Politechnika Krakowska im. T. Kościuszki

Faculty of Mechanical Engineering

Production Department

ERASMUS STUDIES

Diploma Dissertation

Bachelor's Degree in Industrial Organization Engineering

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STUDY ABOUT MANUFACTURING SYSTEM DESIGN

(Layout, organizational parameters, performance analysis)

ESTUDIO SOBRE EL DISEÑO DE SISTEMAS DE FABRICACIÓN

(Layout, parámetros organizativos, análisis de rendimiento)

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KRAKÓW, ACADEMIC YEAR 2021 – 2022

ABSTRACT

This document collects the final degree project that studies the manufacturing system design systems in a theoretical-practical way.

The constant changes in demand, an increasingly globalized world and competition pose, every day, a challenge for companies to have profitable and efficient production processes. In addition, the elevation of the complexity in supply chains, involving more and more organizations involved, means that companies must be flexible and resilient to problems and variability. Within the framework of this reality is where the importance of studying the production processes of a line lies, making it as advantageous as possible while adjusting to changes effectively.

This work focuses on the design of production processes from both a theoretical and practical point of view, using all the knowledge learned in the last years of the degree and turning them into a hypothetical framework that allows identifying areas for improvement of the company in question and seeing, clearly, the importance of these concepts, including: continuous improvement, layout design, KPI within a control panel focused on cost savings, multidisciplinary selection technique, VSM, mathematical selection heuristics or financial concepts to study the profitability of the projects, choosing at the end the best alternative among the proposals.

KEYWORDS: layout, continuous improvement, lean manufacturing, KPI, redesign, implementation, financial profitability.

RESUMEN

Este documento recoge el trabajo de fin de carrera que estudia el diseño de sistemas de producción de forma teórico-práctica.

Los constantes cambios en la demanda, la globalización y el aumento de la competencia suponen, cada día, un reto a las empresas para tener procesos productivos rentables y eficientes. Además, el aumento de la complejidad en las cadenas de suministro, abarcando cada vez organismos implicados, hace que las empresas deban ser flexibles y resilientes a los problemas y la variabilidad. En el marco de esa realidad es donde reside la importancia del estudio de procesos de producción de una línea, haciéndola lo mas ventajosa posible a la vez que se ajusta a los cambios de forma eficaz.

El trabajo enfoca ese diseño de procesos productivo desde el punto de vista tanto teórico como practico, utilizando todo el conocimiento aprendido en los últimos años del grado y volcándolos en un marco hipotético que permita identificar áreas de mejora de la empresa en cuestión y ver de forma clara la importancia de estos conceptos que incluyen: mejora continua, diseño de un layout, KPI dentro de un cuadro de mando enfocado a el ahorro de costes, técnica de selección multidisciplinar, VSM, heurísticas matemáticas de selección o conceptos financieros para estudiar la rentabilidad de los proyectos.

PALABRAS CLAVES: layout, mejora continua, lean manufacturing, KPI, rediseño, implementación, rentabilidad financiera.

ACKNOWLEDGMENTS

Quisiera dedicar una breve nota de agradecimiento a las personas que me han hecho más fácil la realización de este Trabajo de Fin de grado y los años de carrera.

Primero de todo a Francisco, por haber sido mi apoyo y mi pilar durante estos años. Sin él nada de lo que hay en esta tesis habría sido posible, no solo en lo académico sino también en lo personal. Se que aguantarme no es fácil, pero tu haces que todo parezca más sencillo y, con paciencia y cariño, me has demostrado una vez más que eres indispensable en mi vida.

También a mi hermano Guillermo, que me ha ido guiando a lo largo de la carrera y que me dio un empujón cuando no tenia nada claro este TFG. Guille eres un ejemplo a seguir y espero algún día llegar a ser la mitad de buen ingeniero que eres tu.

Tampoco puedo olvidar a mis compañeros Irene y Álvaro, con los cuales he sufrido, reído y disfrutado durante toda la carrera, entre exámenes imposibles y trabajos en grupo eternos. Gracias, chicos, por todo lo que me habéis aportado estos años, sin vosotros no habría podido.

A mis compañeras de piso en Cracovia. Pilar, Rocío, Maricarmen e Irene (la 5ª), habéis hecho divertido algo que parecía imposible, le habéis dado una vueltita a este campamento eterno que ha sido el Erasmus. Gracias por ser lo mejor de mi experiencia y por ayudarme en los momentos de pánico. Es para reflexionar lo que os quiero.

A mis padres, en especial a mi madre, que es y siempre será mi heroína, por la superación y la fortaleza que siempre ha demostrado. Sois imprescindibles en mi vida y siempre estaré orgullosa de ser vuestra hija. Gracias por cuidarme y quererme tanto.

Y, por último, y aunque parezca curioso, a mi perro Darwin porque, aunque él no lo sepa, he disfrutado cada momento estudiando con el tumbado a mi lado y gracias a él he superado tandas y tandas de exámenes, con sus recibimientos al volver a casa, los paseos por el parque o su cabeza en mi mesa impidiéndome escribir bien. Darwin, gracias por ser mi mejor amigo.

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CHAPTER 1. INTRODUCTION

1.1. Purpose of the thesis

The purpose of this final degree project is to carry out a detailed study of current production processes, analyzing the present and future logistics and industrial scenario and the most relevant points to be considered by companies wishing to have a satisfactory performance in this area.

In order to understand this study, a theoretical and practical project will be carried out, proposing a series of premises prior to the practical application part, where all this knowledge will be applied in a hypothetical case extracted from the Operation Management course.

This hypothetical case will present a production line of a furniture factory that manufactures 3 different types of domestic furniture pieces. From this line will be extracted all the information concerning the organization, performance, and productivity, and later analyze its layout and its efficiency data through KPIs within a control panel focused on cost savings. Finally, a series of improvements in the layout will be proposed. This will allow to extract some conclusions related to different types of layouts, efficiency and profitability.

In this way, and as a summary extracted from the previous points, the key points that must be reached in order to achieve the objectives of the thesis are:

- A series of theoretical points that allow the reader to understand the scenario where the project is developed. These concepts must be reflected in the practical part of the work, just as everything established in the second part must be correctly justified with the theory of the first part.
- Planning of the production line, with a correct and precise layout, reflecting the present situation in which it is found.
- Proposal for improvement of the past layout situation, explaining the strengths and weaknesses and arguing whether it should be implemented or not.
- Study of the performance and efficiency of the layout.
- Proposal of an improvement in the capacity, profitability, and efficiency of the line.
- Conclusions after the study of present and proposed layouts.

All these objectives will be achieved thanks to the knowledge acquired in the 4 years of the Industrial Organization Engineering Degree, including the tools and methodologies learned during the degree, and from the master's degree in Advanced Production, Logistics and Supply Chain Engineering, which will allow a high degree of detail when explaining the concepts.

1.2. Justification of the thesis

The justification for this thesis is both personal and academic.

On a personal level, the study of production processes and, above all, of the organizational parameters is one of the topics that have aroused my interest throughout my four years of degree studies. Therefore, the decision to carry out this subject has been motivated mainly for this reason, the enthusiasm to finish my studies learning and applying this acquired knowledge.

On the other hand, the second reason for the selection of this topic is purely academic since, in order to conclude the Degree in Industrial Organization Engineering and to acquire the accrediting title of these studies, it is necessary to present a final thesis where topics related to the degree are dealt with. That is why this final work will apply the knowledge acquired in the different subjects of the degree, such as: Programming and Control of Production and Operations (PCPO), Human Resources (RRHH), Quantitative Methods (MCOI), Cost Analysis and Selection of Industrial Investments (ANCOS), High Performance Teams for Continuous Improvement (EAR) or Operations Management and ERP Systems (OMERP).

1.3. Structure of the thesis

Finally, to conclude the first chapter of this thesis, the structure to be followed throughout the document will be specified.

This final work will be divided into 5 large sections called chapters, which also will be divided into more detailed subsections that will be related to each other. In this way each chapter will deal with a topic independent of the rest, but always related to the objectives set out in point 1.1.

The first chapter is the one that is concluded with this section, where the key points to understand the project have been established, as well as the justification and objectives of the thesis. Chapter 2 will be the theoretical part of the project, where all the concepts necessary to understand it will be studied. This Chapter 2 will have its application in the rest of the chapters. Chapter 3 will deal with the practical part of the thesis, introducing the company to be studied and applying all the knowledge learned in the previous chapter to analyze the organizational parameters. Chapter 4 will be about the layout, where the current organization, the points to improve and the proposal will be presented. The selection tools studied in Chapter 2 will also be used to choose the best possible option.

Chapter 5 will continue with the study of the company, designing a performance evaluation system with KPIs that will allow us to choose the best option based on these indicators.

With respect to the economic analysis of the alternatives, in this thesis it will only be presented theoretically in Chapter 2, because this topic would require a very large extension and could be considered more appropriate for a final master's thesis, not a bachelor's thesis.

With all these points, a series of conclusions will be drawn, which will conclude the study and, therefore, the thesis.

CHAPTER 2. CONCEPTUAL FRAMEWORK

2.1 Introduction to the theorical knowledge

After the first, more general, part of the thesis, where the basis for its successful completion has been established, Chapter 2 will be introduced, which will establish the theoretical framework of the final work.

As mentioned in Chapter 1, subsection 1.3, this thesis is conceived as a theoretical-practical work, being this chapter the first and only one that will deal with the theory of the project and, therefore, a fundamental part to understand the concepts that will be applied in the second part of the thesis, the application to the case.

The knowledge that will be explained has been learned and extracted from different sources, since the thesis touches on various topics, so it will be related to different subjects of the Industrial Organization degree. At the same time, the transcendentality of this section resides in the fact that everything exposed in the theoretical part must be reflected in the practical part and vice versa, so the information that will be collected in this Chapter 2 will be very rich in knowledge.

This theoretical framework will be divided into 3 large sections, which will refer to the title of this thesis: Layout, organizational parameters, performance analysis, and an extra one, only from a theorical point of view, about economic analysis.

These sections will be:

(a) <u>LAYOUT section</u>

The first topic to study will be the one referred to Layout design, a tool widely used in plant and warehouse management and that is covered in several subjects of the Industrial Organization degree, such as Warehouse Design and Management or High-Performance Teams for Continuous Improvement.

This section requires special attention in terms of subject matter, since it is the basis for a satisfactory understanding of the practice, which will be based on the design of the present layout of the company and the search for an improvement for the future, so the concepts must be well established.

Some of the concepts to be studied are: VSM technique, time analysis TAK TIME, DTD, TC, OEE, SLP... in other words, this section will establish all the concepts that have to do with production, line times and line distribution, which will be what will be later improved through the proposed alternatives.

(b) ORGANIZATIONAL PARAMETERS section

The second major block of theory will be the one that refers to all the organizational parameters of the case study. These parameters have also been studied throughout the career in subjects such as HPTCI or Fundamentals of Business Organization among others, but almost all subjects deal with them in one way or another.

(This is the block that interests me most on a personal level, as I specified in point 1.2).

Throughout this part of the thesis, more general concepts will be discussed when analyzing a company/company from the inside at an industrial level. This part will talk about SWOT, PESTEL or PORTER analysis among others, will be presented and establish the strategy followed by this type of companies in the furniture industry, the organizational culture of a company and its importance, the division of responsibilities and the organization of jobs.

With all these concepts, the profile of the sector in which the company operates, its strengths and weaknesses and its organizational culture will be completed.

This section is important because it offers a more human view of the company and allows to enter into the gears of the line, without focusing so much on numbers or data and allowing the end of the thesis to have a global picture of the company, in addition to the production line to be treated.

(c) PERFORMANCE ANALYSIS section

Finally, to conclude the conceptual framework, performance indicators will be discussed. This section will deal with the analysis of KPIs, and the study of performance through those indicators.

These concepts can be studied during the third year of the degree, in the subjects of Integrated Information Systems, Cost Analysis and Accounting Analysis, and therefore the theoretical information will be extracted from the notes acquired in these subjects.

To understand these chapter, it will be necessary to explain what a KPI is, its function and objective within an organization, what a control panel focused on cost savings is, what cost savings is, etc. Once these concepts are clear, it will be possible to study the best option based on performance and economy savings.

Therefore, once the theoretical analysis of these three main blocks is finished, it will be possible to apply them in practice, allowing the reader to understand what is being done at each step and completing a useful guide when it comes to finding justification for the steps in the rest of the chapters of the thesis.

2.2 Production analysis and line distribution

In this first section will be explained all the theory related to the plant distribution and production analysis.

To make the process easier and more understandable, it will start from the moment in which the plant is defined and then study the whole production and its timing. Once the present part of the distribution and production is clear, it will explain the techniques to identify the areas that can be improved in a distribution and how to distinguish which improvements are more urgent and which are less:

2.2.1 Line distribution or layout

Plant layout can be defined as the way in which resources are organized within the available space (García Sabater, 2020).

This plant layout is usually closely linked to the type of product to be produced on the line, the volume of product to be produced, the variety and the route they will follow. All these concepts must be clearly defined in order to have a correct plant layout.

There are several types of plant layout, but in this thesis, there are going to be studied the four most significant ones: fixed position, by product and functional as pure style and hybrid layout as the sum of several of them.

(a) <u>Fixed layout:</u>

As its name suggests, the plant layout by fixed position is one in which the subject that undergoes the transformation remains static and it is the personnel, machinery and materials that pivot around it depending on the needs it has.

This type of distribution is common in low production volumes and high product variability (García Sabater, 2020).

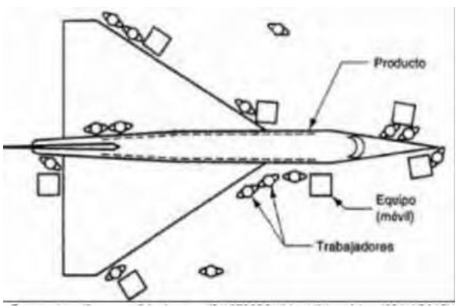


Figure 1. Fixed layout (Source: https://repositorio.uarm.edu.pe)

(b) <u>Product layout:</u>

The following type of distribution is widely used in the furniture sector, since it is the one in which the product moves within the line, passing through different treatment areas.

This type of distribution is common with high production volumes and low product variability (García Sabater, 2020).

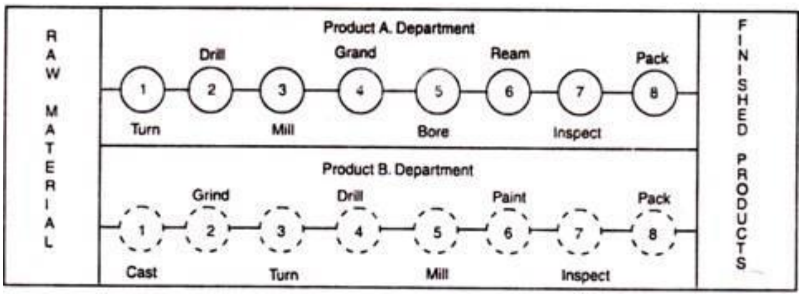


Figure 2. Product or Line Layout (Source: https://www.yourarticlelibrary.com)

(c) Functional layout:

The last type of pure distribution is known as functional. In this type of set up the line is divided into functional work areas and the product moves from one to the other depending on where it is in the manufacturing process.

This type of distribution is common with medium production volumes and variability (García Sabater, 2020).

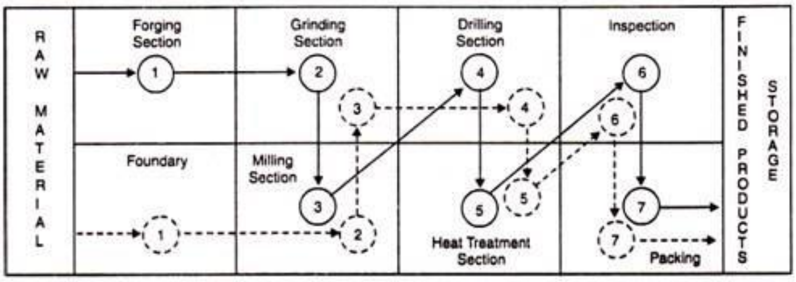


Figure 3. Process or Functional Layout (Source: https://www.yourarticlelibrary.com)

(d) Combination type of layout:

The last type of distribution and the most variable of all the previous ones. This type of distribution is based on work cells, where the machines that are going to produce a type of product are grouped, closing the production to each process within the cell.

The best-known hybrid distribution is the so-called ``U-shaped cell". This type of cells are short assembly lines where workers are located inside the U, creating a flexible workspace and a united work environment (García Sabater, 2020).

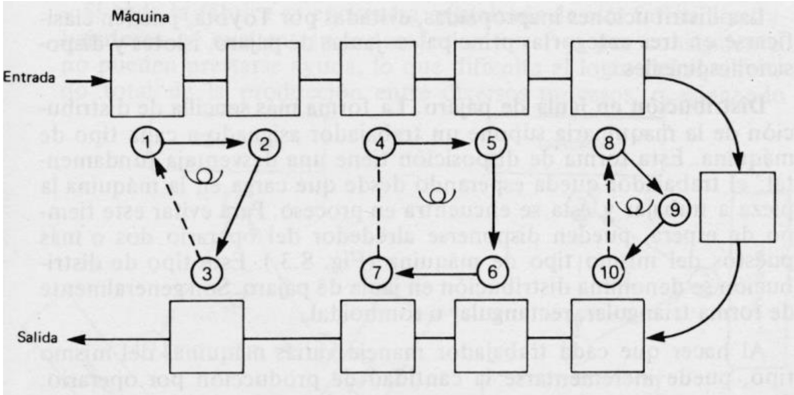


Figure 4.Combination type of layout (Source: http://curso-jit.blogspot.com)

To choose which type of distribution is more correct for the production level of the line to be studied, it is best to make a matrix of variability and productivity volume, since it will depend on these factors that it adapts more or less to the production line without affecting its efficiency.

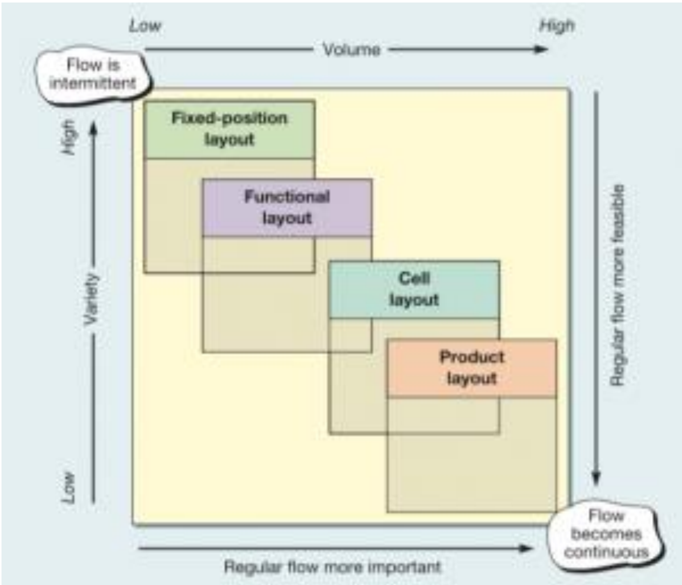


Figure 5.Choice of plant layout type (Fuente: http://evaluador.doe.upv.es)

2.2.2 Industrial production systems

(a) <u>Mass production:</u>

This type of production will occur when the product to be produced is invariable in terms of standards and manufacturing characteristics. When these characteristics occur at an industrial level, it can be named Mass Production (García Sabater, 2020).
Some of the advantages of this type of production are:

- Medium-high quantity to be manufactured.
- Type of manufacture with automatic or mechanized processes and few adjustments.

- Low skilled labor.
- Very low inventory in process.
- The line must have a constant maintenance service.
- This type of production will allow to plan inventories to reduce storage or machinery costs.

On the other hand, the disadvantages will be:

- There are no unique pieces, which means that the originality of the final product is lost.
- It can cause operator fatigue by repeating monotonous operations.
- It can generate job losses due to automation.
- Small retailers have problems competing with large mass manufacturers.
- Demand must be well planned to avoid cost overruns due to stock in the warehouse if not enough is sold.
- Need of initial capital to be able to adapt the factory.

The following illustration shows an example of this type of line:

Figure 6. Production line of Coke (Source: http://tiposdeproduccioningunet.blogspot.com)

(b) Bach production:

The other type of production line is one in which the line instead of being continuous in series is divided into batches of identical products, but in small quantities. This type of line is also known as 'batch production' because it is not constantly in process but is stopped because the operations are carried out one batch at a time.

In addition, this type of production is more assured than in-line production, since the batches are sold to the customer before manufacturing, i.e. (id est), in advance of production (García Sabater, 2020).

The advantages of this type of production will be:

- Greater flexibility when producing and assuming changes.
- It is a type of production more useful for small companies.
- It has less expense of preparation or adaptation of the plant.
- Less initial capital investment.
- It is possible to isolate the machinery.

On the other hand, the disadvantages of batch production will be:

- Changeover between production batches.
- Because production is not constant, there will be downtime.
- It is more difficult to forecast product demand.
- Poorer material handling.
- The production line is no longer balanced which makes scheduling more difficult.
- Lower production volume and more difficult to produce in large quantities.
- There is a bottleneck that sets the pace of production.

The following illustration shows a batch production:

Figure 7.Batch production line (Source: http://tiposdeproduccioningunet.blogspot.com)

Finally, to fully understand batch production, it is necessary to explain what a bottleneck is.

- Bottleneck (BN): the bottleneck or BN will be any element that generates a decrease in the production rate. It will be the part of the line that sets the pace of the whole process.
  Normally the bottleneck in batch production is an oven or something similar, which causes the batches to stop for longer than the rest of the operation. Even with this, the bottleneck will simply be the slowest machine in the whole process. Reducing the duration at this point is the goal of every process engineer because reducing the BN time will also improve the batch cycle time and therefore increase productivity.

2.2.3 Systematic Layout Planning (SLP)

The SLP (Systematic Layout Planning) methodology was proposed in 1973 by Muther as a method to be used in plant layout. Nowadays SLP is used all over the world to optimize industrial spaces. Despite the antiquity of this technique, it has been updated and perfected with new tools and functions, which give it the flexibility and usefulness it has today.

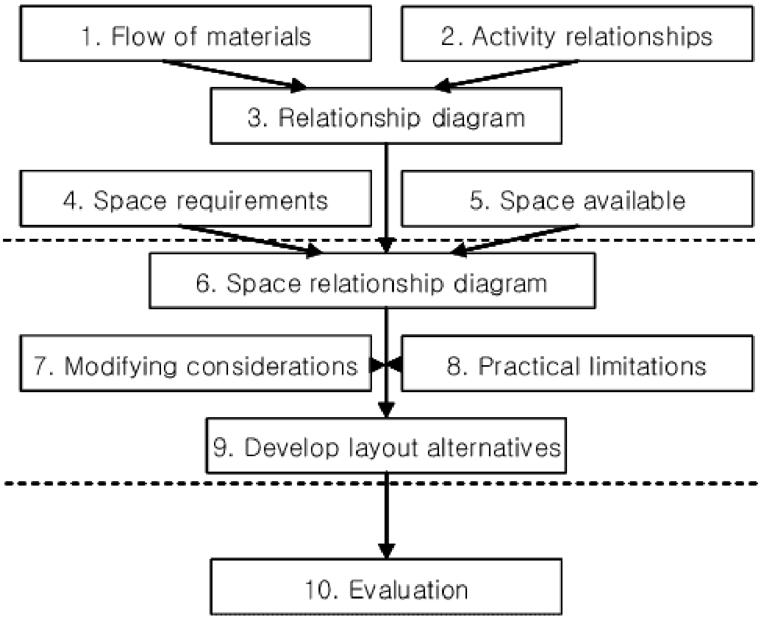


Figure 8. SLP scheme (Source: Bathwadekar 2015)

To perform a good analysis of the plant layout with the SLP there are several points to consider (Blasco Andres, 2020):

- The amount of product to be manufactured on the line.
- The type of product to be manufactured in the line, considering materials, manufactured or purchased parts, semi-finished products...
- The sequence of operations (also known as route) that the product will go through until its completion.
- The manufacturing and completion times of a product on the line.
- The support operations for the manufacturing and assembly of the product.

Within the definition of SLP, different tools or intermediate steps have been developed to make this method as accurate as possible. These tools will be:

(a) <u>Relational activity matrix (RAM):</u>

This matrix is used to classify the relationship between two processes, assessing the suitability of the proximity between them.

To carry out the classification, there are 6 different levels: Absolutely important, especially important, important, ordinary, unimportant and undesirable (García Sabater, 2020).

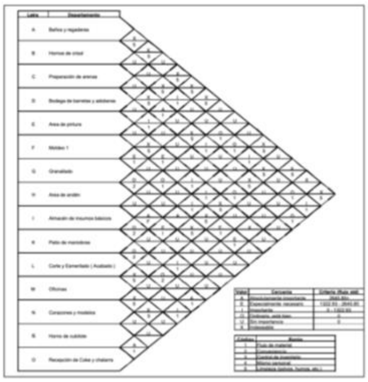


Figure 9.Relationship matrix (Source: García Sabater, 2020)

(b) <u>Activity relationship diagram (ARD):</u>

This diagram graphically represents the relational matrix, through a defined color code and considering all the previously determined relationships.
With this new tool you can have a clearer view of the plant layout since it illustrates the spatial representation of the line (García Sabater, 2020).

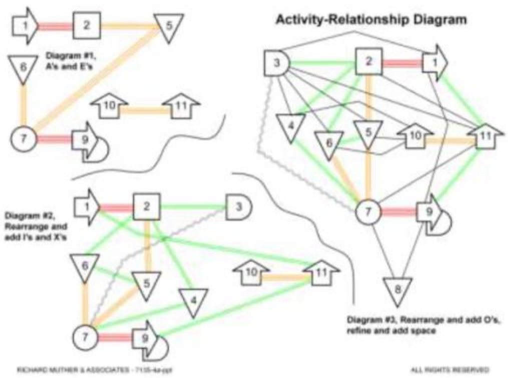


Figure 10. Activity relational diagram (Source: García Sabater, 2020)

(c) <u>Dual network:</u>

The dual graph was designed by the author community as a complementary tool to this technique. The main function of this graph is to improve some additional aspects and the representation of the SLP.

In this way, this tool is created by joining the two previous ones and helps to avoid skipping any step in the capture of information (García Sabater, 2020).

Figure 11. Dual graph (Source: Canet Garibo, 2020)

2.2.4 Value Stream Mapping

The VSM methodology allows to graphically represent the value chain of a group of products, the materials that compose it and the complete flow of information. With all the data obtained, it is possible to eliminate activities that do not generate value and give more relevance to those that do (García Sabater, 2020).

The way to perform a VSM is by means of a series of defined graphic symbols that represent step by step the value chain of the products in the line. In addition, the VSM also uses mainly time-based indicators, such as: cycle time (CT), Dock to Dock time (DTD), Overal Equipment Efficiency (OOE), Takt time and measurement of intermediate inventories. All these indicators will show the real state of the production flow in the VSM (García Sabater, 2020).

The steps to successfully complete a VSM will be:

- Search and choice of a suitable product family, in the practical case of this thesis it will be done with 5 home furniture products.
- Application of the VSM tools, clearly indicating what the symbolism used refers to.
- Once the VSM is finished, techniques will be used to identify improvement opportunities to optimize the layout and production line.

Therefore, the definition of the above-mentioned time indicators will be:

(a) <u>Cycle time (CT)</u>

Cycle time can be defined as the time it takes to process a part on the line. That is, from the time a part is obtain until the part immediately after the first one is obtain also.

Figure 12. Cycle time example (Source: HTTPs://www.monografias.com)

(b) Dock to dock time (DTD)

The dock-to-dock time is all the time it takes to obtain the finished product starting from the procurement of the raw materials that will form it.

Therefore, it is easy to personify that it will be obtained through the sum of all the process times from the time the materials enter the line until the final product is ready.

$$\begin{aligned}\boldsymbol{DTD} &= \boldsymbol{raw\ materials\ inventory} + \boldsymbol{work\ in\ progress\ inventory}\\ &\quad + \boldsymbol{production\ time} + \boldsymbol{finished\ product\ inventory}\end{aligned}$$

Equation 1. Dock to dock equation (Source: own elaboration)

(c) Takt time (TT)

It will be the minimum time it should take to produce the final product in order to meet the demand deadlines required by the customer.

$$\boldsymbol{TAKT\ TIME} = \frac{\boldsymbol{available\ time\ (by\ months, day, weeks, shift)}}{\boldsymbol{\#\ of\ units\ demanded\ by\ customer}}$$

Equation 2. Tack time equation (Source: own elaboration)

(d) Labor productivity (LP)

The following indicator measures the productivity that workers have when it comes to production.

$$\boldsymbol{LP} = \frac{\boldsymbol{\#\ of\ units\ produced}}{\boldsymbol{\#\ of\ man - hours}}$$

Equation 3. Labor productivity (Source: own elaboration)

(e) Overall equipment efficiency (OEE)

Finally, the OEE indicator measures the capacity of a machine to perform an operation. This indicator consists of 3 different variables:

- **Availability:** relates the net operating time and the actual machine time, also known as operating time.
- **Efficiency:** relates the time it takes to produce X parts to the ideal cycle time and the machine's actual or operating time.
- **First Time Through (FTT):** represents how many parts are perfect without the need to fix them versus how many are produced in total.

This concept will be discussed in the future in the section on indicators.

2.2.4 Improvement identification techniques

To continue with the analysis on-line distribution and production it is necessary to talk about decision making and identification of areas for improvement of the studied production line.

As mentioned in the previous section, when performing the value chain with the VSM it is common to find the parts where improvements can be made through the techniques that will be explained below.

The 2 techniques to identify areas of improvement that are going to be studied in this thesis will be: 5 Why technique and finally Ishikawa diagram.

(a) 5 Why's Technique (5W)

The following tool is one of the most widely used in the engineering field, due to its easy understanding and its speed-effectiveness ratio.

The 5 Why's technique is a tool for the root cause analysis of a problem that is applied by asking consecutively during 5 rounds the Why's of the different levels. In this way it is possible to go deeper into the origin of the problems that the thesis wants to solve.

It is necessary to point out that depending on the complexity of the problem to be analyzed, more or less rounds of questions can be asked, since sometimes less than 5 is enough and sometimes 7-8 will be necessary.

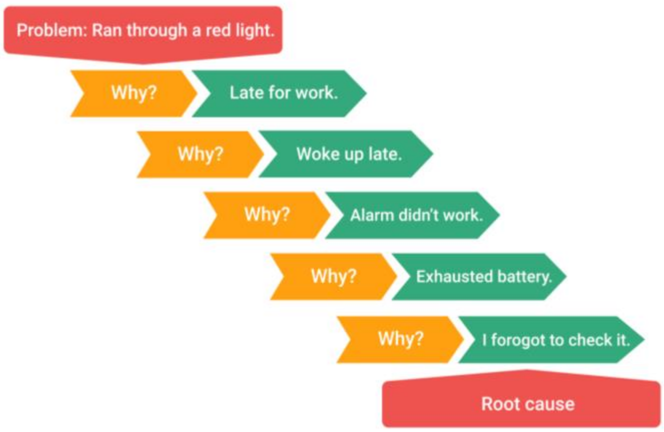


Figure 13. 5 WHY Example (Source: https://kanbanize.com)

(b) Ishikawa Diagram

The last method to identify the root causes of a problem will be the Ishikawa diagram, also known as fishbone diagram due to its characteristic shape.

The way to apply it is mainly visual since in the center a straight line will be drawn (central thorn) that will lead to the problem to be solved and, starting from this thorn, branches of the causes that are originating this problem will emerge from different perspectives.

In this way, the principle that follows this method is the cause-effect, that means a problem can be divided into different guilty causes.

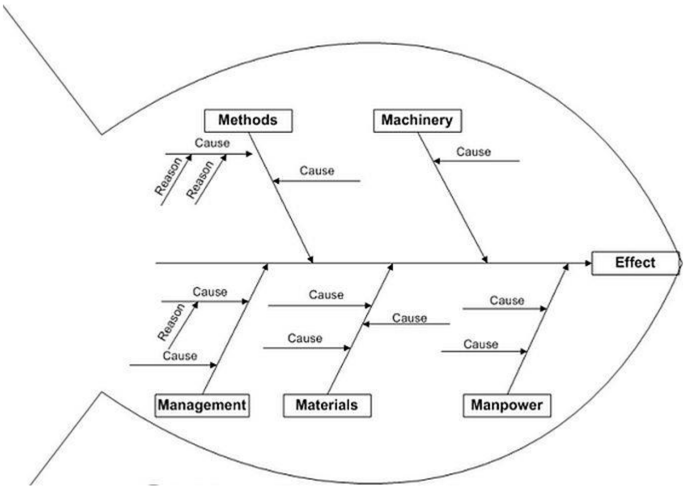


Figure 14. Ishikawa example (Source: https://kanbanize.com)

2.2.5 Prioritization and timing of improvements

As already mentioned in the introduction to this point 2.2, in order to complete the theoretical analysis of the line distribution in the plant, it is necessary to distinguish which measures are more urgent and which can wait to be carried out. For this function, tools of timing and prioritization of actions in the projects will be used.

In this case this subpart will mention the two most important ones: the Gantt chart and the BWM method.

(a) <u>Gantt chart</u>

This graphic tool allows the planning and scheduling of the production processes carried out on the line. In this way, through the use of the Gantt chart, it will be possible to represent the production and, therefore, monitor the different activities that make it up.

The data that can be obtained by applying this tool are the start and end times of each activity, as well as its actual vs. planned duration. With all these, the total project duration can be reliably obtained.

The following image shows a Gantt chart that has been developed:

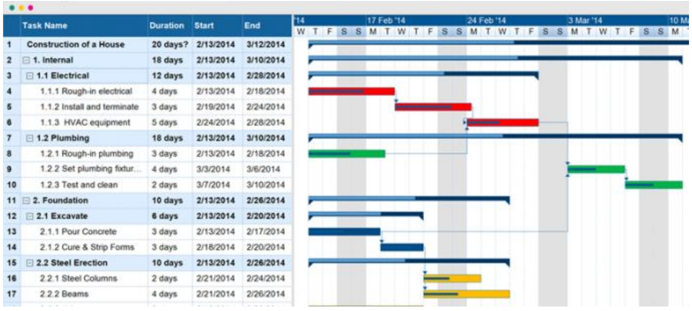


Figure 15. Gantt Chart (Source: https://www.gantt.com)

(b) Best Worst Method (BWM)

The BWM method is a so-called ``multicriteria'' decision technique, i.e., the final decision will not depend on one variable but on more than one.

The method itself is applied with a pre-built Excel where the variables are entered (Jafar Rezaei). Looking at this Excel it is easier to understand how it works, but the key points are:

- Best worst method requires 2n-3 comparative data to be able to analyse n number of items.
- A consistency ratio should be proposed to verify the correct performance of the comparisons and to confirm the reliability of the comparisons.
- When comparing the BWM method with others as well known as the Analytic Hierarchy Process (AHP), it is the first one that achieves better results.

Therefore, there are now add the Excel screenshots where can be clearly seen the steps to follow to apply it:

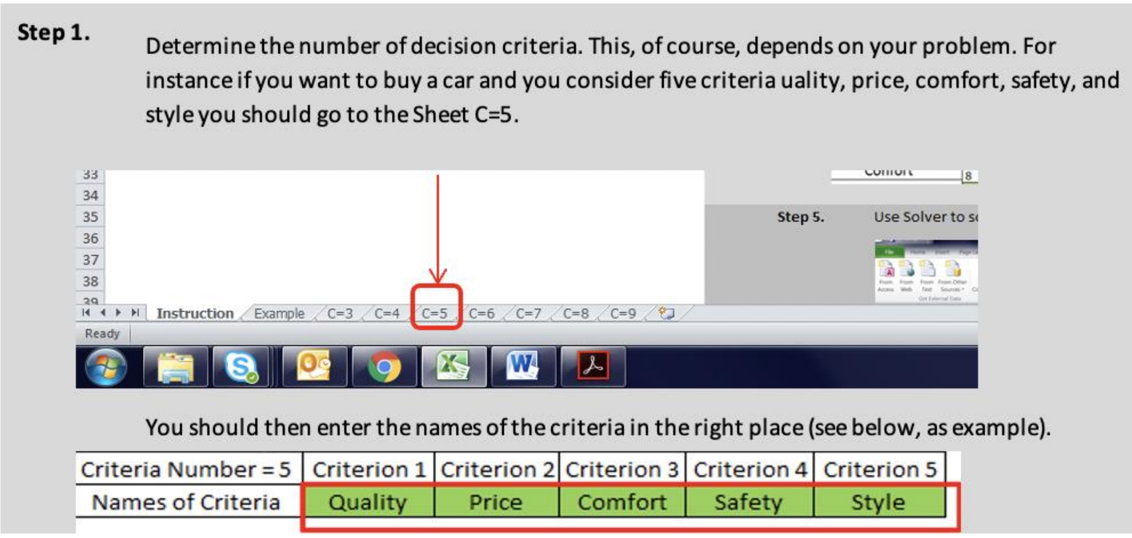


Figure 16. First stop to apply BWM (Source: Jafar Rezaei)

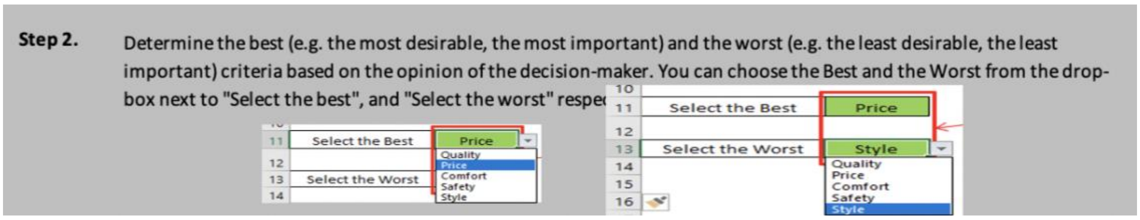


Figure 17.Step 2 to apply BWM (Source: Jafar Rezaei)

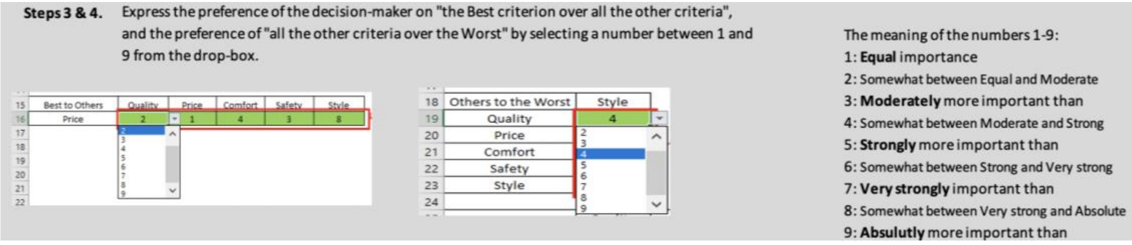


Figure 18. Step 3/4 to apply BWM (Source: Jafar Rezaei)

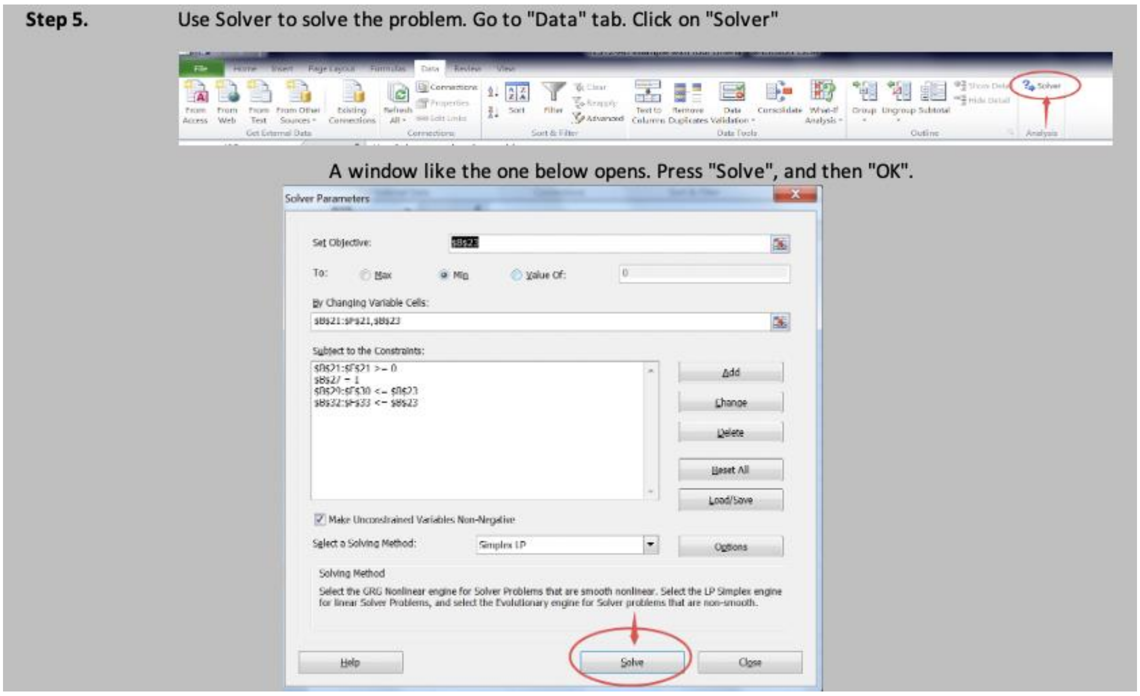


Figure 19. Step 5.1 to apply BWM (Source: Jafar Rezaei)

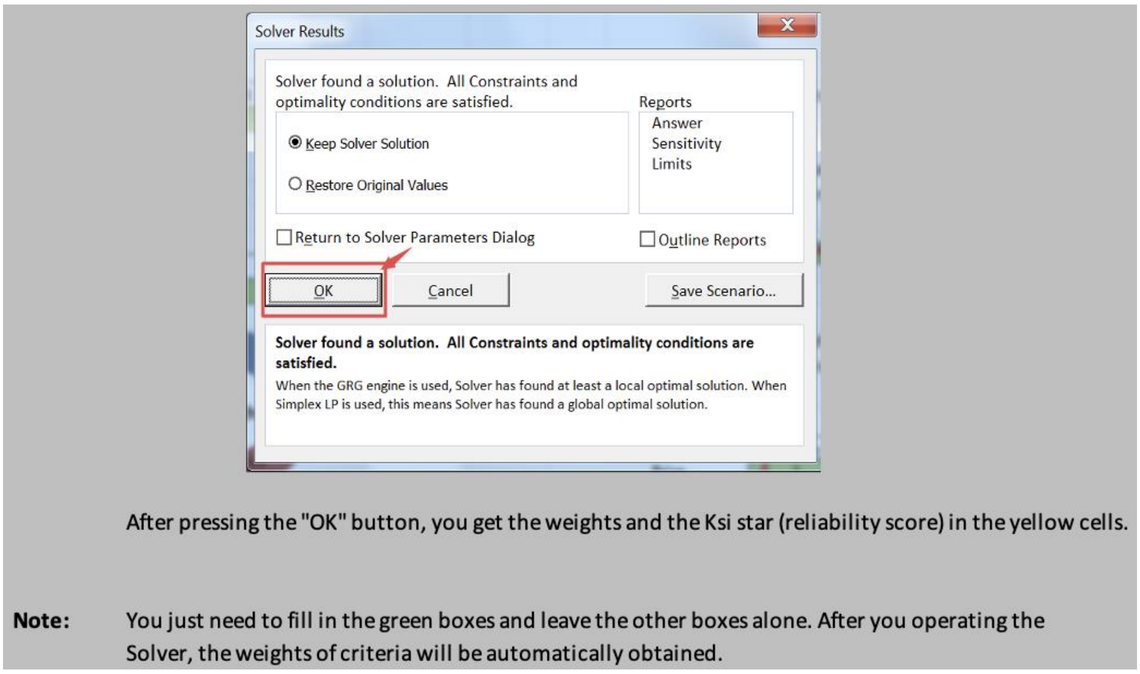


Figure 20. Step 5.2 to apply BWM (Source: Jafar Rezaei)

Finally, here is a practical example of how it would be applied and what would be displayed in Excel if used:

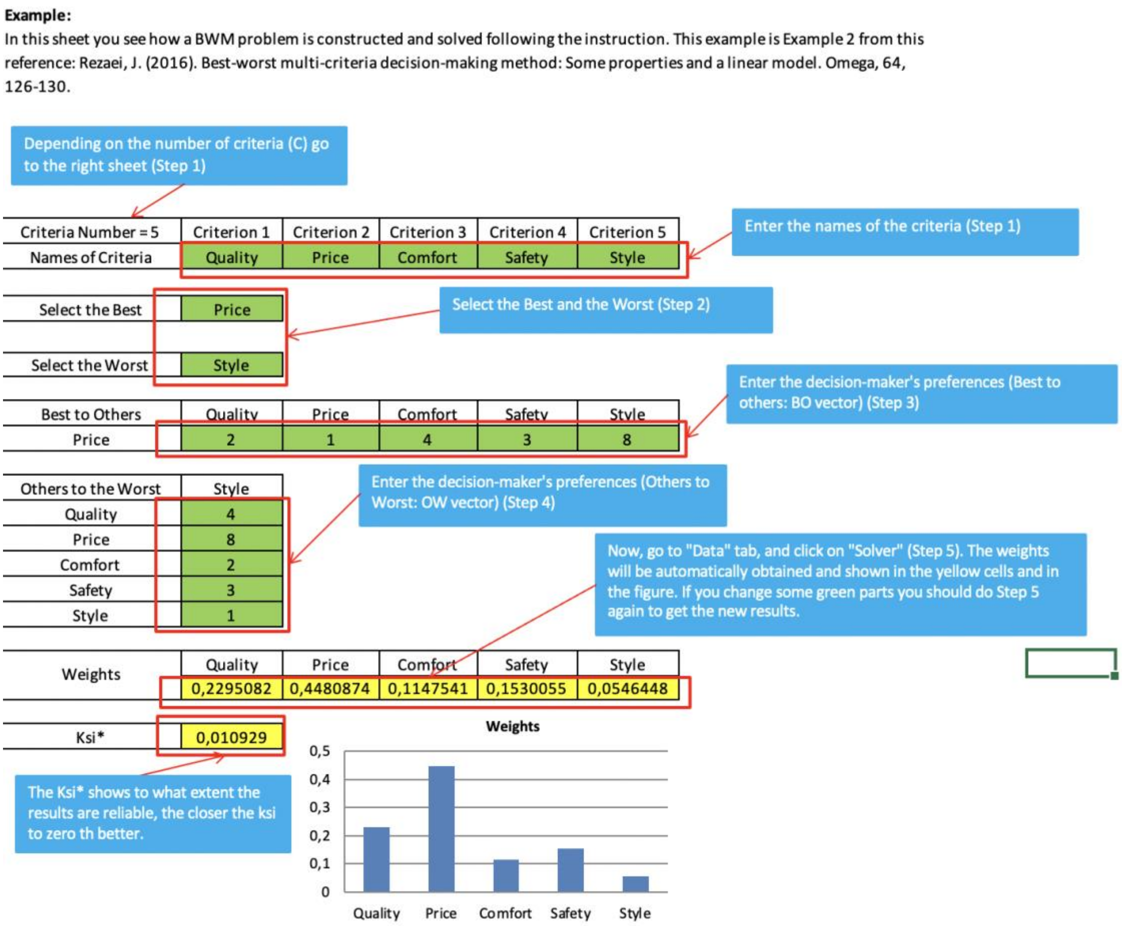


Figure 21. Example on how to apply BWM (Source: Jafar Rezaei)

2.3 Organizational parameters

The next theoretical topic to be studied is the one that has to do with the organizational parameters, that is, the tools or indicators that all productive companies have.

These parameters are the ones that will inform about the state of the organization in relation to the competition or about itself, that will indicate the areas that can be improved and the strategies that should be followed to optimize the organization.

All the information that will be provided in this section comes from the practices of the Strategic Management course taken in the 4th year of the degree. In these practices were taught all the necessary knowledge to analyze a company based on its parameters, so it will be the notes of (McGraw-Hill/Irwin, 2003) which will be used as a theoretical guide.

With all this, the points to be explained will be: Pestel analysis, Porter's 5 forces analysis, SWOT matrix, study of the Value Chain and, finally, analysis of the possible strategic proposals. All these tools will be applied in the case study, starting in Chapter 3.

2.3.1 PESTEL analysis

The analysis using the PESTEL matrix serves mainly to clearly identify all the external forces that may be affecting the organization.

This tool is widely used, and its abbreviation is, in itself, the definition of its function since the letters that make it up mean: political, economic, social, technological, environmental and legal (PESTEL) (McGraw-Hill/Irwin, 2003).

This matrix is usually used in companies as it allows to previously study the company's environment, before making financial investments and new business plans, which is why it will be included in financial feasibility studies.

In order to carry out this analysis there are a series of questions that should be asked and that will facilitate the preparation:

- What is the political situation in the country and how can it affect the industry?
- What are the predominant economic factors?
- How important is culture in the market and what are its determinants?
- What technological innovations may appear and affect the market structure?
- Is there existing legislation regulating the industry or are there likely to be any changes in this regulation?
- What are the environmental concerns for the industry?

2.3.2 Porter´s 5 forces

The following tool is called Porter's tool as it was proposed by economist Michael Porter in his book "Competitive Strategy" in 1980.

This chart will help companies to measure and analyze their resources against five forces that can affect them. These 5 forces are: bargaining power of customers, bargaining power of suppliers, threat of new entrants, threat of new substitute products and rivalry among competitors.

Once they have completed this analysis, companies will be aware of their weaknesses and will be able to plan and establish new measures or strategies that will enable them to improve their position in the face of the weaknesses shown by applying Porter (McGraw-Hill/Irwin, 2003).

The best way to apply this tool is by weighting each of the strengths out of 10, i.e., giving a value to the position of the company to be analyzed with each of the strengths (1 being little strength or threat and 10 being much strength or threat). Once all the strengths have been evaluated, a pentagon-shaped graph showing the areas for improvement or the company's strong areas should be drawn up.

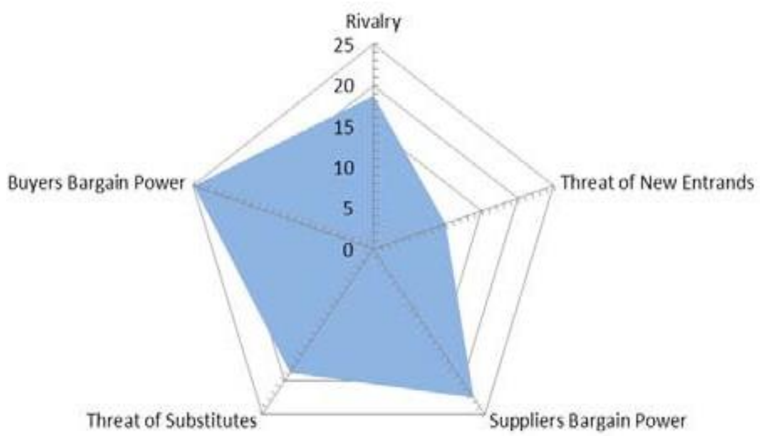


Figure 22. Graph representation of Porter's 5 Forces Model (Source: https://www.researchgate.net)

2.3.3 SWOT analysis

The tool to be presented here is one of the best known and explained in the Industrial Organization Engineering course due to its efficient results and ease of application.

The SWOT analysis, by its acronym: Strengths, weaknesses, opportunities and threats, allows the entrepreneur, or interested party, to analyze the reality of his company, brand or product in order to be able to make decisions in the future with the greatest possible security (McGraw-Hill/Irwin, 2003).

SWOT analysis cannot be the only means of analyzing the company, but if used in conjunction with the other tools mentioned in this section 2.3, it can help to establish organizational strategies that will lead the company to success. In order to carry out a good SWOT analysis, two analyses should be carried out, the internal and the external, as shown below:

(a) Internal analysis:

It refers to the Strengths and Weaknesses (S and W) of the company under study. In this first phase, an accurate picture of the situation of the company itself will be obtained.

(b) External analysis:

Subsequently, in the external analysis, the company's Opportunities and Threats (O and T) will be studied. In this way, the company's environment will be looked at and opportunities for investment and improvement or solutions to the present threats will be sought.

Figure 23. SWOT analysis (Source: https://www.wordstream.com)

2.3.4 Value chain

Finally, the last organizational parameter necessary to complete a good analysis of the company will be the value chain.

This tool is widely used in the world of industry as it allows the company that uses it to determine the competitive advantage, they have compared to other companies operating in the same sector (McGraw-Hill/Irwin, 2003).

In this way, for the realization of the Value Chain, the most relevant areas of the company should be examined and analyzed to understand, in a simplified and theoretical way, which are the sources of income, the costs and the differentiation of the company.

The steps to correctly apply this tool are as follows:

1. Identify the sub-activities for each primary activity.
2. Identify sub-activities for each support activity
3. Analyse the value and costs of the identified activities
4. Identify all the connections or linkages that connect all the previously identified activities.
5. Determine which activities need to be optimized or improved to maximize the value offered to customers

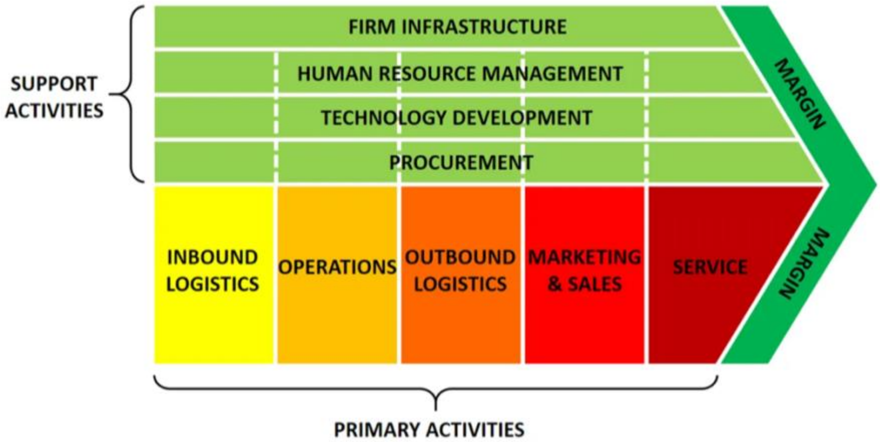


Figure 24. Chain Value explained by name (Source: https://www.business-to-you.com)

2.4 Performance analysis systems

The last section of the title of this thesis is the one that refers to the measurement of the performance of the production line.

In this subsection it will be studied the theoretical part of all the indicators or systems that can be used to accurately study the performance of a production line, a company or a given system.

All the information that is going to be provided with respect to these topics will be extracted from the notes of the SIIO course, which is taken in the 3rd year of the degree, and from the master's degree in Advanced Production, Logistics and Supply Chain Engineering, which will allow a high degree of detail when explaining the concepts.

With all this, the concepts to be explained will be: brief introduction about performance analysis, what is a balanced scorecard, what is a KPI and what strategies and indicators can be applied in a control panel oriented to cost savings, which is the strategy that will be applied later in Chapter 5.

2.4.1 Introduction to performance analysis

Performance measurement systems can be defined as the set of elements or components that are interrelated and allow a global and/or partial approach to measure the performance of an organization or entity.

This measurement should be performed periodically in order to know all the critical points of performance and develop a work plan to reduce weaknesses, identify opportunities and increase strengths.

The necessary steps to perform a measurement are:

- A method or tool with well-defined structured steps to obtain relevant performance information.
- A way to collect and store all the above information.
- A framework in which to measure that information (performance data) and contextualize it.

The importance of performance analysis lies in the fact that competitiveness among companies is changing from a local or specific issue to a common problem for all companies involved in the value chain of a product or service.

In short, performance evaluation should be performed for the entire supply chain involved in the generation of the product/service, or the same for the business process, people, organization, technology and physical infrastructure of that chain.

2.4.2 Balanced Scorecard (BSC)

The first thing to understand is what a BSC is. This tool is relatively new and is beginning to be implemented in large companies to help top management to decide which measures should be taken, order them and focus on the ultimate goal to be achieved with these measures.

The BSC can be understood as the flight system of an aircraft. This system is essential for pilots to be able to carry out their function without complications, due to the complexity of this task. In this case, the flight system provides them with information on essential items such as fuel levels, speed, altitude, destination and other indicators that together make up the environmental map of the trip. If one of these instruments fails, it can be a terrible disaster, just as it can happen in a company.

That is why, like pilots, managers must be able to see the bigger picture of their organization, controlling several areas simultaneously and avoiding deviations from their established course or objective.

Thanks to the Balanced Scorecard, management can simultaneously look at the business from four key areas: finance, customers, the business internally and R&D, and correct errors or obtain information without being overloaded, as the BSC limits the number of measures and summarizes the most relevant information given.

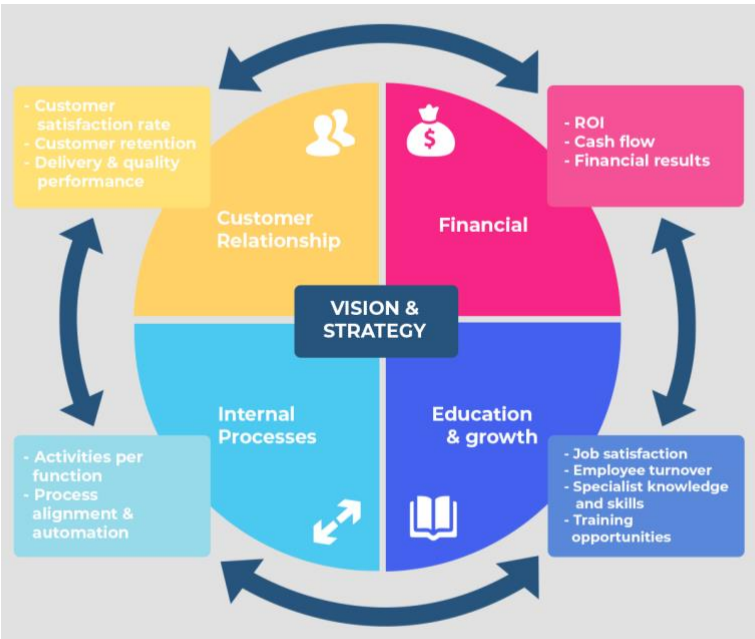


Figure 25. BSC areas (Source: https://www.professionalacademy.com)

Therefore, in order to perform a BSC correctly, certain steps must be followed:

1. Identify which of the 4 areas indicated in Figure 25 the BSC is to be oriented to.
2. Choose the objectives to be achieved by the end of the BSC.

3. For each of the objectives, at least one strategy to achieve it should be indicated. It is recommended that for each objective more than 2 strategies are sought.
4. For each strategy a KPI must be calculated whose result is significant.
5. All parameters must be quantified to understand if you are getting better or worse. For example, you want to increase revenue by 5% by reducing expenditure by 10% and with the KPI above 80%.

2.4.3 Key Performance indicators (KPI)

All remarkable strategic models start with how you measure business results. KPIs, help you measure strategic, financial and operational performance against your goals, metrics or industry benchmarks.

KPIs are critical to understanding performance because they allow you to create a framework for measuring agility and continuous process optimization by tracking leading indicators.

Using a framework that provides a combination of outcome KPIs and leading indicators not only helps track financial performance, but also helps to:

- Focus and motivate employees to achieve results or solve critical problems.
- Reinforce business vision and commitment to customers.
- Provide early warning systems for risk reduction.
- Foster an innovation and growth mindset, data-driven culture.

Drive continuous process optimization not only reduces costs and increases profits, but also eliminates friction points and creates the best experience for employees, customers and suppliers.

Traditional business KPIs focus on four key dimensions:

(a) Well-Being

It is always necessary to track economic results or benefits to see if the viability of the process has been achieved. In the business world, investing at a loss has no particular meaning.

(b) Profitability

Understanding how efficient your company is when it comes to converting sales into profits or tracking profits and always working to save on operations is critical.

(c) Growth rate

Business continuity requires always delivering and looking for innovation that will accelerate growth, even during a downturn.

(d) Risk and reward

Companies with low margins are more at risk because they cannot withstand a downturn for long.

Figure 26. Key steps in the KPI process (Source: https://www.techtarget.com)

2.5 Economic analysis of investment alternatives

In order to perform a good analysis of the plant layout alternatives, the economic aspect of these must also be considered.

The objective of this section is to explain, theoretically, all the variables that must be used to carry out a complete economic analysis that will allow to have a framework for the financial evaluation of investment projects. This practical economic evaluation will not be carried out in this thesis, due to its extension and complexity, as previously mentioned. The economic evaluation of projects is necessary in order to minimize the investment risk and the uncertainty that this type of operation entails. In addition, it also helps to predict the payback time of the investment, the cost of the investment and the cost-benefit ratio.

The structuring of this section is simple, there is going to be a brief explanation about what an economic investment project is and what type of variables must be studied to be able to choose between several alternatives or to approve the viability of a single one.

2.5.1 Financial investment project

Described generally, a project is the search for an intelligent solution to a problem that tends to solve a human need, among other things.

Companies address these needs through capital projects that will indicate whether or not the proposed solutions are viable.

"Such an investment project is described as a plan which, if allocated a certain amount of capital and provided with inputs of various kinds, will be able to produce a good or a service, useful to human beings or to society in general." (Baca; 2006:2)

The most important thing when making decisions concerning investment projects in companies is to obtain all the necessary information and apply a logical methodology that takes into consideration all the factors involved and that will affect the final result of the project.

Even with all this, financial investments are not risk-free and future monetary gains may not be as planned in the past, despite a thorough analysis.

"Fortuitous factors, such as strikes, fires, collapses, etc., are not included in the calculations, simply because it is not possible to predict them, and it is not possible to assure that a start-up or any other company is safe from fortuitous factors." (Baca; 2006:2)

(a) <u>Investment evaluation</u>

The most important part of the study is what is known as the 'investment appraisal'. In this first phase, the foundations will be laid to subsequently make the pertinent decisions about the project. All this makes it essential to carry out a good evaluation in order to be able to relate the results to the strategy followed by the company.

2.5.2 Indicators for economic analysis

In this case, 4 fundamental indicators will be analyzed to determine the viability and profitability of a project. Through these values it will be possible to determine whether the investment increases or decreases the company's equity, i.e., whether it is profitable or not.

(a) Net present value (NPV)

The NPV is one of the most widely used criteria when measuring the profitability of a capital investment and consists of updating the collections and payments of the project in order to know whether there will be profit or loss and in what amount.

From a mathematical point of view, the NPV is the comparison between Io (initial investment of the project) with the sum of all the Ft (cash flows expected to be obtained from it) updated based on i (interest rate) at a time t. It is important to note that t is the time interval of the investment and n the number of years of duration (Alvarez; 1995:56).

Three results can be derived from this formula:

- **Positive result:** occurs if NPV > 0 and implies that the investment will generate a profit.
- **Result equal to 0:** occurs if NPV = 0 and implies that the realization of the project will not generate any result, neither profit nor loss.
- **Negative result:** occurs if NPV < 0 and implies that the project will generate losses and therefore should be rejected.

The NPV formula will be:

$$\boldsymbol{NPV = -I_0 + \sum_{t=1} \frac{Ft}{(1+i)^t}}$$

Equation 4. Net present value equation (Source: own elaboration)

(b) Internal rate of return (IRR)

The second way to know if an investment is interesting for the company is through the Internal Rate of Return formula.

The IRR is an indicator in the form of a percentage that allows to measure the viability of a project by determining the collections and payments of this, generating a significant quantitative value. This formula transforms the profitability of the investment to be studied into a percentage (rate of return) that can be compared with the profitability of other low-risk investments and thus compare whether or not it is viable and interesting for the investor.

Mathematically the IRR is easy to calculate once the NPV has been previously calculated (previous point). Simply apply the NPV formula with NPV = 0 and subtracting the i in the denominator by IRR (Alvarez; 1995:60).

The values that can be obtained by performing the mathematical clearing will be:

- **Higher result:** it will be given when IRR > i and it will imply that the project is interesting since the profitability that will be obtained will be higher than the interest that will be demanded by loans.
- **Minor result:** will occur when IRR < i and implies that the project is not interesting or viable since the profitability will be lower than the minimum interest required.
- **Neutral result:** will occur when IRR = i and implies that other indicators should be evaluated, since it is not conclusive in this case.

The IRR formula will be:

$$IRR = -I_0 + \sum_{t=1} \frac{Ft}{(1+IRR)^t} = 0$$

Equation 5. Internal rate of return equation (Source: own elaboration)

(c) Pay-back

The easiest indicator to calculate is the Pay-back of the investment. As its name indicates, it is the time it will take to recover the initial investment, in order to know from when real benefits will be obtained from the project.

Although it is a good method, it is not entirely reliable, since it does not take into account the flows are not updated, it simply makes an algebraic sum of these to join them to the initial investment (Alvarez; 1995:71).

The formula will be:

$$PB_{Period} = \frac{Investment}{Annual\ Cash\ Inflows}$$

Equation 6. Pay-back equation (Source: own elaboration)

(d) Return on investment (ROI)

Finally, the ROI indicator, which measures the profitability of a project as a percentage, will be studied. This indicator is often used in the form of a KPI when it is used to evaluate financial performance.

To apply it, as in the previous cases, a simple formula must be applied and interpreted correctly. In this case, the initial investment must be subtracted from the final value, which will give the net rate of return and this in turn will be divided by the initial investment. The higher the ROI, the higher the profit, but companies should also not rely on miracle investments that promise extremely high return rates and should always investigate the reliability and reality of such investments.

The ROI formula will be, therefore:

$$ROI = \frac{Revenue - Investment}{Investment} x100$$

Equation 7. Return on investment equation (Source: own elaboration)

CHAPTER 3. EMPIRICAL RESEARCH

A fundamental part of this thesis is to understand the practical applications of everything explained theoretically, since without this understanding the work would be incomplete. That is why Chapter 3 is going to present this case that will serve as a descriptive example to Chapter 2.

The first and fundamental thing is to understand that the company, the product and the line that is going to be studied in this section, and in the next ones, is totally fictitious, that is to say, it is a hypothetical case developed for the correct understanding of the thesis and extracted from the notes of the OM-ERP course taught by the tutor professor of this thesis. All data, therefore, will be those provided by Dr. Eng. Jacek Habel.

In addition, for this Chapter will also be applied the practical knowledge learned in the degree of Industrial Organization Engineering, in subjects such as: Business Management, Industrial Work Study, Strategic Management or High-Performance Teams for Continuous Improvement, among others.

The structure to be followed will be similar to the one presented in section 2.4 on Organizational Parameters: first, a brief introduction of the case will be given and, within this section, the fictitious company, the products to be produced in the line and the supply chain of these products will be explained. Subsequently, once the case is presented, the company will be studied by applying the classic tools: SWOT analysis, PESTEL, PORTER and the Value Chain.

After this brief introduction, the practical case of this thesis is presented:

3.1 Case study introduction

IQUEA is a company known worldwide for its good quality home furniture at a very competitive price, which is sold in Poland, France, Italy, Spain, Sweden, Holland and Ukraine. This company currently has a very famous product line called Elippe where you can find 56 different types of products related to storage and surfaces, such as: shelves, bedside tables, desks, individual shelves... all produced in good quality wood which gives them an elegant and vintage look while making them durable and resistant to water and dust.

In this thesis there are going to be studied only 3 of the products and the line will not include the cutting, just the assembly of the pieces. That is why this whole case will start from a warehouse of intermediate products, from where all the parts that come from cutting will be extracted, until reaching the final product warehouse, where the 3 types of furniture will be inventoried, already finished and ready to be packed and shipped to the many stores spread throughout Poland. For the study of these 3 products there are assembly instructions and the list of materials and accessories needed.

After this brief introduction to the case, we proceed to explain the list of products and the supply chain through which the necessary materials are obtained:

3.1.1 Product description

As mentioned in the previous point, there is going to be studied the production line of 3 different products, of which the are the instructions and materials necessary to assemble them correctly.

IQUEA always includes very detailed instructions for all its products, since they have the option of assembling them at home, but in this case, it will be studied the factory assembly line, which delivers to the customer the finished furniture ready to be placed, without the customer having to worry about the assembly.

This line, called M, produces EL2S/4/5, ELO6D/15/13,5 and EL4S/7/9 in equal parts, that is, it will not produce more of one type than the other at the moment and the material used in manufacturing process is a kind of MDF (Medium Density Fiberboard made from dry wooden chips) or HDF (High Density Fiberboard).

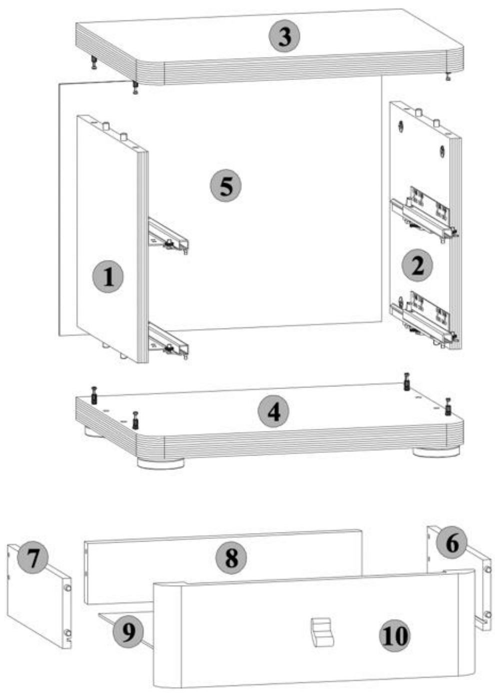
Therefore, these 3 products are explained one by one:

(a) <u>EL2S/4/5</u>

The first piece of furniture is a bedside table or side table, normally used in bedrooms. This bedside table is made up of a main piece and two sub-pieces called drawers, which fit inside the main piece and can be extracted thanks to telescopic slides.

As shown in the picture, the furniture is made up of 10 different pieces, and 14 types of accessories, where there will be screws, nails, glue, etc...

Symbol elementu Značka dílu Element symbol Jel elemek Symbol elementu	Wymiary Rozměry Measurements Nagyság Rozmery	Kod Kód Code Kód Kód	Paczka Krabica Paket Csomagban Balík
1	326x300	S20-149	1/3
2	326x300	S20-150	1/3
3	474x360	S20-230	2/3
4	474x360	S20-231	2/3
5	464x358	S20-906	2/3
6	297x100	S20-536	1/3
7	297x100	S20-537	1/3
8	398x86	S20-513	1/3
9	409x321	S20-932	2/3
10	466x145	S20-013	3/3



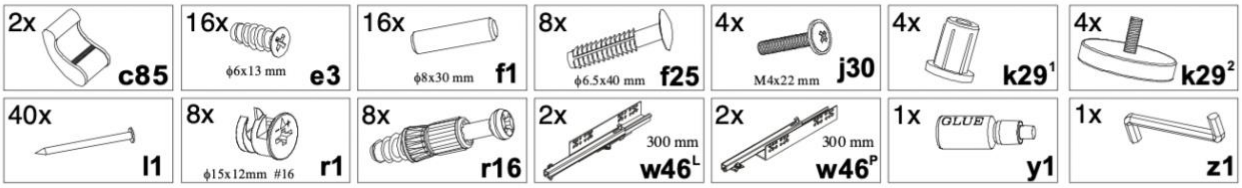
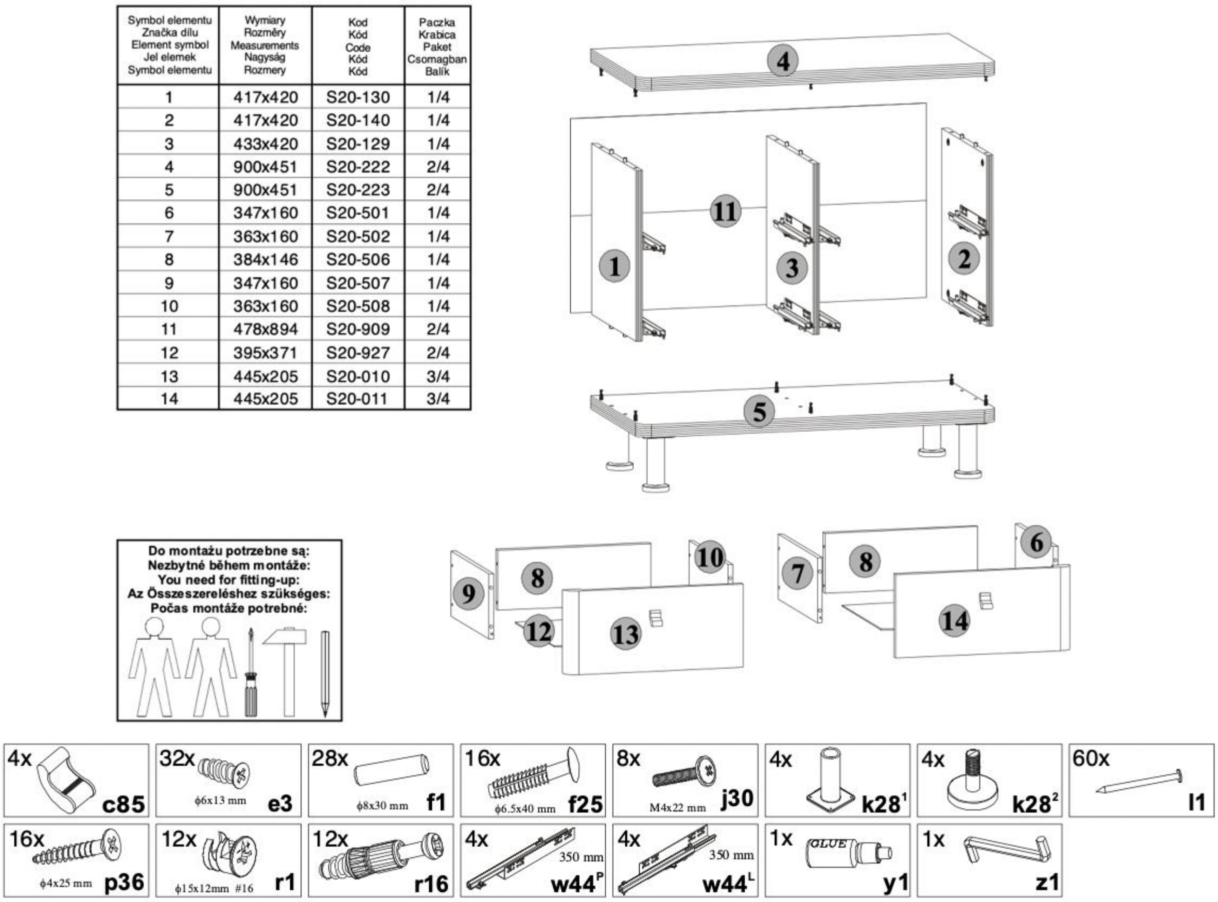


Figure 27.Assembly instructions for EL2S/4/5 (Source: BRW Sp. z o. o)

(b) EL4S/7/9

The next product to be studied will be a sideboard with four drawers to store clothes in the dressing room. This sideboard will be composed of a large common piece, with a uniform surface on top, and 4 independent drawers that are assembled separately and that are extracted with telescopic slides.

As shown in the assembly picture, it consists of a total of 14 different pieces and 15 accessories for assembly (nails, screws, slides...).



Symbol elementu Značka dílu Element symbol Jel elemek Symbol elementu	Wymiary Rozměry Measurements Nagyság Rozmery	Kod Kód Code Kód Kód	Paczka Krabica Paket Csomagban Balík
1	417x420	S20-130	1/4
2	417x420	S20-140	1/4
3	433x420	S20-129	1/4
4	900x451	S20-222	2/4
5	900x451	S20-223	2/4
6	347x160	S20-501	1/4
7	363x160	S20-502	1/4
8	384x146	S20-506	1/4
9	347x160	S20-507	1/4
10	363x160	S20-508	1/4
11	478x894	S20-909	2/4
12	395x371	S20-927	2/4
13	445x205	S20-010	3/4
14	445x205	S20-011	3/4

Figure 28.Assembly instructions for EL4S/7/9 (Source: BRW Sp. z o. o)

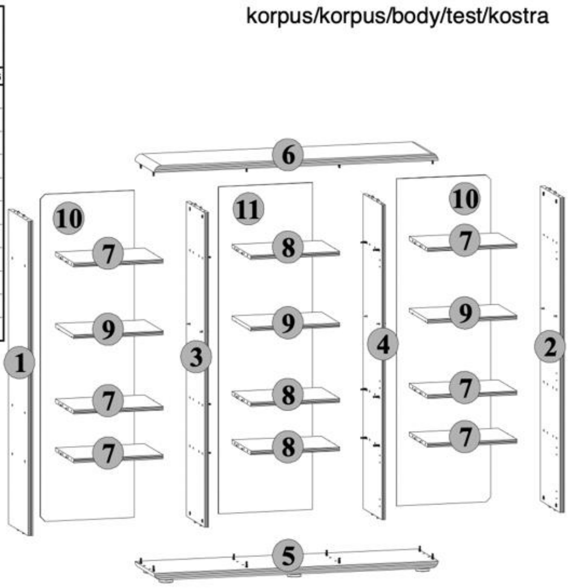
(c) ELO6D/15/13,5

Finally, the last part that is going to be studied is the production of a large piece of furniture. Specifically, this piece of furniture is a living room or dining room shelf with a total of

12 shelves separated from each other. This type of furniture will be formed by an external structure of 2 and 2 planks and then will be added the relevant shelves and separations.

As shown in the picture, 11 different types of pieces and 12 accessories are needed to make this shelving unit.

Symbol elementu Značka dílu Element symbol Jel elemek Symbol elementu	Wymiary Rozměry Measurements Nagyság Rozmery	Kod Kód Code Kód Kód	Paczka Krabica Paket Csomagban Balík	
			ELO/15/13,5	ELO6D/15/13,5
1	1464x345	S20-108	1/3	1/4
2	1464x345	S20-109	1/3	1/4
3	1464x327	S20-113	1/3	1/4
4	1464x327	S20-114	1/3	1/4
5	1350x345	S20-206	3/3	3/4
6	1350x345	S20-205	3/3	3/4
7	423x327	S20-303	2/3	2/4
8	423x327	S20-304	2/3	2/4
9	423x327	S20-307	2/3	2/4
10	1522x447	S20-914	1/3	1/4
11	1522x447	S20-915	1/3	1/4



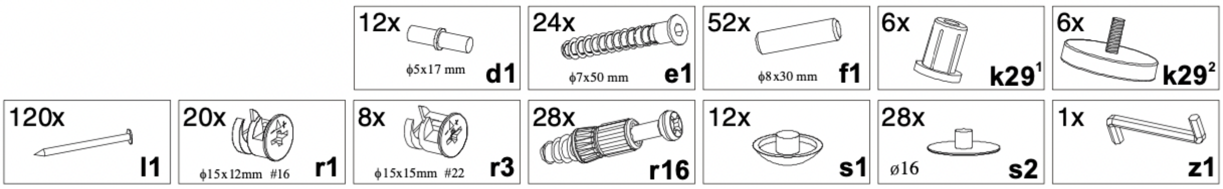


Figure 29.Assembly instructions for ELO/15/13,5 (Source: BRW Sp. z o. o)

3.2 PESTEL analysis

To carry out this first analysis, it will be answered the questions explained in section 2.3.1 and summarize the answers obtained by analyzing the situation in each case.

- What is the political situation in the country and how can it affect the industry?
- What are the predominant economic factors?
- How important is culture in the market and what are its determinants?
- What technological innovations may appear and affect the market structure?
- Is there existing legislation regulating the industry or are there likely to be any changes in this regulation?
- What are the environmental concerns for the industry?

POLITICAL	ECONOMIC
○ Political instability in eastern Poland, with the war between Ukraine and Russia, may worsen the quality of materials or accessories. ○ Brexit and conflicts in several European countries may affect brand expansion and European trade.	○ High inflation in all European countries. ○ Economic slowdown resulting from Covid, with EU aid to improve the situation. ○ Rising fuel and electricity costs, due to the Ukrainian crisis.
TECHNOLOGICAL	**SOCIAL**
○ Strengthen the e-commerce platform experience is a must to provide a perfect customer experience. ○ Generate good customer reviews is mandatory for business growth.	○ IQUEA must follow cultural norms when creating its brand to avoid cultural repercussions from different countries. ○ Companies must resolve customer complaints in different countries to improve their situation.
ENVIRONMENTAL	**LEGAL**
○ IQUEA must adapt its production to a more sustainable model that follows the environmental agenda set by the EU. ○ IQUEA must work to adapt the energetic system to use renewable energy	○ IQUEA is required to comply with the labor laws of the countries in which its production facilities are located. ○ IQUEA must follow the COVID legislation expansion. ○ IQUEA must comply with current European environmental regulations.

Table 1. PESTEL analysis (Source: own elaboration)

3.3 Porter´s 5 forces

As stated in the previous chapter, Porter's analysis is based on five key points to better understand the firm or company to be studied, in this case IQUEA.

3.3.1 Customers bargaining power

IQUEA is a company that competes globally with many others, as the sector is quite saturated with large and small companies that make good quality furniture. This is why customers will have a high bargaining power, competition will be high and customers will have a high variety to choose from.

3.3.2 Suppliers bargaining power

The bargaining power that its suppliers have, on the contrary, is nil, as IQUEA works with Polish wood companies, which are quite common, so they have nothing different that makes suppliers indispensable for production. IQUEA wants to have a good relationship with its suppliers, so it signs long-term contracts that are quite beneficial for the company.

3.3.3 Threat of new entrants

The threat of new entrants to the industry is low and there is little chance that IKEA will ever again compete at the level of another furniture company, as the current market is saturated and requires significant financial investment and expertise to become a furniture retailer on the same scale in the countries where IQUEA operates.

3.3.4 Threat of new substitute products

The threat of substitute products and services is small, as IQUEA's quality and brand strength is very difficult to match, so finding a substitute would be very difficult.

3.3.5 Rivalry among competitors

The turnover in the home and office furniture sector is very high, so the company will be under high pressure. All in all, the company is the market leader in Poland, and expects to be the market leader in the other European countries in which it operates. Moreover, expansion into the rest of the world is already a real project and is expected to achieve a market share worthy of competing with large retailers such as Walmart or Designs Inc.

3.4 SWOT analysis

As it was studied in the theory part, the SWOT analysis measures the Weaknesses, Threats, Strengths and Opportunities that a company has with respect to the inside and outside of it.

In this section it will be performed the analysis applied to the company IQUEA:

WEAKNESSES	THREATS
○ Lack of exclusivity or customization. ○ Limited product range. ○ Lower visibility due to lack of advertising. ○ Simplicity of products.	○ Increased competition due to globalization. ○ Change in consumer habits. ○ Variable and changing consumer habits. ○ Economic crisis or loss of purchasing power of the middle class. ○ Ukraine war crisis and increase of prices. ○ More austere mentality of society.
OPPORTUNITIES	**STRENGTHS**
○ Expansion into new markets in countries adjacent to Poland, like Hungary or Slovakia. ○ Increase in online sales ○ Increased sales due to the more demanded vintage style ○ Technological and production advances	○ Brand Reputation in Poland. ○ Experience in the furniture sector. ○ Customer knowledge and personalized service. ○ Good relationship with the supplier. ○ Continuous search for process innovation. ○ Pursuit of internationalization and brand expansion.

Table 2. SWOT analysis IQUEA (Source: own elaboration)

As can be seen in the graph, there are two marked areas: the internal analysis of the company itself and the external analysis of the sector's environment.

Regarding the internal, what weakens the company the most at the moment, with the strategy they are following, is the simplicity and standardization of their products. This type of cost leadership strategy is worse in the newer European markets, where differentiation comes at a better price. In any case, the company's strengths are remarkable, having a strong brand backing and a nationwide reputation as the backbone of its operations.

On the other hand, with respect to brand opportunities, expansion into other less explored European countries is the most notable, but the development of the online brand and technologies would also increase productivity. Finally, in terms of threats, the crisis and competition due to globalization would be the most important points to consider.

3.5 Value chain

As explained in the theoretical part, for the creation of the value chain it is necessary to identify the primary and secondary, or support, activities. By identifying these, it will also be clear which are the sources of income, costs and differentiation of the company.

In this case, it will be as follows:

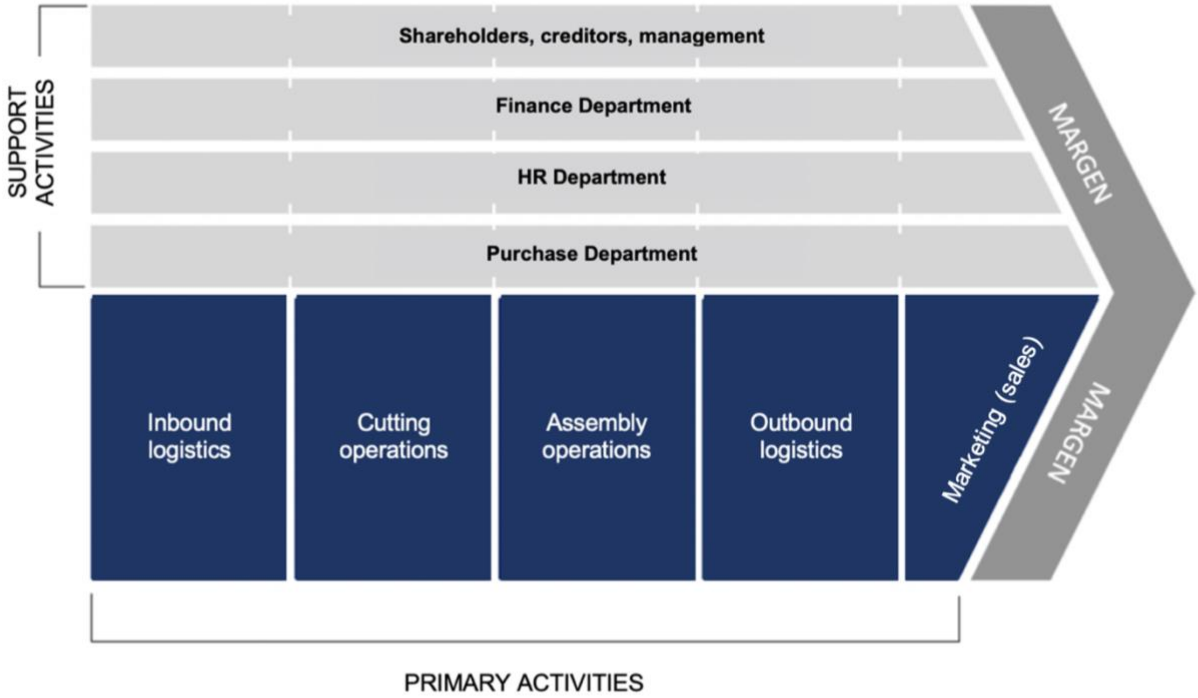


Figure 30. Value Chain of IQUEA (Source: own elaboration)

3.5.1 Activities carried out

(a) Inbound logistics

IQUEA has its own warehouse with raw materials (wood, plastic accessories, metal parts...) brought by its suppliers, so it is always covered to continue producing, without having problems of supply or stock breakage.

(b) Production operations

In this part the part of cutting the raw materials and the part of assembling them to make the final piece of furniture will be joined. Between both operations there will be an intermediate storage of already cut pieces.

From these two operations will come out the final pieces or final product, but in this thesis only the assembly part will be studied, after the intermediate storage until the final storage.

(c) Outbound logistics

Once the product is finished, in this section it will be studied about the logistics operations or shipments to stores and online customers.

(d) Marketing (sales)

Finally, IQUEA will have a sales and marketing service that must also be considered in the value chain. This service will be in charge of the pre- and post-sales service of products (online and in-store), advertising and marketing.

3.5.2 Relationship between activities

(a) Inbound logistics

Communicates with Cutting operations and Purchase department to manage purchases and inventory of necessary materials.

(b) Production operations

The two activities will communicate with each other to balance stocks and production levels. It will also receive information from the Purchase department and send information to Outbound logistics.

(c) Outbound logistics

Receiving information from production, you will communicate with marketing and sales.

(d) Shareholders, creditors and management

Being the highest point in the company's hierarchy, management will talk to almost all departments involved in production. These will be: HR, finance, purchasing and production. In this way they will be able to provide information to shareholders and creditors will know about the solvency of the plant.

(e) Financial Department

It should be in contact with the cash flows, i.e. purchasing and HR for salaries, for example.

(f) HR Department

Shall be related to cutting and assembly to meet staffing needs.

(g) Purchase Department

It will be closely related to production and inbound and outbound logistics.

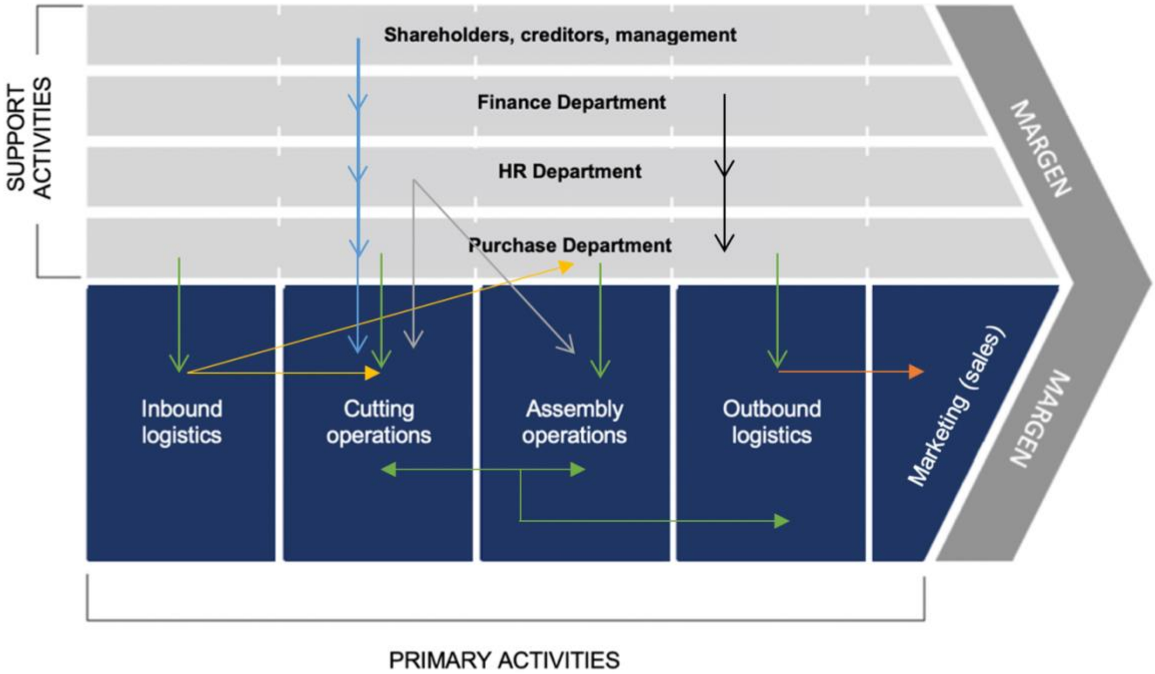


Figure 31.Value Chain relationships of IQUEA (Source: own elaboration)

CHAPTER 4. LAYOUT DESIGN

This Chapter 4 begins the central part of the practical analysis of the IQUEA company already presented in the Chapter 3.
This section has already been presented theoretically in Chapter 2, and many of the concepts have already been studied, but now is when it is finished understanding what is the Layout analysis of a company and the information that is needed and extracted from this analysis.

To complete this chapter will be used the data provided by the tutor of this thesis, as well as the diagrams and distributions that are in the PDF of the OM-ERP course. These data will be altered to some extent, to achieve the desired manufacturing volumes given the level of the IQUEA company, but at no time will be loosed sight of the Excel and the realistic sense of the case.

Thus, it is only worth remembering that this is a fictitious case study, which has no real basis in terms of companies, but it is the perfect reflection of the theoretical and practical part necessary to understand the subject well.

In this chapter 4 will also be applied the academic resources from different subjects, all of them belonging to the Industrial Organization Engineering Degree and the master's degree in Advanced Production, Logistics and Supply Chain Engineering. These subjects will be: Design of Production and Logistics Systems, Work Study, Programming and Control of Production and Operations or OM-ERP, among others.

Therefore, the structure of the chapter will be quite simple and easy to understand, in order to have all the information well synthesized.

Chapter 4 will be divided into 3 main thematic blocks. The first one will be the present layout of the 3 product lines, where the current distribution will be studied and the time and resources needed for this will be calculated. In other words, the first part will study the present. Once it is finished, the future will be studied, or the second alternative, presenting a layout with a different distribution to the first one and including the corresponding diagram. From this it will be also calculated the time and resources used, in order to be able, in block 3 of the chapter, to make a comparison between the two layouts, the present and the future, studying which one is more beneficial and which one has more advantages or disadvantages.

With all this, the introduction is finished, and the first block of the Chapter 4 is presented:

4.1 Current layout

Figure 32 below shows a simplified presentation of the current layout of the IQUEA company.
For the realization of the diagram, the online Diagram program has been used, which allows to introduce all the elements present in a plant, in order to easily understand the distribution that is followed in this one. In addition, this layout is based on the notes of the OM-ERP course, and as can be seen, it follows a distribution by product, with three well-defined zones.

4.1.1 Layout figure

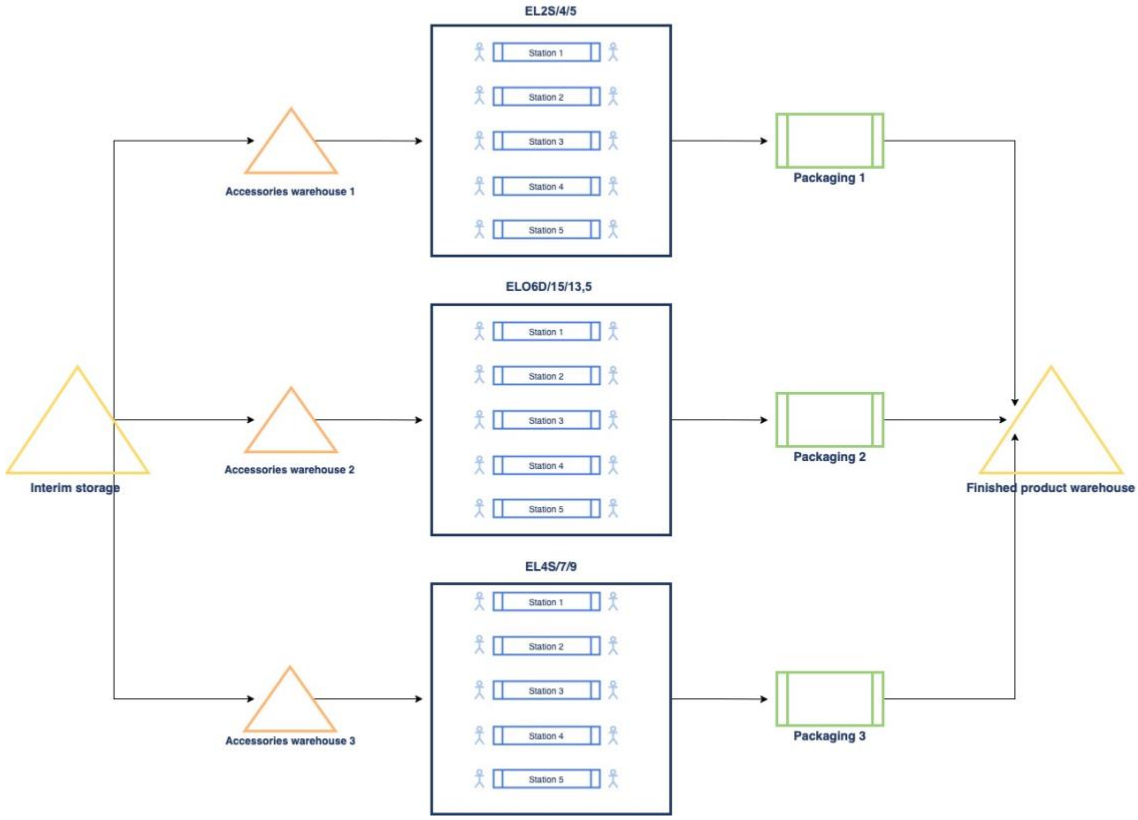


Figure 32. Present Layout (Source: own elaboration)

SYMBOL	NAME	DEFINITION
	Interim storage Final storage	The products will be deposited waiting for the next operation. In the intermediate stage, the wooden parts cut in the previous stage or the semi-assembled parts. In the other, the final stage the finished product will be left, waiting to be shipped. The inter-station storage will follow a FIFO system for operator 2, who will receive the material from the first operator and finish assembling it.
	Assembly station Packaging station	Where operations are performed on the raw material. On these square tables works an operator who is in charge of the task, either assembly or packaging.
	Station operator	The worker who will be in charge of assembling or packaging the product, making it ready for final storage.
	Material arrow	Indicates the movement of some material, either raw material, ready to pack or finished product.
	Accessory warehouse	Warehouse to supply the different stations with the necessary materials for each product.

Table 3.Explanation of the symbols of the Layout diagram (Source: own elaboration)

What is shown in Figure 32 can also be represented following the 3D scheme provided by the tutor of this thesis but increasing by 5 the number of stations with two operators.
In this way, it can be clearly seen how the 2 operators needed to make each piece of furniture work:

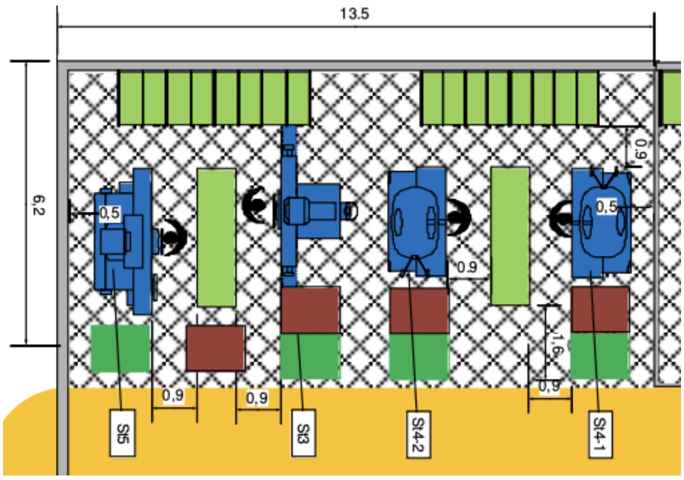


Figure 33. 3D Layout Explanation (Source: Dr inż. Jacek Habel (Ph.D. Eng.), 2022)

As can be seen in the 3D representation, there are 2 workers per complete station (each of the tables will be called station (T1, T2...Tn), with the measures of 6.75x6.2 per station, and 5 complete stations together.
It must be understood that Figure 33 is only a small adaptable representation, but it is not the complete Layout, since the accessory materials warehouse, for screws, wood blocks, etc., final warehousing, etc. are missing.

4.1.2 Analysis of the current layout

Once the current layout of the assembly part of IQUEA has been determined, it is necessary to study the implications of this distribution in the process time and in the use of material resources and personnel.

To carry out this more detailed study, many measurement tools can be used, but in this case the scheme to be followed to obtain all the information will be: first the data to be used with respect to times per activity will be introduced, explaining the meaning of each variable, then the data of accessories and resources to be used for each of the three products studied will be introduced and, finally, the time tables per product/total activities and the calculation of the most useful time parameters (cycle time, time in each station, time between initial and final storage...) will be carried out.

In this way, through the data provided by Dr inż. Jacek Habel, the most descriptive parameters of the current layout distribution will be obtained.

(a) Time required by activity

CODE	DESCRIPTION	ACTIVITY TYPE	TOOLS	TIME (S)
AA01	Take the (component) from input warehouse and put on work table	Auxiliary	Manually	**24**
AA01B	Take the (small component, like part of drawer) from input warehouse and put on work table	Auxiliary	Manually	**6**
AA02	Put the (assembled component) back in output warehouse	Auxiliary	Manually	**18**
AA03	Take the (component) from input warehouse and put on work table and (make something more)	Auxiliary	Manually	**30**
AA04	Left the (component) on work table	Auxiliary	Manually	**1**
AA05	Take the (component) from work table and (e.g. put in right position)	Auxiliary	Manually	**3**
AA06	Pull out sliders of drawer (left & right)	Auxiliary	Manually	**2**
AA07	Close the drawer	Auxiliary	Manually	**1**
AA08	Put the assembled furniture to place of storage (main warehouse)	Auxiliary	Manually	**120**
AA09	Rotate (component)	Auxiliary	Manually	**2**
MA01	Take the (accessory) from box and put it to the corresponding hole	Assembly	Manually	**6**
MA02	Using a screwdriver, tighten the (accessory)	Assembly	Screwdriver	**18**
MA03A	Using a hammer, hammer the (accessory like wooden dowel; loose connection)	Assembly	Hammer	**4**
MA03B	Using a hammer, hammer the (accessory like muff, tight connection)	Assembly	Hammer	**20**
MA04	Connect two components using hand force	Assembly	Hands	**6**
MA05	Connect three components using hand force	Assembly	Hands	**8**
MA05	Use Allen key to tighten (accessory)	Assembly	Allen key	**5**
MA06	Tighten the (accessory) by hand	Assembly	Hands	**5**
MA07	Hit the nail with a hammer	Assembly	Hammer	**5**
MA08	Apply necessary amount of glue	Assembly	Glue	**6**
MA09	Put on sliders the drawer in right position	Assembly	Hands	**20**
QC01	Check visually the (component) in case of any damage	Quality check	Visually	**5**
QC02	Visually check the proper position (of what)	Quality check	Visually	**2**
QC03	Use caliper to check distance	Quality check	Caliper	**5**
QC04	Pay attention to the correct connection	Quality check	Visually	**4**
QC05	Check the diagonal lengths	Quality check	Measuring tape	**10**
QC06	Adjust the right placement of drawer by screw	Quality check	Measuring tape	**20**

Table 4. List of activities and their durations (Source: Dr inż. Jacek Habel (Ph.D. Eng.), 2022)

CODE	NAME	DEFINITION
AA_n	Auxiliary action	Activities that are essential to complete the process, but not as a main activity but as a secondary support.
MA_n	Main assembly action	Main activities to complete the product, which make up the manufacturing process, from begging to end.
QC_n	Quality check	Essential activities for the correct realization of the assembly process. They can be performed manually (by sight, touch, etc.) or with measuring tools adapted to quality.
Tools	Tools	Tools that will allow the completion of the indicated activity. They can be manual (skill/strength of the operator) or automatic (screwdriver, nail gun...).
Time	Time per Activity	The time required to complete that task, from the start of the activity until it moves on to the next one. The best way to measure short activities accurately is in seconds.

Table 5. Explanation of terms (Source: own elaboration)

(b) Required accessories and resources

Continuing with the necessary data, this will be the list of accessories depending on the product to be made. Each product has a different code, which will allow a quick identification when making the list of tasks and times.

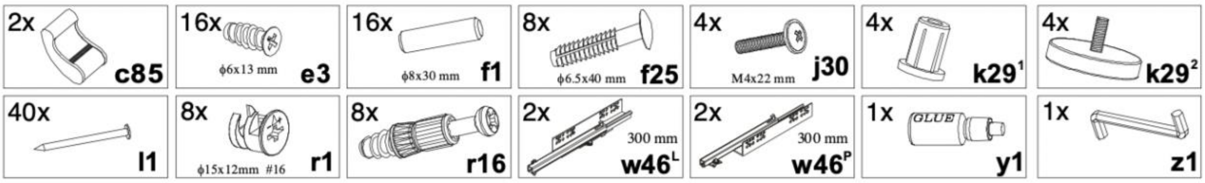


Figure 34. Assembly accessories for EL2S/4/5 (Source: BRW Sp. z o. o)

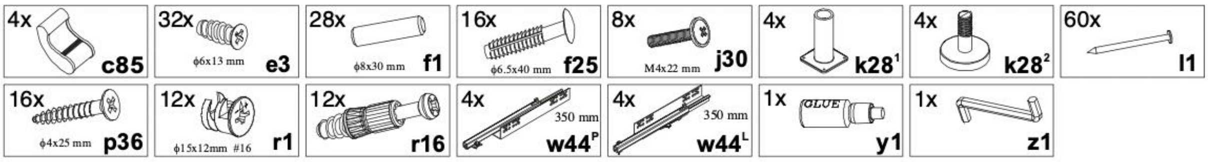


Figure 35. Assembly accessories for EL4S/7/9 (Source: BRW Sp. z o. o)

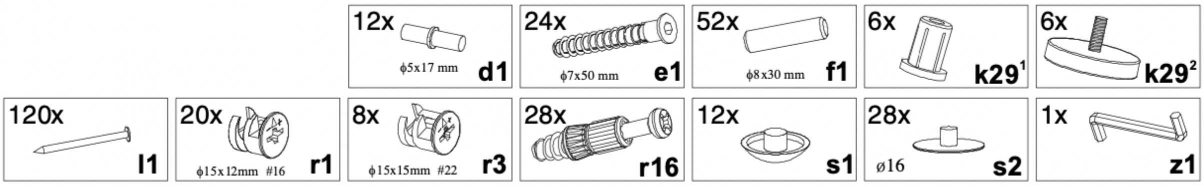


Figure 36. Assembly accessories for ELO/15/13,5 (Source: BRW Sp. z o. o)

This information is shown in the following table with the name, code, description and furniture in which it is used. In this way you can see what is in common from one product to another.

CODE	NAME	2S/4/5	4S/7/9	15/13,5
C85	Door handle	x	x	
e3	Euro Screw for drawer	x	x	
f1	Wooden dowel fluted	x	x	x
f25	Plastic peg	x	x	
j30	Screw	x	x	
K29^1	Muff base of leg	x		x
K29^2	Adjustable plastic leg	x		x
l1	Nail	x	x	x

Table 6. Accessories data per product (Source: own elaboration)

CODE	NAME	2S/4/5	4S/7/9	15/13,5
r1	Excenter fitting	x	x	x
r16	Twister screw-in dowel	x	x	x
$W46^L$	Left drawer slider	x		
$W46^P$	Right drawer slider	x		
y1	Wood glue WIKOL	x	x	
z1	Allen key	x	x	x
$K28^1$	Base of plastic leg		x	
$K28^2$	Plastic leg		x	
p36	Screw		x	
$W44^L$	Left drawer slider		x	
$W44^P$	Right drawer slider		x	
d1	Steel dowel			x
e1	Confirmat screw			x
r3	Excenter fitting #22			x
s1	Bolt plug			x
s2	Eccentric plug			x

Table 7. Accessories data per product (Source: own elaboration) (2)

As you can see in Excel, the materials already cut have also been identified, i.e. the boards correctly identified.

CODE	NAME	2S/4/5	4S/7/9	15/13,5
S20-149	Left side of body	x		
S20-150	Right side of body	x		
S20-230	Top wall of body	x		
S20-231	Bottom wall of body	x		
S20-906	Back wall of body	x		
S20-536	Right side of drawer	x		
S20-537	Left side of drawer	x		
S20-513	Back wall of drawer	x		
S20-932	Bottom wall of drawer	x		
S20-013	Drawer front	x		

Table 8. Material data per product 1 (Source: own elaboration)

CODE	NAME	2S/4/5	4S/7/9	15/13,5
S20-130	Side wall		X	
S20-140	Side wall		X	
S20-129	Inner wall		X	
S20-222	Side wall		X	
S20-223	Inner wall		X	
S20-501	Drawer side wall		X	
S20-502	Drawer side wall		X	
S20-506	Back of drawer		X	
S20-507	Drawer side wall		X	
S20-508	Drawer side wall		X	
S20-909	Back wall		X	
S20-927	Drawer bottom		X	
S20-010	Forehead drawers		X	
S20-011	Forehead drawers		X	

Table 9. Material data per product 2 (Source: own elaboration)

CODE	NAME	2S/4/5	4S/7/9	15/13,5
S20-108	Side wall			X
S20-109	Side wall			X
S20-113	Inner wall			X
S20-114	Inner wall			X
S20-206	Bottom wall			X
S20-205	Top wall*			X
S20-303	Shelf1			X
S20-304	Shelf2			X
S20-307	Shelf3			X
S20-914	Back wall L&R			X
S20-915	Back wall C			X

Table 10. Material data per product 3 (Source: own elaboration)

Also, in terms of labor resources, in each of the work groups there will be 10 workers divided in pairs. These workers will be distributed half and half, the first one being in charge of the part of inserting screws or nails and the second one of assembling the previously prepared boards.

Thus, for product type 1 there will be 10 employees as a resource, for product type 2 there will also be 10 and for product type 3 there will also be 10. For packaging, there will be 1 worker in every station, so in total there will be 33 workers in the morning, and 23 workers in the afternoon (product 4S only has one shift).

(c) Time tables per product

OPERATION	DESCRIPTION	TIME/ACT	TIME/ACT	TIME/OPE
		S	**MIN**	**MIN**
OP01	Equipping the MDF boards with the appropriate accessories	**596**	**9,933**	**9,933**
T101	Equip the **C3** board with **r16**	151	2,517	
T102	Equip the **C4** board with **r16**	151	2,517	
T103	Equip the **C1** board with **r1** and **f1**	147	2,45	
T104	Equip the **C2** board with **r1** and **f1**	147	2,45	
OP02	Assembly of main body (assembly unit 1)	**899**	**14,983**	**14,983**
T201	Connect SC1 with SC3	74	1,233	
T202	Connect SC2 with SC3	50	0,833	
T203	Connect SC4 with SC1 and SC2	62	1,033	
T204	Install plastic legs k29	174	2,9	
T205	Install back wall C5	539	8,983	
OP03	Assembly of drawer (assembly unit 2)	**529**	**8,817**	**8,817**
T301	Install dowels f1 in C6	58	0,967	
T302	Install dowels f1 in C7	58	0,967	
T303	Make a frame of drawer. Connect C6, C7 & C8 with f25	169	2,817	
T304	Connect C10 with drawer frame by glue	47	0,783	
T305	Install bottom C9 in drawer frame	23	0,383	
T306	Connect C9 with drawer frame by nails l1	100	1,667	
T307	Install door handle c85 with j30 screw	74	1,233	
OP04	Final assembly of furniture	**722**	**12,033**	**12,033**
T401	Install sliders w46P in right wall C2	238	3,967	
T402	Install sliders w46L in left wall C1	226	3,767	
T403	Install drawers	258	4,3	
				45,766

Table 11. Time data for product EL2S/4/5 (Source: Dr inż. Jacek Habel (Ph.D. Eng.), 2022)

OPERATION	DESCRIPTION	TIME/ACT	TIME/ACT	TIME/OPE
		S	**MIN**	**MIN**
OP01	Equipping the MDF boards with the appropriate accessories	**1006,00**	**16,77**	**16,77**
T101	Equip the **C4** board with **r16**	203,00	3,38	3,38
T102	Equip the **C5** board with **r16**	203,00	3,38	3,38
T103	Equip the **C1** board with **r1** and **f1**	147,00	2,45	2,45
T104	Equip the **C2** board with **r1** and **f1**	147,00	2,45	2,45
T105	Equip the **C3** board with **r1** and **f1**	147,00	2,45	2,45
T106	Equip the C3 board with w44P and e3	159,00	2,65	2,65
OP02	Assembly of main body (assembly unit 1)	**410,00**	**6,83**	**6,83**
T201	Connect SC4 with SC14	74,00	1,23	1,23
T202	Connect SC2 with SC14	50,00	0,83	0,83
T203	Connect SC2 with SC124	50,00	0,83	0,83
T204	Connect SC5 with SC1 and SC2	62,00	1,03	1,03
T205	Install plastic legs k28	174,00	2,90	2,90
T301	Assembly of main body (assembly unit SB2)	679,00	11,32	11,32
T401	Assembly of main body (assembly unit SB3)	656,00	10,93	10,93
OP03	Assembly of drawer (assembly unit 2)	**889,00**	**14,82**	**14,82**
T501	Install dowels f1 in C6 & C7 & C9 & C10	232,00	3,87	3,87
T502	Make a frame of drawer. Connect C6, C7 & C8 with f25	169,00	2,82	2,82
T503	Connect C13 & C14 with drawer frame by glue	94,00	1,57	1,57
T504	Install bottom C12 in drawer frame	46,00	0,77	0,77
T505	Connect C12 with drawer frame by nails l1	200,00	3,33	3,33
T506	Install door handle c85 with j30 screw	148,00	2,47	2,47
OP04	Final assembly of furniture	**509,00**	**8,48**	**8,48**
T601	Install drawers	396,00	6,60	6,60
T701	Install drawers	113,00	1,88	1,88
				46,90

Table 12. Time data for product EL4S/7/9 (Source: Dr inż. Jacek Habel (Ph.D. Eng.), 2022)

OPERATION	DESCRIPTION	TIME/ACT	TIME/ACT	TIME/OPE
		S	MIN	MIN
OP01	Assembly boards 1-8 with their respective accessories	**2228**	**37,13^**	**37,13**
T101	Assembly board C1 with R3, F1, D1	251	4,183	
T102	Assembly board C2 with R3, F1, D1	251	4,183	
T103	Assembly board C3 with R1, F1, D1, R16	461	7,683	
T104	Assembly board C4 with R1, F1, D1, R16	461	7,683	
T105	Assembly board C5 with R16	255	4,25	
T106	Assembly board C6 with R16	255	4,25	
T107	Assembly board C7 with F1	95	1,583	
T108	Assembly board C8 with F1, R1	199	3,3176	
OP02	Assembly the central shelves 1/2/3/4/7	**1122**	**18,7**	**18,7**
T201	Assembly board SC7,SC1,SC3 together with E1, S1	561	9,35	
T202	Assembly board SC7, SC2, SC4 together with E1, S1	561	9,35	
OP03	Assembly the lateral shelves 3/4/8	**232**	**3,867^**	**3,867**
T301	Assembly board SC137, SC247 together with S2	232	3,867^	
OP04	Assembly the top/bottom shelves 5/6	**381**	**6,35**	**6,35**
T401	Assembly board SC348 together with K29, S2	381	6,35	
OP05	Finish the assembly by adding the rear parts 10/11	1563	**26,05**	**26,05**
T501	Assembly board SC6 together with L1	1563	26,05	
				92,097

Table 13. Time data for product ELO/15/13,5 (Source: Dr inż. Jacek Habel (Ph.D. Eng.), 2022)

(d) <u>Organizational data per product</u>

NAME	TPV	Dw	WT	NS	PI
	P	D	H	SH	MIN
2S/4/5	14000	5	8	2	20
4S/7/9	7000	5	8	1	20
15/13,5	9000	5	8	2	20

Table 14. Important data for the time/resource study (Source: Dr inż. Jacek Habel (Ph.D. Eng.), 2022)

The terminology used in this last table refers to:

- **TPV**: Total volume production demanded. It is the minimum quantity of product needed in a year with the 5 stations production.
- **DW**: is the number of working days per week of the line.
- **WT**: is the number of hours to be worked per shift, without considering interruptions.
- **NS**: is the number of shifts to be performed.
- **PI**: is the time of interruptions per shift, measured in minutes.

(e) **Final result**

After all the information given in the previous sections, the most important time results will be:

PRODUCT	TOTAL ASSEMBLY	TOTAL INSPECTION	TOTAL PACKAGING	TOTAL WAIT	TOTAL MOV	CICLE TIME
	MIN	MIN	MIN	MIN	MIN	MIN/P
2S/4/5	41,28	4,48	5,00	20,00	5,00	75,77
4S/7/9	33,30	13,60	5,00	20,00	5,00	76,90
15/13,5	80,73	11,37	5,00	20,00	5,00	122,10

Table 15. Cycle time per product and station (Source: own elaboration)

The time spent in packaging will be considered, which in this case is indicative since the actual data have not been obtained. Therefore, the cycle time will cover all the movements represented in the Layout of figure 32, from the intermediate product storage to the final storage.

PRODUCT	CICLE TIME	TIME AVAL	TOTAL PROD STATION	TOTAL STATION	TOTAL PROD W	TOTAL PROD M	TOTAL PROD Y
	H/P	H/W	P/W		P/W	P/M	P/Y
2S/4/5	1,26	76,65	60,70	5,00	303,50	1214,00	14568,01
4S/7/9	1,28	38,50	30,04	5,00	150,20	600,78	7209,36
15/13,5	2,03	76,65	37,67	5,00	188,33	753,34	9040,03

Table 16. Total production in total (all stations) based in the cycle time (Source: own elaboration)

PRODUCT	TPV (STATION)	ESH WEEK	ESH YEAR	PROD INTENSITY	TACK TIME
	P/Y	H/W	H/Y	P/H	H/P
2S/4/5	2800,00	76,65	3985,80	0,70	1,42
4S/7/9	1400,00	38,50	2002,00	0,70	1,43
15/13,5	1800,00	76,65	3985,80	0,45	2,21

Table 17. TT and P based in the TPV of one station (Source: own elaboration)

Therefore, once the calculations have been completed, it can be seen that the cycle time per hour and product in any of the stations is always less than the Tack Time, so the minimum production demand, indicated in the TPV parameter, will be more than met.
By calculating the production in two ways (TC and TPV) it is possible to verify that there will be no problems of stock out or production overdemand.

With the TC, P and TT parameters it is possible to finish the temporal analysis of the current layout since they are very significant parameters when determining the improvement or worsening of a line layout.

As a conclusion, it is important to understand that the marked CT is per station (2 workers), but it would be enough to multiply it by the total number of stations (5 per type of product) to obtain the total CT for that product.

Also, the total production per year will be by type of product but when calculating the Tack time, it has been preferred to do it by station to be able to check it with the previous CT, so the TPV has been divided by the total number of stations working in the type of product.

4.2 Layout proposal

Once the current situation of the layout of the 3 products is clear, the improved or future layout must be carried out. It is important to emphasize that in order to carry out this process, the assembly of the products will be reorganized, without paying attention to the previous one, allowing much more operational flexibility. Also, it is possible that this proposed layout does not improve the present result, so the present may be better than this one.

4.2.1 Layout figure

The most optimal layout for this case will be the one that focuses on the process, not so much on the product, so the combined layout will be applied, mainly by process, but there may be product areas. This type of layout was explained in the theoretical part, in section 2.2.1, subsection B.

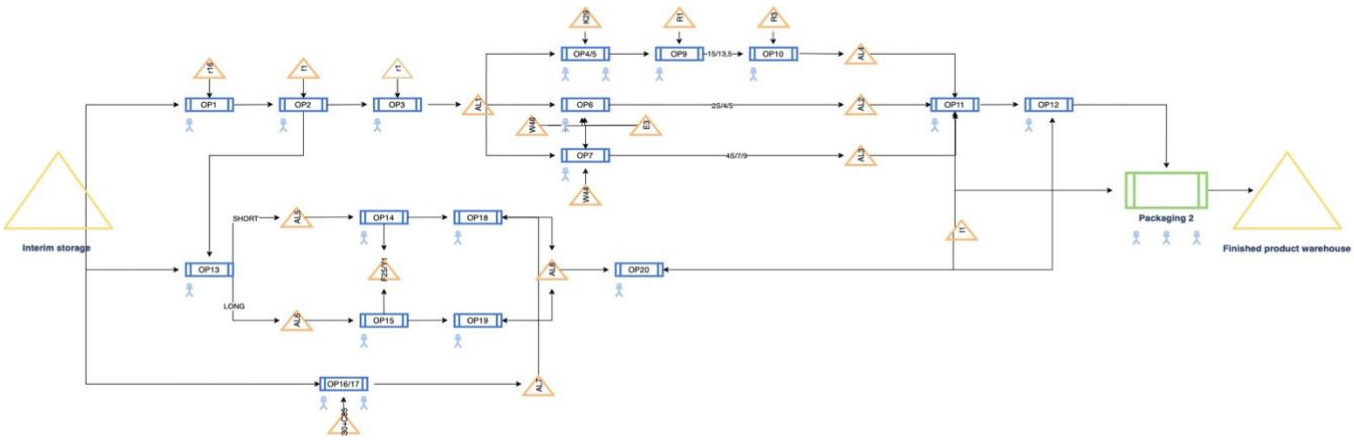


Figure 37. Future Layout (Source: own elaboration)

To understand this layout, a few quick clarifications will be made:

- The first thing is to emphasize that the start and end warehouses have not been changed, but the packaging part has been reduced to one station. In this way, all the furniture will be arriving at this station, and they will work in parallel, regardless of the type of furniture that arrives. Moreover, the shelf type 15/13,5 will arrive before the other two types as it has no drawers and therefore operation 12 is not necessary for it.
- Operations 1, 2 and 3 are common to all the furniture, therefore, the pieces will simply be added to all the tables, without separation. Afterwards, they will all be stored in the first storage location AL1.
- After AL1, a distinction must be made between one piece of furniture and another since the process changes. The two bedside tables will need rails for the drawers, so they will be placed on the tables that need them. Meanwhile, in the operations above, the tops will be placed in a joint operation on the 15/13.5 type cabinet and on one of the boards of the 2S cabinet. Once these independent processes per product are finished, all the pieces will be stored in the 3 final warehouses.

- Finally, in operation 11 the piece I1 will be applied to all the furniture already formed, which will finish the structure of all of them, but only the shelf will go to the packaging part.

Parallel to all this, will be the drawer area, where the 2 types of drawers, short and long, will be formed:

- From the first operation OP1 some of the pieces will be lowered and separated in operation 13 into long boards or short boards, both in divided warehouses. Both pieces will use F25 type dowels fixed with glue to continue, but the separation is given by the facility to identify the type of drawer that is each one.
- Then it will be added the wood with handle already fixed that have been made in the parallel activity number 16 and 17 (screw and handle go together) and that was waiting in the warehouse AL7, and it will be let dry the 15 minutes of glue.
- Once all the drawers are dry, will be added the bottom of the drawer (with pieces type I1 obtained from the same warehouse as before) easy to identify so it is enough with one operation, and will move them all up to operation 12 where they will be assembled with the structures finished before.
- Once all the furniture is finished, they will go directly to packaging, to avoid knocks they will not go on the pallets, and from there to the final warehouse.
- In addition, all the required materials will come from specific warehouses where the operators will go to get them.

4.2.2 Analysis of the proposed layout

To understand the improvement, it will be necessary to analyze the times of this second layout, since the improvement in time is decisive. There is no doubt that other factors such as yields or economic analysis will also have to be analyzed, but this won't be done in this thesis.

(a) <u>Timetables per product</u>

To study the times a series of clear premises will be applied, always remembering the hypothetical case on which all these improvements are based. The time calculation will be given as a guide since it is all hypothetical and there is no real confirmation of the times and activities to be carried out:

- The first idea is that the time for 2 of the 3 products under study will be reduced. This is due to the fact that the drawers and the external structure will no longer be made in a row but will be made in parallel and, therefore, the production will be marked by the slower of the two parts into which it is divided. This division is very marked in Figure 37, where above is the part in charge of the structure of the cabinet and below the drawers of the 4S and 2S.

- The second idea is centered on past and future times. The past times established their duration based on the Annexes table, and took into account the material changes and the operations that had to be performed at each station. However, in the layout that is being analyzed now, the processes are much simpler and standardized, which makes it possible to reduce set-up times, changeovers, etc. This is why all the previous times will be multiplied by a factor of 70%, since it is assumed that 30% of the time is reduced by standardizing the processes.
- The times are indicative, this layout has not been implemented so they are only theoretical improvements that can be made in the plant, but in no case, this is the real data of these movements.
- With respect to the furniture type 15/13,5, by following the same route, the operations will not change and simply multiply the time spent by the factor of 70%. In this way, this will be the one that will set the production rate, since it will take the longest time.

OPERATION	DESCRIPTION	TIME/ACT	TIME TOTAL
		S	**MIN**
OP01	Equip the C3 board with r16	105,7	1,76
OP02	Equip the C4 board with r16	105,7	1,76
OP03	Equip the C1 board with f1	60,2	1,00
OP04	Equip the C2 board with f1	60,2	1,00
OP05	Equip the C1 board with R1	42,7	0,71
OP06	Equip the C2 board with R1	42,7	0,71
OP07	Install plastic legs k29	119,7	2,00
OP08	Install sliders w46P in right wall C2	166,6	2,78
OP09	Install sliders w46L in left wall C1	180,6	3,01
OP10	Connect SC1 with SC3	51,8	0,86
OP11	Connect SC2 with SC3	35	0,58
OP12	Connect SC4 with SC1 and SC2	43,4	0,72
OP13	Install back wall C5	377,3	6,29
		1391,6	23,19
OP14	Install dowels f1 in C6	40,6	0,68
OP15	Install dowels f1 in C7	40,6	0,68
OP16	SEPARAR LARGAS/CORTAS	14	0,23
OP17	Make a frame of drawer. Connect C6, C7 & C8 with f25	118,3	1,97
OP18	Connect C10 with drawer frame by glue	32,9	0,55
OP19	Install bottom C9 in drawer frame	86,1	1,44
		332,5	5,54
OP20	Install door handle c85 with j30 screw	51,8	0,86
		51,8	0,86
OP21	Install drawers	180,6	3,01
		1572,2	**26,20**

Table 18. Product 2S/4/5 new process (Source: own elaboration)

OPERATION	DESCRIPTION	TIME/ACT	TIME TOTAL
		S	MIN
OP01	Equip the C4 board with r16	142,10	2,37
OP02	Equip the C5 board with r16	142,10	2,37
OP03	Equip the C1 board with f1	60,20	1,00
OP04	Equip the C2 board with f1	60,20	1,00
OP05	Equip the C3 board with f1	60,20	1,00
OP06	Equip the C1 board with r1	42,70	0,71
OP07	Equip the C2 board with r1	42,70	0,71
OP08	Equip the C3 board with r1	42,70	0,71
OP09	Equip the C3 board with w44P and e3	111,30	1,86
OP10	Connect SC4 with SC14	51,80	0,86
OP11	Connect SC2 with SC14	35,00	0,58
OP12	Connect SC2 with SC124	35,00	0,58
OP13	Connect SC5 with SC1 and SC2	43,40	0,72
OP14	Install plastic legs k28	121,80	2,03
OP15	Assembly of main body	475,30	7,92
		1466,50	**24,44**
OP16	Install dowels f1 in C6 & C7 & C9 & C10	162,40	2,71
OP17	SEPARAR LARGAS/CORTAS	14,00	0,23
OP18	Make a frame of drawer. Connect C6, C7 & C8 with f25	118,30	1,97
OP19	Connect C13 & C14 with drawer frame by glue	65,80	1,10
OP20	Install bottom C12 in drawer frame	32,20	0,54
OP21	Connect C12 with drawer frame by nails l1	140,00	2,33
		532,70	**8,88**
OP22	Install door handle c85 with j30 screw	103,60	1,73
		103,60	**1,73**
OP23	Install drawers	277,20	4,62
OP24	Install drawers	79,10	
		1743,70	**29,06**

Table 19. Product 4S/7/9 new process (Source: own elaboration)

To make the two tables (18 and 19) both groups of activities have been added, and the longest (bottleneck) has been added to the activity of installing the crates, which will be waiting for the previous activities to finish.

With all this, the timetable of assembly will be:

NAME	2S/4/5	4S/7/9	15/13,5
TIME (MIN)	26,20	29,06	56,51
TIME (SEC)	1572,20	1743,70	3390,60
OPERATION	15,00	13,00	10,00

Table 20. Summary of resources and times with the proposed distribution (Source: own elaboration)

This improvement is more than remarkable, since it marks the economic and resource savings and can be given thanks to the ease of a single worker to do a simple job if it does not require tool changes or displacements to the warehouse, making processes much simpler and mechanical.

(b) Final result

PRODUCT	TOTAL ASSEMBLY	TOTAL INSPECTION	TOTAL PACKAGING	TOTAL WAIT	TOTAL MOV	CICLE TIME
	MIN	MIN	MIN	MIN	MIN	MIN/P
2S/4/5	26,20	2,98	5,00	20,00	5,00	59,18
4S/7/9	29,06	3,16	5,00	20,00	5,00	62,22
15/13,5	56,51	7,96	5,00	20,00	5,00	94,47

Table 21. Cycle time per product (Source: own elaboration)

As can be seen in the image, the assembly time is reduced, as well as the inspection times, since some of the operations in the first two products change and, in addition, the 70% factor must be applied. The movements, waits and packaging remain the same, because they are standards that have been previously assumed.

With all this, cycle times are significantly reduced in all types of furniture, and it is the third product that will set the pace of the line, as it is the product with the longest cycle time.

PRODUCT	CICLE TIME	TIME AVAL	TOTAL PROD STATION	TOTAL STATION	TOTAL PROD W	TOTAL PROD M	TOTAL PROD Y
	H/P	H/W	P/W		P/W	P/M	P/Y
2S/4/5	0,99	76,65	77,71	1,00	77,71	310,84	3730,05
4S/7/9	1,04	76,65	73,91	1,00	73,91	295,65	3547,86
15/13,5	1,57	76,65	48,68	1,00	48,68	194,73	2336,79

Table 22. Total production based in the cycle time (Source: own elaboration)

Therefore, to calculate the production that can be carried out, it will be necessary to work out the cycle time in hours, as well as to calculate how much time is worked in total.
Before the 4S product only worked one shift, but due to the standardization process, now it also works 2 shifts. With this the final production that can be achieved is shown in the table above.

PRODUCT	TPV (STATION)	ESH WEEK	ESH YEAR	PROD INTENSITY	TACK TIME
	P/Y	H/W	H/Y	P/H	H/P
2S/4/5	14000,00	76,65	3985,80	3,51	0,28
4S/7/9	7000,00	76,65	3985,80	1,76	0,57
15/13,5	9000,00	76,65	3985,80	2,26	0,44

Table 23. TT and P based in the TPV of all the line (Source: own elaboration)

With respect to the tack time and the productive intensity, it can be seen that they give lower numbers than the cycle times. This is due to the fact that before the line used to work with 5 stations per product, and now it only works with one station. This is why the production will have to be adjusted to meet expectations.

4.3 Layout conclusions

To conclude the layout section, some conclusions will be offered on what has been studied, by way of conclusion and choice of alternatives:

- The two layouts proposed are hypothetical since there is no real data available on this plant, because it does not exist today.

- The times applied have been extracted from the power points of the OM-ERP course and can be found in the tables attached in the annexes section.

- Regarding the first layout, the number of operators per station was 2, because it was one of the requirements established in the assembly instructions of each product. With this, it was decided to have 5 stations per product, in order to obtain a higher production. These 5 stations are equal to each other, and all leave their products in the packaging area, which has only 1 operator. That is why the number of operators in the first layout is 11 per product/shift.
  The summary of the first layout will therefore be as follows:

PRODUCT	TPV YEAR (1 STATION)	ESH (YEAR) (1 STA)	CICLE TIME	CICLE TIME	PROD. INTENSITY	TACK TIME (1S)	PROD. REAL (1S)	PROD. REAL (TOT)	# STATION	# EMPLOY
	P/Y	H/Y	MIN/P	H/P	P/H	H/P	P/Y	P/Y		
2S/4/5	2800,00	3985,80	75,77	1,26	0,70	1,42	2913,60	14568,01	5,00	11,00
4S/7/9	1400,00	2002,00	76,90	1,28	0,70	1,43	1441,87	7209,36	5,00	11,00
15/13,5	1800,00	3985,80	122,10	2,04	0,45	2,21	1808,01	9040,03	5,00	11,00

Table 24. Summary of first plant layout data (Source: own elaboration)

Therefore, the production per shift will be: 6.09 P/shift or 30.4 P/line.

- On the other hand, the second layout focuses on the process, keeping some stations per product. Therefore, this layout could be called combined. Regarding the operators, there would be one per operation, i.e., if there were two operations, there would be two working together. In addition, in the packaging area there should be 3 operators, due to the high demand of this station. With all this, the distribution means that 22 workers would be needed per shift, with two shifts per day.
  The summary table of the second layout would be:

PRODUCT	TPV YEAR (1 STATION)	ESH (YEAR) (1 STA)	CICLE TIME	CICLE TIME	PROD. INTENSITY	TACK TIME (1S)	PROD. REAL (1S)	PROD. REAL (TOT)	# STATION	# EMPLOY
	P/Y	H/Y	MIN/P	H/P	P/H	H/P	P/Y	P/Y		
2S/4/5	14000,00	3985,80	59,19	0,99	3,51	0,28	3730,05	3730,05	1,00	17,00
4S/7/9	7000,00	3985,80	62,22	1,04	1,76	0,57	3547,86	3547,86	1,00	15,00
15/13,5	9000,00	3985,80	94,47	1,57	2,26	0,44	2336,79	2336,79	1,00	12,00

Table 25. Summary of second plant layout data (Source: own elaboration)

As can be seen in the image, the tack time is much lower than the cycle time, because, although the cycle time has improved compared to the previous situation, now there is only one line, not 5 as before. This is why the tack time will be lower, and it will not be possible to cope with the demand with only these operators and a single line. On the other hand, in this case the production per shift would be: 7.59 P/shift or 7.59 P/line.

Seen the results, it is obvious to say that the improvement proposal does not improve the line, but rather worsens it in these circumstances. This may be due to the fact that there are certain products that do not accept production by process, due to the difficulty of standardizing operations. In this case this is a clear example that, by improving the times, production worsens.

In summary, after these key points, it can be said that the most appropriate layout for this plant would be the first one. Sometimes improvement proposals fail to adapt to manufacturing, as in this case, and simply remain as a proposal. Perhaps in another sector, in which the products can be easily standardized, in which only one type of furniture is produced, production could be improved by moving from product to process.

In the following section it will be discuss a series of improvements to the line, which could be useful to reduce time, waste, or to adapt the proposal to the current factory.

4.3.1 Plant layout improvements

Finally, and to end the chapter on plant layout, a series of theoretical improvements will be proposed that could increase the competitiveness of the line.
These improvements can be made both in the present layout and in the proposal made in the previous section, turning it into a more attractive and competitive alternative, something that at the moment it does not achieve.
In this case 3 improvements will be discussed, which will affect the quality of the product in particular:

(a) <u>Quality station</u>

The first theoretical improvement that should be mentioned would be the creation of a quality control station, which can check the correct condition of the parts at the beginning and end of the line. This measure is intended for the present layout, although it could also be implemented in the proposed layout.

The main idea is to reduce defect rates, avoiding working on parts that do not meet the expected quality standards. In this case the station should be set up before entering the transformation area, before the 5 workstations, and also before entering the packaging area, to avoid sending parts with defects.

At the moment the quality tasks are performed by operators, who spend a very high amount of time (Table 15) to check each piece. By creating these product stations those times would disappear, gaining in cycle times and productivity. Thus, hiring 2 quality inspectors could increase production and reduce process times, as well as reduce operator fatigue per product.

The advantages of this improvement also include increased customer satisfaction, who would receive a better-quality product than before, which would improve the brand image and perceived value of the company.

(b) Rework station

To continue with the improvement mentioned in the previous section, it would also be a good idea to set up a rework station for the parts that are removed from the quality station. This improvement would go hand in hand with the previous one, although it can also be implemented only depending on the controls by the operators that are made right now.

In this case, the improvement is very simple: a rework station where simple faults in the parts can be solved, thus avoiding waste. In this case, the parts come with a defect:

NAME	TPV	Dw	WT	NS	PI	B %
	P	D	H	SH	MIN	
2S/4/5	14000	5	8	2	20	1%
4S/7/9	7000	5	8	1	20	2,0%
15/13,5	9000	5	8	2	20	2,5%

Table 26. Information about quality ((Source: Dr inż. Jacek Habel (Ph.D. Eng.), 2022)

Where B is the number of units that must ultimately be removed due to defects. By implementing the rework measure, with one operator, production could be increased by almost the totality of that percentage.

The main idea in implementing this measure would be to make rework batches. These batches, which should be calculated the products that conform them, would pass to a post with an operator who would be in charge of observing if the failure has or not a feasible solution. If not, it would simply be discarded, but if it is possible, it would be fixed and sent back to the production line to continue the process.

This improvement can only be applied to parts with slight defects, where it will not affect the final performance of the product. Things like filing an edge, or a corner, but not cracks, flaws in the wood or other problems that would change the final piece of furniture.

(c) Increase in the number of workers

Finally, the most drastic improvement would be to apply in the proposed layout a sufficiently large increase in personnel to bring production up to the present level, reducing cycle times. This increase in personnel would be significant, since it would increase production from 7.59 P/shift or 7.59 P/line, by four. In this way it could have been a line with shorter cycle times and higher production.

Obviously, to be able to carry out this measure, to increase the personnel, the economic benefit should be compared with the cost of quadrupling the number of operators that are at the moment, that is why it is simply a proposal, it will not be attempted to be carried out in this thesis.

For the moment, the proposal is not attractive, but the way to make it attractive would be through this increase in personnel.

4.4 Theorical layout proposal

In addition to what has been commented in the previous points, it has been decided to make a theoretical proposal of a hypothetical layout with a workshop type organization.

The decision not to include it in the conclusions is because this layout will not have plausible calculations or distributions, it will simply be studied with the theory applied to this case what would happen if implementation is attempted with this layout, but because the production requirements would not be met, it will not be considered as the other two.

Therefore, the section will remain as follows:

4.4.1 Boceto of the theoretical layout

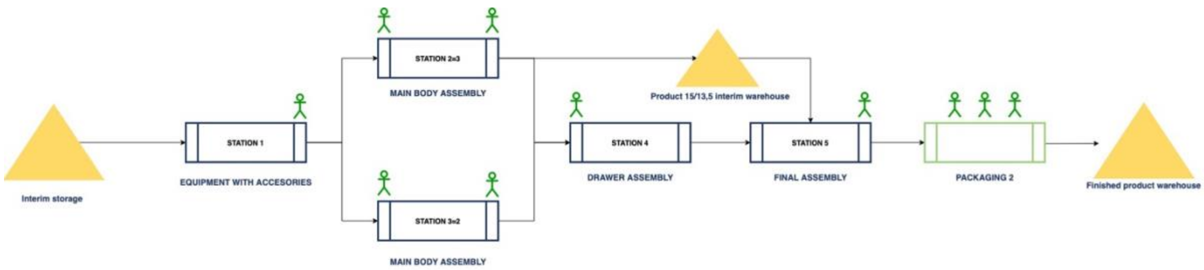


Figure 38. Theorical Layout (Source: own elaboration)

4.4.2 Theoretical study

This short section will be divided into: effect on resources, effect on time and effect on production.

(a) <u>Resource effect:</u>

In the proposed layout, the stations will be divided into 5 stations, where one operator will work at a time. These stations will be in charge of making the three pieces of furniture together but changing the tools and processes from one type to another. Therefore:

- The first station will be responsible for putting the fixtures on all the boards, regardless of where they come from. This will fulfill OP 1 of all the furniture, and the parts that make up this operation can be found in Annexes of this thesis.
- The second and third stations will be responsible for assembling the main body of all the furniture. In this station there should be more than one operator due to the complication and size of the task. In addition, due to the demand, it will be assumed that there are two number 2 stations performing the same task in parallel.

- The fourth station will be responsible for assembling the drawers of the furniture if it has one, since the 15/13.5 rack does not have a drawer unit, so the type 3 furniture will be left in an intermediate storage area until the next station.
- Finally, at station five, the furniture will be assembled and sent to packaging.
- The proposed 3 people will be maintained in the packing station, due to the volume of product and the difficulty of packaging.

Therefore, a total of 10 operators will be needed to perform the operation and 6 stations if the packing station is considered. However, if there were only one operator per station, only 6 operators would be needed in total, or 5 if there were only one assembly station instead of two.

A point to highlight is that in this type of production the operators must have a high level of knowledge since the process is not very standardized and with a higher level of instructions and complexity than the production in line or by product. This is why operators will have more value here than in other layouts.

(b) <u>Time and production effect:</u>

With respect to the times, it is much more complicated to calculate without data, but understanding the type of production per shop that you will have, it is easy to see that the times increase, since the tool changes, the times between stations and the slower production will end up being reflected in these.

If the cycle time increases the production will decrease, since in the Job Shop lines the production volumes are lower due to the more heterogeneous processes.

This is why this type of distribution works best with Make To Order systems, where it is the customer who takes the first step and places an order for certain units and then the plant can start working.

In this case, if IQUEA did not have the system present and the volume of customers was smaller, a less standard and more exclusive product could work.

(c) <u>Final conclusion:</u>

Therefore, this would be the theoretical approach to improvement, which would not be applicable to this case because of the low production level and the Make to Order, but it is interesting to understand that the same product can be worked in different ways, depending on what you want to achieve with respect to the customer and the manufacturing volume.

Once the above concepts are clear, it is possible to make a table showing the advantages and disadvantages of this type of system, compared to the conventional ones that have been studied at the beginning of this chapter.

The table would be as follows:

ADVANTAGES	DISADVANTAGES
○ Adaptable to rapidly changing production environments, due to its adaptability and flexibility. ○ Increased operator satisfaction, due to task variability and heterogeneity of tasks. ○ Low investment in specific machines, which allows lower costs at the beginning of the line. The machines are general purpose.	○ When using general purpose machinery, they will have a lower throughput when processing materials. ○ It is necessary to train the operators and pay them more, because their training is higher as they have more combined skills. ○ Materials will be handled less efficiently and quickly. ○ More complex quality controls due to the familiarity of the workers and the piety of processes and products. ○ Difficult to assign costs to each product, making it difficult to understand which product is or is not profitable, as the separation is complicated.

Table 27. Comparison of advantages and disadvantages (Source: own elaboration)

CHAPTER 5. PERFORMANCE ANALYSIS

This chapter will focus on the third fundamental element of this thesis, which is included in the title of the thesis: the performance analysis of IQUEA's production line.

It also marks the beginning of the last part of this thesis: performance and cost saving study. That is why it is of vital importance to correctly understand everything that is going to be established here, since the conclusions of this thesis will have to take these two sections into account.

Performance analysis has already been discussed theoretically in chapter 2, which focused on explaining the procedures to carry out a performance analysis but did not provide practical knowledge. It will be throughout this chapter 5 when this knowledge will be practically studied, using a balanced scorecard, with a closed strategy and applying a series of KPI indicators that allow to obtain the interesting results for the study.

To complete the whole chapter, there will not be needed very precise data, but, if necessary, they will be extracted from the information provided by the tutor of the thesis, which have already been used in the previous chapters.

It is also important to note that much of the information that will be used to complete the study is hypothetical, as well as some of the information used in the previous chapters. This is due to the fact that, as has been commented on several occasions, the company has no real reflection, and therefore it is a fictitious case to apply the theory previously studied.

With respect to the knowledge that will be used in this topic, it can be said that there will be a lot of knowledge coming from the master's degree in Advanced Production, Logistics and Supply Chain Engineering, and the notes are kept of several subjects that mention it. These subjects will be: Performance Management Systems, Integrated Information Systems, Work Study or Programming and Control of Production and Operations, among others.

Finally, the structure for this chapter will be very simple, since it will simply be made an integrated scorecard.

Chapter 5 will be divided into two main groups: the balanced scorecard and the explanation of the balanced scorecard. In the scorecard, the objectives, strategies and KPIS will be established, and the resolution of the scorecard will be carried out. Once the results are clear, the following sections will explain the results obtained. This should explain the objectives set and the selection of strategies to achieve these objectives, the meaning of each KPI studied and the result it has given. Once the scorecard is clear, a series of conclusions will be drawn as a summary.

With all this, the introduction is finished, and let's move on to the first point: the scorecard.

5.1 Balanced Scorecard

GOAL	TYPE	#	STRATEGY	#	KPI
G1 Reduction of defective parts by 10%, improving the process at the first time	PROCESS	GS1.1	Increase the number of courses offered to workers that focus on adequate training in order to avoid carelessness, negligence, misuse or irresponsibility	KPI1	$\boldsymbol{NUMBER\ OF\ COURSES\ ON\ QUEALITY\ THAT\ HAVE\ BEEN\ PROMOTED\ BY\ THE\ COMPANY}$
		GS1.2	Increase in optimized processes, with designs that reduce waste and more precise machines that ultimately allow for increased optimization and reduced waste	KPI2	$\boldsymbol{FIRST\ TIME\ THROUGH} = \frac{TOTAL\ PARTS\ RUN\ - TOTAL\ DEFECTS}{TOTAL\ PARTS\ RUN}$
G2 Reduction of raw material costs by 5%	FINANCIAL	GS2.1	Make accurate inventories of the amount of raw materials being used to manufacture the products, to know exactly how much is being used and how much is really needed.	KPI3	$\boldsymbol{INVENTORY} = \frac{INVENTORY\ REFERENCE\ NUMBER}{TOTAL\ REFERENCED\ NUMBER}$
		GS2.2	Application of the EOQ system to reduce inventory cost in the warehouse. This system will reduce start-up, supplier, and storage costs.	KPI4	$\boldsymbol{EOQ\ PRODUCTS} = \frac{NUMBER\ OF\ EOQ\ PRODUCTS}{TOTAL\ PRODUCTS}$
G3 Reduction of absenteeism by 5%	LEARNING & GROWTH	GS3.1	Formalizing an employee's attendance expectations in a written document, establishing maximum days for personal business, vacation and bonus .	KPI5	$\boldsymbol{ABSENTISM} = \frac{ABSENT\ EMPLOYEES}{TOTAL\ NUMBER\ OF\ EMPLOYEES}$
G4 20 % increase in revenue	FINANCIAL	GS4.1	Increase sales channels. One of the alternatives proposed above would be to incorporate an online sales service. The number of physical stores in the country could also be increased.	KPI6	$\boldsymbol{NUMBER\ OF\ ACTIVE\ SALES\ CHANNELS}$
G5 Reduction of production stops by 30%	PROCESS	GS5.1	Execution of the planning with the support of an ERP software, which allows to centralize all the necessary information to develop in time and form the updates of the plans, to have a better control and to give a continuous follow-up to the fulfillment of the tasks.	KPI7	$\boldsymbol{AVAILABILITY} = \frac{PLANNED\ PRODUCTION\ TIME - MACHINE\ DOWNTIME}{PLANNED\ PRODUCTION\ TIME}$
G6 Increase the level of customer satisfaction by 10%	CUSTOMER	GS6.1	Encouraging customer loyalty, trying to ensure that they find in the brand a confidence that makes them always choose it	KPI8	$\boldsymbol{LOYALTY} = \frac{NUMBER\ OF\ REPEAT\ CUSTOMERS}{TOTAL\ NUMBER\ OF\ CUSTOMERS}$
		GS6.2	Reduce customer complaints due to poor quality or manufacturing errors by 15%.	KPI9	$\boldsymbol{NUMBER\ OF\ COMPLAINTS\ FILED}$
		GS6.3	Reduce the response time to customers after a complaint by 10%.	KPI10	$\boldsymbol{RESPONSE\ TIME} = \frac{AVERAGE\ RESPONSE\ TIME\ T}{AVERAGE\ RESPONSE\ TIME\ T-1} \leq 90\%$

Table 28. Balanced scoreboard oriented towards cost savings (Source: own elaboration)

5.2 Conclusions drawn from the Scoreboard

After finishing the Scoreboard, it will be briefly explained the points that have been summarized in it, as well as draw a series of conclusions that will later serve to complete the last section of this thesis.

With this, this section will be divided into 3 subsections, which will refer to the three main blocks of the panel, which will be: objectives, strategies and KPIs.

5.2.1 Conclusions drawn from the set goals

In this balanced scoreboard oriented towards cost savings, 6 clear objectives have been established, which will translate into savings both in the long term and in the short term. These objectives have in turn been divided into 4 major groups which have already been mentioned in the theory and the company will be analyzed from all possible sides: personnel, customers, processes and financial.

Therefore, explaining one by one the sectors and relating them with the objectives that have encompassed:

(a) <u>Process area</u>

In this first sector there are 2 objectives: G1 and G5. Both are related to production and the changes that can occur in production that result in a reduction of costs.

The first objective aims to reduce the number of defective parts obtained, and to increase the ratio of parts that come out right the first time. This can be translated in the short-medium term into a 10% reduction in the expenditure allocated to these parts, due to the reduction of the purchase without utility, the gain in production and the improvement of the customers' response to the products.

On the other hand, the second process-oriented objective will be to reduce production stoppages by 30%. Currently machines have to be stopped for 20 minutes per shift, as shown in Table 15, but if that downtime could be reduced to 14-15 minutes that excess time could be used to continue production in the shift, not to mention that the start-up time and expense of stopping and starting again is high.

In order to reduce downtime, production could be stopped in the 8 hours after production shifts end, stopping when operators are on break or performing another task, so that it would not be so necessary, or speeding up overhaul and repair operations.

(b) <u>Financial area</u>

Continuing with the analysis of G2 and G4 objectives, must now focus on the financial area of the company and the changes that can be made in this area to save costs.

The first objective is to reduce material costs by 5%. This adjustment could be treated as an unrealistic target, but due to the volume of production of the factory and the number of suppliers, it is common in large companies to adjust, little by little, the prices of their raw materials in order to be able to continue with that supplier.

The second objective is a 20% increase in total turnover. This objective, together with the previous one, despite being ambitious, is typical of large companies in an expansionary phase, such as the one studied in this thesis.

In addition, in a changing environment, with an increase in demand in this type of market, an increase in sales can be presented, which translates into a higher turnover and market share, which, in turn, allows to negotiate more on the price of raw materials.

(c) <u>Learn & growth area</u>

In this area there is only one objective, because in this work it has not been looked so much at the issue of workers and labor. In this case, objective G3, seeks to reduce absenteeism by 5%, since this will allow us to establish clearer production objectives and avoid supply problems or lack of workers on the machine.

This problem may be due to justified or unjustified absences, but if a 5% reduction is achieved, it would also include the lack of justification, which in the long run is the one that causes the most problems, due to its variability.

(d) <u>Customers área</u>

Lastly, in terms of objectives, there will be G6, oriented towards the brand's customers. In this case, the main objective will be to increase customer satisfaction by 10%, which will ensure loyalty and continuity with the services offered.

This objective is one of the most decisive with respect to customers due to the increased competition in this sector in Europe, so securing a large customer base is very important to remain market leader.

(e) <u>Final point</u>

Now that the objectives have been specified, it is necessary to explain how they have been quantified as a percentage. This task is complicated and one of the weak points of a Scoreboard due to its subjectivity and difficulty of programming.

In this case it has been simply used some indicative parameters extracted from one of the practices of the Performance Management Systems course, where a series of percentages were offered based on the area to be reduced, but it may also be the case that this percentage should be studied. For this task, a balancing study should be carried out between resources expended and benefit obtained.

Therefore, if to reduce expenditure by 5% it is necessary to invest 10% in machinery, this percentage is not favorable and therefore should not be made, but if, on the other hand, you want to reduce customer complaints by 5% by investing 2% in hiring an additional person, this change is acceptable and advisable.

Therefore, and by way of summary, in order to establish a cost reduction limit, a realistic objective must be set, and the cost-benefit curve must be delimited as much as possible.

5.2.2 Conclusions drawn from the set strategies and KPIs

Continuing with the analysis of the table, the next step is to study the strategies and the KPIs that represent them, as has already been done with the objectives to be achieved. These strategies will be the way to meet the previous objectives, so they will be closely linked to them, so that if the objectives change, the strategies will also have to change. On the other hand, each strategy is linked to a KPI, so it will be also briefly explained what links these two parameters and why this indicator has been chosen.

To order this section it will be used each of the objectives where the strategies are included, therefore there will have a total of 10 strategies to meet 6 objectives, which will be:

(a) <u>Strategies for goal G1</u>

The first two strategies to be studied will be GS1.1 and GS1.2, both referring to the Process area.

In the case of the first strategy, it will focus on the operators who are part of the production process, so it could also belong to the learning & growth area, but due to the context it is possible to put it in the process area.

The strategy to reduce defects will be to give courses to the operators, where they will be given notions of quality, explanations about negligence and care of the pieces, etc. This knowledge can be applied later when they perform the transformation operations, being more careful, paying more attention, or knowing better the process they are performing.

The KPI chosen for this first strategy will be very simple:

$$\textit{NUMBER OF COURSES ON QUALITY THAT HAVE BEEN PROMOTED BY THE COMPANY}$$

Equation 8. Number of course system (Source: own elaboration)

It will simply measure the number of courses that have been held for this topic, which if all goes well should be higher and higher as time goes by.

On the other hand, the second strategy will be the one that refers to the production process itself. Improving the clarity of the machines, the time it takes to prepare the piece or to perform the operation, etc. It can make a difference to the quality of the final product and reduce material waste.

The KPI used is well known, the FTT, and is used all over the world to study the quality of the processes and products being manufactured.

$$\boldsymbol{FIRST\ TIME\ THROUGH} = \frac{TOTAL\ PARTS\ RUN\ - TOTAL\ DEFECTS}{TOTAL\ PARTS\ RUN}$$

Equation 9. FTT equation (Source: own elaboration)

The formula is very simple to understand, just enter the total number of parts produced minus the parts with defects, divided by the total. In this way, a percentage of good parts vs. bad parts will be obtained, which will allow a study of whether the changes improve or worsen the previous situation. The bigger the FTT the better the production.

(b) <u>Strategies for goal G2</u>

The next two strategies will be those of the finance area, GS2.1 and GS2.2, which aim to reduce the cost of raw materials by 5%.

As mentioned before, this objective was ambitious, due to the breadth it covered, but it will be explained why this was chosen, the strategies to carry it out and the KPIs that will be used.

The first strategy will be to carry out a good inventory control, to understand how much is used, how much is purchased and if there is a surplus that can cause an expense. This type of control can drastically reduce costs, since an overpurchase with a high inventory and stock cost is a very common failure. This is why the KPI indicator will be used:

$$\boldsymbol{INVENTORY} = \frac{INVENTORY\ REFERENCE\ NUMBER}{TOTAL\ REFERENCED\ NUMBER}$$

Equation 10. Inventory KPI equation (Source: own elaboration)

It measures the product you have in inventory and compares it with the total product available. This will allow an exhaustive control of what you have and what you should have, avoiding overstocks.

On the other hand, strategy two will be the application of a system widely used in production: EOQ. This system allows to reduce the inventory cost, because it affects the launch cost (what it costs for a supplier to send an order) and the price of product storage. Therefore, the KPI will be:

$$\boldsymbol{EOQ\ PRODUCTS} = \frac{NUMBER\ OF\ EOQ\ PRODUCTS}{TOTAL\ PRODUCTS}$$

Equation 11. EOQ products KPI equation (Source: own elaboration)

Where the number of products manufactured using the EOQ system will be divided by the total number of products manufactured. The higher the number the better the effect of this technique can be seen and the greater the inventory savings.

(c) Strategies for goal G3

Goal 3 was the one related to absenteeism, within the Learn & growth area. To complete this objective there is only one strategy, the GS3.1, which is present in large companies due to its great usefulness: a formal attendance document.

This document will contain all the information regarding time off and absences of each employee. These unexcused absences will have an admissible maximum, from which the company could take legal measures on the employee, and also a series of granted times: vacations, days for personal matters, etc.

By formalizing this and making the unions or workers aware of the consequences of not complying with this treaty, absenteeism could be reduced.

The KPI used to see the evolution will be:

$$\boldsymbol{ABSENTISM} = \frac{ABSENT\ EMPLOYEES}{TOTAL\ NUMBER\ OF\ EMPLOYEES}$$

Equation 12. Absentism KPI equation (Source: own elaboration)

This indicator should be smaller and smaller, because the smaller the numerator (absenteeism) the smaller the total number.

(d) Strategies for goal G4

The next strategy was also related to the financial area, since the main objective to be achieved is to increase turnover by 20%.

This increase can be achieved by increasing the distribution and sales channels for the products. That is why, as mentioned in previous chapters, the company wishes to expand the number of physical stores it has in Poland and make an online sales portal available to customers, where its products can be delivered to their homes. This would enable the company to outperform its competitors and increase its customer base by allowing a larger area of action.

The KPI used to monitor the development of this strategy will be:

$$\boldsymbol{NUMBER\ OF\ ACTIVE\ SALES\ CHANNELS}$$

Equation 13. Sales channels KPI equation (Source: own elaboration)

This parameter will have to increase in order to be able to prove that the initial situation is improving.

(e) Strategies for goal G5

The next goal also has only one strategy to carry it out, the GS5.1 strategy. This will be oriented to the Process area and will be directly related to the stops that have to be made in the factory.

These stops have already been seen before that currently last 20 minutes, so in order to reduce them by 30% it is proposed to follow a strategy of support with ERP software. This type of software helps companies to centralize all their information, including that related to production, so it allows to control the improvements of the plant, tasks, and processes.

In this way, it is proposed that through this system, plant shutdowns can be controlled, and it can be clarified when the best time is to carry out the shutdown, what type of shutdown is necessary, on which machine, etc. By standardizing and automating the process of controlling the machines, it will be possible to reduce the time in which the operator is carrying out the supervision.

To carry out this strategy, the KPI will be followed:

$$\boldsymbol{AVAILABILITY} = \frac{PLANNED\ PRODUCTION\ TIME - MACHINE\ DOWNTIME}{PLANNED\ PRODUCTION\ TIME}$$

Equation 14. Availability of machine equation (Source: own elaboration)

This should increase as time goes by, since the shorter the stoppage the less the production time will have to be subtracted.

(f) Strategies for goal G6

Finally, the last three strategies are those related to the customer area, with the objective of increasing the level of customer satisfaction.

The first of these three strategies is to improve the company's position through customer loyalty. If the customer has confidence in the company, he will always repeat the purchase of furniture and will not be interested in looking for these items in other brands. Therefore, it is necessary to improve the brand image and foster loyalty between IQUEA and its customers.

The KPI that will indicate whether or not to improve this aspect will be:

$$\boldsymbol{LOYALTY} = \frac{\boldsymbol{NUMBER\ OF\ REPEAT\ CUSTOMERS}}{\boldsymbol{TOTAL\ NUMBER\ OF\ CUSTOMERS}}$$

Equation 15. Customers loyalty KPI equation (Source: own elaboration)

This parameter should increase as time goes by, to know that the proposed objective is being achieved. The more repeat customers, the better the brand image and the more market share you will have.

The second strategy seeks to reduce consumer complaints to the company. These complaints can be about lack of quality, problems with shipments, co-refunds, etc.

In this case it is necessary to focus on the complaints surrounding poor product quality and production, related to point G1. Improving quality will also improve the image that customers have and make them more loyal and more satisfied with the company.

The KPI for this strategy will be:

$$\boldsymbol{NUMBER\ OF\ COMPLAINTS\ FILED}$$

Equation 16. Complaints KPI equation (Source: own elaboration)

Which obviously should be reduced to 0 (or close to it). It is a very simple indicator, but one should simply seek to reduce it.

To finish with this goal, the last strategy will be to reduce the response time to the previously mentioned complaints. The company's customer service must be improved so that the customer feels that he is being listened to and that his problem can be solved.

This aspect is very important, since it can make the difference between a company that actively listens to its buyers and one that does not, so improving response times and customer service is crucial to improve our position with respect to the competition.

The KPI that can be used to measure this is:

$$\boldsymbol{RESPONSE\ TIME} = \frac{\boldsymbol{AVERAGE\ RESPONSE\ TIME}\ T}{\boldsymbol{AVERAGE\ RESPONSE\ TIME}\ T-1} \leq \mathbf{90}\%$$

Equation 17. Response time KPI equation (Source: own elaboration)

That the average response time at time T must be less than the time at the previous time of measurement T-1, so that the 10% reduction indicated is met.

With all of the above, the entire balanced scoreboard is explained. If the proposed strategies can be carried out, observing their evolution over time through the KPIs, it will be possible to meet the objectives and, in the end, achieve significant cost savings in the company.

5.2.3 Other interesting KPIs

This extra section has been developed because the KPIs used above are not all the ones that could be interesting in this type of cases, but the proposed strategies did not refer to any of them.

Therefore, three additional KPIs will be explained, which may be of interest when developing a more comprehensive Scoreboard:

(a) <u>Overall Equipmente Effectiveness (OEE)</u>

The first indicator that is going to be analyzed is the most common among companies and the one most studied in engineering because of its great versatility in all production areas.

OEE is the cumulative measure of three separate factors: Availability, Performance, and Quality and, together, these can provide a good measure of the relative success of your plant's production. Such information is critical when trying to determine benchmarks for improving your company's production process.

The formula for applying this indicator is as follows:

$$\boldsymbol{OEE} = \frac{RUN\ TIME}{PLANEED\ PRODUCTION\ TIME} \times \frac{ACTUAL\ MACHINE\ SPEED}{DESIGN\ MACHINE\ SPEED} \times \frac{NUMBER\ OF\ GOOD\ PRODUCTS}{TOTAL\ PRODUCTS\ MADE}$$

Equation 18. OEE KPI equation (Source: own elaboration)

The final result of this indicator should be a percentage and the higher it is the better the quality of the line.

As for the division of these 3 divisions, it is also possible to find the OEE referred to as:

$$\boldsymbol{OEE} = AVAILABILITY \times PERFORMANCE \times QUALITY$$

Equation 19. OEE simplified concepts (Source: own elaboration)

The QUALITY parameter has been seen before in the objective number G5, in a less summarized form, and the explained concepts have already been mentioned in the 2.2.4 (e) section.

(b) Inventory turnover ratio

Inventory turnover, or inventory turnover, is a measure of how quickly inventory is replenished in a given period of time. In other words, it shows how many times an item has gone through the entire business process, i.e., the sale, delivery and payment of an order.

This metric helps logistics managers to assign each reference a turnover type based on the ABC method, where A is high turnover and C is minimum turnover. This information facilitates a more appropriate classification of products within the warehouse based on demand levels.

The formula for applying this indicator is as follows:

$$\boldsymbol{INVENTORY\ TURNOVER} = \frac{ECONOMIC\ VALUE\ OF\ SOLD\ REFERENCES}{AVERAGE\ INVENTORY\ VALUE}$$

Equation 20. Inventory turnover KPI equation (Source: own elaboration)

(c) Stock out

This KPI indicates the number of times that the company has not been able to meet the demand for products required by the customer(s) because it is out of stock.

The formula for applying this indicator is as follows:

$$\boldsymbol{STOCK - OUT} = \frac{UNCOMPLETED\ ORDERS}{TOTAL\ NUMBER\ OF\ ORDERS}$$

Equation 21. Stock-out KPI equation (Source: own elaboration)

CHAPTER 6. FINAL CONCLUSIONS

The delivery of this thesis marks the end of the degree of Industrial Organization Engineering, being embodied in this document all the most important knowledge learned in the 4 years of career. Therefore, and to close this final work, are to be provided a series of general conclusions, summarizing the main points that have been studied throughout these months of work and maintaining the order of the document, so that it is easier to understand which chapter refers to each of the conclusions drawn.

This work was planned from the beginning as a theoretical-practical thesis, due to the complexity of obtaining data from a real company while on academic exchange in a foreign country, therefore, it has been possible to observe a clear line between these two concepts, which in the long run have been completed and intertwined, allowing an in-depth analysis of the organizational parameters, the analysis of the performance of a line and the design of a layout.

A noteworthy point would be the difficulty of finding certain data on the company and its distribution and how this fact has sometimes made it difficult to justify some assumptions, especially in section 4 of the layout, or the lack of data to complete some points of a section, such as the KPIs to analyze the performance of the line, which have only been presented theoretically.

The first theoretical concept studied was layout analysis, where certain theoretical tools were explained, which are very useful in the analysis of line performance. In order to perform this analysis, the most general concepts have been explained, which include the type of plant layout, systematic layout planning, or SLP, value stream mapping, or VSM, and the types of organization and improvement prioritization techniques.

Subsequently, the most important organizational parameters of a company have also been studied, including PESTEL, SWOT, PORTER and value chain analysis. These 4 tools allow a company to better analyze the inside and outside of its company, being able to be aware of the threats around it and allowing to have an updated and strong company competitively speaking. These analyses are of vital importance nowadays, due to the increasing competition and pressure on companies to improve and adapt to the desires of a changing and capricious society.

In line with the above, it has been also studied the most important points to take into account in order to perform a performance analysis of a company or production line. The tool that has been seen in depth has been the balanced scorecard, oriented to cost savings in this case. This concept extracted from the master is one of the most important for managers who want to know the strategies and indicators to achieve their organizational objectives, so it was essential to apply it in this thesis.

To finish with the theoretical analysis, there have been explained the economic parameters that must be taken into account when studying various investment alternatives. These parameters are the ones that mark the viability of a project and allow a company to analyze, in a superficial but efficient way, whether a project is worthwhile or not. A noteworthy point of this economic analysis is that in this thesis it has not been possible to carry it out in a practical way, due to the difficulty and the extension it would have, as well as the lack of data to support the correct calculations. That is why, as explained in the corresponding section, it has simply been left as a guide for future theses but has not been carried out.

Once the practical analysis has been completed, has moved to study the fictitious company called IQUEA. This Polish company dedicated to the furniture sector is the perfect example of a company that wants to expand its market and expand into the rest of Europe, as well as promote the sale of products online, an area that has not yet been discovered in the company. With all this, when performing the 4 situation analysis mentioned above, it is seen that it is a strong company, with a great future projection, with a good brand image in Poland and with a remarkable capacity for innovation but, on the other hand, it is in a highly competitive sector, with a little personalized product and with external problems such as the armed conflict in Ukraine, the change of tastes in customers or the prices of materials due to an economic crisis in Europe. All these concepts have been summarized in a series of tables that provide a perfect understanding of the company's future, and allow managers to make decisions about that future.

In particular, at the production level, 3 different types of products were studied, out of the many that are marketed, and a first layout of the line was proposed. This type of layout has allowed us to see that they are currently manufacturing at a constant rate of 6.09 P/shift or 30.4 P/line, with a total of 33 workers per shift and a distribution per product. The complete data of this first layout is as follows:

PRODUCT	TPV YEAR (1 STATION)	ESH (YEAR) (1 STA)	CICLE TIME	CICLE TIME	PROD. INTENSITY	TACK TIME (1S)	PROD. REAL (1S)	PROD. REAL (TOT)	# STATION	# EMPLOY
	P/Y	H/Y	MIN/P	H/P	P/H	H/P	P/Y	P/Y		
2S/4/5	2800,00	3985,80	75,77	1,26	0,70	1,42	2913,60	14568,01	5,00	11,00
4S/7/9	1400,00	2002,00	76,90	1,28	0,70	1,43	1441,87	7209,36	5,00	11,00
15/13,5	1800,00	3985,80	122,10	2,04	0,45	2,21	1808,01	9040,03	5,00	11,00

Table 29. Present layout (Source: own elaboration)

In order to study whether the present situation could be improved, a second layout has been proposed, oriented to the process, so that the data obtained from this second layout have been as follows:

PRODUCT	TPV YEAR (1 STATION)	ESH (YEAR) (1 STA)	CICLE TIME	CICLE TIME	PROD. INTENSITY	TACK TIME (1S)	PROD. REAL (1S)	PROD. REAL (TOT)	# STATION	# EMPLOY
	P/Y	H/Y	MIN/P	H/P	P/H	H/P	P/Y	P/Y		
2S/4/5	14000,00	3985,80	59,19	0,99	3,51	0,28	3730,05	3730,05	1,00	17,00
4S/7/9	7000,00	3985,80	62,22	1,04	1,76	0,57	3547,86	3547,86	1,00	15,00
15/13,5	9000,00	3985,80	94,47	1,57	2,26	0,44	2336,79	2336,79	1,00	12,00

Table 30. Proposed layout (Source: own elaboration)

Therefore, this second layout proposal has not been able to improve the first one established, because the resources were in only one station and not in 5 as before.

Finally, a theoretical proposal of a layout divided by Job-Shop has also been made, where it has been possible to observe the differences in resources and production with respect to the two previous proposals. This section has served to highlight the usefulness of this type of production systems when trying to customize a product and work with orders and not with stocks.

With all that has been seen, it is possible to consider a series of improvements on the present situation, where a quality station could be introduced, to reduce defects and improve the final product, a rework station for defective parts, to reduce the waste of poorly finished parts or, in case of not having an economic limit, could be tried to increase the number of workers in the second proposal to see if it would be beneficial in the long run by multiplying the number of operators by four. These proposals have simply been presented but their feasibility and profitability will not be studied in this thesis.

Once it is clear the layout section has been studied the performance of the company, making an integrated control panel, and orienting it to cost savings. In order to carry out a good study of the performance, 6 objectives of 4 different areas of the company and 10 strategies to meet these objectives have been proposed. In order to be able to analyze the progress of the company as it applies these strategies, 10 complementary KPIs have been developed, which easily and simply measure different areas of the company. These KPIs are clearly explained and the values that should be given to be able to say that the initial situation is improving, but precise data have not been given because many of those needed were not available.

With this, the analysis of the company has been completely closed, and it is now possible to analyze whether or not the objectives established at the beginning of this thesis have been fulfilled. These objectives sought a complete work that would allow the reader to understand a simple productive analysis, without the need for complex concepts.

The first thing that can be affirmed is that a broad theoretical framework has been provided to the reader, who has been able to verify each theoretical concept in the practical part and, if not, as in the case of the economic analysis, has had a clear justification of why it was not going to be performed in the analysis of the company. Two layouts have also been made, one of the initial situation and a proposal, and both have been compared and analyzed, delivering conclusions on the suitability of changing to the proposed proposal and with 3 possible scenarios that would improve the line in terms of capacity, profitability, and efficiency.

Finally, the objectives of the performance analysis have also been fulfilled with an integral control panel oriented to cost savings, with its consequent strategies and indicators.

This concludes the last chapter of conclusions of this thesis and, therefore, the thesis itself.

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ANNEXES

Annex A: data collection sheet for the temporary calculation of furniture 2S/4/5

IDA	IDQ/Dr	Description	Tools	Single Time [s]	Multiple	Time per activity [s]	TPA [min]
OP01	Drw_1	Equipping the MDF boards with the appropriate accessories				596	9,9
T101		Equip the **C3** board with **r16**				151	
AA01		Take the C3 from input warehouse and put on flat place (work table)		24	1	24	
	QC01	Check visually the **C3** in case of any damage		5	1	5	
MA01		Take the r16 from a box and put it to the corresponding hole in C3		6	4	24	
	QC02	Visually check the proper position r16 at right angle to the C3		2	4	8	
MA02		Using a screwdriver, tighten the r16	Screwdriver	18	4	72	
AA02		Put the equipped SC3 back in output warehouse		18	1	18	
T102		Equip the **C4** board with **r16**				151	
AA01		Take the C4 from input warehouse and put on flat place (work table)		24	1	24	
	QC01	Check visually the **C4** in case of any damage		5	1	5	
MA01		Take the r16 from a box and put it to the corresponding hole in C4		6	4	24	
	QC02	Visually check the proper position r16 at right angle to the C4		2	4	8	
MA02		Using screwdriver, tighten the r16	Screwdriver	18	4	72	
AA02		Put the equipped SC4 back in output warehouse		18	1	18	
T103		Equip the **C1** board with **r1** and **f1**				147	
AA01		Take the C1 from input warehouse and put on flat surface (work table)		24	1	24	
	QC01	Check visually the **C1** in case of any damage		5	1	5	
MA01		Take the r1 from a box and put it to the corresponding hole in C1		6	4	24	
	QC02	Check position of r1, arrow should be in direction to the edge		2	4	8	
MA01		Take the f1 from a box and put it to the corresponding hole in C1		6	4	24	
	QC02	Visually check the right position of f1		2	4	8	
MA03A		Using a hammer, hammer the f1	Hammer	4	4	16	
	QC03	Don't exceed 10 mm of f1! Use calliper to check the distance	Calliper	5	4	20	
AA02		Put the equipped SC1 back in output warehouse		18	1	18	
T104		Equip the **C2** board with **r1** and **f1**				147	
AA01		Take the C2 from input warehouse and put on flat surface (work table)		24	1	24	
	QC01	Check visually the **C2** in case of any damage		5	1	5	
MA01		Take the r1 from a box and put it to the corresponding hole in C2		6	4	24	
	QC02	Check position of r1, arrow should be in direction to the edge		2	4	8	
MA01		Take the f1 from a box and put it to the corresponding hole in C2		6	4	24	
	QC02	Visually check the right position of f1		2	4	8	
MA03A		Using a hammer, hammer the f1	Hammer	4	4	16	
	QC03	Don't exceed 10 mm of f1! Use calliper to check the distance	Calliper	5	4	20	
AA02		Put the equipped SC2 back in output warehouse		18	1	18	
OP02	Drw_2	Assembly of main body (assembly unit SB1)				360	6,0
T201		Connect SC1 with SC3				74	
AA01		Take the SC3 from input warehouse and put it vertically on a clean surface (work table)		24	1	24	
AA03		Take the SC1 from input warehouse and put it vertically on a clean surface (work table) with straight angle to the SC3		30	1	30	
MA04		Connect SC1 with SC3, use hand force to push the SC1		6	1	6	
	QC04	Pay attention to the correct connection (no gap between SC1 and SC3 and straight angle)		4	1	4	
MA06		Use Allen key z1 to tighten the excentre fitting r1 with retaining pin r16	Allen key	5	2	10	
T202		Connect SC2 with SC3				50	
AA03		Take the SC2 from input warehouse and put it vertically on a clean surface (work table) with straight angle to the SC3		30	1	30	
MA04		Connect SC2 with SC3, use hand force to push the SC2		6	1	6	
	QC04	Pay attention to the correct connection (no gap between SC2 and SC3 and straight angle)		4	1	4	
MA06		Use Allen key z1 to tighten the excentre fitting r1 with retaining pin r16	Allen key	5	2	10	
T203		Connect SC4 with SC1 and SC2				62	
AA03		Take the SC4 from input warehouse and put it vertically on a clean surface (work table) with straight angle to the SC1 & SC2		30	1	30	
MA05		Connect SC4 with SC1 & SC2, use hand force to push the SC4		8	1	8	
	QC04	Pay attention to the correct connection (no gap between SC4 and SC1 & SC2, and straight angle)		4	1	4	
MA06		Use Allen key z1 to tighten the excentre fitting r1 with retaining pin r16	Allen key	5	4	20	
T204		Install plastic legs k29				174	
MA01		Take the muff base of leg k29-1 from the box and put it to the corresponding hole in SC4		6	4	24	
MA03B		Use the hammer to knock **k29-1** down		20	4	80	
	QC02	Make sure the **k29-1** has reached the end		2	4	8	
MA01		Take the adjustable plastic leg k29-2 from the box and put it to the corresponding muff hole k29-1		6	4	24	
MA06		Tighten the leg **k29-2** with muff **k29-1** by hand		5	4	20	
AA02		Put the frame SB1 back in output warehouse		18	1	18	

OP02	Drw_3	Assembly of main body (assembly unit SB2)				539	9,0
T301		Install back wall C5				539	
AA03		Take the assembled main body of furniture SB1 from input warehouse and put with the front side to the ground		30	1	30	
	QC05	Check the diagonal lengths - they must be the same, use the measuring tape, if necessary adjust the position		10	2	20	
AA01		Take the C5 from input warehouse and put it on back side of the main body SB2		24	1	24	
	QC01	Check visually the **C5** in case of any damage		5	1	5	
MA01		Take the nail l1 from box and put it in right position		6	30	180	
	QC02	Distance between nails should be equal (10-15 cm)		2	26	52	
MA07		Hit the nail l1 with a hammer	Hammer	5	30	150	
	QC02	Visually make sure the l1 has reached the end		2	30	60	
AA02		Put the assembled SB2 back in output warehouse		18	1	18	
OP02	Drw_4	Assembly of main body (assembly unit SB3)				464	7,7
T401	Drw_4	Install sliders w46P in right wall C2				238	
AA01		Take the assembled main body of furniture SB2 from input warehouse and put it on a flat surface (work table)		30	1	30	
MA01		Take the w46P right slider from box and put it in right place (hold in hand)	Hands	6	2	12	
MA01		Take the e3 screw from box and put it in right hole (make at least half turn by hand)		6	8	48	
MA02		Tighten the e3 with screwdriver	Screwdriver	18	8	144	
	QC02	Visually check the proper position of w46P		2	2	4	
T402	Drw_4	Install sliders w46L in left wall C1				226	
MA01		Take the w46L left slider from box and put it in right place (hold in hand)	Hands	6	2	12	
MA01		Take the e3 screw from box and put it in right hole (make at least half turn by hand)		6	8	48	
MA02		Tighten the e3 with screwdriver	Screwdriver	18	8	144	
	QC02	Visually check the proper position of w46L		2	2	4	
AA02		Put the assembled SB3 back in output warehouse		18	1	18	
OP03	Drw_5	Assembly of drawer (assembly unit 2)				471	7,9
T501	Drw_I	Install dowels f1 in C6				58	
AA01B		Take the C6 from input warehouse and put it on a clean surface (work table)		6	1	6	
	QC01	Check visually the **C6** in case of any damage		5	1	5	
MA08		Take a glue **y1** and apply necessary amount of glue into selected hole in **C6**		6	2	12	
MA01		Take the wooden dowel **f1** from container and push it in the corresponding hole in **C6**		6	2	12	
	QC02	Visually check the right position of f1		2	2	4	
MA03A		Using a hammer, hammer the f1	Hammer	4	2	8	
	QC03	Don't exceed 10 mm of f1! Use calliper to check the distance	Calliper	5	2	10	
AA04		Left equipped SC6 on table		1	1	1	
T502	Drw_I	Install dowels f1 in C7				58	
AA01B		Take the C7 from input warehouse and put it on a clean surface (work table)		6	1	6	
	QC01	Check visually the **C7** in case of any damage		5	1	5	
MA08		Take a glue **y1** and apply necessary amount of glue into selected hole in **C7**		6	2	12	
MA01		Take the wooden dowel **f1** from container and push it in the corresponding hole in **C7**		6	2	12	
	QC02	Visually check the right position of f1		2	2	4	
MA03A		Using a hammer, hammer the f1	Hammer	4	2	8	
	QC03	Don't exceed 10 mm of f1! Use calliper to check the distance	Calliper	5	2	10	
AA04		Left equipped SC7 on table		1	1	1	
T503	Drw_II	Make a frame of drawer. Connect C6, C7 & C8 with f25				169	
AA05		Take the SC6 and put it vertically on work table		3	1	3	
MA01		Take the plastic dowel f25 from a box and push it in the corresponding hole in SC6		6	2	12	
MA03B		Using a hammer, hit the dowel f25 to go through the hole, but not to the end (half)	Hammer	10	2	20	
	QC02	The dowel f25 should not exceed more than 5 mm outside SC6		2	2	4	
AA01		Take the C8 from input warehouse and put it vertically on work table		24	1	24	
	QC01	Check visually the C8 in case of any damage		5	1	5	
MA04		Connect SC6 and C8 together in right position using hand force		6	1	6	
	QC02	Visually check the straight angle		5	1	5	
MA03B		Using a hammer, hit the dowel f25 to the end (second half)	Hammer	10	2	20	
AA05		Take the SC7 and put it vertically on work table		3	1	3	
MA01		Take the plastic dowel f25 from a box and push it in the corresponding hole in SC7		6	2	12	
MA03B		Using a hammer, hit the dowel f25 to go through the hole, but not to the end (half)	Hammer	10	2	20	
	QC02	The dowel f25 should not exceed more than 5 mm outside SC7		2	2	4	
MA04		Connect SC7 and C8 together in right position using hand force		6	1	6	
	QC02	Visually check the straight angle		5	1	5	
MA03B		Using a hammer, hit the dowel f25 to the end (second half)	Hammer	10	2	20	
T504	Drw_III	Connect C10 with drawer frame by glue				47	
AA01B		Take the C10 from input warehouse and put it on work table		6	1	6	
	QC01	Check visually the C10 in case of any damage		5	1	5	
MA08		Take a glue **y1** and apply necessary amount of glue into selected hole in **C10**		6	4	24	
MA05		Connect C10 with C6 & C7 together in right position using hand force		8	1	8	
	QC04	Pay attention to the correct connection (no gap between C10 and C6 & C7, and straight angle)		4	1	4	
T505	Drw_IV	Install bottom C9 in drawer frame				23	
AA09		Put the drawer frame of the top side to the ground		2	1	2	
AA01B		Take the C9 from input warehouse and put it on work table		6	1	6	

	QC01	Check visually the C9 in case of any damage		5	1	5	
MA05		Connect C9 with drawer frame by inserting it into the groove in C6 & C7		8	1	8	
	QC02	Visually check right position. The C9 should not exceed outside the frame.		2	1	2	
T506	Drw_V	Connect C9 with drawer frame by nails I1				**100**	
	QC05	Check the diagonal lengths - they must be the same, use the tape measure, if necessary adjust the position		10	2	20	
MA01		Take the nail I1 from box and put it in right position		6	5	30	
	QC03	Distance between nails should be equal (10-15 cm)		5	3	15	
MA07		Hit the nail **I1** with a hammer		5	5	25	
	QC02	Visually make sure the I1 has reached the end		2	5	10	
T507	Drw_VI	Install door handle c85 with j30 screw				**74**	
MA01		Take the door handle c85 from a box and put it to the right position		6	1	6	
MA01		Take the screw j30 from a box and put it to the corresponding hole in C10		6	2	12	
MA02		Using screwdriver, tighten the j30	Screwdriver	18	2	36	
	QC02	Visually make sure the j30 has reached the end and door handle c85 is stable		2	1	2	
AA02		Put the assembled SD back in output warehouse		18	1	18	
OP04	Drw_4,6	Final assembly of furniture				**258**	**4,3**
T601	Drw_6	Install drawers				**258**	
AA01		Take the assembled drawer SD from input warehouse and put on work table		24	2	48	
AA06		Pull out both sliders w46L and w46P		2	2	4	
MA09		Put on sliders the drawer in right position		20	2	40	
	QC06	Adjust the right placement of drawer by screw		20	2	40	
AA07		Close the drawer		1	2	2	
	QC02	Visually check the proper position of drawer		2	2	4	
AA08		Put the assembled furniture F07 to place of storage		120	1	120	

Annex B: data collection sheet for the temporary calculation of furniture 4S/7/9

IDA	IDQ/Dr	Description	Tools	Single Time [s]	Multiple	Time per activity [s]	TPA [min]
OP01	Drw_1	Equipping the MDF boards with the appropriate accessories				**1006**	**16,77**
T101		Equip the **C4** board with **r16**				**203**	
AA01		Take the C4 from input warehouse and put on flat place (work table)		24	1	24	
	QC01	Check visually the **C4** in case of any damage		5	1	5	
MA01		Take the r16 from a box and put it to the corresponding hole in C4		6	6	36	
	QC02	Visually check the proper position r16 at right angle to the C4		2	6	12	
MA02		Using a screwdriver, tighten the r16	Screwdrivr	18	6	108	
AA02		Put the equipped SC4 back in output warehouse		18	1	18	
T102		Equip the **C5** board with **r16**				**203**	
AA01		Take the C5 from input warehouse and put on flat place (work table)		24	1	24	
	QC01	Check visually the **C5** in case of any damage		5	1	5	
MA01		Take the r16 from a box and put it to the corresponding hole in C5		6	6	36	
	QC02	Visually check the proper position r16 at right angle to the C5		2	6	12	
MA02		Using screwdriver, tighten the r16	Screwdrivr	18	6	108	
AA02		Put the equipped SC5 back in output warehouse		18	1	18	
T103		Equip the **C1** board with **r1** and **f1**				**147**	
AA01		Take the C1 from input warehouse and put on flat surface (work table)		24	1	24	
	QC01	Check visually the **C1** in case of any damage		5	1	5	
MA01		Take the r1 from a box and put it to the corresponding hole in C1		6	4	24	
	QC02	Check position of r1, arrow should be in direction to the edge		2	4	8	
MA01		Take the f1 from a box and put it to the corresponding hole in C1		6	4	24	
	QC02	Visually check the right position of f1		2	4	8	
MA03A		Using a hammer, hammer the f1	Hammer	4	4	16	
	QC03	Don't exceed 10 mm of f1! Use calliper to check the distance	Calliper	5	4	20	
AA02		Put the equipped SC1 back in output warehouse		18	1	18	
T104		Equip the **C2** board with **r1** and **f1**				**147**	
AA01		Take the C2 from input warehouse and put on flat surface (work table)		24	1	24	
	QC01	Check visually the **C2** in case of any damage		5	1	5	
MA01		Take the r1 from a box and put it to the corresponding hole in C2		6	4	24	
	QC02	Check position of r1, arrow should be in direction to the edge		2	4	8	
MA01		Take the f1 from a box and put it to the corresponding hole in C2		6	4	24	
	QC02	Visually check the right position of f1		2	4	8	
MA03A		Using a hammer, hammer the f1	Hammer	4	4	16	
	QC03	Don't exceed 10 mm of f1! Use calliper to check the distance	Calliper	5	4	20	
AA02		Put the equipped SC2 back in output warehouse		18	1	18	
T105		Equip the **C3** board with **r1** and **f1**				**147**	
AA01		Take the C3 from input warehouse and put on flat surface (work table)		24	1	24	
	QC01	Check visually the **C3** in case of any damage		5	1	5	
MA01		Take the r1 from a box and put it to the corresponding hole in C3		6	4	24	
	QC02	Check position of r1, arrow should be in direction to the edge		2	4	8	
MA01		Take the f1 from a box and put it to the corresponding hole in C3		6	4	24	
	QC02	Visually check the right position of f1		2	4	8	
MA03A		Using a hammer, hammer the f1	Hammer	4	4	16	
	QC03	Don't exceed 10 mm of f1! Use calliper to check the distance	Calliper	5	4	20	
AA02		Put the equipped SC3 back in output warehouse		18	1	18	
T106		Equip the C3 board with w44P and e3				**159**	
AA01		Take the SC3 from input warehouse and put on flat surface (work table)		24	1	24	

	QC01	Check visually the **SC3** in case of any damage		5	1	5	
MA01		Take the w44P and e3 from a box and put it to the corresponding hole in W44P		6	8	48	
	QC02	Visually check the proper position e3 at right angle to the C3		2	8	16	
MA01		Using a screwdriver, tighten the e3		6	8	48	
AA02		Put the equipped SC3 back in output warehouse		18	1	18	
OP02	Drw_2	Assembly of main body (assembly unit SB1)				**410**	**6,83**
T201		Connect SC4 with SC14				**74**	
AA01		Take the SC4 from input warehouse and put it vertically on a clean surface (work table)		24	1	24	
AA03		Take the SC1 from input warehouse and put it vertically on a clean surface (work table) with straight angle to the SC4		30	1	30	
MA04		Connect SC1 with SC4, use hand force to push the SC1		6	1	6	
	QC04	Pay attention to the correct connection (no gap between SC1 and SC4 and straight angle)		4	1	4	
MA06		Use Allen key z1 to tighten the excentre fitting r1 with retaining pin r16	Allen key	5	2	10	
T202		Connect SC2 with SC14				**50**	
AA03		Take the SC2 from input warehouse and put it vertically on a clean surface (work table) with straight angle to the SC14		30	1	30	
MA04		Connect SC2 with SC14, use hand force to push the SC2		6	1	6	
	QC04	Pay attention to the correct connection (no gap between SC2 and SC14 and straight angle)		4	1	4	
MA06		Use Allen key z1 to tighten the excentre fitting r1 with retaining pin r16	Allen key	5	2	10	
T203		Connect SC2 with SC124				**50**	
AA03		Take the SC3 from input warehouse and put it vertically on a clean surface (work table) with straight angle to the SC124		30	1	30	
MA04		Connect SC3 with SC124, use hand force to push the SC3		6	1	6	
	QC04	Pay attention to the correct connection (no gap between SC3 and SC124 and straight angle)		4	1	4	
MA06		Use Allen key z1 to tighten the excentre fitting r1 with retaining pin r16	Allen key	5	2	10	
T204		Connect SC5 with SC1 and SC2				**62**	
AA03		Take the SC5 from input warehouse and put it vertically on a clean surface (work table) with straight angle to the SC1 & SC2 & SC3		30	1	30	
MA05		Connect SC5 with SC1 & SC2 & SC3, use hand force to push the SC5		8	1	8	
	QC04	Pay attention to the correct connection (no gap between SC5 and SC1 & SC2 & SC3, and straight angle)		4	1	4	
MA06		Use Allen key z1 to tighten the excentre fitting r1 with retaining pin r16	Allen key	5	4	20	
T205		Install plastic legs k28				**174**	
MA01		Take the muff base of leg k28-1 from the box and put it to the corresponding hole in SC5		6	4	24	
MA03B		Use the hammer to knock **k28-1** down		20	4	80	
	QC02	Make sure the **k28-1** has reached the end		2	4	8	
MA01		Take the adjustable plastic leg k28-2 from the box and put it to the corresponding muff hole k28-1		6	4	24	
MA06		Tighten the leg **k28-2** with muff **k28-1** by hand		5	4	20	
AA02		Put the frame SB1 back in output warehouse		18	1	18	
OP02	Drw_3	Assembly of main body (assembly unit SB2)				**679**	**11,32**
T301		Install back wall C11				**679**	
AA03		Take the assembled main body of furniture SB1 from input warehouse and put with the front side to the ground		30	1	30	
	QC05	Check the diagonal lengths - they must be the same, use the measuring tape, if necessary adjust the position		10	2	20	
AA01		Take the C11 from input warehouse and put it on back side of the main body SB2		24	1	24	
	QC01	Check visually the **C11** in case of any damage		5	1	5	
MA01		Take the nail l1 from box and put it in right position		6	40	240	
	QC02	Distance between nails should be equal (10-15 cm)		2	31	62	
MA07		Hit the nail l1 with a hammer	Hammer	5	40	200	
	QC02	Visually make sure the l1 has reached the end		2	40	80	
AA02		Put the assembled SB2 back in output warehouse		18	1	18	
OP02	Drw_4	Assembly of main body (assembly unit SB3)				**656**	**10,93**
T401	Drw_4	Install sliders w44P in right wall C2				**334**	
AA01		Take the assembled main body of furniture SB2 from input warehouse and put it on a flat surface (work table)		30	1	30	
MA01		Take the w44P right slider from box and put it in right place (hold in hand)	Hands	6	2	12	
MA01		Take the e3 screw from box and put it in right hole (make at least half turn by hand)		6	12	72	
MA02		Tighten the e3 with screwdriver	Screwdrivr	18	12	216	
	QC02	Visually check the proper position of w44P		2	2	4	
T402	Drw_4	Install sliders w44L in left wall C1				**322**	
MA01		Take the w44L left slider from box and put it in right place (hold in hand)	Hands	6	2	12	
MA01		Take the e3 screw from box and put it in right hole (make at least half turn by hand)		6	12	72	
MA02		Tighten the e3 with screwdriver	Screwdrivr	18	12	216	
	QC02	Visually check the proper position of w44L		2	2	4	
AA02		Put the assembled SB3 back in output warehouse		18	1	18	
OP03	Drw_5	Assembly of drawer (assembly unit 2)				**889**	**14,82**
T501	Drw_I	Install dowels f1 in C6 & C7 & C9 & C10				**232**	
AA01B		Take the C6 & C7 & C9 & C10 from input warehouse and put it on a clean surface (work table)		6	4	24	
	QC01	Check visually the **C6 & C7 & C9 & C10** in case of any damage		5	4	20	
MA08		Take a glue **y1** and apply necessary amount of glue into selected hole in **C6 & C7 & C9 & C10**		6	8	48	
MA01		Take the wooden dowel **f1** from container and push it in the corresponding hole in **C6 & C7 & C9 & C10**		6	8	48	
	QC02	Visually check the right position of f1		2	8	16	
MA03A		Using a hammer, hammer the f1	Hammer	4	8	32	
	QC03	Don't exceed 10 mm of f1! Use calliper to check the distance	Calliper	5	8	40	
AA04		Left equipped SC6& SC7& SC9 & SC10 on table		1	4	4	
T502	Drw_II	Make a frame of drawer. Connect C6, C7 & C8 with f25				**169**	
AA05		Take the SC6 and put it vertically on work table		3	1	3	
MA01		Take the plastic dowel f25 from a box and push it in the corresponding hole in SC6		6	2	12	
MA03B		Using a hammer, hit the dowel f25 to go through the hole, but not to the end (half)	Hammer	10	2	20	
	QC02	The dowel f25 should not exceed more than 5 mm outside SC6		2	2	4	
AA01		Take the C8 from input warehouse and put it vertically on work table		24	1	24	
	QC01	Check visually the C8 in case of any damage		5	1	5	
MA04		Connect SC6 and C8 together in right position using hand force		6	1	6	

	QC02	Visually check the straight angle		5	1	5	
MA03B		Using a hammer, hit the dowel f25 to the end (second half)	Hammer	10	2	20	
AA05		Take the SC7 and put it vertically on work table		3	1	3	
MA01		Take the plastic dowel f25 from a box and push it in the corresponding hole in SC7		6	2	12	
MA03B		Using a hammer, hit the dowel f25 to go through the hole, but not to the end (half)	Hammer	10	2	20	
	QC02	The dowel f25 should not exceed more than 5 mm outside SC7		2	2	4	
MA04		Connect SC7 and C8 together in right position using hand force		6	1	6	
	QC02	Visually check the straight angle		5	1	5	
MA03B		Using a hammer, hit the dowel f25 to the end (second half)	Hammer	10	2	20	
T503	Drw_III	Connect C13 & C14 with drawer frame by glue				**94**	
AA01B		Take the C13 & C14 from input warehouse and put it on work table		6	2	12	
	QC01	Check visually the C13 & C14 in case of any damage		5	2	10	
MA08		Take a glue **y1** and apply necessary amount of glue into selected hole in **C13 & C14**		6	8	48	
MA05		Connect C13 & C14 with C6 & C7 & C9 & C10 together in right position using hand force		8	2	16	
	QC04	Pay attention to the correct connection (no gap between C13 & C14 and C6 & C7 & C9 & C10, and straight angle)		4	2	8	
T504	Drw_IV	Install bottom C12 in drawer frame				**46**	
AA09		Put the drawer frame of the top side to the ground		2	2	4	
AA01B		Take the C12 from input warehouse and put it on work table		6	2	12	
	QC01	Check visually the C12 in case of any damage		5	2	10	
MA05		Connect C9 with drawer frame by inserting it into the groove in C6 & C7		8	2	16	
	QC02	Visually check right position. The C9 should not exceed outside the frame.		2	2	4	
T505	Drw_V	Connect C12 with drawer frame by nails l1				**200**	
	QC05	Check the diagonal lengths - they must be the same, use the tape measure, if necessary adjust the position		10	4	40	
MA01		Take the nail l1 from box and put it in right position		6	10	60	
	QC03	Distance between nails should be equal (10-15 cm)		5	6	30	
MA07		Hit the nail **l1** with a hammer		5	10	50	
	QC02	Visually make sure the l1 has reached the end		2	10	20	
T506	Drw_VI	Install door handle c85 with j30 screw				**148**	
MA01		Take the door handle c85 from a box and put it to the right position		6	2	12	
MA01		Take the screw j30 from a box and put it to the corresponding hole in C10		6	4	24	
MA02		Using screwdriver, tighten the j30	Screwdrivr	18	4	72	
	QC02	Visually make sure the j30 has reached the end and door handle c85 is stable		2	2	4	
AA02		Put the assembled SD back in output warehouse		18	2	36	
OP04	Drw4,6,7	Final assembly of furniture				**509**	**8,5**
T601	Drw_6	Install drawers				**396**	
AA01		Take the assembled drawer SD from input warehouse and put on work table		24	4	96	
AA02		Pull out both sliders w44L and w44P		2	4	8	
MA01		Put on sliders the drawer in right position		20	4	80	
	QC01	Adjust the right placement of drawer by screw		20	4	80	
AA07		Close the drawer		1	4	4	
	QC02	Visually check the proper position of drawer		2	4	8	
AA08		Put the assembled furniture F07 to place of storage		120	1	120	
T701	Drw_7	Install drawers				**113**	
AA01		Take the assembled furniture F07 from input warehouse and put on work table		24	1	24	
AA09		Rotate the legs to adjust the height.		2	4	8	
	QC02	Visually check the proper position of drawer		20	4	80	
AA02		Put the assembled furniture F07 to place of storage		1	1	1	

Annex C: data collection sheet for the temporary calculation of furniture 15/13,5

IDA	IDQ/Dr	Description	Tools	Single Time [s]	Multiple	Time per activity [s]	TPA [min]
OP01	Drw_1	Assembly boards 1-8 with their respective accessories				**2228**	**37,13**
T101		Assembly board C1 with R3, F1, D1				**251**	
AA01		Take C1 from W1 and putting it on WT1	M	24	1	24	
	QC01	Check that C1 does not have any problem	V	5	1	5	
MA01		Take 2xD1, 4xR3, 4XF1 and put them in their place	M	6	10	60	
	QC02	Check for the correct position of the accessories	V	2	10	20	
MA02 MA03A AA02		With the respective tool, tighten the accessories in C1	Screwdriver	18	6	108	
		With the respective tool, tighten the accessories in C1	Hammer	4	4	16	
		Put SC1 in the WF1	M	18	1	18	
T102		Assembly board C2 with R3, F1, D1				**251**	
AA01		Take C2 from W1 and putting it on WT1	M	24	1	24	
	QC01	Check that C2 does not have any problem	V	5	1	5	
MA01		Take 2xD1, 4xR3, 4XF1 and put them in their place	M	6	10	60	
	QC02	Check for the correct position of the accessories	V	2	10	20	
MA02		With the respective tool, tighten the accessories in C2	Screwdriver	18	6	108	
MA03A		With the respective tool, tighten the accessories in C2	Hammer	4	4	16	
AA02		Put SC2 in the WF1	M	18	1	18	
T3		Assembly board C3 with R1, F1, D1, R16				**461**	
AA01		Take C3 from W1 and putting it on WT1	M	24	1	24	
	QC01	Check that C3 does not have any problem	V	5	1	5	
MA01		Take 4xD1, 4xR1, 4XF1, 6XR16 and put them in their place	M	6	18	108	
	QC02	Check for the correct position of the accessories	V	2	18	36	
MA02		With the respective tool, tighten the accessories R1/D1	Screwdriver	18	6	108	
MA03A		With the respective tool, tighten the accessories F1	Hammer	4	4	16	
AA09		Rotate C3	M	2	1	2	

MA02		With the respective tool, tighten the accessory R16/D1	Screwdriver	18	8	144	
AA02		Put SC3 in the WF1	M	18	1	18	
T4		Assembly board C4 with R1, F1, D1, R16				**461**	
AA01		Take C4 from W1 and putting it on WT1	M	24	1	24	
	QC01	Check that C4 does not have any problem	V	5	1	5	
MA01		Take 4xD1, 4xR1, 4XF1, 6XR16 and put them in their pla	M	6	18	108	
	QC02	Check for the correct position of the accessories	V	2	18	36	
MA02		With the respective tool, tighten the accessories R1/D1	Screwdriver	18	6	108	
MA03A		With the respective tool, tighten the accessories F1	Hammer	4	4	16	
AA09		Rotate C4	M	2	1	2	
MA02		With the respective tool, tighten the accessory R16/D1	Screwdriver	18	8	144	
AA02		Put SC4 in the WF1	M	18	1	18	
T5		Assembly board C5 with R16				**255**	
AA01		Take C5 from W1 and putting it on WT1	M	24	1	24	
	QC01	Check that C5 does not have any problem	V	5	1	5	
MA01		Take 8XR16 and put them in their place	M	6	8	48	
	QC02	Check for the correct position of the accessories	V	2	8	16	
MA02		With the respective tool, tighten the accessories R16	Screwdriver	18	8	144	
AA02		Put SC5 in the WF1	M	18	1	18	
T6		Assembly board C6 with R16				**255**	
AA01		Take C6 from W1 and putting it on WT1	M	24	1	24	
	QC01	Check that C6 does not have any problem	V	5	1	5	
MA01		Take 8XR16 and put them in their place	M	6	8	48	
	QC02	Check for the correct position of the accessories	V	2	8	16	
MA02		With the respective tool, tighten the accessories R16	Screwdriver	18	8	144	
AA02		Put SC6 in the WF1	M	18	1	18	
T7		Assembly board C7 with F1				**95**	
AA01		Take C7 from W1 and putting it on WT1	M	24	1	24	
	QC01	Check that C7 does not have any problem	V	5	1	5	
MA01		Take 4XF1 and put them in their place	M	6	4	24	
	QC02	Check for the correct position of the accessories	V	2	4	8	
MA03A		With the respective tool, tighten the accessories F1	Screwdriver	4	4	16	
AA02		Put SC7 in the WF1	M	18	1	18	
T8		Assembly board C8 with F1, R1				**199**	
AA01		Take C8 from W1 and putting it on WT1	M	24	1	24	
	QC01	Check that C8 does not have any problem	V	5	1	5	
MA01		Take 4XF1, 4XR1 and put them in their place	M	6	8	48	
	QC02	Check for the correct position of the accessories	V	2	8	16	
MA03A		With the respective tool, tighten the accessories F1	Screwdriver	4	4	16	
MA02		With the respective tool, tighten the accessory R1	Screwdriver	18	4	72	
AA02		Put SC8 in the WF1	M	18	1	18	
OP02	Drw_2	Assembly the central shelves 1/2/3/4/7				**1122**	**18,70**
T201		Assembly board SC7, SC1, SC3 together with E1, S1				**561**	
AA01		Take SC7, SC1 and SC3 from W2 and putting it on WT2	M	24	3	72	
	QC01	Check that SC7, SC1, SC3 does not have any problem	V	5	3	15	
MA01		Take 12xE1, 12xS1 and put them in their place	M	6	24	144	
	QC02	Check for the correct position of the accessories	V	2	24	48	
MA02		With the respective tool, tighten the accessories in E1	Screwdriver	18	12	216	
MA03A		With the respective tool, tighten the accessories in S1	Hammer	4	12	48	
AA02		Put SC137 in the WF2	M	18	1	18	
T202		Assembly board SC7, SC2, SC4 together with E1, S1				**561**	
AA01		Take SC7, SC2 and SC4 from W2 and putting it on WT2	M	24	3	72	
	QC01	Check that SC7, SC2, SC2 does not have any problem	V	5	3	15	
MA01		Take 12xE1, 12xS1 and put them in their place	M	6	24	144	
	QC02	Check for the correct position of the accessories	V	2	24	48	
MA02		With the respective tool, tighten the accessories in E1	Screwdriver	18	12	216	
MA03A		With the respective tool, tighten the accessories in S1	Hammer	4	12	48	
AA02		Put SC247 in the WF2	M	18	1	18	
OP03	Drw_3	Assembly the lateral shelves 3/4/8				**232**	**3,87**
T301		Assembly board SC137, SC247 together with S2				**232**	
AA01		Take SC137, SC247,SC8 from W3 and putting it on WT3	M	24	2	48	
	QC01	Check that SC137, SC247 does not have any problem	V	5	2	10	
MA01		Take 12xS2 and put them in their place	M	6	12	72	
	QC02	Check for the correct position of the accessories	V	2	12	24	
MA04		Connect SC137 and SC247 using hand force	H	6	2	12	
MA03A		With the respective tool, tighten the accessories in S2	Hammer	4	12	48	
AA02		Put SC348 in the WF3	M	18	1	18	
OP04	Drw_4	Assembly the top/bottom shelves 5/6				**381**	**6,35**
T301		Assembly board SC348 together with K29, S2				**381**	
AA01		Take SC348,SC5,SC6 from W4,W1 and putting iton WT4	M	24	3	72	
	QC01	Check that SC348, SC5,SC6 does not have any problem	V	5	3	15	
MA01		Take 6xK29, 16xS2 and put them in their place	M	6	22	132	
	QC02	Check for the correct position of the accessories	V	2	22	44	
MA04		Connect C5, C6 with SC348 using hand force	H	6	2	12	
MA03A		With the respective tool tighten the accessories K29,S2	Hammer	4	22	88	
AA02		Put SC12 in the WF4	M	18	1	18	
OP04	Drw_5	Finish the assembly by adding the rear parts 10/11				**1563**	**26,05**
T401		Assembly board SC6 together with L1				**1563**	
AA01		Take SC12, C10,C11 from W5, W1 and putting it on WT5	M	24	3	72	
	QC01	Check that SC6, C10, C11 does not have any problem	V	5	3	15	
MA01		Take 120XL1 and put them in their place	M	6	120	720	

	QC02	Check for the correct position of the accessories	V	2	120	240	
MA04		Connect C10, C11 with SC6 using hand force	H	6	3	18	
MA03A		With the respective tool tighten the accessories L1	Hammer	4	120	480	
AA02		Put SCF in the WFF	M	18	1	18	
						5526,00	92,10