Introducing Lean Production at the Bolivian Wood Refining Company
Dicomad S.R.L.

A Minor Field Study

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Master of Science Thesis
Title: Bringing order to chaos - A minor field study of a Bolivian wood refining company

Topic: This is a study about order and organization in a wood refining company in Bolivia.

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The MFS Scholarship Programme offers Swedish university students an opportunity to carry out two months’ field work, usually the student’s final degree project, in a country in Africa, Asia or Latin America. The results of the work are presented in an MFS report which is also the student’s Master of Science Thesis. Minor Field Studies are primarily conducted within subject areas of importance from a development perspective and in a country where Swedish international cooperation is ongoing.

The main purpose of the MFS Programme is to enhance Swedish university students’ knowledge and understanding of these countries and their problems and opportunities. MFS should provide the student with initial experience of conditions in such a country. The overall goals are to widen the Swedish human resources cadre for engagement in international development cooperation as well as to promote scientific exchange between universities, research institutes and similar authorities as well as NGOs in developing countries and in Sweden.

The International Office at KTH the Royal Institute of Technology, Stockholm, Sweden, administers the MFS Programme within engineering and applied natural sciences.

Åsa Andersson
Programme Officer
MFS Programme, KTH International Office
Abstract
This report focuses on potential ways to improve the reliability of the production process at the wood refining company Dicomad S.R.L. in Santa Cruz de la Sierra, Bolivia. The main theory used has been Lean Production, as this theory suits the circumstances of the company well. Disorder has been the biggest problem, which has caused the safety in the factory to be below an acceptable level. Dicomad has two different businesses – producing decking and furniture. The decking production is fairly standardized whereas the furniture production is customized. The study was carried out during the summer and fall of 2009.

The analysis has resulted in changes in the layout of the factory such that a clearer work flow as well as proper order can be maintained. More specifically, three new layout suggestions have been made. The first suggestion makes big changes in the layout creating the “optimal” layout for the current situation. The second makes slightly smaller changes and the third makes small, but important changes to the layout. Our choice of the three is the second suggestion which constitutes the best compromise given the current layout. This suggestion will bring substantial benefits in form of a clearer flow, more organized inventory and separation of the two businesses but does not include a strenuous movement of the molder. Furthermore, each operation in the factory has been scrutinized and suggested improvements have been made to banish disorganization. Suggestions include redesign of machines, addition of collecting mechanisms for material and creation of best practices for machines. The greatest improvements have been possible within the furniture manufacturing as the factory was originally designed for decking production only. Additionally, proposals about improving the light, the air quality and the general organization and cleanliness of the factory have been made.

Only suggestions are presented, as the time available for the study was limited and any implementations were beyond our scope.

Keywords: Wood, Decking, Bolivia, Lean production, Organization, MFS, Minor Field Study
**Sammanfattning**

Denna rapport syftar till att föreslå möjligheter att förbättra pålitligheten av produktionsprocessen vid träförädlingsföretaget Dicomad S.R.L. i Santa Cruz de la Sierra, Bolivia. Lean Production har i största hand använts som teoretisk grund, då denna teori gör sig särskilt lämpad till de rådande omständigheterna kring Dicomad. Oordning har varit största problemet i fabriken, vilket har lett till att säkerheten legat under en acceptabel nivå. Dicomad har två olika verksamheter inom sin fabrik – produktion av möbler samt produktion av trällar för utomhusbruk. Trallproduktionen är till största del standardiserad medan möbelproduktionen är helt kundspecifik. Studien utfördes under sommaren och hösten 2009.


Endast förslag till möjliga förbättringar har gjorts, då tidsramen för studien var begränsad och implementeringar ej hans med.
Resumen
Este informe se centra en las posibles vías para mejorar la fiabilidad del proceso de producción en la empresa de refinación de madera Dicomad SRL en Santa Cruz de la Sierra, Bolivia. La teoría principal utilizado ha sido Lean Production, cómo esta teoría se utiliza bien en las circunstancias de la empresa. Desorden ha sido el mayor problema, que ha causado la seguridad en la fábrica por debajo de un nivel aceptable. Dicomad tiene dos empresas diferentes - la producción de revestimiento y de muebles. La producción del revestimiento está bastante estandarizado mientras que la producción de muebles es personalizada. El estudio se llevó a cabo durante el verano y el otoño de 2009.

El análisis ha dado lugar a cambios en el diseño de la fábrica de manera que un flujo de trabajo más clara, así como el orden correcto se puede mantener. Más concretamente, tres propuestas de diseño se han hecho nuevas. La primera sugerencia hace grandes cambios en el diseño para crear la "óptima" diseño para la situación actual. La segunda hace cambios un poco más pequeño y la tercera hace pequeños, pero importantes cambios en el diseño. Nuestra elección de los tres es la segunda sugerencia, que constituye el mejor compromiso, dada la disposición actual. Además, cada operación en la fábrica ha sido objeto de control y sugeridas de mejora se han hecho para desterrar la desorganización. Las mayores mejoras han sido posibles en la fabricación de muebles, como la fábrica fue diseñada originalmente para la producción de revestimiento solamente.

Sólo se han hecho sugerencias, como el tiempo disponible para el estudio fue limitado y las implementaciones fueron más allá de nuestro alcance.
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1. Introduction

Section 1.1 of this chapter gives the reader a brief introduction to the country and city in which the thesis has been carried out. A short introduction to the company can be found in section 1.2 and a brief summary of previous studies in the section thereafter. The problem discussion in section 1.4 is narrowed down to the aim of the study (1.6) and the specific thesis questions (1.7). Part 1.8 describes the delimitations and section 1.9 explains the design of the paper.

1.1 Bolivia

Bolivia is the poorest country in South America with 67.3 % (USAID 2008) of the population living below the poverty line and a life expectancy of only 66.9 years. Illiteracy is also a big problem, especially among women with a rate of 19.3 % (USAID 2009). With a size more than twice that of Sweden and altitudes spanning from 90 to 6485 meters above sea level Bolivia is bound to have vast natural resources. The mountains are rich in minerals and metals of which tin is the most prominent (Washington Post 2009). It has the second largest reserves of natural gas in South America as well as a fair amount of oil (BBC 2009). The eastern part of the country features fertile farming land as well as dense jungle. Except from farming the resources themselves, a country so rich in culture and natural diversity has great potential as a tourist destination.

25 percent of the country is suitable for forestry and today about one fourth of these lands are under sustainable forestry management. About 1.5 million hectares of land is certified by the Forest Stewardship Council (FSC), making Bolivia the world leader in this aspect. The forest industry is made up of around a thousand companies employing approximately 50 000 people directly and 250 000 indirectly. (Cámara Forestal de Bolivia, 2004)

Apart from writing this paper as a thesis for the Royal Institute of Technology and for the wood refining company Dicomad S.R.L. (from now on referred to as Dicomad) we hope that our work will, to some extent, help develop Bolivia in general and the Santa Cruz region specifically.

1.1.2 Santa Cruz

Santa Cruz de la Sierra, more commonly known as Santa Cruz, is the biggest and fastest growing city in Bolivia with a population of over 1.6 million (World Gazetteer 2009). The rapid expansion is largely due to agriculture of primarily soybeans, sugarcane and rice as well as petroleum and gas mining. Other notable products of the city are wood products, leather and alcohol. (Encyclopædia Britannica Online 2009).

Most of the wood companies, including Dicomad, are small to mid-sized (CADEFOR, 2009).

1.2 Dicomad

Dicomad is a wood refining company founded in 2005 in Santa Cruz de la Sierra, Bolivia. Its main products are decking, flooring and garden tiles but these have recently been accompanied by various carpentry products such as tables, chairs, drawers, desks etc. The decking, flooring and tiles are made of hardwood whereas the carpentry products are made of softwood. The ingoing material to all products is planks of various sizes.

The reason for starting the carpentry has been the severe blow to the other business that Dicomad has taken during the global financial crisis that started in 2008. At the time of writing the company
has no new orders for decking, flooring or tiles and is surviving solely on the carpentry business. The latter one is not bringing close to the same volumes as the original business, but it secures a more stable and reliable income.

Dicomad partly provides a service of refining a customer’s commodity and partly is the owner of the whole process, i.e., Dicomad buys the input material themselves.

The original business is targeted at international customers. Dicomad has or has had customers in Spain, Japan, Mexico and the USA. The carpentry business is today solely targeted at the local market in Santa Cruz.

At peak production, at the end of 2008, Dicomad had 25 employees working in two shifts, but at the time of this study there were only five employees working one shift.

1.3 Previous Studies
Since the establishment of the company, there have been four studies made at Dicomad. The first one was carried out by Engineers Without Borders (INUG) in the northern summer of 2007. The next one was made one year later, also this time by INUG. The third study was made in early 2009 and resulted in a Master’s Thesis at the department of Information and Control Systems at the Royal Institute of Technology, Stockholm. The fourth study was finalized in the beginning of August 2009.

The procedure and goal of all previous reports have followed the same approach; identify the strengths and the weaknesses and suggest solutions to the weaknesses, primarily within the area of production, secondly within marketing. The study made by Osbeck & Widén (2007) resulted in major changes to the factory layout, leading to a clear and logical workflow. This improved the profitability of the company considerably.

Birgersson & Knutsson (2008) looked widely at the business suggesting improvement opportunities regarding factory logistics, maintenance and cleaning, quality controls, machinery and business plan. Their suggestions were, in our opinions, quite vague and have not resulted in any major changes.

The work made by Warström & Westerborn (2009), focused on implementing some concepts from the Lean Production and Six Sigma philosophies. They looked at such things as product portfolio, takt time, maintenance, customers and staff organization. They further suggested an implementation plan for their suggestions. The implementation of the solutions proposed by Warström & Westerborn had not been made at the start of this study. At the time of their work, the production was running at low levels, which somewhat affected their work.

Lason and Hedberg’s (2009) work was quite different to the previous studies in that it only focused on possible usage of the waste from the main production. They recommended a few products that could be made from the waste material.

1.4 Problem Discussion
There are many things that can be improved at Dicomad. Even though the company has improved the organization of the factory, it still reeks of chaos. Given the terrible maintenance and
organization of the floor space this has to be a primary focus area. Unfortunately, because of the severe hit Dicomad has taken in the current global economic climate, the options of what to study at the company are greatly reduced. Furthermore, Dicomad’s management has had trouble stating any specific problem areas in today’s production as the main focus at the moment is on finding new customers.

As written in chapter 1.3, earlier studies have focused on such diverse areas as factory layout, maintenance and cleaning, product portfolio, product expansion opportunities, business goals, factory logistics, quality controls, machinery, takt time, staff organization and customers. Although these studies have spanned quite a large area there is much to be done in most of these fields and there were many things the previous studies did not address or focus enough on.

As this is a Master’s Thesis within the area of production the focus of this paper will be in-factory improvements. Besides, any suggestions regarding other parts of the business, such as product development or customers would be much too affected by cultural or case specifics, which would be very hard to grasp in the short study period. Therefore, Mr. Gonzalez, the CEO, is better off dealing with these issues himself.

One aspect the studies of Birgersson & Knutsson (2008) and Warström & Westerborn (2009) have in common is that they are quite vague in their recommendations. They have both, for example, recommended improvements in maintenance and order but not really suggested exactly what to do. Considering this, more specific recommendations would be very helpful to Dicomad and give them more concrete goals to strive for. Given the current state of the factory, it would be most helpful for Dicomad to suggest how they can improve the general layout, even out production, maintain and organize the factory as well as enhance specific operations in terms of ergonomics and efficiency. The suggestions stated within these areas will be sustainable in the long run and very helpful to Dicomad even in times of higher output.

Finally, since the company today only employs five people the existing working situation is quite extraordinary. All the suggestions will be based on today’s situation but it will be kept in mind that there will be times of higher production in the future and that the suggestions shall be maintainable in such a situation as well.

1.5 Thesis Question
The thesis will have a few questions on two levels:

- **Plant level**
  How can the production in a normal state be evened out over time? How can the layout of the factory be improved for less waste? How can the working conditions be improved?

- **Process level**
  How can ergonomics be improved? How can cleaning and organization of each micro workplace be improved? How can change-over times be reduced?
1.6 Aim
The aim of this study is to suggest a number of changes Dicomad should apply in its factory in order to reduce mistakes, improve working conditions and raise efficiency. The aim is that the suggestions should be applicable in the long run and that Dicomad should be able to implement them on their own.

1.7 Delimitations
The thesis will only focus on in-factory changes. Everything that goes on outside of the factory with customers or suppliers is left for other studies or Dicomad themselves.

Only suggestions will be given about what should be done. Hence, all implementations will be left for Dicomad to do. This is due to the limited time of the study.

No attempts at quantification of what the recommendations could lead to in terms of faster production or increased revenue will be made since all such quantifications would be nothing else than qualified guessing.

1.8 Paper Design
The paper starts with a description of the method used for the study in chapter 2. Relevant theories are covered in chapter 3 and chapter 4 describes the current situation of the company, Dicomad, in detail. The issues raised in chapter 4 are then analyzed and dealt with in chapter 5 were suggestions are also put forward regarding how to deal with the issues at hand. Chapter 6 shortly concludes chapters 4 and 5. In chapter 7 the study is criticized and suggestions for future research are given. References are to be found in chapter 8.
2. Method
As the chapter heading indicates, this part of the thesis aims at describing how information has been gathered and how and why the data at hand has been used. A discussion concerning the reliability, validity and scalability can be found in section 2.2-2.4.

2.1 Information collection
The information used to assess Dicomad’s current situation will be collected through talking to the owner and employees as well as studying the production in detail. More official interviews, or meetings will be held with the CEO and owner, Mr. Fabio Gonzalez del Rio. He will give background information about the company, the working conditions in Bolivia, the history etc. For more in-depth knowledge about the workflow and each process the work at each machine will be studied in detail and the workers will be questioned to get a full understanding of the processes.

No quantifications will be made regarding work times, takt time or inventory times as the products are in essence custom made and thus the paths and work times vary greatly. The uneven order cycles create a difficult inventory managing process. The fact that the company only will produce a number of different furniture and one type of simple decking during the time of the study makes it hard to do any quantitative studies of the production.

2.2 Reliability
The company has been visited virtually every working day during a period of around seven weeks and each day the processes in use have been studied. For the carpentry, each process has been studied at least five times or more and the reliability is therefore very high. For the decking production the reliability is somewhat lower since it has been running for a substantially shorter time (only around two weeks). Thus this part of the production is not based on as many observations and several parts of a “normal” production state have not been studied at all.

Regarding more general information about the company and other information gathered through interviews and previous reports the reliability can be considered to be high. With the information of several earlier reports and fresh interview material more or less converging, the information presented herein can be considered as reliable.

2.3 Validity
As Dicomad was only producing one type of decking, with three employees during the time of the study the validity for the decking/flooring line is not the best. For a greater validity more different parts would have had to be studied in full production with 10+ employees. Regarding the carpentry the validity can be said to be higher as several products were studied in production. Furthermore the number of employees in the carpentry section is not planned to rise above two, thus the state that was studied can be considered to be the normal state.

2.4 Scalability
In the production layout consideration has been taken to the fact that some machines that are not used today will be used in the future. Thus the scalability must be seen as decent. The fact remains, however, that not all machines were in use during the time of the study and so some parts are based on assumptions and predictions.
The scalability for the process micro studies is total as these are entirely unaffected by the production volumes, the layout, the specific worker or other factors. While the observed behavior today is definitely affected by the specific employee that performs the job, a perfect future state will not be.
3. Theoretical Background
In this section different theories relating to the analysis will be covered. Lean production is the foundation of the theoretical background. Hence, a large part of this chapter (3.1) aims at describing what lean production is and why this theory was chosen for this work. Section 3.2 covers the theoretical background of flow analysis. Part 3.3 concerns the theory of planning, in which forecasting has an important role. The last part of this chapter gives a mathematical formulation of how an optimal portfolio of products should be chosen.

3.1 Lean production
Lean production is a philosophy of working that originates from Japan and Toyota. It is not only a set of tools to make a company more efficient, but a philosophy that should be seen and felt throughout the whole company. Womack & Jones (2003) give the following introduction to lean thinking:

“It provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. In short, lean thinking is **lean** because it provides a way to do more and more with less and less - less human effort, less equipment, less time, and less space – while coming closer and closer to providing customers with exactly what they want.”

It almost sounds too good to be true and even if lean production in practice might not quite live up to this it is still a powerful philosophy to improve a company. The reason why lean production has been chosen as a theoretical base out of a set of many other production philosophies is due to the simple fact that lean can be properly used when a company produces relatively large volumes of a small number of products, which is the case for Dicomad. Also, some parts of the lean philosophy have proved to be very effective for all kinds of companies.

3.1.1 Muda (Waste)
Lean production can in essence be explained as a philosophy of eliminating waste or *muda* as it is called in Japanese. Taiichi Ohno, the “father” of lean production, listed the following prime contributors of waste:

- **Defects**: Producing defective items and the precautions taken against producing defective items.
- **Waiting**: Waiting for repairs of machines or because of material shortage. Also when employees stand around waiting for a machine to process a part. Excessive work-in-progress (WIP) because of large batch production is another part of waiting or defective parts requiring rework.
- **Transportation**: Transporting items from one process to the next. This is caused by inefficient factory layout, overly big machines, or large batch processing.
- **Inventory**: Unnecessary inventory at any stage of the production. This is most often caused by the company producing to forecasts instead of actual customer orders.
- **Motion**: Unnecessary movement of personnel. This also includes the very important factor of ergonomics. Good ergonomics are important both to prevent injuries and to prevent product defects.
- Overproduction: Producing in excess of demand. This leads to a number of costs including overly large warehouses, unnecessary employees and machinery, unnecessary materials and energy usage, and hidden problems in the production.

- Processing: Unnecessary or ineffective steps of production. This can also include doing more or something else than the customer needs. For example an engineering driven company sometimes can make products with unnecessary technology features not asked for or even understood by the customer. Other examples of overprocessing are unnecessary controls, double work, unnecessary packing between processes. (Nicholas & Avi, 2005)(Dennis, 2002).

There is an eight type of waste often cited but not stated by Ohno.

- Knowledge disconnection: Unused human capital – not taking full advantage of the knowledge within a company by not letting it come out or not diffusing it effectively (Dennis, 2002) (von Axelson, 2005).

### 3.1.2 The house of lean production

The philosophy of lean production is often visualized as a “house”. Dennis (2002) represents the house in the following way:

![Figure 1.1. The house of lean production. Source: Dennis, 2002](image)

The base of the house is **stability** and **standardization**. The walls are producing **just-in-time** and **jidoka**, or automation with a human mind. The roof, or the goal, is **customer focus** – to deliver the highest quality possible to the lowest cost in the shortest amount of time. Finally, the heart of the lean system is **involvement** – everyone in the company should be part of and in charge of the improvement process.

As seen in figure 1.1 a number of lean tools are connected to each part of the house. These are in alphabetical order:
• 5S
• A3 thinking
• Abnormality control
• Flow
• Heijunka
• Involvment
• Jidoka
• Kaizen circles
• Kanban
• Lean design
• Poka-yoke
• Problem solving
• Pull system
• Robust process
• Safety activities
• Separate human and machine work
• Standardized work
• Suggestions
• Takt time

Some of the above tools are applicable in this study and some are not. Thus, we will present below the most interesting ones to our work.

Another way of looking at lean production is the 4P Model presented in figure 1.2.

![4P Model](image)

*Figure 1.2. The 4P Model. Source: Liker (2004).*
Philosophy - Long term thinking. This is the base. Decisions should be based on long term thinking, even if short term financial aims cannot be achieved.

Process - Eliminate waste. This part has been described in detail above.

People and Partners - Respect and challenge the people. The employees as well as the suppliers should be respected, challenged and helped at all times.

Problem solving - Continuous Improvement. Decisions should be made slowly with consciousness. Once one decision has been made, the implementation should be rapidly made. This together with the other “layers” of the diagram should bring the company to a state at which it finds itself at continuous improvement.

3.1.3 5S
The 5S’ are five points to guide a factory in the process of keeping a tidy workplace. The idea is that a clean and ordered work environment will lead to less waste such as looking for tools and fewer mistakes will be done. The 5S’ are:

*Seiri* (sorting) – is focused on the removal of unnecessary items. A good way of locating redundant tools is by red-flagging them when they are not used, then evaluate whether they are actually needed and if not move them to a more appropriate location in the workplace or discard them. Of course unneeded tools can also be found by green-flagging the used ones, which might be easier. Sorting is a good way of freeing valuable floor space.

*Seiton* (set in order) – means storing everything efficiently. For each single item in a factory one should evaluate which place would be ideal for it. Where should tools be placed so one can reach them as quickly as possible when needed? Where should trash cans, brooms, mops and buckets be placed? There should be a dedicated and clearly marked place for everything. Floors should be painted with lines indicating where machines and tools should be. Shelves should be marked and tools hung on boards with clear markings, such as outlining, for each tool. The goal is that one should always know where to go to get something.

*Seiso* (shine) – means cleaning. Everything should be cleaned very regularly, at least daily. Not only is it nicer to work in a clean environment but keeping everything shining will instantly reveal problems with equipment, oil leaks, vibrations, misalignment, breakage etc. This prevents machine failure and halting of production as problems can be discovered in time to do something about them.

*Seiketsu* (standardize) – means setting up procedures to ensure that best practices are followed. This can include creating lists of what 5S procedures to do every day/week to ensure that they are done consistently.

*Shitsuke* (sustain) – means to make sure the good level of order and cleanliness is kept once it has been implemented. This also means to make improvements of the original procedures - to always strive for perfection. This is a hard task as most people resist change and easily fall back into old routines.
3.1.4 The steps to lean production

Womack & Jones (2003) name five steps to follow in order to create a lean enterprise.

- Specify value: The first step is to define value from the ultimate customer’s point of view. Value can be such things as product specifications and time of delivery.

- Identify the value stream: The value stream is the set of specific actions that are needed to bring a product through the three critical management tasks of any business: the problem-solving task from concept to launch of production, the information management task including order-taking through detailed scheduling to delivery and finally the physical transformation task of transforming raw material to a finished product in the customer’s hands. When identifying the value stream three types of actions relating to value are typically encountered – (1) directly value adding activities, (2) activities that do not create value but are unavoidable with the current technology (type one muda), (3) activities that do not add value and are immediately unavoidable (type two muda).

- Flow: This third step in essence means to look at the whole value-chain to try and make it flow. Instead of dividing a company into departments where each department only deals with part of the value chain of a product the organization should be focused around the whole value-chain of a specific product. Also, items should be produced in a flow, one by one through the whole process and not in batches with large amounts of work-in-progress (WIP).

- Pull: When the first three steps have been implemented the whole company should work much more effectively being able to develop and produce items in a much shorter time than before. Then it is time to start letting the customer pull value i.e. products out of the company. When products can be made in such a short time that no inventory of finished goods is required all items can be produced to order.

- Perfection: Perfection is the idea that when all the steps have been implemented one should go over them again and again and again to see what can be improved. The lean way of thinking is something that should include the whole organization and always be on everyone’s mind.

3.2 Flow analysis

3.2.1 Process flow analysis

The theory behind the process flow analysis presented in Olhager (2000) has been used in this chapter. According to Olhager (2000) “a process flow analysis is a method for documenting activities in detail in a compact and graphical way in order to better understand the process and to clarify potential process improvements”. The general procedure of a flow analysis should comprise the following steps:

1) Identify and categorize the activities of the process
2) Document the process as a whole
3) Analyze the process and identify potential improvements
4) Recommend suitable changes of the process
5) Implement the suggestions

Due to the limited time and extent of this study, step number five above will be left to the company.

There are different schemes and diagrams to visualize the flow depending on the purpose of the analysis. The symbols which are to be used and their meanings are described below.

O – Operation
An operation is defined as an activity which in some way transforms the ingoing good. One example is for instance the cutting of a board.

T - Transport
The transportation of a good from one place to another one, without changing the properties of the good, is defined as transport.

C – Control
To verify that the result of an activity fulfills the quality requirements, a control stations are used.

S – Storage
When an object lies in the storage area waiting to go to an operation or control activity, it is considered to be in storage.

D – Delay
The meaning of delay is when an object is in a queue for some of the activities above.

A process flow scheme should be constructed in such way that the reader gets an unambiguous view of the production line. For every activity, questions such as why? When? For how long? should be answered. Table 3.1 shows a typical presentation of a process flow scheme.

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>O</th>
<th>T</th>
<th>C</th>
<th>S</th>
<th>D</th>
<th>Time</th>
<th>Distance (m)</th>
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</tbody>
</table>

Table 3.1. Template process flow scheme. Source: Olhager (2000).
3.2.2 Layout diagram
To get a good overview of the physical arrangement of machines, storage areas control station, a layout scheme has to be made. As can be found in chapter 4.2, a map of the factory has already been made. However, a layout scheme should include only the relevant part of the process. It has to be made in such way that the reader easily understands how the production flows.

3.3 Planning
The following mathematical problem can be formulated to find the highest possible even production speed, given that the production is based on orders.

\[
\begin{align*}
\text{Max } & P \\
\text{such that } & jP \leq O_0 + \sum_{i=1}^{j} D_i, \quad j = 1, \ldots, N \\
& P > 0
\end{align*}
\]

Where
\[
P = \text{The highest pace of production (pieces per unit time)}
\]
\[
O_0 = \text{Initial order}
\]
\[
j = \text{Period index}
\]
\[
D_i = \text{forecasted demand for period } i
\]

The \( N \) constraints correspond to the fact that the accumulated production has to be less or equal to the initial order size plus the accumulated sales. The above expression is equivalent to a system of equation with \( N + 1 \) inequalities and only one unknown variable, \( P \). The solution to this system of equation can easily be obtained. The difficult part is, however, to forecast the \( D_i : s \).

3.4 Forecasting
3.4.1 Qualitative forecasting
Qualitative forecasts are intuitive forecasts and are based on subjective estimations. Examples of qualitative forecasts are surveys and expert reports.

3.4.2 Quantitative forecasting
Quantitative forecasting models build upon historical data. The most common models are called time series models, in which case the data is ordered chronologically with constant time steps, for instance a day, a week, or a month. The idea is to use old outcomes of one variable such as the demanded quantity of a specific product, and to use these outcomes to predict what the next outcome of the same variable will be the next time step.

Another quantitative approach to forecasting are so called casual models such as regression analysis and econometric models. In these, the outcome of one variable is assumed to depend on other
variables. One example could be that one tries to explain the demand of a good by variables such as weather and economic indicator variables.

The models which will be used in this report are time series models. Two such models are presented in detail below.

A time series can be divided into five components:

- Trend (T). A successive increase or decrease of a variable.
- Season (S). A pattern which return after a certain amount of time. Different seasons of the year is one example, economic cycles another one.
- Level (L). The level is the general average of the variable.
- Noise (N). Random variations which cannot be explained and do not have any specific pattern.

One way of combining the variables is via a multiplicative model:

\[ D = TSCLN \]

Another approach is to use an additive model, in which case all effects are assumed to start from a 100%-level, that is, sales in one period which lies 10% above the grand average results in a seasonal effect of 1.1.

\[ D = T + S + C + L + N \]

3.5 Choice of product portfolio

It is of great importance to investigate which products that should be produced given the available resources. To this end, a static point of view is taken over the horizon which is considered, that is, it is assumed that no new products are being developed. The goal is to find the best mix of products and the quantity of each product that has to be produced to maximize revenue. It is assumed that the fixed costs are unalterable.

\[
\begin{align*}
\max & \quad c_1 x_1 + c_2 x_2 + \cdots + c_n x_n \\
\text{subject to} & \quad a_{11} x_1 + a_{12} x_2 + \cdots + a_{1n} x_n \leq b_1 \\
& \quad a_{21} x_1 + a_{22} x_2 + \cdots + a_{2n} x_n \leq b_2 \\
& \quad a_{m1} x_1 + a_{m2} x_2 + \cdots + a_{mn} x_n \leq b_m \\
& \quad x_1, x_2, \ldots, x_n \geq 0
\end{align*}
\]

Where

- \( c_i \) = Contribution margin of product \( i \)
- \( x_i \) = Quantity produced of product \( i \)
- \( a_{ij} \) = Requirement of resource \( j \) to produce one unit of product \( i \), \( j = 1, \ldots, m \)
- \( b_j \) = The maximal supply of resource \( j \).
The constraints say that the use of each resource must be equal to or less than the total supply of this resource. The last constraint simply says that a negative number of any products produced is not allowed.
4. Current state of the factory

In order to analyze how the company can improve the reliability and speed of production, a proper analysis of the current state has been made in this chapter. First, a description of the different businesses of the company has been made. Section 4.2 describes the general layout of the plant and section 4.3 shows what the flow of the material looks like for the different business and 4.4 describes it through a process flow scheme. 4.5 explains how Dicomad categorize the quality of its different products. The working conditions are described in part 4.6 and a description of Dicomad’s previous and current customers can be found in section 4.7. The last section of this chapter, 4.8, describes each micro process of the production.

4.1 Businesses

Dicomad has two production lines. The main one is used for producing decking (see figure 4.1 (b)) and flooring and the other one produces custom made furniture (see figure 4.1 (a)).

4.1.1 Decking, tiles and flooring

For these products hardwood is used as the input material. Examples of hardwood that they commonly use are Ipé (Tajibo, Ironwood), Curupay (Curupaú) and Rosewood (Sirari). The first name indicates the international commercial name and the one in parenthesis the local name. Common for all these wood types, except the fact that they are esthetically magnificent, is that they can resist extreme climates very well. The wood is supplied by the customer and Dicomad is purely in charge of refining it to the final product. The positive aspect of this is that Dicomad does not need to bind any capital. Furthermore, the lead time will be shorter than if they would have bought their own wood. The negative aspect is that a general quality level will be hard to maintain. Many customers blame Dicomad for having done a bad job when the final product does not match the customers’ expectations, even though the reason for the poor quality of the final product is bad wood. Occasionally, Dicomad buys the wood themselves and refines it accordingly. The production of decking and flooring was running at very low levels during this study because of the global economic situation. In good times, the production line employs 15 workers in two shifts, but for the moment only 3 persons are employed. Some customers are in debt to the company and it is rather unsure if this money will be secured in the future. This has led to a lot of temporary storage areas in the factory for products which they have produced but not received the payment for.

4.1.2 Carpentry

In order to survive the hard times, Dicomad has established a second business line, a small carpentry with two employees. It produces doors, chairs tables and other similar products. The responsible carpenter is rather skilled and can produce almost whatever a customer asks for. In contrary to the decking, these products are sold solely to the domestic market. The input material to the carpentry, always softwood, is bought by Dicomad. The big difference between hardwood and softwood for Dicomad is that the tools used for hardwood wear out much faster than when treating softwood. Furthermore, it takes around four times longer to cut and drill hardwood.

Common for both of their businesses is that nothing is produced unless they have a customer for the good, i.e., an order is necessary to initiate the production. Even though their main business is running at very low levels, it has to be mentioned that their production levels also in good times are rather uneven. This is clearly a big problem, since an irregular production makes the planning of the business difficult and it makes it hard to maximize revenue. Especially the management of the
workers becomes very hard, since every worker requires around 3 months of training before being productive (Mr. Gonzales). Also in the view of the CEO, this uneven demand of their goods is the biggest problem for the company at the moment. Another problem which currently exists, and has existed since the establishment of the company, is that the workers are unreliable in many ways. Frequently, workers do not show up at work for unknown reasons.

4.2 Plant layout
Figure 4.2 shows the current plant layout. Note the many storage areas. Still, the figure does not fully convey the disorder in the factory. Many of the unmarked areas are filled with finished or intermediate products, raw material, waste, tools or disassembled machines. Machines will henceforth be referred to by the numbers given in figure 4.2.
1. Sandpapering machine (not in use)
2. Sandpapering machine (carpentry)
3. Drill (not in use)
4. Saw/drill (not in use for the moment, otherwise in carpentry)
5. Molder (decking)
6. Air cylinder (used for spray painting, mostly used by other company)
7. Saw (for width, length and cross, mostly used by carpentry)
8. Saw (not in use, otherwise for round shapes)
9. Saw (not in use)
10. Planer (for adjusting thickness, decking and carpentry)
11. Planer (for beveling, decking)
12. Drill (decking)
13. Drill (decking)
14. Saw (for adjusting length, decking)
15. Saw (for beveling, decking, carpentry)
16. Work table
17. Grinder (for tools)
18. Grinder (for tools)
19. Planer (not in use at the moment)
20. Saw (for adjusting width and thickness, broken down)
21. Planer (for straightening boards, carpentry)
22. Saw (for adjusting width and thickness, decking)
23. Drill (carpentry)
24. Work table (carpentry)
25. Work table (carpentry)

A. Space used by another company
B. Finished goods
C. Finished and intermediate goods for other company
D. Finished and intermediate goods
E. Raw material
F. Finished and intermediate goods
G. Finished goods
H. Finished goods
I. Intermediate goods
J. Finished goods
K. Intermediate goods
L. Finished goods
M. Cupboard for lamp, protective equipment and some tools
N. Intermediate goods
O. Painting of furniture (used by other company)
P. Tool storage
Q. Toilet
R. Office
S. Office
Figure 4.3. Example of disorderly (a) and orderly (b) storage.

Figure 4.3 (a) shows an example of how different inventories are mixed. Raw material (foreground) is mixed with intermediate goods just behind. In (b) finished, packaged products are stored in a good and orderly way.

Figure 4.4 shows the desired state of the factory according to Mr. Gonzalez. This is the state that would be reached if all customers collected their goods on time. The fact is, however, that this state seems to never have been reached according to earlier reports on the company.
Figure 4.4. Plan of the factory as Dicomad wants it. Scale 1:200

A. Space used by another company
B. Raw material
C. Intermediate goods
D. Finished goods
E. Cupboard for lamp, protective equipment and some tools
F. Painting of furniture
G. Tool storage
H. Toilet
I. Office
J. Office
4.3 Flow of material

4.3.1 Flow of material for carpentry

The used machines are for the carpentry sandpapering machine 2, saw 7, planer 10, planer 21 and drill 23.

Figure 4.5 shows a fairly typical material flow for the carpentry products. Since the parts vary greatly in appearance, very different processing is required and thus the flow may look quite different from that of figure 4.5. For example planer 10 is quite frequently used. In the flow demonstrated in figure 4.5 raw material (typically around five boards) is first taken to a random place in the factory, for example (1). In (2) the boards are cut lengthwise to a good width. They are then transported to (3) where the plane adjusts for possible curves in the material on two sides. When the two sides are
straight the cut boards are taken back to (2) to be cut into the exact desired width and length. Pieces can also be cut diagonally by this machine. When the pieces have the right shape they are taken either to the drill (5) or the sandpapering machine (4) to get the final finish. After this the pieces are taken to the working tables (6) either for assembly or for temporary storage in wait for other pieces to be included in the final assembly. The finished products are then taken to a new random place, for example (1), to be kept there until delivery. In a typical process the saw (2) performs three to six different sawing operations with the saw having to be changed over between each operation.

4.3.2 Flow of material for decking/flooring

The regularly used machines for decking and flooring are saw 22, molder 5, saw 14, saw 15, planer 11 and drills 12 and 13. Occasionally saw 7 is used. For special shapes saw 8 is used, this will in that case happen after step 6 in the process flow shown in figure 4.6. Saw 20 is normally used together with or instead of saw 22, but was during the time of the study broken.

Figure 4.6. Material flow for decking production.
Figure 4.6 shows the flow of a decking product requiring most of the possible steps of manufacturing. Many products do not include all the steps shown in figure 4.6. Products can go directly from step four to step nine or from seven to nine.

The sorted raw material boards are taken into the factory and stored at (1) just next to the first machine. The raw boards are then cut to the right width and thickness (2). Between the two operations the boards are stored on the floor close to (3). Thus, the boards are cut, carried to (3), carried back to (2), cut again and then carried back to (3). The boards are then processed in the molder (4) where they get the right shape before they are stored at (5). The next step is to cut the long boards to the right length (6) which is normally done in saw 14, but at full production saw 7 is also used for this purpose. The boards will after this operation be stored, most likely close to the machine performing process (6). Next is the beveling operation, (7), of the short end of the now short boards. For garden tiles, around one third of the boards are drilled (8) to allow for assembly with other boards in square tiles. The tiles are then assembled and stored (9) before they are packaged (10) and stored as finished products (11). Note that the locations of the different kinds of inventories are quite random and can appear in other places than those indicated in figure 4.6.

4.4 Flow analysis

As mentioned in the introductory chapters, Osbeck and Widén (2007) suggested how to modify the layout of the factory such that an optimized flow could be achieved. Dicomad implemented that layout accordingly and they are happy with it today, but in order to rule out the fact that there might be another arrangement which is more effective, a process flow analysis will be carried out. Furthermore, this analysis is essential for the project as whole in order to understand what and how the products are being produced. Table 4.1 shows the current state of the process flow. The table presented in chapter 3.2.1 has been used. As operation times and especially storage times vary greatly, all times shown in table 4.1 are estimates. We have omitted most transports as the distances are negligible. The step numbers concur with figure 4.6. As the first three steps in table 4.1 occur outside the factory and are not shown in figure 4.6 these have been named i, ii and iii.
Process flow scheme for deckings, current state

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>O</th>
<th>T</th>
<th>C</th>
<th>S</th>
<th>Operators</th>
<th>Time</th>
<th>Distance (m)</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>i</td>
<td>Classification of input material</td>
<td>X</td>
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<td></td>
<td>3</td>
<td>10 seconds</td>
<td></td>
<td></td>
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<tr>
<td>ii</td>
<td>Wait for transport</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hours-days</td>
<td></td>
<td></td>
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<tr>
<td>iii</td>
<td>Transport of input material</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>2 minutes</td>
<td>60 meters</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Wait for saw</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>1-2 days</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>Saw</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>1-2 days</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td>Wait for molder</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>1-2 days</td>
<td></td>
<td></td>
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<tr>
<td>4</td>
<td>Molder</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>30-60 sec</td>
<td>Molder 5</td>
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<tr>
<td>5</td>
<td>Wait for cutting length</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>1-2 days</td>
<td></td>
<td>Optional</td>
<td></td>
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<tr>
<td>6</td>
<td>Cutting length</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>30-60 sec</td>
<td>Optional. Saw 14</td>
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<tr>
<td>7</td>
<td>Beveling</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>30-60 sec</td>
<td>Optional. Planer 11 or 15</td>
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<tr>
<td>8</td>
<td>Drilling</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1-2 minutes</td>
<td>Optional. Drill 12 or 13</td>
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<tr>
<td>9</td>
<td>Wait for packaging</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>1-2 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Packaging</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>5-10 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Wait for transport</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>weeks</td>
<td></td>
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</tbody>
</table>

Table 4.1. Process flow scheme for decking production.

4.5 Quality

Dicomad categorizes the quality of their products according to a 3-level system; A, B and Local Market. A-quality means no defects on the wood. B-quality means that there are some defects on the product, but not on the visible side. Products classified as Local Market can never be sold to any international customers due to too many defects.

There can in essence be said to exist two types of quality deficiencies: those already in the raw delivered wood and those created by the process. Deficiencies in the wood are such things as wormholes and rotten parts. The problem with these kinds of imperfections is that they can only be located quite late in the process, after the molder and then a lot of work will have already been done on the piece of wood. The easiest way around this problem is to buy better wood, but as Dicomad primarily provides a refining service on wood that the client has already bought it is hard for them to control the quality of incoming materials.
The second type of product quality deficiency that is created by Dicomad itself is for example bad finishes on products. The most common problem is a bad result from the final beveling operation on the short end of grooved anti-slip boards. The beveling process creates small splinters leading to both an unsatisfying look and a potential risk for injuries. These and similar problems are typically caused by running material too fast through machines or working with blunt blades. Dicomad knows how to get around this issue only they do not bother for all their products as many customers do not demand the highest quality. Thus, according to Mr. Gonzalez, these shortcomings are not a problem.

4.6 Working conditions
The working conditions in the factory at the time of the study were, quite frankly, appalling. The four main problems are (1) light, (2) air quality, (3) dirt on the ground and (4) general disorganization. A lesser problem is the noise level. Most machines are very loud, but ear protection is available at the workers’ disposal. The problem is that they do not use it.

The light is decent in the front parts of the factory as sunlight comes through the front doors. For the rest of the space, the light is dreadful. On the left wall (seen from the entrance) there are some small holes to let in light and a couple of bigger windows. On the right side there are only the couple of windows. These do not, however, add much light. There are four rows of fluorescent lamps hanging evenly spread out from the ceiling and some other ones scattered around the walls of the factory. Most of these are turned on during the full working day and do add some light, but not nearly enough.

Regarding the bad air quality it is caused by sawdust. Mostly the saws, but also other machines create huge amounts of sawdust that shoot off in all directions contaminating the air. No machines, except for the molder, have vacuuming constructions and there is virtually no movement of air in the factory. There are protective masks at the workers’ disposal.

The dirt on the ground has the same root cause as the bad air – sawdust. It is not physically dangerous in the same way as the dust in the air but it makes working harder as it covers things. It can often be hard to see what kind of wood is which as it is covered in a thick layer of sawdust. While not a direct physical danger, the sawdust can be an indirect cause of peril as it significantly increases the risk of fires. Furthermore, an unclean factory is an important indicator of the general level of ambition. If one does not think cleaning is important, one might very well start slacking off on other things as well.

The disorganization is a symptom of the same cause as the dirt – disregard for order. Disorganization is evident in all aspects of the work. To start with, the layout of the factory is far from optimal. It was created two years ago, with somewhat different machines and before the carpentry section was started. Still, despite large changes in the work it has remained the same. Additionally, there are many unused machines sitting idly around the factory. Secondly, the organization of inventory is probably the most evident proof of the lack of order. Raw material is mixed with finished and intermediary products all around the factory. Some products have sat in the same place for over six months and an estimated 60 % of the factory space is occupied by products in different stages of production. There are no indicators at all of where to store inventory, work spaces for machines or walkways. Furthermore there is no standardized way of using machines and no instructions exist.
Figure 4.7. Examples of dirt and disorganization. Upper left: Thick layer of sawdust on floor after sawing operation. Upper right: two types of wagons standing idly at a random place in the factory. Lower left: intermediary products waiting between two machines. Lower right: huge pile of wooden chips from planer.

Figure 4.8. Examples of unused machines. UL: Broken down saw. UR: Drill. LL: Saw. LM: Sandpapering machine, never used. LR: Saw.
Examples of disorder can be seen in figures 4.7 and 4.8.

4.7 Customers
As of today, Dicomad has only domestic customers. The positive side of such customers is that the payment is made directly at delivery. The negative aspect is that they are not trustworthy in terms of meeting payments. The company used to have international customers from Japan, Mexico, Spain and the USA. These customers are much more reliable than the domestic ones. However, Dicomad’s business with these parties is on hold. There are ongoing negotiations with some of the customers of how to proceed the collaboration. Based on the outcome of these negotiations, the production will be set accordingly. Worth mentioning is that these customers are often only intermediaries; Dicomad is often not aware of who the final user of their products are.

4.8 Processes
4.8.1 Sorting
Today the first inventory of raw material (figure 4.9) is located outside the factory in an open area on the ground. The wood is either covered by plastic tarpaulin or not covered at all. Before transport into the factory and the second raw material storage the wood is classified according to width. This is done with the help of a manager and requires two people for the lifting. The wood is then transported by a wagon pulled by hand into the factory storage. Hence each board, which can weigh up to 100 kilos, is handled three times in the process necessitating many strenuous lifts.

4.8.2 Sandpapering machine 2
Sandpapering machine no. 2 (figure 4.10) is used in the production of furniture. The piece to be sandpapered is laid on the wooden board beneath the band and as the band is rotated it is pressed against the piece by an operator using a wooden chock. The wooden board can be slid laterally on two rails allowing for easy insertion/retiring of the processed piece into the machine. During each sandpapering process, the piece is checked several times visually to ensure an even and smooth surface in all areas. The wooden board is more or less in chest height. The setup time for this machine is virtually zero and the sandpaper band has a very long lifetime. A fair amount of sawdust is created from this machine.
4.8.3 Molder 5
The molder, seen in figure 4.11, is used as the second or third machine in any decking or flooring product. It includes five different saws and planers that together can create virtually any cross section shape. When the boards exit the machine they have their final shape but not the correct length. The molder is the only machine with a vacuum devise to get rid of sawdust, thus it is harder to move around the factory than the other machines. The boards are inserted into the machine manually by an operator and once in they are fed forward automatically by the machine. A current problem is that the molder uses great amounts of power and cannot be run at the same time as saws 20 or 22 due to a weak transistor.

In full production the blades have to be changed at least every six hours and the change takes two hours. In reality they are changed as often as every four hours to ensure premium surface quality. Thus, the time of changing blades is 1/3 of the total working time. The changes are done at lunchtime and at the end of the day to minimize the loss of production time but they are still clearly affecting the uptime. Apart from changing blades, regular changeovers of the machine take one to two hours as the calibration tools are not precise. Although clear gauges for readjusting the saws and planers are installed in the machine, for each setup a few test boards have to be run and measured and the machine recalibrated. Fortunately, changeovers are seldom as one order normally consists of only one type of wood profile and thus the molder does not have to be readjusted more often than every two weeks at most. Still, the uptime of the machine is close to 60 %, a terrible figure.

When the board of wood exits the machine it is received by a second operator who then places it on the floor in wait for further transport.
Figure 4.11. Molder no. 5 used in the decking production to create the final cross-section of a board.

4.8.4 Saw 7

Saw no. 7, seen in figure 4.12, is used by the carpentry for cutting wood into the right length, width and to cut diagonally. It is made up of two tables of which the left one is movable laterally along two rails. Between the two tables is the blade. The tables themselves are clean and all fixtures are created with the help of a board and/or a piece of wood and a clamp. The right measurements are retrieved by manual measuring.

The right, fixed table is used for cutting the width of long boards. In that case the board is pushed through the saw by hand. This process requires two people; one for pushing the board through the machine and one for receiving it on the other side. To cut the right length the left table is instead used and the piece of wood is held still as the table is moved. In this case a fixture is set up on the left table to hold the wood still and ensure that the correct length is cut. This process only requires one operator.

Each setup takes around 30 seconds to five minutes depending on the following operation, and as wood is cut in batches of no more than a few boards at most, and each board is processed in this machine a typical number of three to six times, the changeover times add up to at least 50 % of the total time spent at the machine.

A lot of sawdust is created from this machine. There is also much waste in form of cut-off pieces of wood. These are thrown on the ground in front of the machine and cleaned up at a later time.

Changing of blades takes around 15 minutes but is rarely done as this machine normally only works with soft wood.
4.8.5 Planer 10

Planer no. 10 is used for getting the right width of boards. It is only used by the carpentry. The cut boards of wood are inserted manually by an operator into the backside of the machine as seen in figure 4.13. Another operator receives the board on the other side and either hands it back to the first operator to be inserted again or puts it on the ground to later be moved to the next process. This machine creates large amounts of wooden chips that exit the machine through the hole in the upper mid part of the machine as seen in figure 4.13. They are steered forward by the piece of metal on top of the machine and end up on the ground in front of it. The chips are later cleared away by hand. No tools are needed for this machine except for changing the blades which takes 30 to 60 minutes. Fortunately it is not done often as the machine only works with soft wood. The correct height is set using the wheel seen on the left side of the machine in figure 4.13. The process only takes a few minutes.
4.8.6 Saw 14
Saw no. 14, shown in figure 4.14, is used for cutting processed planks of wood out of the molder into correct lengths. The plank is placed on a movable table which is then moved forward to cut the wood. The correct length is adjusted on the left, movable part of the machine with the help of a fixed measure. Only one operator is needed to work the machine.

Saw 14 produces considerable amounts of sawdust, although not as much as saw no. 7 or no. 22 as it only cuts boards on the short side.

An important function of the machine is to cut away bad parts with, for example, wormholes in them. Accordingly, there is a fair bit of waste, around 24 % (Warström & Westerborn, 2009). It is the operator who performs the quality check, visually, and decides which parts to cut away.

4.8.7 Planer 21
Planer no. 21, seen in figure 4.15, is used to straighten boards for the carpentry. The long board of wood is pushed through the machine manually by one operator and received by another one. The machine can be used by only one worker both pushing and receiving the piece of wood but this is not optimal as it increases the risk of mistakes. To stabilize the movement there is a metallic caliper on the right side. The thickness of the plane is set by adjusting the blade height-wise with a wheel on one side of the machine. This process only takes a few minutes. Each piece of wood is processed in the machine a number of one up to ten times depending on how straight it was to start off with.

The waste from the machine is wooden chips, which come out of a hole in the lower back end of the machine. This ends up on the floor and is later removed by sweeping and putting the waste in bags by hand.

Changing of the blades takes around 30 minutes but is not done very often as the machine only processes soft wood. It includes using different tools such as wrenches, measuring tape and pieces of wood.
Figure 4.15. Planer 21 used by the carpentry to straighten boards. The operator is readjusting the machine in the picture.

4.8.8 Saw 22
Saw 22, shown in figure 4.16, cuts incoming boards into the correct width. The board is pushed through the machine by one operator and received by another one. The cut boards are then placed on the floor before transport to the next machine. The machine consists of a table with a blade in the middle and a wooden board on the right side which decides the width of the cut boards. The width is measured manually using a tape measure and adjusted with the help of a wrench to loosen and fasten two screw nuts. Big adjustments are made by moving two screws connected to the wooden board in pre-made holes in the working table. Smaller changes are made by moving the wooden board construction along the screws in length-wise holes in the construction. These holes are five centimeters long and hence changes of up to five centimeters can be made fairly quickly, whereas bigger changes take considerably longer. All changes take between one and ten minutes.

This machine creates large amounts of sawdust both upwards and downwards. Also, long pieces of waste boards are created and placed on the floor to the side of the machine and later transported out of the factory to be stored at the yard in wait for possible further use.

The blade must be changed around once every four hours in full production which takes around 15 minutes.
4.8.9 Packaging
Shorter planks of around 50 cm to be used for garden tiles are usually packaged 100 together, five in width and 20 in height. This is most often done at a worktable next to the molder. Packaging is done by two employees manually by tying plastic straps around the planks. One worker stands on the ground to steady the strap while the other stands on the table leaned over the pack of planks to fasten the two ends of the plastic strap together with a metallic clip. Afterwards, the package of wood, weighing around 65-105 kg, is lifted by the workers by hand from the worktable to a pallet on a lift. This lift is both extremely bad for the back as well as being dangerous as the risk of dropping the package on toes or feet is high.

4.8.10 Summary of processes
Table 4.2 lists the scrutinized processes.

<table>
<thead>
<tr>
<th>Process/machine</th>
<th>Business</th>
<th>Purpose</th>
<th>Process number in figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorting</td>
<td>Both</td>
<td>Organizing raw material</td>
<td>-</td>
</tr>
<tr>
<td>Sandpapering machine 2</td>
<td>Carpentry</td>
<td>Smoothing product surface</td>
<td>Step 4, fig. 4.5</td>
</tr>
<tr>
<td>Molder 5</td>
<td>Decking</td>
<td>Creating final cross-section</td>
<td>Step 4, fig. 4.6</td>
</tr>
<tr>
<td>Saw 7</td>
<td>Carpentry</td>
<td>Various sawing operations</td>
<td>Step 2, fig. 4.5</td>
</tr>
<tr>
<td>Planer 10</td>
<td>Carpentry</td>
<td>Adjusting thickness</td>
<td>-</td>
</tr>
<tr>
<td>Saw 14</td>
<td>Decking</td>
<td>Sawing length</td>
<td>Step 6, fig. 4.6</td>
</tr>
<tr>
<td>Planer 21</td>
<td>Carpentry</td>
<td>Straighten boards</td>
<td>Step 3, fig. 4.5</td>
</tr>
<tr>
<td>Saw 22</td>
<td>Decking</td>
<td>Saw width</td>
<td>Step 2, fig. 4.6</td>
</tr>
<tr>
<td>Packaging</td>
<td>Decking</td>
<td>Packaging</td>
<td>Step 10, fig 4.6</td>
</tr>
</tbody>
</table>

Table 4.2. Summary of scrutinized processes.
5. Analysis and improvement suggestions

Based on the theoretical background and the current state analysis, suggestions of how the production can be improved are been made in this chapter. Paragraphs 5.1, 5.2 and 5.3 shortly describe the matters of evening out the production, optimal portfolio choice and planning. In 5.4 possible new layouts are discussed. The working conditions are addressed in 5.5 and finally each process is discussed individually in 5.6.

5.1 Evening out the production

Transparency from Mr. Gonzales side has been a big problem in order to do both quantitative calculations on how the production can be evened out. The required data was simply not provided by Mr. Gonzales. Hence, the theory has not been used, but still left in the report in case Mr. Gonzales whishes to use the theory presented.

5.2 Optimal portfolio choice

The lack of transparency by Mr. Gonzales has made the choice of a revenue maximizing portfolio impossible. The required data was simply not given by Mr. Gonzales.

5.3 Planning

One of the main questions in this paper is to come with suggestions of how the production of Dicomad can be evened out. As mentioned earlier in the report, the great variation in demand of Dicomad’s products has lead to difficulties in terms of hiring personnel and in general terms running the business in an optimized way. The total production of the factory has to some extent evened out thanks to the carpentry. However, the goal in this section is to analyze the decking business and try to even out the flow of this production line as a standalone entity. The reason for this is that the decking business is the most profitable part of the company, and Mr. Gonzales has expressed his wish to have an investigation made as described above. The Following questions have to be answered:

- What shall be produced?
- What quantity shall be produced?
- When shall the production take place?
- Which resources shall be used?

The lower speed of production as a consequence of the leveled out production during low-demand periods, such as the prevailing state, has to be weighed against the importance of fast deliveries. It is hard to quantify “the importance of fast deliveries”. However, Mr. Gonzales has not provided the required data in order to accomplish the desired calculations in order to come up with an answer of how the planning should be done.

5.4 New layout

Below three new factory layouts are presented – major, medium and minimal reorganization - with the purpose of creating a clearer flow of material, especially in the carpentry section of the factory. The changes will also improve other factors such as creating larger dedicated storage spaces and simplifying cleaning. The different proposals will need various amounts of effort to be realized going from most to least effort. In this section the previously used numbers are kept to see which machines have been moved around.
5.4.1 Major reorganization

The first suggestion, shown in figure 5.1, is the most radical one. Major changes are made to the factory layout. First of all, the rented space (A) and its storage space (C) are kept in the same place as they are close to their office (S) and a lot of movement happens between these three areas.

![Figure 5.1. Major reorganization layout.](image)

Regarding the carpentry the machines 1, 3 and 4 are moved to the upper left corner of the factory as they are not in use. The long term goal should be to get rid of these machines by selling them if no plans of using them exist. The same goes for machines 9 and 19 from the main business. The air pump (6) is moved close to the back door as its only use is to provide air pressure for spray painting, which is done outside at the back of the factory. Regarding the actual process, the two planers 10 and 21 will be moved to create a work group with saw 7 at the beginning of the carpentry line. This
work group has two main reasons. First of all the layout reduces transport of material, as these machines are often used in various sequences a various number of times to process a part. The workgroup-layout makes it clear that there is no given flow through these machines. Instead they should collectively be seen as one process to create the final shape of a piece before surface smoothing and assembly.

The workgroup-layout has the additional advantage of simplifying waste removal. As all machines are placed around an imaginary circle the waste will end up in the same place. With a movable waste basket in the middle most waste is easily collected directly in the basket and that which ends up on the floor is faster collected for all three machines simultaneously than for each one individually. When one bag is filled with garbage it is removed and another one put in the holder. A holder for a plastic bag roll will be placed on the wall next to the machines.

As the carpentry products are made in very small batches a small raw material storage is designated on the upper side of machine 7. This will not be bigger than to accommodate a few boards.

The second work group in the carpentry is more or less identical to the current look, only it has been moved further into the factory. It consists of the sandpapering machine (2), the drill (23) and the two work tables (24 and 25). The blackboard which currently hangs above the work tables is moved to hang on the wall above the drill instead.

Behind the work tables, in the current location of the second work group for the carpentry is the finished products inventory for the carpentry. Finished products should not be stored anywhere else. There are no real intermediary storage spaces designed into the line as the work in progress (WIP) is, and should be, kept very low.

Regarding the main business the two saws 20 and 22 are moved to a parallel position as these perform the exact same task. Before these, there is a small raw material inventory of 5x6 meters. As it has been estimated that the factory is too small to store all raw material within it, the exterior is used as the main raw material storage and this small storage is only used to store one batch of sorted boards. It is important that the area is five meters wide as boards can be up to five meters and it is advantageous to store the boards in the direction of the flow to reduce unnecessary movement.

After the first sawing operation there is a large buffer as the saws and the molder cannot currently be run simultaneously. This buffer is 5x4 meters and can consequently accommodate one 20 foot container of material (6x2 meters).

The molder (5) has been moved to fit in the line. This is a difficult operation as it is a big machine with a vacuuming pipe going to the left wall. In order to move the machine, the pipe would accordingly have to be extended with additional material. Alternatively, the vacuuming machine would have to be moved to sit outside the north wall.

After the molder the batch size can, and should be radically reduced to avoid unnecessary buffers. Thus a smaller buffer is designed in after the molder. It is long to accommodate the still long boards. Next is the sawing into the correct length, done in saw 14. Remember that this operation is
occasionally done in saw 7 as well during high production. Hence, saws 7 and 14 are placed on alternate sides of the buffer to reduce transports.

If decking is produced, the cutting of the length will be the last operation and the finished boards of wood will be transported to the packaging operation (16). For some special products such as fences the saw number 8 will be used to saw the correct shape of the boards. Next for these products as well as tiles the short boards will beveled on the short side in machines 15 and 11. Notice how these are placed in a 45 degree angle to shoot wood chips in the same direction for easier cleaning. In this mini work group a waste basket like the one in the first work group of the carpentry is placed between the machines to simplify cleaning. As some parts in the carpentry are also beveled these machines are placed in close connection to the carpentry.

For some products, such as tiles, some parts are drilled after the beveling operation to allow for screws. This is done in drills 12 and 13.

The next and final two steps are assembling the boards to finished products and then packaging them or just packaging the boards without assembly. This is done at the two work tables at 16. After this operation the finished and packaged products are transported to the finished products inventory.

The two machines that sharpen tools (17, 18) are moved to the south wall to be separated from all production.

One slight problem with the suggested layout apart from the fact that it will need fairly large movements of machines is that the machines used for the main business are placed right between the west wall and the four columns in the middle of the factory. It is somewhat preferable to keep machines close to walls or the pillars as electric cables can be kept off the floor. In the suggested layout the cables will have to be placed on the floor. This is, however, not a major problem and not important enough to consider another layout.

5.4.2 Medium reorganization
Since the molder would be quite difficult to move another layout has been developed which does not include any movement of this machine. The layout, shown in figure 5.2, resembles the one shown in figure 5.1 to a large extent. The carpentry section is identical except for the fact that saw 7 and planer 10 have switched place. The reason for the swap is to get saw 7 as close to saw 14 as possible as the latter one has inevitably been moved down in the factory compared to figure 5.1.

The main business line much resembles the one in figure 5.1 as well, only it has been moved slightly along an imaginary square in the factory. Instead of beginning in the northeast corner of the factory and finishing close to the west exit it now starts in the middle north part of the factory and instead ends up closer to the east exit. The main problem with this layout is that the finished products inventory will be more spread out. The largest part of it is still in the middle of the factory, but a small area is also placed in the northeast corner. The raw material area is kept small and moved to the west compared to the location in figure 5.1. The positive aspect of this inventory layout is that if
it is realized that it would be optimal with a larger raw inventory and smaller finished products inventory it will be very simple to adjust for.

Another slight drawback of this layout compared to the previous one is that the beveling machines (15 and 11) are placed farther away from the carpentry. As they are quite seldom used by the carpentry this is not, however, a big issue. Besides, the factory is very small so there is only a few meters difference in walking distance compared to the previous suggested layout.

As in the previous layout, carpentry goods will enter and exit through the west gate and main business goods through the east.

Figure 5.2. Medium reorganization layout.
5.4.3 Minimal reorganization

The last layout suggestion looks somewhat different to the two previous ones. Here, only the most urgent machine moves have been realized. This suggestion, shown in figure 5.3, does not require the same effort as the two previous ones regarding machine moves. Still it looks quite different to the prevailing layout.

![Diagram](image)

In figure 5.3 only two machines have been moved to the northwest corner of the factory, namely saw 9 and planer 19. Machines 3 and 4 have instead been moved to the wall close to their original location. In this way they are not in the way of movements between the two carpentry work stations. Nonetheless, they can be utilized from the positions close to the wall if needed in the future. A similar move has been made with sandpapering machine 1. It has simply been turned 90 degrees and moved to the wall to get it out of the way. This machine cannot be used in the position suggested in figure 5.3. If the 90 degree move is left out, however, the machine will function in the new position.
Otherwise the second work group in the carpentry is left intact. The first work group looks the same as in figure 5.2. The move of planers 10 and 21 is absolutely essential. Furthermore, the air pump (6) sits in the same position as in figures 5.1 and 5.2 as it makes no sense keeping it where it was at the time of the study.

Regarding the main business, fairly big changes have been made as they are considered to be necessary to create a somewhat clear flow. Nonetheless, the moves have been kept to a minimum and as short as possible.

The saws 20 and 22 are moved to the same position as in figure 5.2 and the molder is kept in place. A difference in this suggestion compared to the previous ones is that the saw 14 has not been moved. Still, with the move of saw 7 these two do not sit too far apart from each other. Saw 8 has to be moved to be included in the regular production line. Beveling machines 11 and 15 are placed in the same mini work group as in the other suggestions and in about the same place. The drills 12 and 13 have been moved slightly to make room for the inventory but are still placed next to the same pillar as before. Finally, work table 16 has been moved down to complete the line.

The two tool sharpeners remain in the current position.

The big drawback with this layout is the considerably smaller inventory and the fact that the carpentry will not have its own inventory clearly separated from the main business one.

Also, the fact that a few unused machines have not been completely removed from the used part of the factory floor creates unwanted disorder and is also an obvious contributor to the waste of floor space resulting in less inventory space.

5.4.4 Comparison of the three suggestions

It is clear that the first suggestion is the optimal one and that the last one has the least advantages from a lean production perspective. The first one has the clearest “line” layout for the main business and the clearest divide between work area and inventory. Actually, the designed raw and finished products inventory is slightly bigger for the second layout than for the first with 272 against 268 m2. The first layout is still preferable as the inventory is much better divided. The third layout has a considerably smaller storage area of 198 m2 due to the inferior arrangement of the machines.

The choice of which layout to actually implement, i.e. which one is best given the previous look, is not, however, as easy as saying which one is the best in general. The third suggestion has the advantage of requiring the least work to get in place. All the same, it does need considerable machine movement. The first and second suggestions are very similar regarding the movements of machines. The only real difference is that the molder is not moved in the second suggestion. This, however, is a big difference as the molder requires a considerable amount of work and time to be moved. Given this fact, the suggestion is to go for layout number two. It is far superior to layout number three but does not need that much more work to realize and it is almost as good as layout number one without needing to go through the trouble of moving the molder.
<table>
<thead>
<tr>
<th>Criterion</th>
<th>Major reorg.</th>
<th>Medium reorg.</th>
<th>Minimal reorg.</th>
<th>Current state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear flow</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Speed</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Transportation</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Storage space</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Ease of reorganization</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Separation of businesses</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>26</strong></td>
<td><strong>27</strong></td>
<td><strong>19</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

*Table 5.1. Comparison of the three layout suggestions with the current state. The numbers are given on a scale from one to five where five is good and one is bad.*

In table 5.1 a quantification of the benefits of the different layouts has been attempted. The numbers are based on observations of the work environment and qualitatively weighed by the authors. This ranking concurs with the previous discussion about the layout suggestions as it points to the medium reorganization as the best alternative.

**5.5 Working conditions**

**5.5.1 Light**

Improving the light is one of the most urgent issues for Dicomad and it is such an easy problem to correct. There are a number of ways in which to increase the light. First of all it is necessary to let more sunlight into the working area. This is easiest done by making windows and light holes in the roof. Regarding the walls, some attempts have already been made to improve the light by punching out a few bricks. This has, however, not made a big difference as a hole the size of a brick does not let in nearly sufficient light. Figure 5.4 shows a couple of different ways to let more light in through the walls. (1) shows the current look of the west wall and (2) a wall with more and larger windows. These windows should just be holes in the wall to let air through. (3) shows another solution using bricks with holes in them. Of course (2) and (3) in figure 5.4 could be combined to bring even more light into the factory. Considering the current look the best option would, nonetheless, be (2), i.e. creating more and bigger windows in the existing wall as building half a new wall would require a large investment in both labor and material. Observe that figure 5.4 only shows the west wall. Of course these changes should be implemented on all walls.

An additional advantage with “opening up” the factory is that it will create better air circulation hopefully reducing the dust levels somewhat.
It is furthermore possible to let more light in through the roof, which today is completely shut. The operation of cutting a few holes in the metallic roof and covering them with acrylic glass is not a difficult one and does not require a large investment.

A third and easy way of increasing the light is to paint all walls and possibly the floor white. This will spread the light better in the factory as well as exposing dirt.

The above changes will all enhance the light in the factory at daytime and thereby improve the working conditions as well as reduce the energy usage (today around 15-20 fluorescent lights are lit constantly). The factory is, however, also functional at nighttime which means artificial light will still be needed. It is crucial that better lamps are installed to bring sufficient light to the factory in the dark hours. The total energy usage will likely be reduced anyway with the increase of sunlight. The current fluorescent lights are evenly spread out above the floor in a good way; the only problem is the quality of them. Additional lights should also be installed on the walls around the factory pointing downward or upward so as not to dazzle the operators.

5.5.2 Air quality
Regarding the air quality, the only way of really improving it is by installing a proper vacuuming system. This option does, however, require an investment that is not affordable for the moment.
Another way of improving the air is by opening up the factory by using the techniques described in chapter 5.5.1, using bricks with holes or more windows. This will create a natural air circulation in the factory, which will hopefully blow away some of the sawdust.

5.5.3 Dirt on the ground and disorder
These are really two different issues, but they have been clumped together since the solution to both of them more or less spells 5S. Before beginning with that, however, it should be noted that the measures to improve air quality will also improve the dirt situation - less dust in the air means less dust on the ground.

From here the suggestions to improve cleanliness and disorder will follow the steps of 5S.

Sorting – will concern tools used in the factory. The actual tool storage is actually well organized and is not in need of an urgent touch up. The big change that can be done regarding sorting is simply taking away the need for some tools. Some machines today require external tools for the set up. These can, to a large extent, be designed away for both quicker set-up times and less disorder. More about this in chapter 5.6.

Set in order – is largely improved through a new factory layout. The layout will only be the beginning, though. So as to keep everything in order the places for everything must be marked. The easiest way of marking floor areas is by placing duct tape on the floor and writing in each area what it should be used for. By using tape, it is easy to change the areas if needed. Note that everything should be marked; machines, trash cans, tools, inventory etc. Nothing other than what is supposed to be within an area should be allowed there. It is evident that the knowledge of setting in order exists in the company today as the tool storage room is well organized; this knowledge only has to be applied to the whole factory.

As described in chapter 5.4 plastic bags for removal of waste should be stored in a holder close to the area where it is needed. If some tools used in setting up machines cannot be designed away these should be stored next to the machine with a clearly marked space for each individual tool. In this way there will never be any insecurities regarding which tools are needed and thus the chance of making mistakes as well as learning curves will decrease. Exact descriptions of micro workplaces will be described in chapter 5.6.

Shine – is a basic concept that will get rid of the dirt and waste in the factory. The first, and best step in getting rid of dirt is by designing a clean factory. By creating the work groups described in chapter 5.4 waste will automatically end up in the same area for a number of machines resulting in easier collection and removal. Further design elements include creating easy access to plastic bags, brooms and other cleaning tools. While design for cleanliness is the best way of getting rid of dirt and waste as it actually prevents the “sickness”, not only treats the symptoms, it will be virtually impossible to reach perfection using this method. Hence, some regular old-fashioned cleaning will be needed.
Figure 5.5. Instructions for cleaning Saw 21.

Attached to each machine there should be clear instructions of how to clean it directly after it has been used. Furthermore, the instructions should include how the machine has to be cleaned weekly, monthly, or whatever time frame is relevant for it. The instructions for Saw 21 can be found in figure 5.5.

Apart from cleaning instructions for each machine, there should also be instructions of how and how often general areas in the factory have to be cleaned. These instructions should be put on the walls around the factory.

*Standardize* - In the same way that there are instructions for how each machine has to be cleaned, there should be instructions of how each machine should be operated. These instructions are placed on the same A4 paper as the cleaning instructions in order to avoid unnecessary objects around the factory. The manuals should have been developed in collaboration with the workers in the factory. For the operating instructions it should say in what exact order the steps should be carried out. For
the cleaning instructions there should be different sections depending on the regularity of the cleaning, e.g. after each use, daily or weekly (see image 5.5 and 5.6).

**Instructions for operating Saw 21**

- Two operators needed.
- Check that machine is clean and that the blade can move freely.
- Adjust the machine to the right width using the scale attached to the machine.
- Turn on using the switch on the wall.
- Operator 1 pushes the boards through the machine manually using the chuck as a stabilizer to get the right width.
- Operator 2 receives the board and hands it back over to Operator 1 if more work is needed or puts it in the buffer zone.
- When all work is done turn off machine.
- Clean machine according to instructions below.

![Image of instruction sheet](image)

**Figure 5.6. Example of an instruction sheet for operating Saw 21.**

These instructions will probably not be used that often as most machines are simple to operate and the workers will know by heart how to do it. However, they fill two important functions. First of all, they could help slightly in the introduction of new operators in the factory. Most importantly though, it is of essence to have written down instructions of how to use a machine for consistency’s sake. In order for workers to be able to communicate ideas about machines it is absolutely vital that they all use them in the same way. If one worker has an idea about how to improve the usage this should be discussed and if it is decided to be implemented new instructions should be made that everyone should follow. Furthermore, the instructions are important to make sure that operating procedures do not change accidentally over time.

*Sustain* – It has to be remembered that the manuals themselves will not make the operators work in a standardized way; the production manager has to teach not only the instructions to new workers,
but also, the importance of following them. He has to regularly check that instructions are being kept and if not discuss and evaluate new ways of working with the operators. Regular monthly checkups should be scheduled, for example the first Monday every month to examine all working procedures.

Moreover, it is of essence that the CEO, Mr. Gonzalez and the production manager work actively to introduce the 5S concepts. It is not sufficient only to print instructions, create a new layout, place lines in the floor etc. All parts of 5S have to be worked with actively to convey the importance of the system to everyone in the factory and make sure it is being followed.

5.6 Processes
Parts 5.1-5.5 have dealt with macro issues in the factory, i.e. the production as a whole. This section will instead deal with each process individually.

5.6.1 Sorting
First of all, it is completely unnecessary to use a manager to classify the width of the boards. This is a very simple process and should not require more than the two people needed for the lifting. Regarding the handling of boards, three lifts is one too much. It is much better to simply divide the boards into the different categories directly on the wagon and then transport them into the factory step by step. The option of not having a raw inventory outside, but instead keeping all raw wood inside the factory has been ruled out due to the limited floor space.

5.6.2 Sandpapering machine 2
We cannot find any ways to improve this process.

5.6.3 Molder 5
The biggest issue with the molder is clearly the horrible uptime. It can be drastically improved by investing in a new type of blades that will allow most of the set up process to take place outside of the machine resulting in a changeover time of just a few minutes. Needles to say, this requires a large investment. This option is not one we will recommend or delve deeper into as we focus on quick, cheap improvements. The same goes for the power problem, which can be solved through buying a new transistor.

Concerning the actual work, it would be optimal if only one person was needed to operate the machine. Then the next one could operate the cutting machine, which only requires one worker, thereby virtually removing the need for a buffer between the molder and the cutting saw. There is really no need for a person working only with receiving processes boards. Instead a construction collecting the finished boards would be better. One example of such a construction is given in figure 5.7.
The board exits on the tilted metal plate which makes it drop down the collector constructed from two bent metal bars. It is easy for the next operator to remove boards from the collector and take them to the next step of operations. This construction leads to somewhat of a fall for the boards, but this should be no problem as they are all made of hardwood. This construction can be very easily made by Dicomad themselves. Of course other types of collectors are possible.

5.6.4 Saw 7
To start with a garbage bag has to be installed so that not all waste ends up on the ground. Currently a lot of unnecessary cleaning is needed. All that is needed is a simple metal frame to hold a garbage bag. Wheels should preferably be installed on the frame for easy transport. If the waste bin is placed just next to the machine it might even collect some of the sawdust.

Regarding the number of operators it seems hard to get around the fact that two are needed for some operations.

The big change that can be created for this machine is shortening set up times and removing the need for all the extra equipment. Today, a separate board, clamp and rule are needed to set up the machine. By instead installing all these into the machine, the flexibility of it might be slightly decreased but set up times will definitely be improved and waste such as searching for tools will be removed. The right and left tables will need different constructions.

On the right a permanent block must be installed to set the cutting width. This can easily be done in numerous ways by Dicomad. One example is making a long hole in the table in the direction that one wants to change the block. Then the block can be moved easily along this rail and fastened with for example a couple of screws. The screws will have knob handles for easy manual fastening and unfastening. The easiest way to get rid of the need for a rule is to simply take part of a tape measure and tape it to the table. A more permanent, but harder, option is to actually carve a measure into the table.

On the right table a somewhat more complicated construction is needed as this side is used to cut lengths as well as diagonals. One solution is to use a block with one screw in each end to fasten it. There will be three rails in the table to move the block. It will be moved laterally along two rails, one at each end of the table. For this movement both ends of the block will move along the parallel rails. To set the block for diagonal cuts the lower end screw will stay in one place but be rotated. The upper end screw will be moved along a quarter circle shaped rail to adjust the angle. Along the parallel rails will be a measure showing distance and along the bent rail there will be a measure showing the angle. Figure 5.8 shows the suggested construction on saw 7.
5.6.5 Planer 10
There seems to be no simple way of getting rid of one operator from this machine as some boards have to be processed several times and the refeeding of the board is most easily done manually.

The only real change that should be done for this machine is to create better waste collection. The solution is very simple. Just install a garbage bag held up by a frame on wheels just as the one suggested for saw 7. Place the bag in the area where most chips end up. When full, remove the garbage bag and install a new one.

5.6.6 Saw 14
For saw 14 we see no other improvement opportunity other than better waste management. We suggest installing two garbage bags as the ones described earlier to throw waste pieces in. The reason for the two bags is that the waste from this saw to a large extent can be used in other products. Thus there is one bag for useless waste and one for potentially useful ditto. Each bag has to be marked clearly to avoid confusion. As most of the sawdust from the machine end up on the backside we suggest placing the bag for useless waste there and the bag for useful waste on the other side. This separation will further help to distinguish the two bags. Preferably, the bags can be in different colors to further differentiate them.

5.6.7 Planer 21
There is not much to do about this machine. There are many things to complain about: the setting of the machine is complicated, it is a bit low which creates a bad working position and the waste in form of wooden chips goes right out on the floor. Unfortunately we see no simple ways of improving any of these problems. If a new machine is bought in the future, Dicomad should keep these problems in mind. Regarding the waste it should be cleaned up right after usage and not left on the ground as it is now. Sadly, we cannot find a simpler solution for the waste collection as it all exits right out on the floor. A vacuuming devise would be optimal.

5.6.8 Saw 22
This machine has several problems that should be dealt with. Many of them are not so easy to get rid of though. Regarding the huge amounts of sawdust created we see no really good solution other than installing a vacuuming machine. In the current situation the most important thing to remember is to clean the work area after each usage so the workplace is not left dirty.

All changes can fairly easily be made by Dicomad themselves.

Figure 5.8. Suggested new look of saw 7 as seen from above.
Secondly, the setting up of the machine should be simplified. The need for a wrench must be removed. Instead we suggest installing handles on the screws for easy manual set-up. Furthermore, a measure should be installed on the table to remove the need for an external one. As mentioned earlier, the simplest way is to simply tape or glue a measure to the table. To ensure precise configuration two measures should be glued to the table, one at the upper end and one at the lower end. The two mentioned changes will seriously help reducing set-up times as well as removing the need for external tools.

Optimally only one worker should be needed to operate this machine. Then the next worker could operate the following machine, the molder, simultaneously. For the moment, however, the molder and saw 22 cannot work at the same time because of the electrical problem. In any case one should always strive for optimization. By constructing a collecting devise for the processed boards only one worker would be needed. One option could be to use a devise such as the one in figure 5.7. As the distance from the point where the board exits the machine to the floor is around 90 cm this type of construction will with an average board width of 3.5 cm be able to hold around 22 boards. We deem this to be sufficient.

5.6.9 Packaging
The packaging process, or rather the handling of the packaged products needs to be changed. First of all there must be a designated table for packaging as indicated in the layout suggestions. It cannot be done at the molder’s table as it is today. Otherwise there is not much to say about the actual packaging. The big problem is the manual lift from the table to the pallet. One way of getting rid of this would be to place the pallet on a table with springs underneath that automatically adjusts itself so that the top of the packages are always level with the packaging table, see figure 5.9. This solution could be a bit hard to perfect as four packages will fit on the surface of one pallet and the table will thus be gradually pushed down for each package that is pushed onto it. A better, but more expensive option could be to use hydraulics to change the level of the table.

![Figure 5.9. Table with springs for moving packaged material in unloaded and loaded state.](image-url)
6. Conclusion
There is much room for improvement at Dicomad. A great deal is, however, dependent on a predictable order supply. Without this the production will be hard to stabilize leading to difficulties of implementing large parts of Lean Production and a necessity to often change the number of employees. Except for the problem with orders, which is partly external, there are two main general areas with improvement potential: the layout and implementation of 5S. The factory is today a mess in serious need of reorganization. The layout was designed before the carpentry was introduced. It is, in other words, designed for a past situation and has not been updated with the production. It is vital to separate the two “lines” – the carpentry and the main business – to avoid people running into each other, machines being used by someone when another person needs them, WIP of different product being randomly scattered around the factory. Also a clear flow must be constructed for the two lines to avoid the abovementioned. A good layout is not the whole solution. In order to be able to fully use it the work must be structured. This can be reached with the 5S method.

If our suggestions are implemented Dicomad will work much more efficiently.
7. Final Remarks
Section 7.1 of this chapter describes future research possibilities at Dicomad. Section 7.2 expresses some critiques against the study.

7.1 Suggestions for Future Research
We will not suggest any future research as our opinion is that none should be done. The Dicomad we visited did not show much will of change. The management showed very little interest in our efforts. If this attitude from the company persists any future research will be a waste of time for all parts. However, many other wood refining companies in the region were visited, and some of them showed a great interest in receiving help in order to improve their businesses.

7.2 Critique of Study
There is much to criticize about the study. The root cause of the problems we experienced was the lack of customer orders, the effect of which was very low production and a preoccupation of the management on other things. Both acted against our planned work, which we consequently could not focus on. This report clearly treats the most urgent problems for Dicomad, and should so be useful for the company. Yet, as a Master’s thesis it does not reach high technical levels. The consistent lack of interest from the management, i.e. the CEO, in our work has severely lowered the amount of information we were able to gather about the company. A further problem was the fact that only the CEO spoke English and our Spanish is less than perfect. From what little we were able to communicate with other employees we gathered that better Spanish would not have helped us much anyway since Dicomad is very top managed and thus any vital information must be collected from the top. The conclusion is that had the company been doing better the situation for the work would have in all ways been better.
8. References

**Books**


**Reports**


Cámara Forestal de Bolivia, (2004), *Guía de industrias de la Madera y Productos Forestales*


Warström & Westerborn, (2009), *Study of improvement possibilities in a wooden industry company in Santa Cruz, Bolivia*. Stockholm: KTH.

**Internet**


Other sources
von Axelson, Jens, (2005), Lean produktion – Introduktion, lecture notes from the course MG 2019 – Integrerad Produktion given at the Royal Institute of Technology (KTH), Stockholm, Sweden, fall semester of 2007.