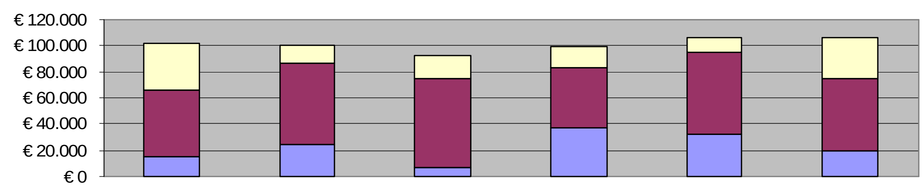
4.4.1 COST

As we explained in Chapter 2, the total production costs are calculated over both direct and indirect costs. Figure 4-8 presents the total costs per product for Riverwood. These costs are taken from GM's cost calculation which is embedded within the software package GP2002. In total, the direct cost for Riverwood over the year 2006 was €131.130. The costs of materials represent the largest part of the total cost price with an average of 62%, followed by labour with 30%. The costs of materials are high due to the needed quality.

	Total	Materials	Labour	Machine
Costs	€ 131.130	€ 80.792	€ 39.961	€ 10.377
% of total		61,6%	30,5%	7,9%

Figure 4-8: Direct costs of Riverwood within the current situation

The total inventory value of Riverwood is given in Figure 4-9, and shows an average inventory value for the last six months of € 100.787. Using the in Section 2.3.1 calculated measure of 24.2%, this means that the inventory costs for Riverwood are around € 24.390 per year.



	31-3-2007	30-4-2007	31-5-2007	30-6-2007	31-7-2007	31-8-2007
Total	€ 101.158	€ 100.781	€ 91.835	€ 98.874	€ 106.193	€ 105.882
Buffer stock after OPP	€ 34.941	€ 14.384	€ 17.247	€ 15.572	€ 11.174	€ 30.696
Semi-finished products stock	€ 51.693	€ 62.085	€ 67.560	€ 46.790	€ 62.715	€ 55.428
Assembly stock	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Buffer stock before OPP	€ 14.525	€ 24.313	€ 7.028	€ 36.512	€ 32.304	€ 19.758

Figure 4-9: Inventory value for Riverwood in the current situation

4.4.2 QUALITY

Although quality is a very important aspect for GM, the internal quality checks are not being registered. During the start-up of this project the production of Riverwood was stopped as the inventory levels were high enough to support the upcoming demand. Therefore it was not possible to perform additional internal quality checks for the Riverwood collection. This means that a null situation of the internal quality is not present for the conclusion (see Figure 4-10).

	Internal check	Service orders
Current	Not registered in current situation.	Registered
Experiment	Registered	Service orders will arrive after the end of the project.

Figure 4-10: Quality check within the current and experimental situation.

Within the current situation GM only registers quality errors that are returned by the customer, creating service orders. Because the delivery of products is done by a transport company and the dealer that sold the product, reducing service orders to zero is not possible. These service orders concern quality errors like transport damage, colour differences between new and older furniture, and doors that are not correctly horizontal.

Transport damage is important to register due to agreements in the contract between GM and the transport company. The differences in colour are extremely difficult to overcome as the colour of older furniture is always different due to sunlight exposure. Concerning the doors that are not correctly horizontal, GM always assembles the chests on a perfect horizontal floor. When the chests are placed on an uneven surface, the doors will look like they were not correctly assembled. Both the colour difference and hanging of the doors are quality errors in the perception of the customer, as a different customer may have another opinion. Also the cause of the error is often not GM's production method, but communication between the customer, dealer, and GM. To reduce these errors GM is now instructing its dealers to ask for samples of old furniture for colour comparison, and sending along instructions with the products.

4.4.3 DELIVERY

Figure 4-11 presents the delivery time and reliability for the Riverwood collection over the first six months of 2007. The data is taken with a query directly from the database of the software package GP2002. The delivery time is calculated from the moment the order is received until the products are delivered at the customer. The actual delivery date is not registered, so for the shipping the maximum of 7 days is calculated over the time that an order is received until it leaves the factory. The average delivery time is the mean of all of the orders within that month, which is clouded by the customer orders where the customer asks for a longer delivery time than the standard 8 weeks. Also, the delivery reliability (48%) is far too low considering GM's competitive objectives. This is because almost all customer orders combine several products out of a single collection. In many cases the semi-finished products inventory does not have all of the required parts in stock for a complete customer order.

		Delivery time (days)			Reliability	
Month	**Total orders**	**Avg**	**Min**	**Max**	**On Time**	**% of total**
January	43	67,5	29	131	29	67,4%
February	41	71,4	23	194	17	41,5%
March	75	73,1	36	183	21	28,0%
April	42	69,4	28	104	17	40,5%
May	58	75,2	24	132	40	69,0%
June	37	80,5	15	103	18	48,6%
Total	**296**	**72,8**	**15**	**194**	**142**	**48,0%**

Figure 4-11: Delivery time and reliability of Riverwood in the current situation

4.4.4 FLEXIBILITY

Considering the volume flexibility GM produces each chest in series of 20 products, which are stored in the semi-finished products inventory. When the customer demand for a product diminishes, GM is unable to completely adjust the production size, resulting in high inventory and costs. In order to calculate the maximum amount GM can produce, we have taken the average value-added time it takes to produce a Riverwood chest (6.19 hours). Because the total production within the current situation is limited by the labour capacity and not machine capacity, we have used the total labour capacity as maximum. Dividing the labour capacity per week of 1330 hours (35 employees * 38 hours) by 6.19 hours per chest, gives an average of 214.8 chest per week. Subtracting the minimum of 20, from the maximum of 214.8, gives a range of 194.8 chests per week.

The mix flexibility of collections at GM is restricted to the choice in varnish or paint, and metalwork that is part of the design. For Riverwood the design is restricted to a single type of metalwork, and therefore gives the customer only a choice in varnish or paint. Regarding the change-over flexibility, the average throughput time is 88 days. We calculated this by adding up both the throughput time upstream and downstream of the OPP. Figure 4-12 presents the throughput time for the Riverwood collection over the first six months of 2007.

		Throughput time (days)		
Month	**Total products**	**Avg**	**Min**	**Max**
January	50	122	54	218
February	85	91	50	107
March	50	96	65	190
April	4	36	29	29
May	80	121	7	163
June	85	59	14	14
Total	**354**	**88**	**7**	**218**

Figure 4-12: Throughput time of Riverwood in the current situation

4.5 CONCLUSIONS

Within this chapter we described the current situation in terms of the theory from the previous two chapters. The following chapter will describe a desired situation. Concluding research question 3:

- Which collection is a good representation of GM's current assortment?

  We have chosen for the collection Riverwood based upon three different reasons. First, Riverwood was introduced in February of the year 2006, making it a collection worthwhile to change. Second, the collection has a healthy average turnover. This is important because we need customers buying the products during the experimental period. And third, the collection is made of both fibre plate and solid wooden panels. Therefore the influence of customer order production can be measured on both flows.

- What is the design of the current process?

  The current process design of GM can be related to a batch process, where machines are set up in a flow and placed together within departments based upon its characteristics. The Order Penetration Point is placed at the inventory for semi-finished products, and an assemble-to-order strategy is being used to offer some variety to the customer.

- Which method is being used for planning & control?

  Both the upstream and downstream flows are using push systems. The upstream flow is using an MRP like method where the production planning is based upon the semi-finished products inventory, and a sales forecast. The production planning for the downstream flow is based upon the throughput time and the planned delivery date of the customer order.

- <u>What are the measures of the current situation regarding the competitive objectives?</u>
  Figure 4-13 presents the current levels for the four competitive objectives.

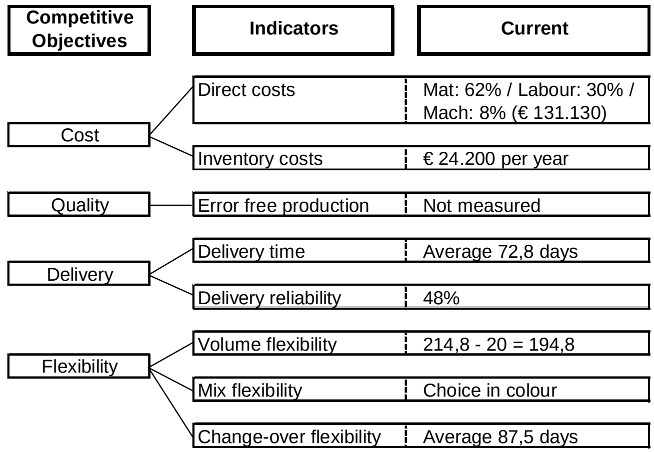


Figure 4-13: Levels of the competitive objectives

5 THE DESIRED SITUATION

Within this chapter we describe the desired situation for GM 'the Furniture Factory' as a company competing on flexibility. Section 5.1, presents desired levels for the competitive objectives, which we will use in Chapter 6 for comparison with the experimental situation. Section 5.2, describes the operational process design including the process type continuum, placing of the OPP, and the product strategy. Finally, in Section 5.3, a choice is made between the several planning & control methods as described in Section 3.3.

5.1 DESIRED LEVELS FOR COMPETITIVE OBJECTIVES

Within this section we describe GM's desired levels for the competitive objectives. As we explained in Section 2.2.1, all four objectives (cost, quality, delivery, and flexibility) are important for customers, even though trade-offs have to be made between them. The desired levels below are formulated together with the management of GM, and are related to their vision of the market.

5.1.1 COST

For the cost as a competitive objective, GM does not use a fixed measure. It remains an important trade-off for every decision, but the maximum cost for a product depends most on its quality in design. In order to control the costs, the maximum increase for direct costs due to this project is 5%. Regarding the indirect costs, GM wants to lower its inventory costs by 50% within the next year. This means that the full 50% reduction in inventory cost cannot be measured during the period of this research. Divided over 12 months, the average reduction in inventory value should be at least 4.2% per month. A linear decrease however is not fully expected, as the products that have a regular demand (also a higher amount in storage) will be sold quickly in the first months. The products with a lesser demand (and less storage) may remain in storage for a longer period.

5.1.2 QUALITY

As described before, quality in the sense of a high performance is not included within this project due to the focus on the production and not designing of products. Still, a high process quality is important since quality remains an important competitive priority of GM. All the products leaving the factory should therefore comply with all GM's standards. These concern colour, smoothness, measurements, material quality, and wood structure.

Within Section 4.4.2, we explained that within the current situation GM only registers the external service orders and not the internal quality errors. Due to the duration of this project, it is not possible to measure the service orders that are a result of the experiment, and it can therefore not be used within the analysis. Concerning the internal quality, GM desires that their cost of internal errors is lower than 1% of the total production cost.

5.1.3 DELIVERY

The growth of competitors from low-wage countries has made the delivery time more important. As many products are shipped in over sea, many foreign manufacturers have a delivery time of 10 to 12 weeks. GM therefore lowered its delivery time in the last 2 years to a standard of 8 weeks. Other competitors that are focussing more on delivery are already down to 4 weeks or even supplying directly from stock, although their assortment is not as large as GM's. To remain competitive inside the market, the desired level of delivery time should not increase to more than the current 8 weeks.

Delivery reliability is still a problem that many furniture manufacturers have, and this also holds for GM. Customer orders often consist of a set of furniture from a particular collection, and it happens that not all the specific products are in stock. Due to the batch production, the throughput times are often too high in order to deliver within the standard delivery time. Some of the dealers that are selling GM's products are already calculating fines over the delayed orders. Within the current situation, we showed that GM's current delivery reliability was 48% over the first six months of the year 2007. For the future GM wants to increase their delivery reliability to 95% in the next year. Like the inventory value, this desired level will not be reached during the period of this research project. An average increase of 4% per month is needed get from 48% to 95% reliability. The increase in delivery reliability however, will most likely not follow a linear path. It is therefore important to show a large increase at the start of the project.

5.1.4 FLEXIBILITY

For GM it is important to increase the volume flexibility by lowering the minimum production series. Because the maximum capacity is equal to the current labour capacity, it is easier to adjust to the market demand by hiring flexible workers. GM is therefore satisfied with the current maximum of 214.8 chests per week. The minimum production series is more difficult to adjust, resulting in higher inventory levels when customer demand diminishes. The desired level for flexibility is therefore defined in a range of 213.8 chests (maximum of 214.8 - minimum of 1 = 213.8).

Higher mix flexibility is desired in order to broaden the choice for the customer. These choices should be based upon a 'standard' design out of GM's assortment. There are several ways possible on how to commercialise variety, although the possible dimensions that are eligible for change remain the same. Therefore, GM wants to be able to vary its product sizes (width, height, and depth), arrangement, type of wood, and colour.

Next to higher mix flexibility, GM wants to improve its change-over flexibility. The change-over flexibility is desired in order to make it easier to introduce new products into the assortment of GM, and to make it possible for project production fully based upon custom designs. As we explained before, the design phase is not included within the scope of this research. We therefore measure the throughput time as it is part of the time to market. GM desires a throughput time of 2 weeks (14 days) in order to quickly produce new products.

5.2 DESIRED PROCESS DESIGN

5.2.1 DESIRED PROCESS TYPE CONTINUUM

Considering the process type as explained in Section 3.2.1, repetitive operations are not designed to compete on flexibility. Within repetitive operations, the line flow is organised making production highly efficient using processes that are mostly automated reducing the need for skilled and expensive labour. Intermittent operations on the other hand fit the flexibility that is desired. A high variety of products is possible due to high skilled labour and more generic equipment. Also the operations flow is more flexible as different products often have different operations flows.

For GM, this means that an intermittent operation is desired using a jobbing or batch process, see Figure 5-1. A project process is not desired, due to the fact that it often has resources devoted more or less exclusively to it. For GM, this is not the case as all the different chests are produced using the same resources. For customised orders, the jobbing process would fit best, as it can deal with very high variety and low volumes. On the other hand, for the products that are sold from GM's assortment a batch production would fit better, as these products are only colour specific.

The two types of processes may be close to each other, but can in fact be very different. A jobbing process uses general purpose equipment and relies on the knowledge of workers to produce a wide variety of products. Machines are arranged in stations, keeping machines together that perform the same activities. Work is passed only to those machines required by it, and in the required order. The volume flexibility is adjusted by adding or removing labour capacity as needed. For batch processes, the sequence of activities tends to be in a line making it less flexible. Dominant flows can be identified, and different production runs are executed for different products.

When we analyse the factory layout in Appendix C, it becomes clear that a dominant flow does exist. Although it is the most common flow, it is not the process flow for every product from GM's assortment. The different resources are already arranged in stations, but transport distances between stations appear to be long for the dominant flow. Depending on the desired process flow, it may therefore be efficient to alter the factory layout.

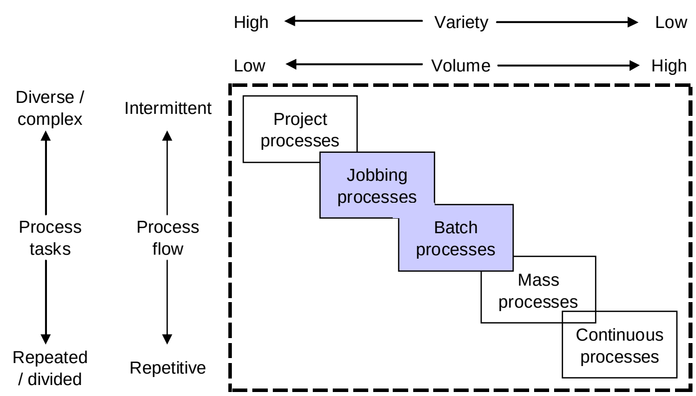


Figure 5-1: Desired process types (Slack et al., 2007, p.94)

5.2.2 DESIRED PRODUCT STRATEGY

In Chapter 3, we described that there are several product strategies possible, ranging from a design-to-order to a make-to-stock strategy. The choice of the product strategy is linked to the placement of the OPP within the operations process. Moving the OPP towards the design phase of the process will result into higher product flexibility. It would still be possible to offer a high variety of goods (mix-flexibility) with an assemble-to-order or even make-to-stock strategy, although this would also result into high inventory and therefore costs. A buy-to-order or design-to-order strategy is therefore desired in order to increase the competitive flexibility, while lowering the inventory value. For the products that are ordered from GM's assortment, a buy-to-order strategy is desired. The products that are based on customer specifications should be produced using a design-to-order strategy, as they will need alteration in their design.

The trade-off that is most important when choosing a product strategy is between flexibility and delivery time. Moving the OPP in order to create more flexibility means that more steps have to be performed from the moment the customer order arrives. The desired delivery time for GM is a standard of 8 weeks. For a buy-to-order strategy this means that the sum of the delivery time of suppliers, production time, and transport time needs to be below 8 weeks. Within a design-to-order strategy, the time to alter the design will have to be added to that of the buy-to-order strategy.

5.2.3 DESIRED PROCESS FLOW

In order to implement the desired product strategy, the OPP is placed at the supplier. This means that for every customer order, resources are requested from the suppliers. Figure 5-2, presents the desired process flow. Raw wood is bought from the supplier in the type of wood that is requested by the customer. It is then processed by the raw wood, panel production, and CNC & traditional department into specific chest parts. Also the fibre plate is bought from the suppliers in the type of wood that is requested. Large plates are then sawed into smaller panels, after which they are transformed into specific parts by the CNC & traditional department. The planed wood and fibre plate flows are combined at the step finishing & assembly, which is a combination of the current processes 7 assembly and 9 finishing and assembly (see Appendix C).

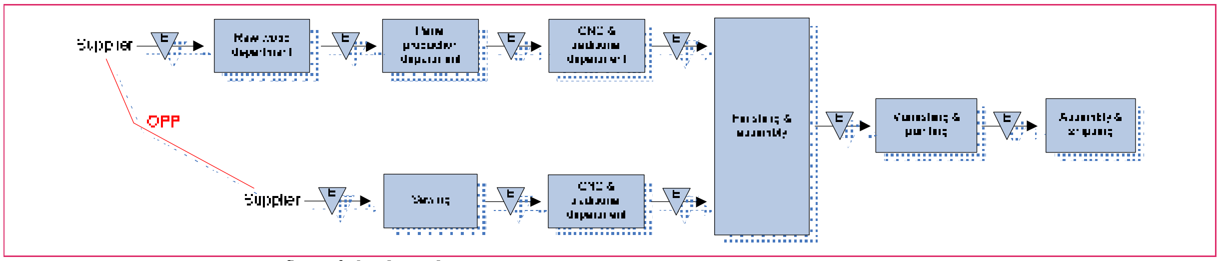


Figure 5-2: Process flow of the desired situation

The above presented desired flow has large similarities with the current situation. The differences are the placement of the OPP which has gone more upstream, and combining the two assembly departments before and after the semi-finished products inventory. The desired flow can accommodate both a buy-to-order and design-to-order strategy. This greatly increases the flexibility, as the customer could actually design a chest completely towards their own ideas, make small adjustments to existing collections, or buy something out of GM's assortment. Changes are possible in the type of wood, product sizes, arrangement of doors and drawers, and colour. It is however limited to the types of wood, and paints that are available.

5.3 DESIRED METHOD FOR PLANNING AND CONTROL

5.3.1 DESIRED MANUFACTURING CONTROL SYSTEM

Within Section 3.3.1, we have described several systems for manufacturing control, namely BS, MRP-II, Kanban, Conwip, LOOR, Polca, and DEWIP. Figure 3-5, presents these systems classified in their level of aggregation, primary control variable, flow complexity, and variety. For GM it is very important that the manufacturing control system is flexible, with a low inventory value. We therefore recommend a system that can handle a high variety, while controlling the WIP. This means that the systems Kanban, BS, and MRP-II are not desired. The complexity of the desired process flow, which we described in Section 5.2.3, is relatively low. Therefore the more complex methods LOOR, Polca, and DEWIP are not required. Also these systems are still not widely used, and there are many different results on their performance in specific situations. This would make the results of implementation more uncertain.

Primary control variable	Level of aggregation: Centralized	Level of aggregation: Decentralized
Throughput	MRP II BS	
WIP	LOOR Conwip	Kanban Polca DEWIP

Flow complexity	Variety: Low	Variety: High
Low	Kanban BS	Conwip
High		MRP II LOOR Polca DEWIP

Figure 5-3: Classification of manufacturing control systems (Lödding et al., 2003, p.44)

The desired system for manufacturing control is therefore Conwip. This means that the level of aggregation is centralized. This does not differ from the current situation, in which MRP is being used. Therefore the centralised function for planning & control does not have to be altered. However, the primary control variable will have to be focused on WIP instead of throughput. In order to achieve this, adjustments to the software program GP2002 may be required.

5.3.2 CONTROLLING THE WIP

Because it is very important for the delivery reliability to have a reliable throughput time, the WIP will have to be controlled for the production process. WIP can be measured for instance in the amount of products, value of products, or value added time. Measuring WIP on the amount of products can work, if the products are alike in the amount of labour they require to produce. If more expensive products on average require more labour to produce than less expensive products, than it is better to measure WIP on total value of products. The most accurate and therefore desired measure for WIP is to measure the total value added time. Although it requires more calculations and detailed information about the production process, it can be directly related to the available labour hours. For the desired situation, we suggest two methods to control the WIP. Within both methods it is important to carefully choose the WIP indicator.

The first possibility is to fully implement the Conwip method, keeping the WIP constant at all times. This means that when the WIP has reached its maximum for a certain period, incoming customer orders will have to be produced before or after that period. When the WIP is below its maximum, it will have to be filled with own production orders based upon a forecast. This could even out the seasonal influences, since products produced in a quiet period can be sold in busy periods. To implement this option there will have to be another inventory placed somewhere within the desired situation. A large disadvantage of this option is that an inventory at the end is not desired. Because the variation in products and especially colour is very high, this would make it very hard to sell these products.

Our advice, however, is to constrain the maximum WIP level instead of keeping it constant. This means that like the Conwip method, customer orders are re-planned when the WIP for a certain period is full. Therefore the WIP can never exceed its maximum, keeping the throughput time levelled. When the WIP is below the maximum for a certain period, it is not filled up, creating excess capacity. On the other hand, in busy periods it is possible that the delivery time will increase substantially, because production cannot start soon enough. Therefore this option will require a flexible workforce so that the capacity can be changed to even out seasonal influences. This is possible as there is currently a job-shop like layout, where the machine capacity is higher than the labour capacity.

5.3.3 PLANNING AND CONTROL SIGNALS

As we described in Section 5.2, the desired strategy is either buy-to-order or design-to-order. Figure 5-4 presents a simplified view of the desired process flow combined with the planning and control signals. The production planning is based upon the customer order information, the current WIP, supplier time of delivery, and throughput time. When the customer order arrives, the standard delivery time of 8 weeks applies. However, it is possible that a customer requests a delivery before or after 8 weeks. Based upon the throughput time and delivery time of suppliers the required start date of purchasing and production is calculated. Based upon the WIP (Conwip) the order can then be confirmed. If an order would exceed the maximum WIP, it will have to be rescheduled to a different week. As explained before, it is possible to increase the maximum WIP as the machine capacity is higher than the labour capacity. Therefore, if a substantial amount of orders have to be rescheduled, it is possible to temporary increase the maximum WIP.

The production planning within the factory is communicated through planning boards. On these boards, the upcoming orders are placed ordered on delivery date. As soon as a station has finished its job, it puts the corresponding order into the planning board of the next sub-process.

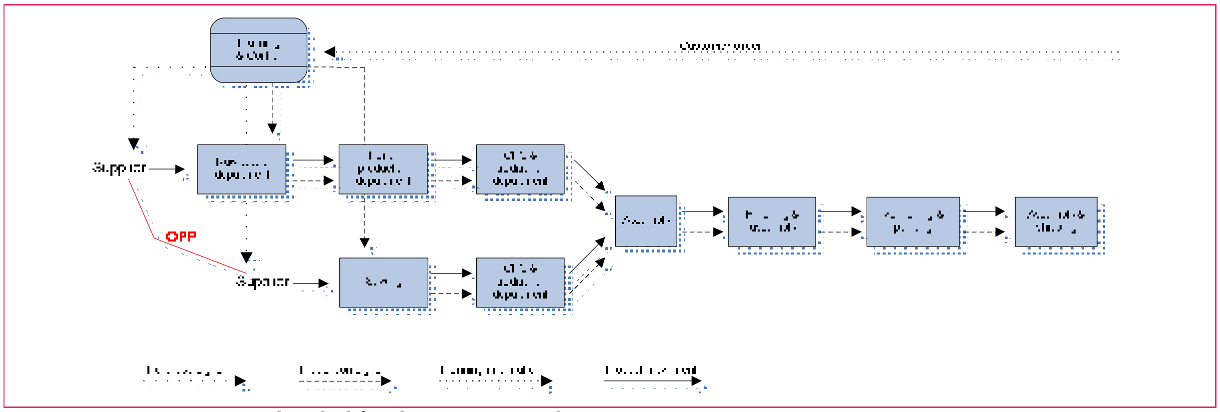


Figure 5-4: Desired method for planning & control

5.3.4 LEAN MANUFACTURING PRINCIPLES

Within the current situation, a customer order only travels through the final three departments. For the desired situation, the OPP is placed at the suppliers, increasing the customer order flow. Because more production processes are within the customer order flow, the chance for errors effecting customer orders is also higher. Therefore it would be desired to implement some of the lean principles we described in Section 3.3.2.

Just-In-Time (JIT)

The throughput time within the desired situation depend on many factors. If products arrive too late at a particular sub-process, it is possible that the delivery date is not met, but calculating a lot of safety time between the processes will create higher WIP. According to the JIT philosophy, productions should be started as late as possible. This will reduce WIP, throughput time and costs. Because JIT requires a stable demand, it will probably not give the desired results. Also, because it tries to improve the same competitive objectives as Conwip, we feel that implementation is not desired.

Single Minute Exchange of Die (SMED)

Unlike in the current situation, the variety within the desired situation is much higher. Therefore batch production will be uncommon, and if it is possible the batches will be much smaller. This means that long change-over times will create a disturbance in the throughput time, and also raise the production costs. By lowering the change-over times, SMED can reduce the impact of these problems within the desired situation.

5S Method

Within the desired situation, the product variety will be much higher than in the current situation. It is therefore important to increase the skill of employees, to reduce the chance for errors. Implementation of the 5S method can help increase the overall workplace morale and efficiency. By including the employees in the decision which resources should be kept, where it should be kept, and how it should be kept, it will build a clear understanding of how work should be done.

Six Sigma

Product quality has always been important for GM, although they never measured the internal quality. In order to control and reduce the chance for errors, it is important to implement internal checks within the desired situation. The set of practices within Six Sigma can eliminate defects and thereby improve the processes. This is very important, because each product error will either disturb the throughput and possibly delivery time, or result into service costs.

5.4 CONCLUSIONS

Within this chapter, several subjects have been described regarding research question 3. A desired situation for GM has been given regarding its competitive objectives, operations process design, and operations planning & control. Although it is not directly related towards the chosen collection for the experiment, there are choices made on the basis of the current situation of the Riverwood collection. This will be taken into account within Chapter 7, which describes an implementation plan towards the desired situation. Concluding research question 4:

- What are the desired levels for the competitive objectives?

  Within this chapter we have given the desired levels for the competitive objectives. In Chapter 6 the results of the experiment will be analysed in comparison with both the desired and current competitive objectives. In Figure 5-5 the desired levels are given together with the current situation.

- What is the desired operational process design for GM?

  We have described the desired process flow based upon an intermittent operation with a buy-to-order strategy. The flow still gives possibilities for a design-to-order strategy when a customer wants a customised product.

- Which method should GM use for planning & controlling its operation?

  In order to create the desired flexibility with a reliable delivery time and low inventory value, we advice Conwip as manufacturing control system. Kanban and BS are not efficient when the variety is high. MRP-II can handle a higher variety but does not control the WIP. The other described systems Polca, LOOR, and DEWIP are designed for more complex process flows, and are less widely used.

  Next to Conwip, it is desired to implement some of the lean principles. SMED can reduce the change-over times, improving the throughput time and direct costs. The 5S method can further improve the overall work morale and efficiency, by including the employees in the evaluation of required resources. To get a better insight into, and reduce the cost of errors, implementation of Six Sigma is desired.

Competitive Objectives	Indicators	Current	Desired
Cost	Direct costs	Mat: 62% / Labour: 30% / Mach: 8% (€ 131.130)	Max increase of 5% on total (€ 6.557)
	Inventory costs	€ 24.200 per year	€ 12.100 per year
Quality	Error free production	Not measured	max 1% of total direct costs (€ 1.311)
Delivery	Delivery time	Average 72,8 days	Max is 56 days (8 weeks)
	Delivery reliability	48%	95%
Flexibility	Volume flexibility	214,8 - 20 = 194,8	214,8 - 1 = 213,8
	Mix flexibility	Choice in colour	Choice in colour, size (width, height, depth), arrangement, and wood type
	Change-over flexibility	Average 87,5 days	14 days (2 weeks)

Figure 5-5: Levels of the competitive objectives

6 EXPERIMENT

Within this chapter, we describe the conducted experiment for the Riverwood collection. Section 6.1, explains our actions taken to perform the experiment. In Section 6.2, we describe the experimental process design and two concessions we had to make regarding the desired situation. Within Section 6.3, we describe the experimental method for planning & control. We describe the new process design and method for planning & control within Section 6.3. The four competitive objectives are then measured and analysed in Section 6.4. The lessons learned during the experiment, which are of interest for the implementation plan (Chapter 7), are described in Section 6.5.

6.1 IMPLEMENTING THE EXPERIMENT

6.1.1 COMBINING THE DESIRED AND CURRENT SITUATION

For the experimental situation we had to make a few concessions in order to implement it within the current situation. Two large concessions had to be made to the process design, creating two new inventories. The first inventory is for storage planed wood, which is placed between the raw wood and panel production department. The second inventory is placed at the assembly process. We will explain the causes and consequences of these concessions within Section 6.2.

Within the current situation many safety buffer inventories exist between sub-processes. Buffer inventory is held against the possibility that the upstream process may be delayed, causing shortage in required materials. Because the experiment is implemented within the current situation, these buffer inventories still exist. Therefore, the throughput time for the experimental situation is actually longer than it needs to be.

6.1.2 MEETINGS WITH EMPLOYEES

We organised several meetings with both the management and employees of GM. The first meeting with GM's management, the experimental situation was developed out of the desired situation. This step was important in order to implement the desired situation without creating a large disturbance in the current situation. The experimental process design was developed within these meetings, along with the calculation of the throughput time. Second, we discussed the experimental situation with the employees, explaining our expectations and requesting their ideas and opinions. Most of these ideas concerned the layout and required information for the production signals. Finally a meeting was held with both the management and employees involved with this project of GM, to evaluate the experiment. During the evaluation we presented the measurements of the competitive objectives, and we asked for ideas and opinions about the experiment.

During the experiment we met twice a week with each employee, in order to evaluate the experiment. Small problems where directly solved, and larger were registered after which a problem solver was assigned. Feedback on the status of the problems was returned to the employee. We will describe the found problems with their implemented solutions in Section 6.5.

6.1.3 PLANNING THE PRODUCTION

Analysing the experiment process flow, we came to the conclusion that the value added time for a single chest is just below two days. To calculate the minimum throughput time, 3 days have to be added to include the time chests need to dry during the gluing, and varnishing & painting process. Next to the 3 days for drying, a maximum of 1 week is agreed with both suppliers and the transport company for delivery towards customers. Because the experiment has to be implemented within the current situation, several buffer inventories are created between the processes. One of these buffers is a clustering on colour, extending the throughput time with another week. This makes the total throughput time 7 weeks.

Because this is still well within the standard of 8 weeks, we have chosen to combine several customer orders into a single production project. This means that one week of customer orders is combined and produced together. This is possible because all the Riverwood products follow the same flow. However, the individual customer order information like colour and measures still has to be communicated towards the production personnel. This is taken into account while creating the production signals and marking the products in the factory. The advantage for a combination of customer orders is less paperwork within the factory, and a small advantage when a particular chest is ordered more than once in that week.

6.1.4 CREATING THE PRODUCTION SIGNALS

In order to create the signals towards the production, we created a new table in the database of GP2002. Every customer order is copied to this table and split into the several product parts that have to be created. Each part is connected to one of the flows it has to follow. From this table we designed several lists that are created each week. The first of these lists consists of the solid wooden panels that have to be created, and is given to the panel production department, after which it is used by the CNC & traditional department. The second list is sent towards the company that saws the fibre plate into specific sizes. The third list is an overview of all the products within that week, which is used within the assembly department.

Upon each of the lists, specific customer order information (wood type, size, arrangement, and colour) is presented. The precise layout is decided together with employees. Next to the customer order lists, the kanban cards for the planed wood and assembly stock are created. We will explain the choice for use of Kanban cards further in Section 6.3. On the cards specific information (wood type, size) about the parts are present for each of the production activities it follows. Both the customer order lists, and Kanban cards are passed on from station to station within the factory. As soon as a job is finished, the corresponding list or card is placed in the planning board of the next process. This is equal to the current situation for GM.

In order to reduce the chance for errors, it is important that product parts are marked within the factory. Therefore at the start of the production, the customer order number and type (top, side, and etcetera) are written on the side of the part. Also suppliers were requested to place stickers on each part, instead of one per pallet. The customer order number corresponds with the lists that are used as production signals.

6.2 EXPERIMENTAL PROCESS DESIGN

6.2.1 PLANED WOOD INVENTORY

Within the desired situation, we described a process design flow based on a buy-to-order strategy. Due to the nature of raw wood and the implementation within the current situation, this is not a realistic option. Raw wood is currently ordered in certain lengths, widths, and heights after which it is put away to dry at the raw wood importer. After the drying process the wood is delivered at GM. This whole process takes about half a year up to a full year, depending on the type of wood. GM has made arrangements so that quantities of the pre-ordered wood is delivered and paid when they actually need it. Although, actually buying it based upon sales orders would either create enormous delivery times or extremely high costs.

The machines that are within the raw wood department are the reason for the second concession that was made. These machines are designed for processing large batches resulting in minimum losses in wood. At the process for shortening, for instance, the wood is cut down to the desired length and impurities are thrown away. With small batches more wood would be wasted when the wood has to be cut due to impurities and the leftover lengths are not desired. Figure 6-1 visualises how two different wooden pieces are being sawed. When sawing a customer order we might want two different lengths, for instance 1 and 2 meters. Within the left piece there is a possibility to create either a single piece of 2 meters or two of 1 meter. For the right piece only 1 meter would actually be of use, and the rest would have to be put back into the raw wood inventory or thrown away. When the machine is doing a large batch of lengths it is possible that both 0.7 meters and 1.1 meters are needed, or at least 0.6 and 1.0 meters which would lower the amount of waste significantly.

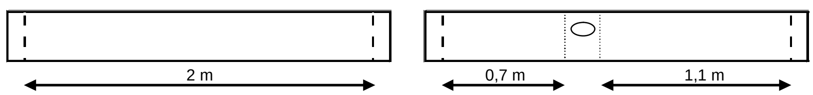


Figure 6-1: Wood shortening

Because of these two concessions, the OPP is placed after the raw wood department at a newly created inventory for planed wood. This concession does not have a big influence. Since the wood is bought in specific lengths, the raw wood department does not change the variability of the wood itself. It does however raise the inventory cost as there is value added to the planed wood, although this does not outweigh the cost reduction for having less waste. The flow for the production of planed wood is presented in Figure 6-2. The production process itself has not been altered from the current situation, except the inventory for planed wood.

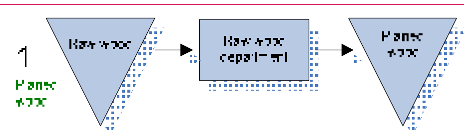


Figure 6-2: Production flow for planed wood (experimental situation)

6.2.2 ASSEMBLY STOCK INVENTORY

For the experiment, two concessions had to be made regarding the desired situation and competitive flexibility. The side tops are parts that require much more work due to their shape. GM therefore wanted to create an additional inventory near the sub process assembly. The concession will lower the direct cost, but also reduce competitive flexibility. For the future, the design of side tops and the way it is being produced can be changed in order to reach the desired situation. Next to the side tops, chest drawers are also kept on stock at the sub process assembly. The front of the drawer is produced separately, because it is different for every chest and will be explained at flow 4 (customer order flow). As the drawers can be used within more than one collection they can be produced in larger batches, reducing the direct costs. Figure 6-3 presents the flow for side tops and drawers.

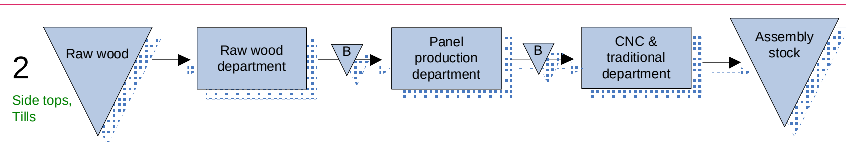


Figure 6-3: Production flow for side tops and drawers (experimental situation)

For plinth production, a third flow is created within the experiment. Plinth is made from waste raw wood that was rejected during sorting. The waste wood is transformed using traditional machines into plinth. As plinth are very easy to create and can be kept in stock in various different sizes for several collections, this does not effect competitive flexibility. Having a different flow for the production of plinth therefore only effects the competitive objective costs. Figure 6-4 presents the production flow for plinth.

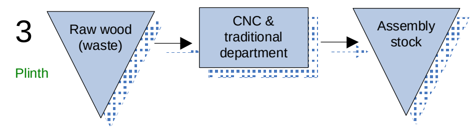


Figure 6-4: Production flow for plinth (experimental situation)

6.2.3 EXPERIMENTAL CUSTOMER ORDER FLOW

For the experiment, the customer order flow is started at three different inventory points, namely the planed wood, fibre plate inventory and assembly stock. The planed wood is being transformed into the front, sides, and top of the chest. The fibre plating is transformed into the bottom and dividing boards of the chests. At the sub process finishing & assembly, both flows are combined together with the side tops, drawers, and plinth which are taken from the assembly stock. As we described in Section 5.2.3, the sub process finishing and assembly is a combination of the former processes assembly, and finishing & assembly. For the last two sub processes no alterations have been made regarding the desired situation. The customer order flow is presented in Figure 6-5.

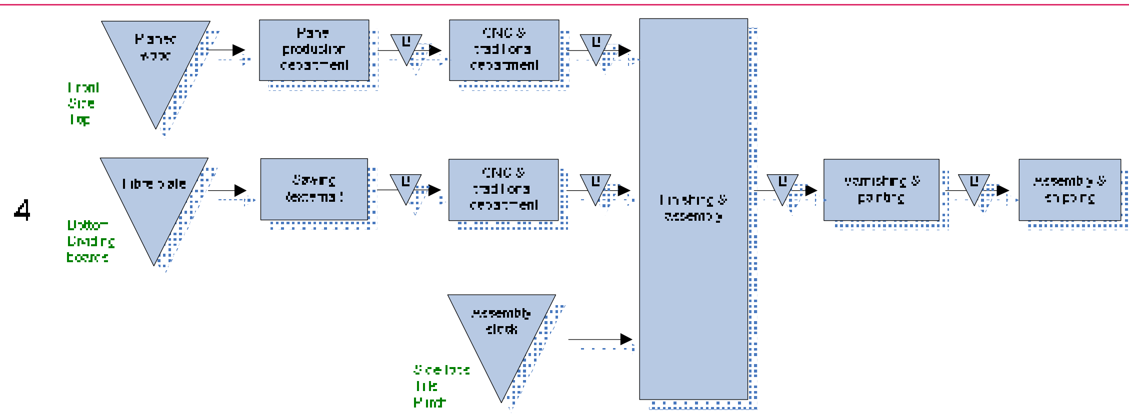


Figure 6-5: Customer order flow for the experimental situation

Within the experimental situation, the processing for sawing of the fibre plate is done externally. Also within the current situation, this step is being outsourced due to lack of specialised machinery to saw the plates reducing waste to a minimum. This means that the fibre plates can be sawed by GM, but doing so would result in high waste. Because the costs for raw materials are very high, a higher cost for the process outweighs the higher amount of waste. Because the external step can be performed and delivered at GM within a single day, it is a cost reduction without reducing either flexibility or delivery. A full representation of the experimental flow is given in Appendix E.

6.3 METHOD FOR PLANNING & CONTROL

6.3.1 EXPERIMENTAL MANUFACTURING CONTROL SYSTEM

For the experimental situation we implemented Conwip as we described in Section 5.3.1. The Conwip loop therefore controls the customer order flow within the experimental situation. Within Section 6.2, we described that there are two new inventories created with three different flows for the production of planed wood, side tops, tills and plinth. In order not to increase the effort needed by the planning and control function, we decided to use a decentralised system to control these three flows. Figure 6-6, presents Kanban, Polca, and DEWIP as possible systems having a decentralised level of aggregation. Because the variance is much smaller for these parts, Kanban should deliver efficient results. Also it is a more proven system than Polca and DEWIP, and it is already being used for the production of tables at GM. We have therefore used Kanban in order to plan and control the production flows 1 to 3 (planed wood, side tops, tills, and plinth).

Primary control variable	Level of aggregation: Centralized	Level of aggregation: Decentralized
Throughput	MRP II BS	
WIP	LOOR Conwip	Kanban Polca DEWIP

Flow complexity	Variety: Low	Variety: High
Low	Kanban BS	Conwip
High		MRP II LOOR Polca DEWIP

Figure 6-6: Classification of manufacturing control systems (Lödding et al., 2003, p.44)

6.3.2 PLANNING AND CONTROL SIGNALS

As we explained before, within the experimental situation The OPP has moved upstream significantly, but not completely. Figure 6-7 presents the planning and control signals including the created planed wood, and assembly inventory. For the parts in the assembly stock (side tops, drawers, and plinth) Kanban cards are used to trigger production, like the planed wood. The cards however are directly sent towards the raw wood department, because there are not any small inventories between the processes. Also for the production of planed wood, Kanban cards are being used.

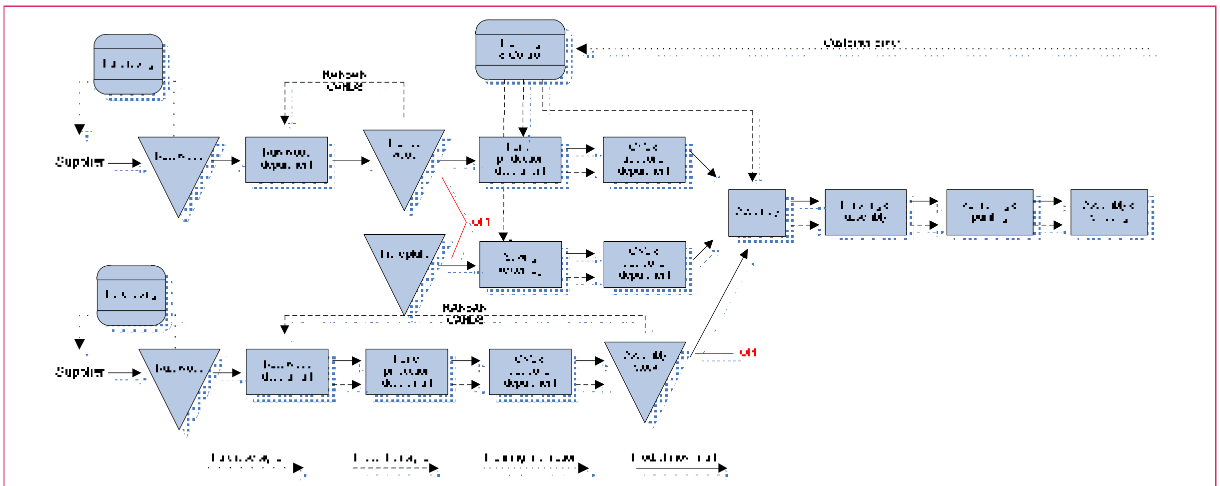


Figure 6-7: Experiment method for planning & control

For the downstream flow, the production is triggered by a customer order released based upon the level of WIP. The products are then pushed through the flow, started from the planed wood and fibre plate inventory. Because the production date of the customer orders is based upon a calculation of the throughput time and the planned delivery date, it is a push method. Although each order is based upon an actual customer order and not a sales forecast.

6.3.3 LEAN MANUFACTURING PRINCIPLES

For the experimental situation, none of the lean manufacturing principles where completely implemented. Because the experiment had to be performed within the current situation, implementation of lean methods would raise the risks of project failure. Implementation of the lean principles will therefore be a part of our recommendations in Section 8.2.

6.4 MEASURING THE COMPETITIVE OBJECTIVES

6.4.1 COST

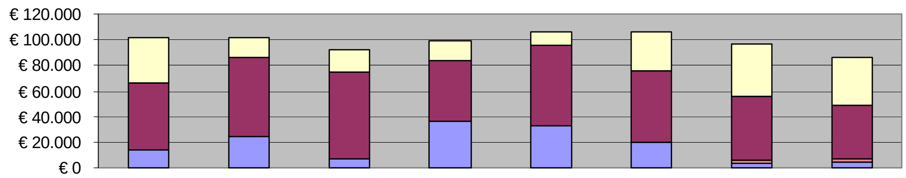
For the analysis of the direct cost difference between the current and experimental situation, we have recalculated the cost for the current situation. Since the individual customer orders are combined on a production list per week, the differences have to be analysed over a whole list instead of individual products. Also with the recalculation of the current situation, higher prices for materials are being ruled out. Within Figure 6-8 an overview of the direct costs are given over the first three experimental production lists. Appendix F gives a detailed calculation for each of the three lists. The direct costs show a slight decrease of 0.3% in list 1, 1.9% in list 2, and an increase of 0.4% in list 3. The decrease in direct costs for the first two lists is unexpected. It may be caused by the extra attention that was created due to the experiment or comfortable calculation of production times by GM within the current situation. The results however are well within the 5% increase as described within the desired situation (see Section 5.1.1).

List		Material	Labour	Machine	Total	% of pre calculation
1	Pre calculation	€ 2.152,31	€ 802,60	€ 150,62	€ 3.105,54	-1,4%
	Experimental	€ 2.152,31	€ 773,92	€ 135,89	€ 3.062,12	
	Difference	€ -	€ 28,68-	€ 14,73-	€ 43,42-	
2	Pre calculation	€ 5.366,79	€ 1.826,35	€ 396,28	€ 7.589,43	-1,9%
	Experimental	€ 5.366,79	€ 1.712,17	€ 367,06	€ 7.446,02	
	Difference	€ -	€ 114,18-	€ 29,23-	€ 143,41-	
3	Pre calculation	€ 6.175,41	€ 2.272,53	€ 439,75	€ 8.887,69	0,4%
	Experimental	€ 6.175,41	€ 2.264,13	€ 481,89	€ 8.921,43	
	Difference	€ -	€ 8,40-	€ 42,14	€ 33,74	
TOTAL	Pre calculation	€ 13.694,52	€ 4.901,48	€ 986,66	€ 19.582,66	-0,8%
	Experimental	€ 13.694,52	€ 4.750,22	€ 984,83	€ 19.429,57	
	Difference	€ -	€ 151,26-	€ 1,82-	€ 153,08-	

Figure 6-8: Cost calculation experimental situation

The first list of customer orders for the experimental situation started production on the 24th of September 2007. Therefore inventory levels did not drop until September. As for the indirect costs, GM wants to lower its inventory costs by 50% (see Section 5.1.1). Within Figure 6-9 the total inventory levels are given for the collection Riverwood, showing a decrease of €8.650 in September and another €11.085 in October. This is a total decrease of €19.735 equalling 18.6% over the first two months. The desired level was a 50% decrease of inventory value before September 2008 (see Section

5.1.1). This is still possible since the semi-finished products stock is valued at €41.230, which when sold will give another decrease of 39%.



	31-3-2007	30-4-2007	31-5-2007	30-6-2007	31-7-2007	31-8-2007	30-9-2007	31-10-2007
Total	€ 101.158	€ 100.781	€ 91.835	€ 98.874	€ 106.193	€ 105.882	€ 97.232	€ 86.147
Buffer stock after OPP	€ 34.941	€ 14.384	€ 17.247	€ 15.572	€ 11.174	€ 30.696	€ 41.808	€ 37.617
Semi-finished products stock	€ 51.693	€ 62.085	€ 67.560	€ 46.790	€ 62.715	€ 55.428	€ 50.078	€ 41.230
Assembly stock	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 2.138	€ 2.920
Buffer stock before OPP	€ 14.525	€ 24.313	€ 7.028	€ 36.512	€ 32.304	€ 19.758	€ 3.207	€ 4.380

Figure 6-9: Inventory value of Riverwood

6.4.2 QUALITY

For the internal quality measuring we made a list of all internal errors during the Riverwood experiment. The errors are described, as well how they were repaired and a solution for prevention. Also an estimate of the costs of the error is made based upon the extra work and material that was needed for repairs. The full list of the internal errors is given in Appendix G. Figure 6-10 gives an overview of the internal error costs. The total costs for the first three lists are; € 72.50 for list 1, € 57.75 for list 2, and € 26.25 for list 3. In Section 5.1.2 we explained that GM's desired level for internal errors is 1% of the total direct costs. For list 1 this is 1.7%, for list 2 0.6%, and for list 3 0.3%. For list 1 this is slightly over the desired level, both list 2 and 3 are well within the desired level. On average the internal error costs are 0.7% of the total direct costs; this is also within the desired level of 1%.

			Internal error costs			
List	Total items	Direct Costs	Labour	Material	Total	Percentage of direct cost
1	13	€ 4.210,75	€ 52,50	€ 20,00	€ 72,50	1,7%
2	24	€ 9.861,01	€ 57,75	€ -	€ 57,75	0,6%
3	22	€ 9.437,88	€ 26,25	€ -	€ 26,25	0,3%
Total	59	€ 23.509,64	€ 136,50	€ 20,00	€ 156,50	0,7%

Figure 6-10: Overview on the internal error costs

6.4.3 DELIVERY

Within the current situation the average delivery time was over 70 days with a delivery reliability of 48%. For the desired situation these should be 56 days and 95% reliability. Since the final two processes of the operations flow are combined for both the current and experimental situation, Riverwood orders have also had delays. Figure 6-11 presents the delivery time and reliability of the experimental situation. The average delivery time for the first list is 71.6 days, for the second list 58.4 days, and 75.1 days for the third list. This is a very small improvement from the 72.8 days for the current situation, but still far above the desired 56 days. The throughput time shows an average of 31.1 days, from the start of production until the products are delivered. This means that over 34 days are lost between the moment an order is received and production is started. This can partly be explained by the summer vacation when the factory is closed for 4 weeks. This is strengthened by customers requesting their orders delivered after more than the standard 8 weeks. On the other hand, these two causes do not have an effect on the reliability as this is measured by the planned and actual delivery date. For the first list the reliability is 46.2%, the second list 62.5%, and the third list 68.2%. This is still much lower than the desired level of 95%, although this level was set for September 2008. When comparing with the current situation (48.0%) the increase was 13% during the experimental period. This is equal to a 6.5% increase per month.

		Delivery time (days)			Reliability	
List	Total orders	Avg	Min	Max	On Time	% of total
1	13	71,6	57	89	6	46,2%
2	24	58,4	38	83	15	62,5%
3	22	75,1	20	177	15	68,2%
Total	**59**	**67,5**	**20**	**177**	**36**	**61,0%**

Figure 6-11: Delivery time and reliability of the experimental situation

6.4.4 FLEXIBILITY

Regarding volume flexibility, the desired minimum series of 1 chest was possible during the experiment. Although they were produced as a batch of Riverwood customer orders, several single chests where present within the batch. Also the average time required per chest dropped with 0.8%, increasing the maximum amount of chest per week to 215.1. Therefore the volume range during the experiment was 214.1 chests (215.1 - 1 = 214.1).

Regarding mix flexibility, a concession was made between flexibility and costs. GM wanted to create an inventory for both the side-tops and plinth at the assembly process. The reason for this is, plinth is made from raw wood that is thrown away at the sorting process, because it is not good enough for panels. It is then cut on traditional machines into small pieces of plinth and does not follow the large flow for panels and fibre plates. Side-tops need a lot more work than other parts, and changeover times for the required machines are higher. This means that the depth of a chest is fixed and cannot be altered for customised orders. GM considers flexibility in depth not as important as both the width and height of a chest. In order to create side-tops on customer order, it is possible to redesign the part so that it requires less changeover time. This would lower the inventory for Riverwood even further and therefore the total production costs.

Within Section 5.1.4, we described the desired level of mix flexibility as the possibility for a customer to vary a product in size (width, height and depth), arrangement, type of wood, and colour. As we explained above, for the experiment only the depth of a chest cannot be varied. However it is a large improvement from the current situation where the customer could only choose in colour. The desired level for change-over flexibility was indicated by a throughput time of 14 days. Figure 6-12 presents the throughput time for the experimental situation. The total average of 31,1 days is above the desired level of 14 days, but a large improvement from the current situation (87,5 days).

		Throughput time (days)		
List	Total orders	Avg	Min	Max
1	13	28,8	24	37
2	24	30,9	25	46
3	22	32,6	17	41
Total	**59**	**31,1**	**17**	**46**

Figure 6-12: Throughput time of the experimental situation

6.5 LESSONS LEARNED

As we explained in Section 6.1.2, formal and informal meetings were organised with employees in order to find and solve problems during the experiment. From these meetings, the following lessons were learned:

- Some problems were caused by errors within the production bill of material. Wrong measures resulted into fibre plate panels that were a few millimetres too big. To solve the problem the panels where shortened, and the recipe was adjusted. If implementation is repeated for other collections, this will have to be thoroughly checked.
- During the first production list, it was unclear what each part on the Riverwood pallet actually was. The number on the part corresponded with the list, but it took too much time to identify it. The type of the part (top, side, and etcetera) was added to the panels solving the problem. Because more information can further reduce the chance for errors, adhesive labels are desired. This can also reduce time at the sorting process. Because of the duration of this project, and different types of labels that will have to be tested wood, this will be a recommendation towards GM.
- While changing the bill of material, it became clear that the software program GP2002 is not designed for flexibility. Each product has a defined type of wood. This means that for each type of wood, the whole product needs to be inserted into the database, along with all of its processes. In order to get a higher flexibility, this will have to be altered. Also this will be a part of our recommendations towards GM in Section 8.2.

6.6 CONCLUSIONS

This chapter has described the experimental situation in which the desired situation is put into practice. The following chapter will describe a future implementation plan for the other collections. Concluding research question 5:

- What is the new operation process design for the collection?

  For the experiment several concessions had to be made towards the desired situation. Two new inventories are created, namely for planed wood and assembly parts. The assembly inventory is filled with the side-tops, tills, and plinth for the Riverwood chests.
- Which method for planning & control is used for the collection?

  For the newly created flows for planed wood, side-tops, tills, and plinth, we implemented Kanban. Because the variation is much lower for these parts, Kanban is an efficient method. The Kanban method is also already a known method at GM, making implementation easier.

  For the customer order flow, we implemented Conwip for the planning and control, which is equal to the desired situation. A full week of customer orders are combined on a production list creating less paperwork within the factory, and a small advantage when two or more of a particular chest are ordered in a single week. After the assembly process a clustering of the customer orders is made based upon colour, this gives a large batch advantage for the process varnishing & painting. It is also required to fit the Riverwood experiment within the current situation.
- What are the measures of the experimental situation regarding the competitive objectives?

  Within Section 6.4, the levels of the competitive objectives are measured and analysed. These levels are concluded in Figure 6-13 along with the current and desired situation. The experiment had positive outcomes concerning direct costs, error free production, and volume flexibility. The other indicators showed improvement from the current situation, but have not reached the desired state.

Competitive Objectives	Indicators	Current	Desired	Experiment
Cost	Direct costs	Mat: 62% / Labour: 30% / Mach: 8% (€ 131.130)	Max increase of 5% on total (€ 6.557)	Decrease of 0,8% on total (€ 1.049)
	Inventory costs	€ 24.200 per year	€ 12.100 per year	€ 20.848 per year
Quality	Error free production	Not measured	max 1% of total direct costs (€ 1.311)	0,7% of total direct costs (€ 918)
Delivery	Delivery time	Average 72,8 days	Max is 56 days (8 weeks)	Average 67,5 days
	Delivery reliability	48%	95%	61%
Flexibility	Volume flexibility	214,8 - 20 = 194,8	214,8 - 1 = 213,8	215,1 - 1 = 214,1
	Mix flexibility	Choice in colour	Choice in colour, size (width, height, depth), arrangement, and wood type	Choice in colour, size (width, height), arrangement, and wood type
	Change-over flexibility	Average 87,5 days	14 days (2 weeks)	Average 31,1 days

Figure 6-13: Overview on the competitive objectives

7 IMPLEMENTATION PLAN

Within this chapter we describe an implementation plan for GM on how to reach the desired situation. Therefore in Section 7.1, all of GMs collections are analysed regarding their life cycle and turnover. Also in this section, we analyse the relation of the collection design with Riverwood. Based upon this data, we make a priority list of collections for the implementation. Within Section 7.2, we describe several steps that have to be taken towards the desired situation.

7.1 COLLECTIONS WITHIN GM'S ASSORTMENT

As we described in Section 4.1, GM's assortment consists of three brands (Delato, Times, and Motto), with each brand having four different collections. On average, GM designs one collection per brand each year. This means that the life cycle of a single collection has an average of four years. Figure 7-1 presents the different collections, along with their start-up date, average turnover per month (over the first 9 months of 2007), and type of material being used.

	Artimo	Rosso	Seaside	Quarto / Linea	Riverwood	Artimo Color	One	Two	Three	Desert	Kingswood	Kent
Brand	Delato	Delato	Times	Delato	Times	Delato	Motto	Motto	Motto	Times	Times	Times
Collection startup	June-2003	Sept-2004	Sept-2004	Sept-2005	Febr-2006	Apr-2006	May-2006	May-2006	May-2006	Feb-2007	Sept-2007	Sept-2007
Average turnover per month	€ 15.390	€ 30.330	€ 23.612	€ 4.504	€ 35.579	€ 4.515	€ 5.517	€ 4.528	€ 3.382	€ 5.259	€ 0	€ 0
Percentage from total turnover	12%	23%	18%	3%	27%	3%	4%	3%	3%	4%	0%	0%
Top	P	P	S	S	S	P	P	P	P	S	S	S
Sides	P	P	S	P	S	P	P	P	P	S	S	S
Bottom	P	P	P	S	P	P	P	P	P	P	S	S
Dividing boards	P	P	P	P	P	P	P	P	P	P	S	S
Front	S	P/Glas	S	P	S	P	S	Glas	P	S	S	S
Legs	P	X	S	X	X	P	X	X	X	X	S	S
Side tops	S	X	S	X	S	S	X	X	X	X	X	X

S = Solid wooden panels
P = FibrePlate
X = Not part of the design

Figure 7-1: GM's collections since sept-2007

7.1.1 PRIORITY WITHIN THE DELATO BRAND

There are currently three completely different collections within the Delato brand, as Artimo Color is simply a different version of the original Artimo collection. Comparing the age of the collections we can conclude that Artimo is the oldest collection, followed by Rosso, Quarto / Linea, and finally Artimo Color. Artimo is already four years old, and Rosso is now three years old. Since they both have the highest turnover within the brand, they are however not likely to be the next collection that will be replaced. With an age of two years and an average turnover of €4.504 Quarto/Linea has the highest chance for replacement.

If we compare the collections Artimo, Rosso and Artimo Color, than our experimental situation Riverwood has a much larger amount of solid wooden panels within the collection. The possibility of an unbalance between the solid wooden panel and fibre plate flows should therefore be evaluated. Also for Rosso a special type of fibre plate is used, because the design required more strength. These plates are produced in small batches based upon specific sizes and delivered in three weeks, which means they are less flexible. A solution for this type of fibre plate will have to be found before Rosso can be produced on customer order with a delivery time below 8 weeks. The fibre plate used for Artimo is equal to the type used for Riverwood.

7.1.2 PRIORITY WITHIN THE MOTTO BRAND

Motto is the youngest brand within GM's assortment, and started in May-2006 with the collections One, Two, and Three. As explained in Section 4.1, the intention of Motto was to expand sales internationally. Since the international dealer network is still a lot smaller than the national, the turnover for the collections are still low. With the low turnover, the risk of inventory is very high. Also considering their age of just over one year, all three collections have priority for production on order.

Like Rosso and Artimo, the Motto collections also use a lot of fibre plate material. Production on customer order could therefore also unbalance the production flows for wooden panels and fibre plates. All three collections use the same type of fibre plate, which is the same as for the collections Riverwood and Artimo.

7.1.3 PRIORITY WITHIN THE TIMES BRAND

The Times brand is the classical design within GM's assortment and therefore uses more solid wood than Delato and Motto. It is also the oldest brand, although it is recently renewed with two collections Kingswood and Kent that started in September 2007. Except for the show models for dealerships, the actual production has not started yet. They therefore have a higher priority for implementation as there is not any inventory made yet. Also both collections are already designed with a higher mix flexibility, both having a high variety. This would mean that a large inventory is needed if they are produced using an assemble-to-order strategy. Since Desert, Kinswood, and Kent are still starting collections the highest chance for replacement would be Seaside.

As we explained above, the main material for Times collection is solid wood. Desert is very similar to Riverwood as a collection and should therefore be easy to implement. Collections like Kingswood, Kent only use solid wood panels and can therefore also unbalance the production flow between the solid wood and fibre plate flow. Implementation of Kingswood and Kent should therefore be accompanied with the implementation of collections that use more fibre plate.

7.2 IMPLEMENTATION STEPS

7.2.1 TIME PATH

Implementing the desired situation for all collections will require several steps. Figure 7-2 presents a time path with three phases, including the collections per phase. Each phase will require 6 months for the preparations, implementation, and evaluation. During the first phase, the collections Rosso, Artimo, Artimo Color, Kingswood, and Kent will be implemented. During the second phase, the collections Desert, One, Two, and Three will be implemented. Finally, during the third phase, the collections Seaside and Quarto/Linea will be implemented. For the second and third phases we planned fewer collections to implement, leaving options for the introduction of newer collections. It is important that during the implementation as described here, separate projects will be started to do further research into the lean principles and their possible effects for GM.

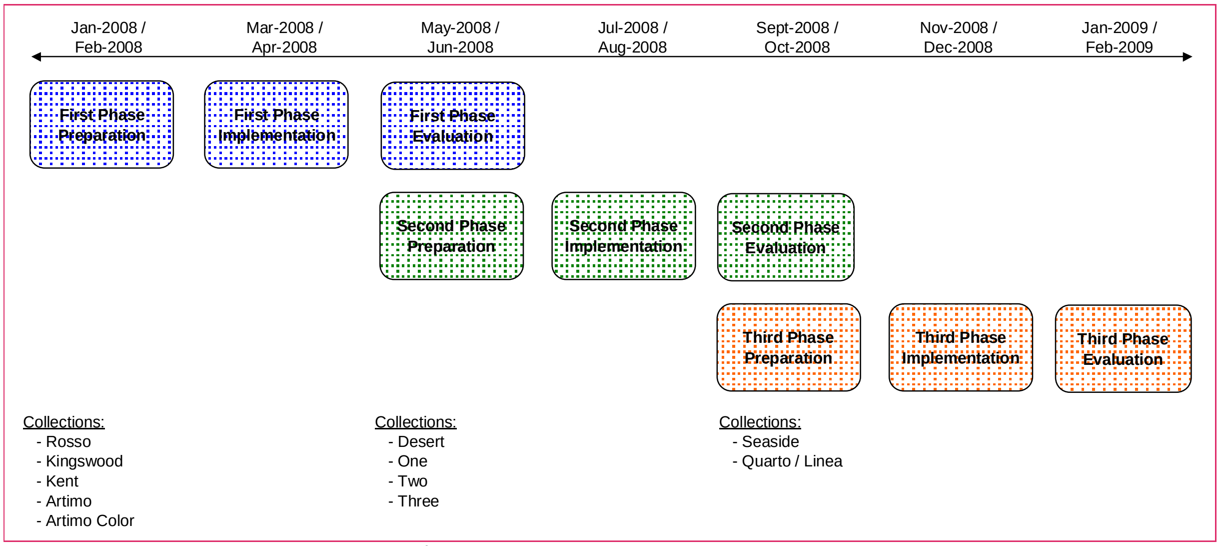


Figure 7-2: Implementation phases for all collections

7.2.2 IMPLEMENTATION ACTIONS

During each phase several actions have to be taken. Here we will address the several actions for the preparation, implementation and evaluation.

Preparation

- For preparation, the collections have to be analysed to get a better view of the different product parts. Important questions here are:
  - From which suppliers are the resources coming from?
  - Can we purchase the resources based upon customer order?
  - What will be the delivery time for the required resources?
  - What will be the total throughput time for each product?
  - How many inventory do we have left?
- For each product part, decide which production flow it will follow. It is important here to make sure that every part is on one of the production lists. If a new list has to be created, because it cannot be combined with one of Riverwood, than include employees in the creation of it.
- Set up a meeting with the employees and explain which collections are going to be implemented. Make them part of the implementation so that input on problems during the implementation and evaluation can be received.

Implementation

- Make sure that the production lists are created and are given to the correct production process. Also make sure that they are placed on the planning board of the next process.
- Remove products from the customer order list that are still in the inventory so that it is depleted.
- Organise informal meetings with employees to gain insight into the problems that arise, so that they can be solved immediately. Register large problems, and keep track of their status.

Evaluation

- Organise a formal meeting where the results of the implementation are presented. Ask for the ideas and opinion of employees on how to improve the next implementation phase.

7.3 CONCLUSIONS

Within this chapter we have first described and analysed the different brands and collections of GM's assortment. Second, we have given a possible implementation plan in order implement the desired state for all collections. To conclude on the research questions:

- Which of GM's collections should be changed regarding their life cycle?

  For each brand the collections are sorted from left having high priority for implementation to right low priority.

  - Delato: Rosso, Artimo & Artimo Color, Quarto / Linea
  - Times: Kingswood, Kent (both equal priority), Desert, Seaside
  - Motto: One, Two, Three (all have equal priority)

- In what way do the collections relate to the experimental one?

  Collections within the brands Delato and Motto use far more fibre plate than the experimental collection Riverwood. Implementation of these collections should therefore be accompanied by a Times collection which use more solid wood. Doing so will balance both the production flows for fibre plate and solid wood.

- What are the steps needed to change all the desired collections?

  For each phase there are three stages; preparation, implementation, and evaluation. Within the preparation stage the design of each collection is described, on which the product parts are divided over the production flows. Then the adjustments to GP2002 can be made so that the production lists can be created. Within the implementation phase it is important to monitor the inventory levels of the semi-finished products inventory. During both phases the problems are registered which will later on be evaluated in the last stage.

  Next to the implementation of the collections, it is important that further research after the effects of lean principles for GM. Actual implementation of the principles will have to wait until at least February 2009.

8 CONCLUSIONS AND RECOMMENDATIONS

Within this chapter, we will conclude on our central research question and give additional recommendations to GM. In Section 8.1, we will first give a brief overview of the six sub questions after which we will our conclusion on the central research question. Within Section 8.2, we will give additional recommendations to GM that have come up during this research project.

8.1 CONCLUSIONS

8.1.1 RESEARCH SUBQUESTIONS

Within the introduction of this research, we state that the goal of the research is to advice GM on how to improve its operations process design and operations planning & control in order to fit with the strategic focus on competitive flexibility. Here we give an overview of the six sub questions:

1) How can flexibility as a competitive objective be measured at GM?
Within Chapter 2, we have given the following definition of competitive flexibility:

> *Competitive flexibility is the ability for a company to produce non-standard orders, to introduce new products, and to accelerate and decelerate production quickly.*

Flexibility is one of the competitive objectives, next to cost, quality, and delivery. Because they are directly related to the market demand, they are constantly evolving adding another objective with each change in the market demand. According to the theory of trade-offs, it is not possible to compete on all the objectives so a company has to make priorities. It is therefore important to measure all competitive objectives when changing the focus towards flexibility. Figure 2-3 (page 18), presents the measures that are used for each competitive objective.

2) What does the theory explain on operations process regarding flexibility?
Intermittent operations have a better fit with competitive flexibility than repetitive operations. This is because intermittent operations are designed for higher product variety and lower production volume. The product strategy should therefore be make-to-order, buy-to-order, or design-to-order. When a make-to-order strategy is not possible, the OPP should be placed upstream as much as possible. Section 3.1, gives a description of the different product strategy's and the OPP.

There are several methods possible to plan and control an operations process. The different methods can be divided into push, pull, or hybrid systems. If a higher variety is desired, methods like BS and Kanban are less efficient. Methods that have a better fit with a flexible organisation are Conwip, MRP-II, Loor, Polca, and Dewip. However, this does not mean that BS and Kanban cannot be used at all within a flexible organisation. Multiple methods can be used at the same time, each controlling different flows. There are also several lean principles and methods that implement these principles. For instance, Six sigma which goal is to minimise product defects, SMED for the reduction of change-over times, and 5S method to improve the overall workplace morale and efficiency.

3) In what way is GM currently managing its operations regarding a single collection?
For the description of the current situation, we have chosen the collection Riverwood out of GM's assortment. Riverwood was introduced in February of the year 2006, has a healthy average

turnover, and its product design combines both fibre plate and solid wood. Section 4.1, described the different collections within GM's assortment and the reasons we based our choice on.

Appendix D gives a complete overview of the current process design. The individual flows are presented and explained within Section 3.2. Within the production process, the OPP is placed at the semi-finished products inventory. Both the upstream and downstream flows are using a push system. For planning and control of the upstream flow, GM is using an MRP like method where the production planning is based upon the semi-finished products inventory, and a sales forecast. For the downstream flow, the planning is based upon the throughput time and the planned delivery date of the customer order. Figure 4-13 (page 38) presents the measures for the competitive objectives within the current situation.

4) What would be a desired method to manage GM's operations in order to become more flexible?

The desired process flow is based upon an intermittent operation with a buy-to-order strategy. The flow still gives possibilities for a design-to-order strategy when a customer wants a customised product. In order to create the desired flexibility with a reliable delivery time and low inventory value, it is desired to implement Conwip as manufacturing control system. Kanban and BS are not efficient when the variety is high. MRP-II can handle a higher variety but does not control the WIP. The other described systems Polca, LOOR, and DEWIP are designed for more complex process flows, and are less widely used. Figure 5-4 (page 44) presents an overview of the method for planning and control within the desired situation.

It is also desired to implement some of the lean principles. For instance, JIT can improve the throughput time, by reducing the safety buffers between processes. SMED reduced the change-over times improving the throughput time and direct costs. The 5S method can further improve the overall work morale and efficiency, by including the employees in the evaluation of required resources. To get a better insight into, and reduce the cost of errors, implementation of Six Sigma is desired.

5) What are the effects on the competitive objectives of the single collection after changing the operation design, and operation planning & control?

For the experimental situation, two new inventories had to be created, namely the planed wood, and assembly inventory. The delivery time for raw wood is currently too long to purchase on customer order. Also the machines within the raw wood department are not suited for customer order production. Within the assembly inventory the side tops, tills, and plinth are stored. This is done because plinth is created from waste wood that was rejected at the sorting department, and side tops take much longer to make. To produce the side tops on customer order, they first have to be redesigned. Appendix E presents an overview of the experimental process design.

The OPP within the experimental situation is placed at the planed wood, fibre plate, and assembly inventory. Except for the side tops, and plinth, the production of all parts are planned and controlled as described within the desired situation. For the side tops and plinth, Kanban cards are created that are sent directly to the raw wood department when production is required. Figure 6-7 (page 51), presents an overview of the method for planning and control within the experimental situation.

Figure 6-13 (page 56) presents the effects of the experiment for each of the competitive objectives. Regarding the desired situation, the level for inventory costs, delivery time, and delivery reliability are not met. Although, both the desired level for inventory costs and reliability are set for September 2008, and are within the expected ranges. The delivery time shows improvement, and is expected to get within the desired level when all the collections are adjusted.

6) Which changes does GM have to implement in order to reach the desired situation?

Based upon the characteristics of each collection within GM's assortment, a priority list is made for implementation. For each brand this priority is:

- Delato: Rosso, Artimo & Artimo Color, Quarto / Linea
- Times: Kingswood, Kent (both equal priority), Desert, Seaside
- Motto: One, Two, Three (all have equal priority)

Based upon the product design, collections within the brand Delato and Motto should be combined with a collection from the brand Times during implementation. Because both Delato and Motto use far more fibre plate than the experimental collection Riverwood, this is balanced with the more solid wood collections of Times. This is expected to give fewer problems during the implementation.

The implementation itself is divided in three phases. Within each phase, several collections are implemented through three stages, namely preparation, implementation and evaluation. The actual activities that have to be taken are described within Section 7.2. Figure 7-2 (page 59) gives an overview of the implementation phases.

8.1.2 CENTRAL QUESTION

Within the introduction chapter, the research question is stated as followed:

> *What are the changes needed regarding GM's operation process design, and operation planning & control, in order to improve the fit between the GM's operations management and strategic focus on competitive flexibility?*

There are a two mayor points for GM to improve its fit with competitive flexibility:

- Move the OPP more upstream.

  The newly created inventory for planed wood can be used for all solid wood parts within the different collections. This inventory can be expanded with different kinds of wood. Also the created fibre plate inventory can be used for many collections. Some collections use a different type of fibre plate for which a different solution has to be sought.
- Change the method for planning & control.

  For the upstream flow a pull system is preferred, using a Kanban like system. A push system is preferred for the downstream flow where the production signal is based upon the customer order. Maximising the WIP within the downstream flow will improve the delivery time and reliability.

8.2 RECOMMENDATIONS

8.2.1 IMPLEMENTATION OF THE DESIRED SITUATION

Our most important recommendation is to fully implement the desired situation on all of the collections within GM's assortment. Concluding on the experiment outcomes, the measured levels are positive for each of the competitive objectives. It is possible that the nature of the experiment has influenced the outcomes, and that the direct costs are actually higher than measured. We do not feel that this will become a problem, as a small increase in direct costs was expected for the implementation of the desired situation. The benefits in competitive flexibility, inventory costs, and delivery are in our opinion more important.

Also for the implementation of the desired situation, it is important to perform further research into the lean principles, and their effects on GMs desired situation. Implementation on the other hand will have to wait until the OPP is replaced for all collections, and planning and control is back to a single situation. If not, it would add too many variables for a proper research.

8.2.2 CONTINUITY IN MEASURING

In order to create continuity, we recommend GM to keep measuring the competitive objectives. As we haven shown in Chapter 2, the competitive objectives are directly related to customer demands, and therefore vital for GM's competitive advantage. Many of the required data are already being stored within the software program GP2002, and only need little adjustment to create weekly or monthly reports. For the experiment within this research, we could not use current data for the error-free production indicator, because GM only registers the production errors that are sent back by the customer. We therefore recommend GM to start a project for internal errors measurement, either before or after implementation of the desired situation.

8.2.3 INTERNAL TRANSPORT

Throughout the factory, there are currently two methods for the transportation of products. Upstream of the OPP, pallets are being used that can be moved by a fork truck. Downstream of the OPP, the products are moved on different kinds of trolleys. Since the OPP has been moved, we recommend GM to adjust their transportation methods. Using a trolley in the CNC & traditional department will reduce transport times within and between departments. Also we expect that it will further reduce the throughput time, as pallets are not put away on shelves waiting for another department to pick them up. Depending on the design of the trolley, it can also reduce the chance for internal errors, and damaging.

8.2.4 PRODUCTION PLANNING PER DAY

Within the current situation, the start and delivery of customer orders are planned per week. Because the experiment had to be implemented within the current situation, this was unaltered. It does however cause a delay in important planning information. If a certain resource is not available, the delay is visible the next week instead of the next day. We therefore recommend GM to start planning customer orders in days instead of in weeks. This is also necessary to further reduce the throughput time and WIP inventory. Alterations to the software package GP2002 are required.

8.2.5 PLANNING AND CONFIRMATION OF CUSTOMER ORDERS

Within the current situation, the customer orders are first imported by the office sales force. The planner schedules the orders for production, which can then be confirmed with the customer by the office sales force. This process can take up to a full week, or even more for customised orders. Within the desired situation, it is possible for the office sales force to schedule the customers orders themselves. Based upon the maximum available capacity for a certain period and the required capacity, it is possible for the office sales force to schedule orders. It will require adjustments to the software package GP2002, and instruction of the office sales force. Also, the planner will have to define the maximum capacity per period.

8.3 DISCUSSION

It is important for a company to create a fit between their competitive objectives and operations management. This research project has shown that for a company to compete on flexibility, it needs to move the OPP upstream, and adjust its method for planning & control to facilitate the operations process. In theory, this gives positive results for al production companies. Those companies that are starting to focus more on competitive flexibility, can use this research project as an informational handbook during their project. Especially the steps that are taking during the experiment, and the lessons learned can be valuable. However, measuring the competitive objectives during the project is necessary, in order to evaluate the costs of change against the benefits.

Within this research project, a list is given of several methods for planning & control. The list of methods is not finite, and may be expanded to further improve the desired situation. The methods for planning & control that are used are those that are most implemented in practice and evaluated. It is therefore sufficient for this research project, but may be too small for companies with a more complex structure.

The results of this research project show improvement on all measured competitive objectives. Because the experiment was conducted within the current situation where only the experimental collection was adjusted, it is possible that the results will be different at the end of the implementation project. It is therefore important to carefully evaluate the competitive objectives during each implementation phase.

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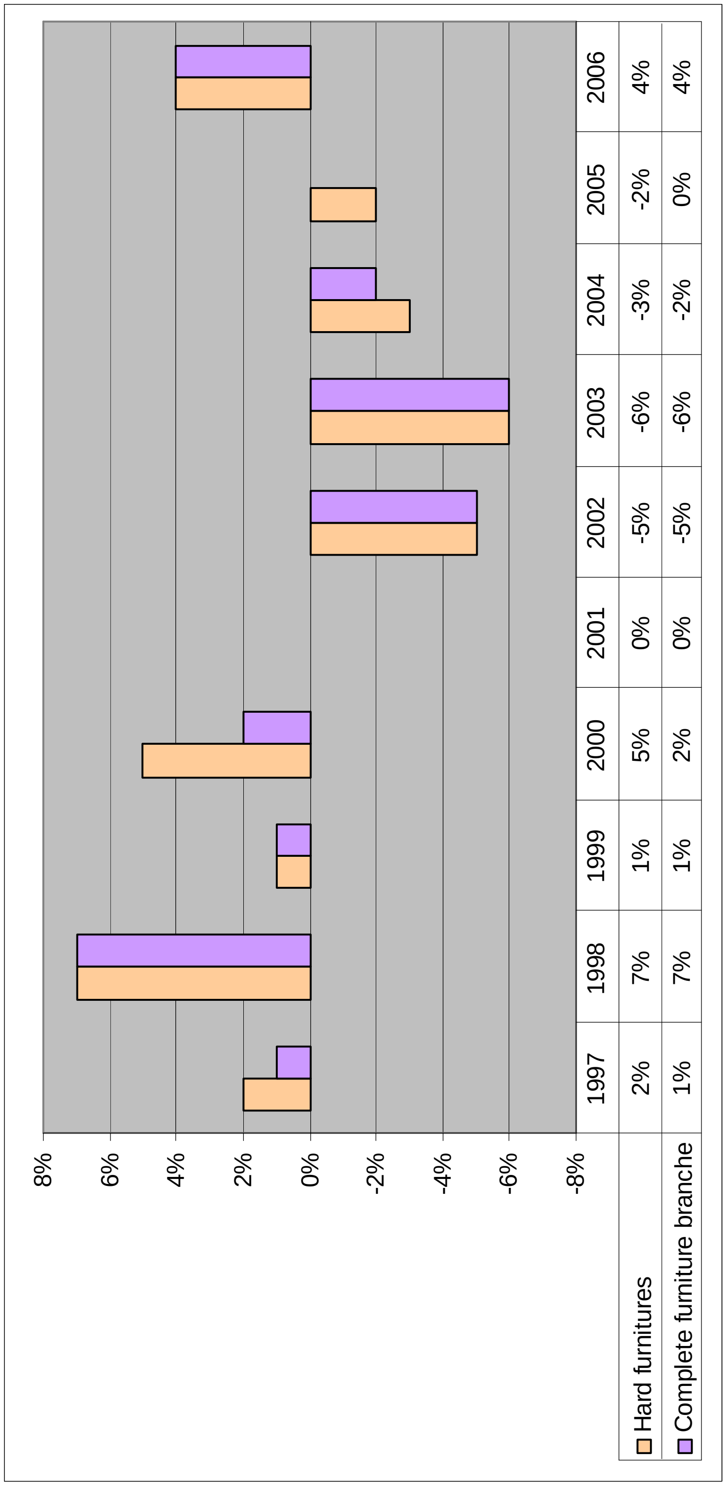
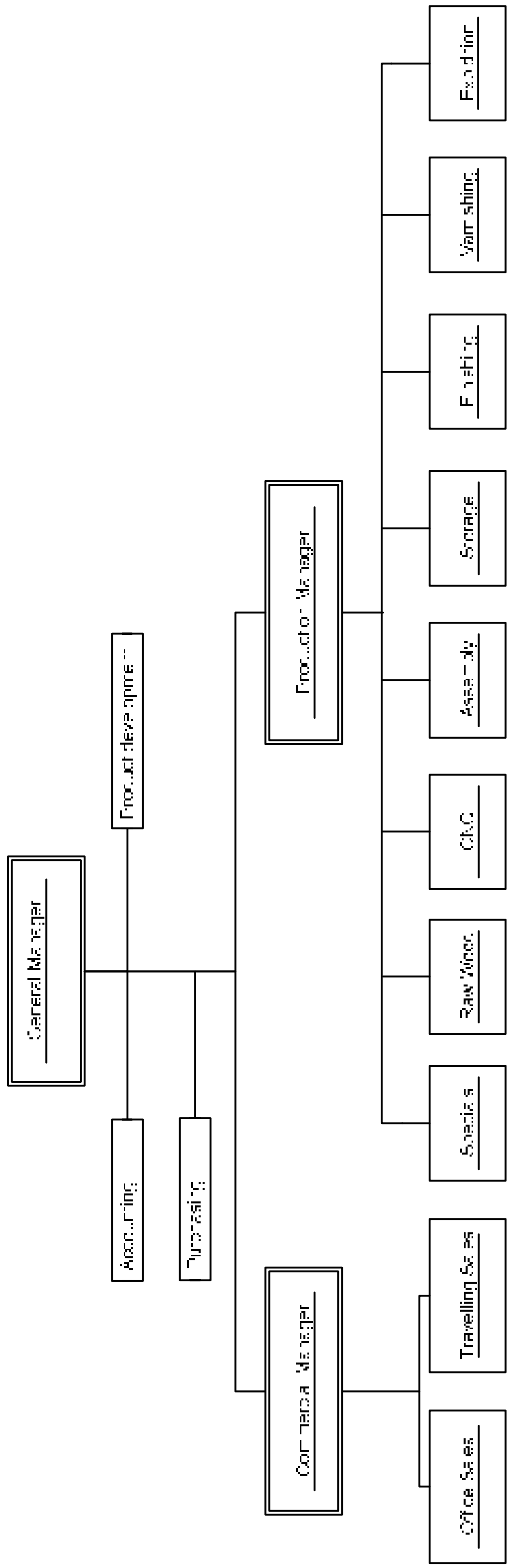
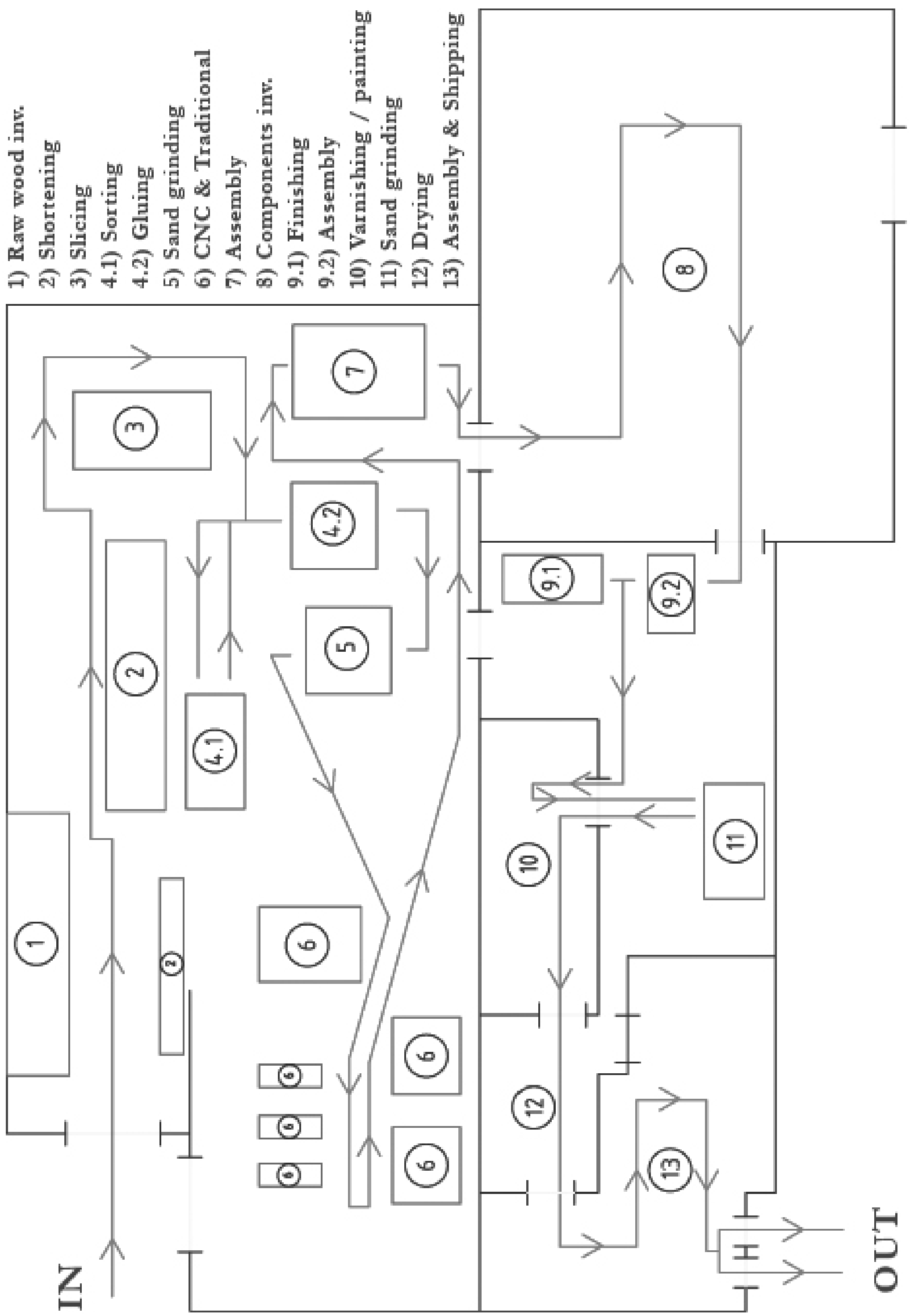


	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Hard furnitures	2%	7%	1%	5%	0%	-5%	-6%	-3%	-2%	4%
Complete furniture branche	1%	7%	1%	2%	0%	-5%	-6%	-2%	0%	4%

Source: CBW 'Rapportage Omzetenquête 4e kwartaal 2006'

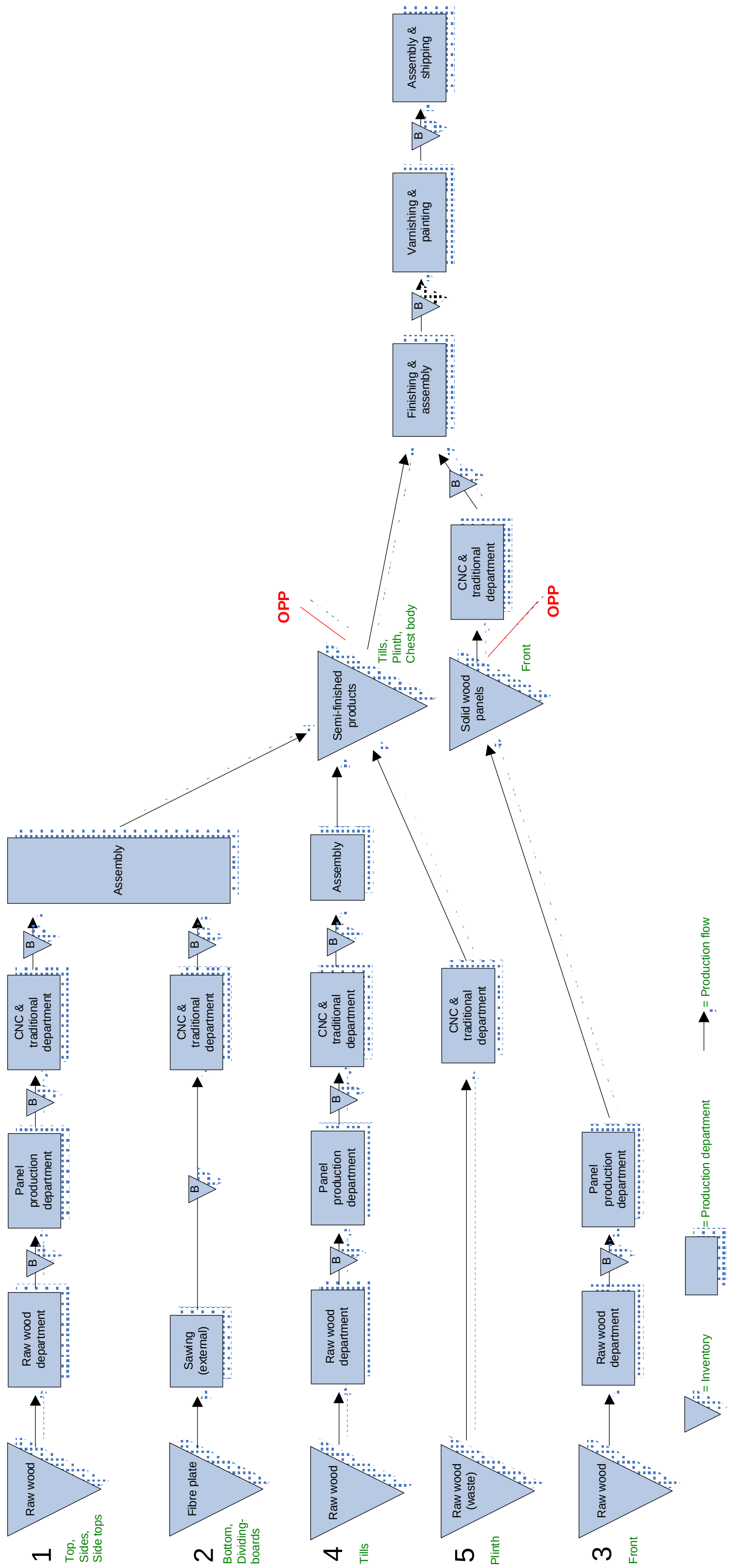


Organisational structure of GM 'the Furniture Factory'

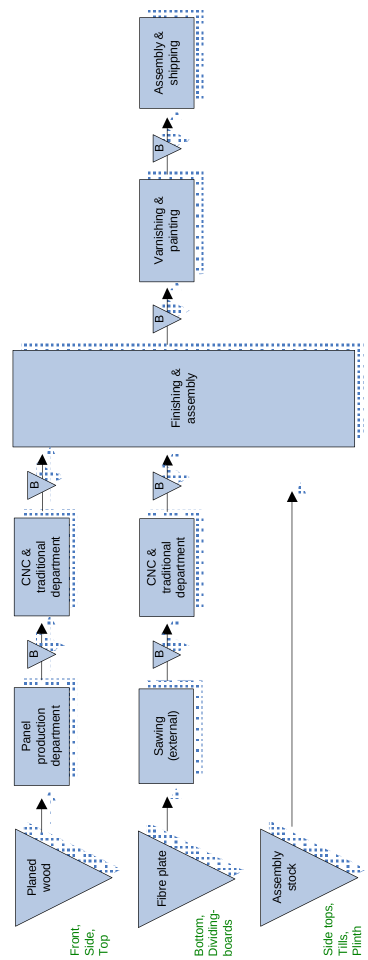


Factory layout of GM 'the Furniture Factory'

APPENDIX D PROCESS FLOW OF THE CURRENT SITUATION



Process flow for Riverwood within the current situation



Process flow for Riverwood of the experimental situation

APPENDIX F DIRECT COST CALCULATION EXPERIMENTAL SITUATION

List 1 Resource	Department	Process	Machine p/h	Time	Machine	Labour	Subtotal	Time	Machine	Labour	Subtotal	Difference Cost	Perc
Raw wood	Raw wood	Dividing	€ 6,80	1,34	€ 9,13	€ 28,20	€ 37,34	1,34	€ 9,13	€ 28,20	€ 37,34		
		Shortening	€ 8,20	1,24	€ 10,15	€ 25,99	€ 36,14	1,24	€ 10,15	€ 25,99	€ 36,14		
		Slicing	€ 14,00	1,12	€ 15,67	€ 23,51	€ 39,18	1,12	€ 15,67	€ 23,51	€ 39,18		
	Panel production	Sorting		3,25		€ 68,23	€ 68,23	3,42		€ 71,82	€ 71,82	€ 3,59	5,3%
		Gluing	€ 5,00	1,92	€ 9,59	€ 40,27	€ 49,86	2,25	€ 11,25	€ 47,25	€ 58,50	€ 8,65	17,3%
		Sand grinding	€ 13,35	0,58	€ 7,79	€ 12,26	€ 20,06	0,25	€ 3,34	€ 5,25	€ 8,59	-€ 11,47	-57,2%
	CNC & traditional	CNC (arrow)	€ 19,00	3,94	€ 74,77	€ 82,64	€ 157,40	3,65	€ 69,35	€ 76,65	€ 146,00	-€ 11,40	-7,2%
Fibre plates	Sawing (external)	Within material costs											
	CNC & traditional	Veneer	€ 2,00	1,58	€ 3,17	€ 33,25	€ 36,42	1	€ 2,00	€ 21,00	€ 23,00	-€ 13,42	-36,8%
		CNC (alberti)	€ 15,00	1,36	€ 20,36	€ 28,50	€ 48,86	1	€ 15,00	€ 21,00	€ 36,00	-€ 12,86	-26,3%
Combi	Assembly	Assembly		6,81		€ 143,01	€ 143,01	8,50		€ 178,50	€ 178,50	€ 35,49	24,8%
		Finishing & Assembly		2,00		€ 42,00	€ 42,00					-€ 42,00	-100,0%
	Varnishing	Varnishing		5,58		€ 117,25	€ 117,25	5,58		€ 117,25	€ 117,25		
	Shipping	Assembly & shipping		7,50		€ 157,50	€ 157,50	7,50		€ 157,50	€ 157,50		
		Subtotal			€ 150,62	€ 802,60	€ 953,23		€ 135,89	€ 773,92	€ 909,81	-€ 43,42	-4,6%
		Material costs					€ 2.152,31				€ 2.152,31		
		Total					**€ 3.105,54**				**€ 3.062,12**	-€ 43,42	-1,4%

List 2 Resource	Department	Process	Machine p/h	Time	Machine	Labour	Subtotal	Time	Machine	Labour	Subtotal	Difference Cost	Perc
Raw wood	Raw wood	Dividing	€ 6,80	3,17	€ 21,56	€ 66,59	€ 88,16	3,17	€ 21,56	€ 66,59	€ 88,16		
		Shortening	€ 8,20	2,90	€ 23,77	€ 60,88	€ 84,65	2,90	€ 23,77	€ 60,88	€ 84,65		
		Slicing	€ 14,00	5,15	€ 72,03	€ 108,05	€ 180,08	5,15	€ 72,03	€ 108,05	€ 180,08		
	Panel production	Sorting		7,33		€ 153,98	€ 153,98	8,4		€ 176,40	€ 176,40	€ 22,42	14,6%
		Gluing	€ 5,00	3,80	€ 19,01	€ 79,85	€ 98,87	3,5	€ 17,50	€ 73,50	€ 91,00	-€ 7,87	-8,0%
		Sand grinding	€ 13,35	1,65	€ 21,99	€ 34,59	€ 56,58	0,25	€ 3,34	€ 5,25	€ 8,59	-€ 47,99	-84,8%
	CNC & traditional	CNC (arrow)	€ 19,00	9,29	€ 176,47	€ 195,05	€ 371,52	8,90	€ 169,10	€ 186,90	€ 356,00	-€ 15,52	-4,2%
Fibre plates	Sawing (external)	Within material costs											
	CNC & traditional	Veneer	€ 2,00	3,33	€ 6,67	€ 70,00	€ 76,67	1	€ 2,00	€ 21,00	€ 23,00	-€ 53,67	-70,0%
		CNC (alberti)	€ 15,00	3,65	€ 54,77	€ 76,68	€ 131,45	3,85	€ 57,75	€ 80,85	€ 138,60	€ 7,15	5,4%
Combi	Assembly	Assembly		14,78		€ 310,43	€ 310,43	16,75		€ 351,75	€ 351,75	€ 41,32	13,3%
		Finishing & Assembly		4,25		€ 89,25	€ 89,25					-€ 89,25	-100,0%
	Varnishing	Varnishing		11,42		€ 239,75	€ 239,75	11,42		€ 239,75	€ 239,75		
	Shipping	Assembly & shipping		16,25		€ 341,25	€ 341,25	16,25		€ 341,25	€ 341,25		
		Subtotal			€ 396,28	€ 1.826,35	€ 2.222,63		€ 367,06	€ 1.712,17	€ 2.079,23	-€ 143,41	-6,5%
		Material costs					€ 5.366,79				€ 5.366,79		
		Total					**€ 7.589,43**				**€ 7.446,02**	-€ 143,41	-1,9%

List 3 Resource	Department	Process	Machine p/h	Time	Machine	Labour	Subtotal	Time	Machine	Labour	Subtotal	Difference Cost	Perc
Raw wood	Raw wood	Dividing	€ 6,80	3,59	€ 24,43	€ 75,45	€ 99,88	3,59	€ 24,43	€ 75,45	€ 99,88		
		Shortening	€ 8,20	3,26	€ 26,72	€ 68,44	€ 95,16	3,26	€ 26,72	€ 68,44	€ 95,16		
		Slicing	€ 14,00	4,68	€ 65,53	€ 98,29	€ 163,82	4,68	€ 65,53	€ 98,29	€ 163,82		
	Panel production	Sorting		9,70		€ 203,60	€ 203,60	11		€ 231,00	€ 231,00	€ 27,41	13,5%
		Gluing	€ 5,00	4,89	€ 24,46	€ 102,74	€ 127,20	4,2	€ 21,00	€ 88,20	€ 109,20	-€ 18,00	-14,1%
		Sand grinding	€ 13,35	1,94	€ 25,96	€ 40,84	€ 66,80	0,45	€ 6,01	€ 9,45	€ 15,46	-€ 51,34	-76,9%
	CNC & traditional	CNC (arrow)	€ 19,00	10,92	€ 207,43	€ 229,26	€ 436,69	11,90	€ 226,10	€ 249,90	€ 476,00	€ 39,31	9,0%
Fibre plates	Sawing (external)	Within material costs											
	CNC & traditional	Veneer	€ 2,00	3,88	€ 7,75	€ 81,38	€ 89,13	1,3	€ 2,60	€ 27,30	€ 29,90	-€ 59,23	-66,5%
		CNC (alberti)	€ 15,00	3,83	€ 57,47	€ 80,45	€ 137,92	7,30	€ 109,50	€ 153,30	€ 262,80	€ 124,88	90,5%
Combi	Assembly	Assembly		21,19		€ 445,09	€ 445,09	25,05		€ 526,05	€ 526,05	€ 80,96	18,2%
		Finishing & Assembly		5,25		€ 110,25	€ 110,25					-€ 110,25	-100,0%
	Varnishing	Varnishing		14,83		€ 311,50	€ 311,50	14,83		€ 311,50	€ 311,50		
	Shipping	Assembly & shipping		20,25		€ 425,25	€ 425,25	20,25		€ 425,25	€ 425,25		
		Subtotal			€ 439,75	€ 2.272,53	€ 2.712,28		€ 481,89	€ 2.264,13	€ 2.746,02	€ 33,74	1,2%
		Material costs					€ 6.175,41				€ 6.175,41		
		Total					**€ 8.887,69**				**€ 8.921,43**	€ 33,74	0,4%

Direct cost calculation for the first list

APPENDIX G QUALITY ERRORS WITHIN THE EXPERIMENTAL SITUATION

		Standards							Cost			
List	Problem description	Preparation	Colour	Smooth	Measures	Material	Wood structure	Repair	Labour	Material	Total	Problem Solving
1	- Fibre plating delivered with wrong measures	X						- 1 milimeter is sandgrinded off	€ 10,50	€ -	€ 10,50	- Recipe is adjusted
1	- Old (inventory) side-tops do not fit with new tops				X			- Holes for connection are adjusted	€ 21,00	€ -	€ 21,00	- Problem will dissapear with new side-tops
1	- Dividing boards not delivered (or ordered)	X						- Fibre plates are sawed in CNC & traditional	€ 21,00	€ 20,00	€ 41,00	- Recipe is adjusted
2	- Bad quality walnut wood					X		- Sorting took longer	€ 15,75	€ -	€ 15,75	- Problem is communicated with puraching department
2	- Damaged (inventory) side-tops			X				- Sand grinded	€ 42,00	€ -	€ 42,00	- Problem will dissapear with new side-tops
3	- It is unclear what each part within the Riverwood batch is (Number on parts is not enough)	X						- It took longer to search out the parts.	€ 21,00	€ -	€ 21,00	- At the sorting process the part description is written on the panels. Adhesive labels are being tested.
3	- Plinth not in stock for customised product (lenght differs)				X			- Plinth where hand made in assembly	€ 5,25	€ -	€ 5,25	- Problem is communicated with the preparation department

Internal errors during the Riverwood experiment