Orders Planning and Raw Materials Management in a Special Vehicles Manufacturer

Maria Inês Milheiro de Oliveira Azevedo

Dissertação de Mestrado

Orientador na FEUP: Prof. Vera Miguéis

Orientador na Empresa: Eng. Diogo Gomes

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

Mestrado Integrado em Engenharia Industrial e Gestão

2018-07-02

Se podes olhar, vê. Se podes ver, repara.
José Saramago

Valeu a pena? Tudo vale a pena
Se a alma não é pequena.
Quem quer passar além do Bojador
Tem que passar além da dor.
Deus ao mar o perigo e o abismo deu,
Mas nele é que espelhou o céu.
Fernando Pessoa

Orders Planning and Raw Materials Management in a Special Vehicles Manufacturer

Abstract

In an environment of accentuated complexity, it is extremely important to guarantee that both the material and information flows are efficient and effective. With an appropriate process mapping, a company can recognize its flaws and therefore find solutions, reducing task rework, disorganization and reduced productivity, among others. This dissertation is inserted in a project of continuous improvement developed in an industrial company of vehicles transformation, in particular ambulances, framed in a growing and expansion strategic option. In this context, companies are changing product development strategies and business and manufacturing processes in order to efficiently implement adequate operating models, such as build-to-order, make-to-order and assembly-to-order to react to the growing individualization of demand.

After material and information flows were mapped, various challenges and improvement opportunities were found. The initial process of processing a potential new order and stocks management, namely raw materials are highlighted in this dissertation.

Many improvement projects were launched, but in this dissertation two of them are particularly referenced. The goal of the first subproject is then to define a new model of purchasing and provisioning to be implemented in the company and the goal of the second subproject is to create a configurator to standardize the process of processing new potential orders. Until then, the decision of placing an order to a supplier was made predominantly in an empirical way and based on the experience of the collaborator in charge of doing it. In this process there were as well several manual and routine operations which were intended to be reduced and automatized. The same was applied to the process of entry of new orders, until then manually processed.

In order to monitor the development of the project with concrete data, performance indexes were defined for each of the two subprojects (model of purchasing and configurator), to be calculated and evaluated every week. Those are a *stockout analysis* (percentage of raw materials stockouts and inventory value) and a *changes analysis* (percentage of changes made to vehicles after they enter production). In the AS-IS situation, the values were 43% and 32%, respectively. Thus, comparatively to the starting values, it was possible to reduce the level of stockouts in 28%, reducing the inventory value and the lack of materials in production. Furthermore, it was possible to reduce the number of changes in 29%, improving one of the factors that was most contributing to the difficulties in production planning. Due to a time restriction to carry out this project, it was not possible to achieve the target proposed of 0% for the percentage of stockouts, but it was possible to reach the target of 5% for the percentage of changes.

The obtained results prove the necessity and benefit of mapping processes and systematize operations. It is important to highlight the fact that in an industrial environment the main difficult in obtaining success is frequently the resistance people offer to change rather than the development of the solution itself.

Resumo

Num ambiente de elevada complexidade, é extremamente importante assegurar que os fluxos de material e informação são eficientes e eficazes. Com um correto mapeamento de processos, uma empresa pode conhecer as suas falhas e assim encontrar soluções para as mesmas, reduzindo retrabalho de tarefas, desorganização, quedas de produtividade, entre outros.

A presente dissertação foi desenvolvida no contexto de um programa operacional de melhoria contínua desenvolvido numa empresa industrial de transformação de veículos, especialmente ambulâncias, enquadrado numa opção estratégica de crescimento e expansão futura. Neste contexto, há uma preocupação crescente das empresas em mudar as estratégias de desenvolvimento de produto e os processos de gestão e negócio para que possam implementar de forma eficiente modelos de operação adequados, como o *build-to-order, make-to-order* e *assembly-to-order*, de forma a reagir adequadamente à crescente individualização da procura.

Após o mapeamento de fluxos de informação e material, encontraram-se diversos desafios e oportunidades de melhoria, dos quais se destacam o processo inicial de processamento de uma potencial nova encomenda e a gestão de stocks, nomeadamente de matérias-primas.

Diversos projetos de melhoria foram lançados, sendo nesta dissertação referenciados com detalhe dois deles. O objetivo do primeiro subprojeto focou-se na definição de um novo modelo de aprovisionamento de matérias-primas para implementar na empresa e o segundo subprojeto endereçou especificamente o desenvolvimento de um configurador de propostas de potenciais encomendas. Até então, a decisão de colocar encomendas a fornecedores era um processo maioritariamente empírico e baseado na experiência de cada colaborador. Deste processo faziam ainda parte um conjunto de etapas manuais e pouco estruturadas que se pretendeu que fossem reduzidas e automatizadas. O mesmo se aplicava ao processo de entrada de potenciais novas encomendas, até então efetuado manualmente.

De forma a monitorizar com dados o progresso, foram definidos indicadores de desempenho para cada um dos dois subprojetos (modelo de aprovisionamento e configurador), a serem calculados e avaliados semanalmente. São esses uma *análise de roturas* (percentagem de roturas de matérias primas e o valor de inventário) e uma *análise de alterações* (percentagem de alterações feitas às viaturas depois de estas entrarem em produção). Na situação atual (*AS-IS)* começou-se com valores na ordem dos 43% e 32%, respetivamente. À data da produção deste documento, os indicadores encontravam-se com 15% e 3%, respetivamente. Devido à restrição temporal para execução deste projeto, não se alcançou a meta de 0% para as roturas, mas alcançou-se (e ultrapassou-se) a meta de 5% para as alterações nos veículos.

Os resultados obtidos comprovam a necessidade e benefício de mapear processos e sistematizar operações. É de realçar o facto de em ambientes industriais a principal dificuldade na obtenção do sucesso ser frequentemente a resistência à mudança por parte das pessoas e não o desenvolvimento da solução em concreto.

Acknowledgements

This document, more than just the result of many hours of work, represents the culmination of a five-years-cycle. Therefore, it is with such pride and gratitude (and a little bit of relief, I must admit!) that I express here my sincere appreciation to the people and entities that helped me throughout the way.

To Kaizen Institute, especially my tutor Diogo Gomes, for all the help concerning this dissertation; my colleagues Hugo, Mariana and André who supported me in the development of this project; and the rest of my colleagues from team "Arroz de Tomate", thank you for welcoming me so well into the team. It is an honour for me to be a Kaizener just like each of you.

To the company where I developed this project, for the opportunity of doing that in its headquarters and for the sympathy I found in everyone who greeted me with a smile, from the shopfloor to the administration.

To Professor Vera Miguéis, my advisor for this dissertation, for all the help concerning the content and structure of it and, above all, for being an example of a great Professor, dedicated and careful with each detail.

To every Professor of the Faculty of Engineering of the University of Porto, for teaching me things I never thought I would be capable to know.

To my real friends, especially Beatriz, Ana and Mariana, for making me feel liked for what I am and for sticking with me through all my ups-and-downs.

To my fiancée, Francisco, a pillar of support, my confident and my best friend. Thank you for taking such great care of Beckie and I.

To my grandma Odete and my grandpa Domingos, my two angels on earth, who have taught me how to read from newspapers when I was five and took care of me every day after school. I will forever cherish the never-ending days in the house I will always call home. I am so lucky to be your granddaughter.

To my sister, Beatriz, for teaching me what is love and acceptance despite all the differences between us. You are brilliant and you will be a great doctor one day. I am a proud sister!

Finally, to my parents. I am but one forever thankful daughter. For all the opportunities, sacrifice and unconditional love. My mum, Cristina, for teaching me what is inconditional love and putting the other one first. And my dad, Prof. Américo Lopes de Azevedo, the one and only responsible for my decision to become an engineer. It is all thanks to you. Your passion, resilience, motivation and work capacity are truly remarkable and inspiring.

To each and all of you, thank you from the bottom of my heart.

Index

1 Introduction 1
1.1 Context 1
1.2 Project Description 2
1.3 Objectives and Research Questions 3
1.4 Methodology 3
1.5 Document Structure 4
2 Theoretical Background 5
2.1 Materials Management 5
2.1.1 ABC Analysis 6
2.1.2 XYZ Analysis 7
2.2 Inventory Management Models 9
2.3 Materials Requirements Planning 11
2.4 Service Level 12
2.5 Customer Order Decoupling Point 12
2.6 One-of-a-kind Products and Mass Customization 15
3 Problem Characterization 19
3.1 Case Study 19
3.1.1 Organisational Chart 21
3.1.2 Information Flow 22
3.2 General Production Process Flow 24
3.2.1 Operating Difficulties and Opportunities Found 27
3.2.2 Service Level 28
3.3 Manufacturing Operations Management Platform 30
4 Analysis and Proposed Solutions 33
4.1 Subproject No. 1: Improving Raw Materials Management 33
4.1.1 Raw materials Segmentation 35
4.1.2 A3 Step 1: Goal Description 37
4.1.3 A3 Step 2: Analysis of the Current Situation (AS-IS) 37
4.1.4 A3 Step 3: Target Definition 37
4.1.5 A3 Step 4: Analysis of Roots and Causes 38
4.1.6 A3 Step 5: Solution Design 38
4.1.7 A3 Step 6: Solution Test 43
4.2 Subproject No. 2: Improving the Process ‘Proposal to Customer’ 44
4.2.1 A3 Step 1: Goal Description 45
4.2.2 A3 Step 2: Analysis of the Current Situation (AS-IS) 45
4.2.3 A3 Step 3: Target Definition 45
4.2.4 A4 Step 4: Analysis of Roots and Causes 46
4.2.5 A3 Step 5: Solution Design 46
4.2.6 A3 Step 6: Solution Test 47
5 Conclusions and Future Developments 49
5.1 Main Conclusions 50
5.2 Future Developments 50
References 53
Appendix A: Improvement Opportunities Brainstoming 56
Appendix B: Categories of References 57
Appendix C: Specific Categories of References 58
Appendix D: Extract of the list with M References 59
Appendix E: Examples of Descriptive Memories 60

Appendix F: Macros for Configurator 62
Appendix G: Standards to Update the Data Base 63
Appendix H: Standards for Commercials 65

Abbreviations

ATO – *Assemble To Order*

BTO – *Build To Order*

BOM – *Bill-of-Materials*

CODP – *Customer Order Decoupling Point*

ERP – *Enterprise Resource Planning*

KPI – *Key Performance Indicator*

MES – *Manufacturing Execution System*

MRP – *Material Requirements Planning*

MRP-II – *Manufacturing Resources Planning*

MOM – *Manufacturing Operations Management*

MTO – *Make To Order*

MTO – *Make To Stock*

OEM – *Original Equipment Manufacturer*

OKP – *One-of-a-kind Product*

OTD – *On-Time Delivery*

ROP – *Reorder Point*

SLA – *Service Level Agreement*

SKU – *Stock Keeping Unit*

SS – *Safety Stock*

VDTD - *Veículo Dedicado ao Transporte de Doentes (Vehicle Dedicated to the Transport of Ill)*

TE – *Transporte Especial (Special Transport)*

TPMR - *Transporte de Pessoas de Mobilidade Reduzida (Transport of People with Reduced Mobility)*

WIP – *Work in Progress*

List of Illustrations

Figure 1 - Global perspective of the methodology 4
Figure 2 - Combination of ABC and XYZ Analysis *in* WZL/FIR 8
Figure 3 - Customer Order Decoupling Point *in* Wikner and Rudberg, 2005 14
Figure 4 - Push-pull production system *in* Gotzfried, 2013 and adapted from Blecker and Abdelkafi, 2006 14
Figure 5 - Mass customization strategies proposed by Lampel and Mintzberg *in* Gotzfried, 2013 16
Figure 6 - Adopting a mass customization strategy implies overcoming the challenge inherent to traditional trade-off cost vs flexibility 17
Figure 7 - 2016 Sales in Percentage of Turnover 19
Figure 8 - The Business Model Canvas of the company in study 20
Figure 9 - Functional organizational chart of the company 22
Figure 10 - Swimlane of the Information Flow 23
Figure 11 - Overview of the production process flow 24
Figure 12 - Examples of possible configurations for a Type A1 Ambulance 25
Figure 13 - Examples of possible configurations for a Type A2 Ambulance 25
Figure 14 - Example of a possible configuration for a B Type Ambulance 25
Figure 15 - Expected demand in number of units per month per vehicle category 27
Figure 16 - Number of stockouts per area when initiating production 28
Figure 17 – Number of customers' complaints between January and May of 2018 29
Figure 18 - Number of changes after production starts 29
Figure 19 - Motives for changes after production starts by the client in the months of January, February and March of 2018 30
Figure 20 - Motives for changes after production starts by the Commercial Department in the months of January, February and March of 2018 30
Figure 21 - Pareto chart of the number of SKUs of the specific categories in raw materials 34
Figure 22- Volume per Transformation 35
Figure 23 - Screenshot of articles per transformation table 36
Figure 24 - Pareto Chart (ABC analysis) 36
Figure 25 - Number of articles per type 36
Figure 26 - Screeenshot of the Stockout Analysis Excel 38
Figure 27 - Decision Flowchart 39
Figure 28 - Criteria defined per category 39
Figure 29 - Supply Routines Defined 39
Figure 30 - Weekly schedule for provisioning routines 40
Figure 31 - Screenshot of the document cover 40
Figure 32 - Screenshot of the Information section 41

Figure 33 - Screenshot of the "2.1 Stock" 41
Figure 34 - Screenshot of the "2.2 Consumption" 42
Figure 35 - Screenshot of the "2.3 Orders" 42
Figure 36 – Screenshot of the “Analysis” 42
Figure 37 - Evolution of the KPI during the project 43
Figure 38 - Changes per section between January and April of 2018 44
Figure 39 - Screenshot of the Excel file with alterations in vehicles 45
Figure 40 - Number of changes per department 46
Figure 41 - Configurator for the B Transformation 46
Figure 42 - % Changes index calculation 47
Figure 43 - Improvement opportunities brainstorming 56
Figure 44 - Example of part of a Descriptive Memory of a vehicle 61
Figure 45 - Extract of the macros for the configurator 62
Figure 46 - Standards to update the data base (part 1) 63
Figure 47 - Standards to update the data base (part 2) 64
Figure 48 - Standards to generate proposal and report 65

List of Tables

Table 1 - Differences between traditional and build-to-order supply chains *in* Deloitte Consulting, 2003.....2

Table 2 - Advantages and disadvantages of JIT, Stock Replenishment and Single Sourcing ...9

Table 3 - Lead time based on 11 samples.....26

Table 4 - Starting Values of KPIs.....37

Table 5 - KPI value at the moment.....44

Table 6 - Categories of References.....57

Table 7 - Specific Categories of References 58

1 Introduction

The dissertation project[1] emerges inserted in a program of operational improvement in a manufacturer of special vehicles[2].

In this chapter, a presentation and context of the project is given. The set goals are described as well as the adopted methodology to reach those.

1.1 Context

The global nature of the markets, with increasing competition, has forced many companies to review their operations strategy (Gunasekaran, 2005). In fact, manufacturing companies are faced with markets which demand a great variety of products, with shorter lead times and smaller but more frequent order quantities, accompanied by more frequent changes. These companies must therefore make their production system more flexible and agile, reduce continuously the production and storage costs and react rapidly to new customer requirements and fluctuations in demand. For these reasons, customer-driven manufacturing, grounded on production models based on make to order (MTO) and assemble to order (ATO) strategies, is the key concept to guarantee future's competitiveness in an environment with high variety of products and small lot sizes.

According to Gunasekaran (2005), make to order as an approach can be defined as ''the value chain that manufactures quality products or services based on the requirements of a customer at competitive prices". This is made within a short period of time by taking advantage of the core competencies of partnering firms or suppliers and information technologies to integrate such a value chain. This strategy presents a level of cost effectiveness, responsiveness and flexibility in a way that allows companies to give to clients the products they have chosen at the time they requested (Gunasekaran, 2005).

Customised manufacturing is an ongoing trend in many production sectors (Simão, Stadzisz and Morel, 2006). In a MTO environment, the production and assembly of products are usually driven by customer requirements (Yang and Fung, 2014). Thus, the ability to fulfil customer orders at the required time and with effective cost determines the competitive advantage in today's dynamic market. This type of environment grants the client the possibility to choose from a range of choices in order to meet his needs in the most desirable way. In this so-called make-to-order environment, the variety and complexity of the supply chain rises several challenges concerning production planning, sourcing and efficiency, among others.

A supply chain consists of a series of activities comprising everything from product development, sourcing, production and logistics, as well as the information systems needed to coordinate these activities (NC State University, 2017). Having this in mind, there are

[1] Part of the curriculum of the Integrated Master in Industrial Engineering and Management of the Faculty of Engineering of the University of Porto.

[2] Due to confidential reasons, the name of the company is not referred.

undoubtedly considerable differences between a traditional supply chain and a build-to-order supply chain, which are summarized in Table 1.

Table 1 - Differences between traditional and build-to-order supply chains *in* Deloitte Consulting, 2003

Reference	**Traditional supply chain**	**Build-to-order supply chain**
Marketing	Push-sell from stock	Pull-build to customer order
Production	Focus on level and stable schedules: fixed order line-up	Customer demand focused on supply chain flexibility
Logistics	Mass approach – non-differentiated	Fast, reliable, customized
Customer relationship	Dealer-owned	Shared across the extended enterprise
Managing uncertainty	Finished goods inventory buffers	Strategic part buffers and information management
Finished goods inventory	High stock control	Low, condensed dealer stock levels
Suppliers	Long lead times	Collaborative/ responsive

Build to Order or Make to Order are a common approach for highly configured products such as special vehicles (vehicles that are adapted and altered to suit a specific purpose). Examples of such vehicles are ambulances, which are equipped for transport of patients and delivery of health care, vehicles adapted for the support and transport of passengers with reduced mobility, vehicles adapted for retail trade or service delivery, vehicles adapted for public security and armed vehicles for the transport of valuables, among others.

Special vehicles can be included in the build to order/ make to order domain, for the reason that they are scheduled and built in response to a confirmed order received from a final customer. Also, it is a type of product that has relatively long lead times and typically implicates a series of activities that are project oriented. Each vehicle is customized and adapted to fit the client preferences and at the same time oblige to what is stipulated by law. It is a complex process which combines the effort from different teams, from electricity to carpentry sections.

1.2 Project Description

Existing for almost four decades, the company in study has grown to be a leader in the Portuguese vehicle transformation market. They are involved in diverse areas such as health, public and private security, commerce and business, and support for people with limited mobility, and do business in three continents - Europe, Asia and Africa - exporting to various countries.

Due to their undisciplined operation and a current growing necessity, a continuous improvement project was born in January of 2018, after a diagnosis was made to the supply chain. The diagnosis covered the entire process from customer order until the vehicle exit. It was concluded that several initiatives should be developed in order to improve the operations through:

- Improving the operational efficiency by reducing operational costs, better space utilization and normalization of operations;
- Improving the flow;
- Improving flexibility.

The present study aims to address some concrete improvement opportunities related to the significant number of raw materials stockouts and to the high number of changes made by the client after production has started.

Thus, this study, with a duration of 5 months, is focused on the perspective of substantially improve the operations of the company through the increase of the flow of the overall process and better management of materials.

This change was only possible through the engagement and the successful contribution of all the core elements in the organization. In a business world increasingly competitive and dynamic, it is crucial for companies to find solutions which can make them more stable before changes and innovations.

1.3 Objectives and Research Questions

Following a diagnosis made, it is intended to carry out an analysis to the current raw materials management model and suggest improvements and new policies to follow as far as their supply is concerned. Another target is to understand the dynamics associated with consumption in order to develop suitable work planning. In particular, in this dissertation project the main objective was to address one of the most concerning causes for inefficient order planning: during the manufacturing and assembly process, there are constant changes that delay and difficult planning and consequently decreases the overall efficiency and effectiveness. Strategies to address all these matters are to be identified and applied.

Having in consideration all the objectives listed above, and to provide orientation for the research project, the following research questions are going to be addressed:

1. How to classify raw materials, components and parts?
2. What are the most suitable replenishment policies and strategies in this context?
3. When to apply those policies?
4. What factors affect orders planning?

1.4 Methodology

The methodology adopted for this study has its grounds on both qualitative and quantitative techniques employed in the perspective of a deductive method (top-down logic).

Qualitative research is primarily exploratory research. Exploratory research is research conducted for a problem that has not been clearly studied. One can, through exploration, develop concepts more clearly, establish priorities, develop operational definitions and improve the final research design (University of Pretoria, n.d.). It is used to gain an understanding of underlying reasons, opinions and motivations. It provides insights into problems and helps to develop ideas or hypotheses for potential quantitative research (Dovetail, 2018). There are five types of qualitative research methods: ethnography, narrative, phenomenological, grounded theory, and case study (Sauro, 2015). In this case, the last type, a real case study, will be used. An empirical approach is followed, since data will be collected directly from experimentation as the basis for calculations, not from theories and abstractions.

On the other hand, quantitative research is used to quantify the problem by generating numerical data that can be transformed into useable statistics.

The global perspective of the methodology can be seen in Figure 1.

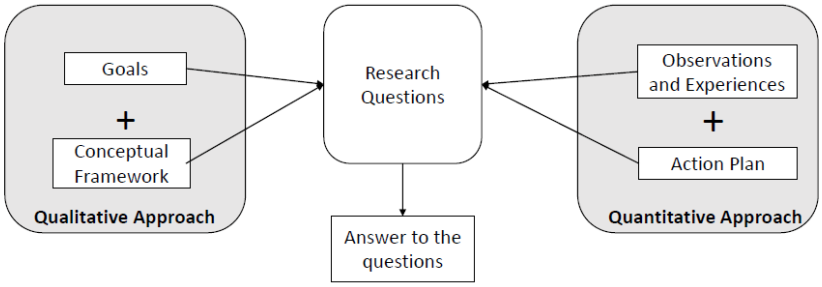


Figure 1 - Global perspective of the methodology

When defining the problem, it was crucial to go to GEMBA (where the work is happening and value is created) to identify MUDA (waste), MURI (overburden) and MURA (unevenness), and gather data on the main process variables of the process. Through this study, the objectives were aligned, combining the company's ambition with the analysis made as yet.

In order to eliminate all the critical causes and sources, an action plan was elaborated in parallel to facilitate the implementation of all the possible improvements that were identified.

There will be the following stages:

- Acquire general awareness of the company;
- In-depth analysis of the operating mode of each department;
- AS-IS state: clear identification of the existing problems as far as raw materials sourcing is concerned as well as the budgeting process for clients;
- TO-BE state: definition of the roadmap to follow in order to solve the problems mentioned above. Segmentation of the raw materials and analysis of its consumption patterns; mathematical definition of variables which can assist stocks management; creation of a tool which can assist the budgeting process;
- Implementation and follow-up of the tools proposed;
- Detail lessons learned and future work.

1.5 Document Structure

This document is comprised by five chapters, where a more detailed explanation of the context and methodology of the product is presented and explained.

The present chapter should be viewed as an introduction to the project and endeavours to present a summary of its main goals as well as the methodology proposed to reach those. It is also provided a brief context of the make to order industry, especially as far as the vehicle transformation industry is concerned.

In Chapter 2, the theoretical context can be found, where the framework with the concepts and methodologies that supported the development of the dissertation is presented.

Chapter 3 details the initial situation (AS-IS) of the project in analysis, with a particular focus on the identification and description of the problem, the productive process and specific operations.

Chapter 4 describes the proposed solutions for the problem, as well as the main results stemming from their implementation and the actions which unleashed a continuous improving vision (TO BE).

Finally, Chapter 5 presents the main conclusions of the work done and also suggests some work guidelines for the future.

2 Theoretical Background

In this chapter, the theoretical foundations which supported the project development are presented. The chapter is divided in the following subjects: Material Management, Inventory Management, Material Requirements Planning, Service Level, Customer Decoupling Point and One-of-a-kind versus Mass Customization.

2.1 Materials Management

Every company needs raw materials and products intended either for further production or selling. These items are known as stocks and are usually located inside warehouses and consumed according to the requirements of the production plan.

The necessity of keeping stocks can be raised due to numerous reasons. Firstly, sometimes it is hard to synchronize the particular moment when the necessity of using the unit arrives and the moment when it becomes available (transaction motive). Secondly, it is necessary to have a safety stock to accommodate demand and delivery time fluctuations (precaution motive). The optimum safety stock is a compromise between the stock rupture cost and the holding cost. Its goal is to ensure supply reliability, taking into account the variability not only of the consumption but also of the replenishment process itself. On the other hand, the plant itself takes some time to materialize operations and processes, which implies the existence of work in process (WIP) (processing motive). Finally, there are also price fluctuations and misalignments between offer and demand (speculation motive).

Seeking the optimization of their operations and depending on which types of parts or products are involved, companies adopt different planning and inventory methods concerning materials management. Usually, in make to order manufacturing environments, the main goal is to guarantee a balance between on-hand raw materials and work-in-process inventory and resulting customer service.

From an operations perspective, the goal of materials management is to provide the supply of raw materials, components and subsystems in the necessary quantity and quality, with on time delivery and at the right place. Thus, it has a key role in improving the creation of value within the company. Moreover, material management also has to ensure low level of investment in raw materials' warehouses, processes' buffers and final products' warehouses. Thus, it is recognizable a crucial trade-off: it is necessary to ensure on time delivery in order to fulfil the desired service level while achieving optimal purchasing performance in terms of price, quantity, quality and timing. In fact, on one hand higher service level is naturally associated to the availability of stocks. If production process is interrupted, customers become dissatisfied when an item is not available (out of stock) or when the conclusion of their order is delayed. On the other hand, a company can reduce costs by reducing inventory. Actually, high cost efficiency involves the reduction of capital invested in inventory, both at input and at WIP in the transformation system (e.g. raw materials, components, WIP and buffers levels, etc.).

The main functions and objectives of materials management are the following:

- Requirements planning, involving the calculation of the required quantity of materials, with the necessary quality, supplied to production on schedule;
- Reducing the level of investment in storages and warehouses;
- Supplying products and spare parts on schedule to sales market;
- Managing purchase orders while taking into account adequate policies, such as time-based and quantity-based reorders systems, and exploring purchasing concepts in terms of price, quantity, quality and timing.

Concerning the order quantity calculation, it is important to define the criteria triggering material planning operations. That is to say, taking into account existing stock levels, outstanding orders, reserved materials and safety stocks. Thus, the function of order initiation and stock control are an essential part of a complete material planning system.

Material planning requires information from a number of company departments in order to carry out its tasks. It also acts as a source of information for many other departments. For example, the purchasing and production lead times have to be taken into account in order to determine the customer orders delivery dates. Also, production planning needs information about the ordering costs and lead times of materials in order to determine the most suitable raw material for parts produced or assembled in-house.

It should also be noted that material management is very demanding in terms of information and linkage between different functions (management of master data, transactions log, inbound logistics, consumptions, etc.). Therefore, it is truly crucial to have integrated database-oriented Enterprise Resource Planning (ERP) systems.

2.1.1 ABC Analysis

In the context of materials management, the ABC analysis is a common inventory classification technique employed by organizations. It could be understood as a method for structuring on-hand inventory into three segments based usually on annual value volume. In fact, each article in a certain segment cannot be treated with the same amount of attention. Therefore, it is recommended to classify the articles into different segments, in this case, A, B and C. The ABC analysis follows the "80-20" rule from the Pareto Principle (this principle states that there are a "critical few and trivial many"). Thus, three segments of products are defined in which, according to several practical applications, the quantitative and value-based shares are described as followed:

- A-products, approximately a share of 20% in the quantity of the products and approximately a share of 80% in the value of these products;
- B-products, approximately a share of 30% in the quantity of the products and approximately a share of 15% in the value of these products;
- C-products, approximately a share of 50% in the quantity of the products and approximately a share of 5% in the value of these products.

The ABC analysis suggests that inventories are not of equal value due to the fact that a reduced number of items can represent a significant capital value, and so, will have a high impact on inventory cost. Thus, this analysis suggests that this segment of products (type A) should be planned carefully. That is to say, A-items are certainly worth to accurately calculate the optimal order quantity, to monitor changes in stock levels and to perform frequent value analysis. On the contrary, for the unimportant and numerous C products no special efforts should be made. The idea is to establish inventory policies that focus resources on the few critical inventory items and not the many trivial ones.

ABC Analysis procedure (based on value):

1. Determination of absolute total costs

$$Absolute\ total\ costs\ =\ yearly\ demand\ \times\ item\ price$$

2. Determination of relative proportions of the total costs

$$Relative\ proportion\ of\ total\ costs\ =\ Absolute\ total\ costs\ /\ Total\ costs$$

3. Sorting according to relative contribution to total costs (in descending order)

4. Accumulation of relative contributions to total costs

5. Classification of materials into three segments

Commonly, this analysis is complemented by a similar but quantity-oriented analysis (consumption, output, etc.), particularly useful at operations level (e.g. shop-floor) to support products flows analysis. Thus, the following steps can be added:

6. Determination of relative quantity proportions

$$Relative\ quantity\ proportion\ =\ Yearly\ demand/\ Total\ demand$$

7. Summation of relative quantity proportions per material segment

Value-based measures of inventory segmentation are not always best suited for operations. Different criteria could be considered to classify each segment considered, for example stock value, annual sales volume, quantity of consumption, service level, amount of demand, turnover ratio, etc. After the criteria is chosen, the articles are ranked and break points are often chosen for the A, B and C segments. Although ABC analysis usually considers three segments, it is possible to have more, depending on the organizations circumstances. Several advantages are recognizable on the ABC Analysis, namely:

- Analysis of complex problems focusing on the essential factors;
- Ease of application to very different situations;
- Visual presentation of the results.

The main limitation that is recognized in the ABC analysis is that it considers only one criterion to define the segmentation considered. In order to overcome this main limitation and namely to increase the flexibility of this analysis tool many researchers have tried to develop the method by adding more criteria when classifying the inventories (Flores and Whybark, 1987; Ramanathan, 2006; Ng, 2007; Chu et al., 2008; Tsai and Yeh, 2008).

2.1.2 XYZ Analysis

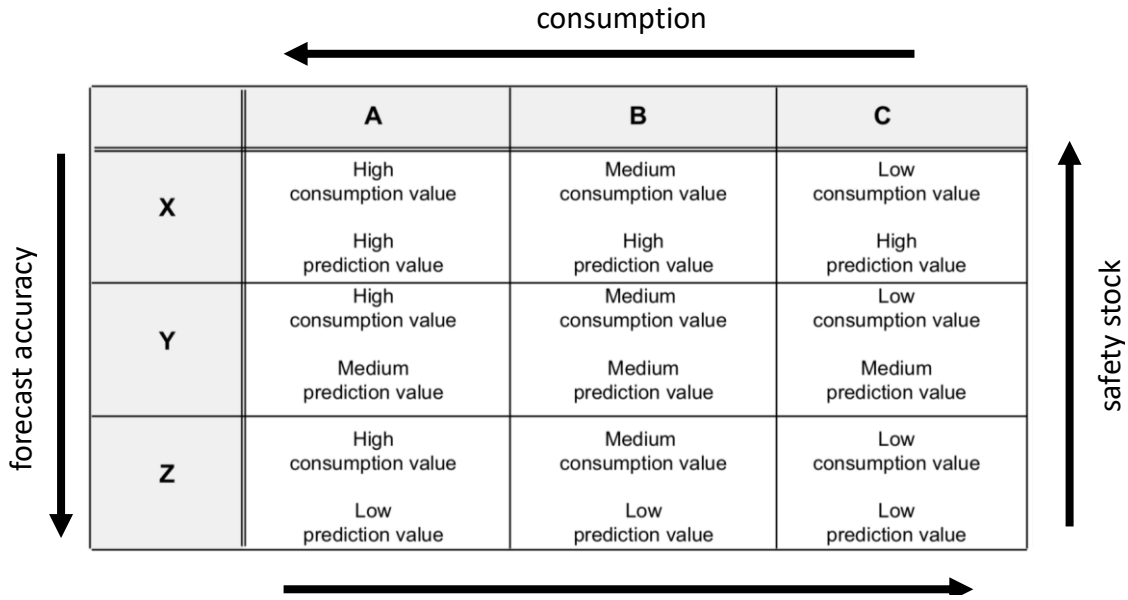
The ABC Analysis is often combined with what is named a XYZ Analysis (analysis of the consumption pattern). The XYZ Analysis focuses on the regularity of the demand or consumption. Basically, this analysis allows to segment the products according to the frequency or variability of their usage. In fact, knowing the variability of demand/consumption it will be possible to adopt suitable planning techniques. For example, if the demanded number of products shows small deviations it will be possible to adopt feasible predictable approaches. On the other hand, with significant deviations in demand, it is not robust to predict future consumption, and thus difficulties and additional costs in storage and material supply are to be expected.

The planning of material sourcing should aim at the future demand, which is estimated with prediction methods. To achieve an efficient use, the XYZ Analysis segments items according to their fluctuations in consumption (Scholz-Reiter, 2012), namely as follows:

- X: To some extent constant consumption, fluctuations are rather flat. In this segment, we consider items with high predictability, e.g. up to 10% of the average value;
- Y: stronger fluctuations in consumption, usually for trend-moderate or seasonal reasons. In this segment, we have items with medium predictability, e.g. 10-50% of the average value;
- Z: completely irregular consumption. Items with low predictability, in particular items with sporadic and unsteady demand.

For the XYZ Analysis, usually the fluctuations in the consumptions are based on the coefficient of variation (Schonsleben, 2007), which is the ratio of the standard deviation of item consumption over a certain period and the average consumption.

Combining the results of the ABC and XYZ analyses gives a matrix containing nine different item segments as illustrated in Figure 2.



	A	B	C
X	High consumption value High prediction value	Medium consumption value High prediction value	Low consumption value High prediction value
Y	High consumption value Medium prediction value	Medium consumption value Medium prediction value	Low consumption value Medium prediction value
Z	High consumption value Low prediction value	Medium consumption value Low prediction value	Low consumption value Low prediction value

Figure 2 - Combination of ABC and XYZ Analysis *in* WZL/FIR

The characteristics of different item segments range from segments with high forecast accuracy and high consumption (known as “AX” items) to item segments with low forecast accuracy and low consumption (known as “CZ” items).

Now the separated products from classes AX, BX, CX, AY, BY, CY, AZ, BZ and CZ can be managed by different principles. E.g. AX-products could be purchased Just-in-time, because a continuous sourcing by a nearby supplier is easier to manage if there are small fluctuations. The same can be thought about an intern production of Z-goods, because the regarded orders for extern suppliers are not interesting and also expensive.

One of the advantages of these analysis is the integration of items with similar characteristics to process them with the same material planning parameters. Since the demand of an item over the past cycles is crucial for its classification, it is important to perform the item classification with consistently defined standards in periodic intervals to include possible changes promptly. The practical experience recommends to perform the classification monthly, quarterly or at least yearly, depending on the industrial branch.

Three main policies of material supply are usually considered: just-in-time, stock replenishment and single-sourcing. Each one presents advantages and disadvantages. The just-in-time policy tries to connect the advantages of both the other two material-supply-policies and to exclude their disadvantages. With the help of contracts, it is arranged with suppliers to deliver the required amount of material on schedule, according to dates determined by the production process of the sourcing enterprise. Concerning the stock replenishment (stock supply), the material is kept in storage until its use. This is the most common supply principle in practice. Finally, single-sourcing, oriented to a specific demand: the sourcing of a material just takes place when it is required, according to a certain production order. A summary of this advantages and drawbacks can be seen in Table 2.

Table 2 - Advantages and disadvantages of JIT, Stock Replenishment and Single Sourcing

	Just-in-time	Stock replenishment	Single sourcing (dependent on requirements)
Advantages	• Low stock levels • Low level of capital and storage costs • Warranty of continuous production process • Low need of coordination	• Warranty of continuous production process • Protection against sourcing risks • Benefit from price advantages	• Low level of capital and storage costs
Disadvantages	• High dependency on supplier	• High costs of storage	• High need of coordination • Danger of supply instabilities • and stagnant production => high costs for the company

A major topic on materials management is what are referred to as inventory management models for independent demand, in contrast to other approaches to cope with dependent demand, namely when the demand of one product can be derived from the demand of another part or product. In the next sections the main approaches commonly followed are described.

2.2 Inventory Management Models

Inventory can ensure different functions in the operations of a company (Heizer and Render, 2018), namely the following ones:

- To decouple operations from fluctuations in demand, providing a stock of items to serve customers' needs (e.g. finished-goods type inventory) and to guarantee protection against unexpected increases in the demand;
- To "decouple" the supplier-customer stages in the production processes (e.g. work-in-process type inventory;
- To take advantage of quantity discounts and to hedge against inflation and upward prices changes (e.g. raw material type inventory).

Inventory management involves planning and control of all types of inventories and, thus, interacts with the activities related to forecasting demand, placing purchase and manufacturing orders, and filling sales orders. When the company only produces after what the customer demands, it is possible to keep the inventory levels at a minimum. However, make to order is not possible for all manufacturing companies because of various cost aspects.

The inventory control is linked to the customers' demands: companies can offer better customer service if they keep higher levels of inventories, which is called delivery service level. Two types of demand for an item are usually considered: the item is either independent or dependent on the demand of other items. Nevertheless, inventory management requires two key decisions related to quantity and time dimensions that must be made frequently (Heizer and Render, 2014): how much to order and when to order. Furthermore, other inventory management decision is deciding if an item should be stocked. If an item is not stocked, the firm must make, assemble, or buy the item in response to customer demand.

Different inventory management models with respect to order timing and order quantity policies can be considered. However, the objective is always to minimize total costs involved. Choosing what to order solves the quantity dimension and determining when to order solves the time dimension. Two main models are usually considered:

- Fixed-order quantity inventory management (Q model) – in this model a predetermined quantity of an inventoried item is ordered when the stock on hand reaches a level named the Reorder Point (ROP). Thus, the inventory level is monitored until it gets to the ROP value; at this time, we resupply with a quantity Q. The ROP is determined by the rate of consumption (D) and the lead time (LT). The quantity on hand at the time and order is launched must be sufficient to satisfy demand during the lead time associated to the replenishment and also cover unexpected deviations (SS – safety stock). Thus, the reorder point can be calculated as

$$ROP = D \times LT + SS$$

Where:

D is the rate of consumption

LT is the supplier's replenishment lead time

SS is the safety stock

- Fixed-time period inventory management (P model) – rather than monitoring the inventory level and ordering when the level gets the reorder point, the item is ordered at regular intervals of time, thus this model requires a periodic review of inventory levels. The order size is determined by the difference between the maximum desired inventory level and the inventory on hand at the time of review.

Q models always consider the same order quantity, and this is an advantage for the supplier. The disadvantage is that the time between call-offs can differ, which leads to more stock keeping units (SKUs) for the supplier.

Due to several uncertainties, internal and external, companies are motivated to maintain a safety stock (SS). Thus, SS represents the planned or actual amount of "extra" inventory used to protect against fluctuations in demand or supply. The uncertainties can be in demand during the lead time or in the length of the lead time. If the safety stock is set too high, the inventory carrying cost will be too high too. If safety stock is set too low, the shortage cost will be too high. When the safety stock dimensioning is being determined, it may be useful to use the service level as a determinant for the number of SKU's in safety stock. The formula is the following:

$$SS = k \times \sigma$$

Where:

k is the safety factor determined from the desired service level

σ is the estimated standard deviation of demand during replenishment lead time

Apart from the two main methods for restocking (the system that uses a constant order volume and the system of periodic monitoring) there are modified versions of models, including the method of constant volume and constant intervals of orders, applied at the known demand. Restocking following this 'push' approach, considering mainly the demand forecasts and performed according to timetable defined in advance, is usually used at the dependent demand conditions. On the other hand, the 'pull' approach is used mainly at independent demand. The most important advantage of restocking models based on this system is the ability for efficient responding to the market needs. If the stock of a certain product is too small or totally used up, the subsequent order is submitted. Moreover, without adequate organizations and operations conditions, such method could not provide a high level of customer service, since the order submitted in reaction to the lack of a given product could not assure its continuous availability.

2.3 Materials Requirements Planning

Three main different classes of methods may be used to plan materials requirements: requirements planning considering known deterministic demand and known production lead times, requirements planning based on forecast techniques and qualitative or judgmental requirements planning.

Requirements planning considering deterministic information related to demand and lead times generate purchase orders and production orders exactly by quantity and time. The procedure takes into account the master plan (plan oriented to independent demand, i.e., final products and spare parts) to calculate the gross requirements and then "explodes" the product BOM (Bill of Materials), breaking it down, to calculate dependent demand, i.e., required quantities as well as the definition of required dates for all parts involved. This method of materials requirement planning is known by the acronym MRP (also, it is associated to comprehensive computer-based planning system for both production and purchase orders - a major module within Enterprise Resources Planning Systems). When planning includes the plan of capacity in addition to planning materials, the module is called MRP-II, acronym for Manufacturing Resources Planning. Typical applications for this type of requirements planning are situations of discrete manufacturing of complex products (e.g. machinery) and those in which the processing time needed to manufacture the products is shorter than the delivery time demanded by the market.

Requirements planning based on forecast techniques involves determining the expected requirements using statistical forecasting methods considering previous consumption values. Different forecasting techniques can be used, such as time-series and causal models. Commonly employed forecasting models are those concerned with identifying and measuring trends in demand. Regardless of the technique chosen, the basic steps to follow remain basically the same. Firstly, it is necessary to determine the consumption pattern for a particular past time period (time series). Then, it is necessary to select an appropriate forecasting approach (constant, seasonal or trend model) based on the objective and the time period covered. This selection depends on different criteria as well as on the characteristics of each forecasting method (last period demand, moving average, exponential, etc.). For example, the *moving average* method excludes accidental irregularities in the course of a time series. Also, if a current consumption value is available, the oldest consumption value of the moving interval is substituted with the current interval. With the exponential method, the weight of the value decreases as the "age" of the values increases. The new forecast value is corrected by a weighted forecast error of the last forecast value. In regression analysis, there is an approximation with a mathematical function which is then extrapolated into the future. Once the proper method is selected, the next task is to make a forecast and evaluate it in terms of potential shortcoming, level of reliability, quality, sources of errors, etc., which essentially gives the inputs for the next forecast and future planning.

Finally, with qualitative or judgmental requirements planning, the determined requirements are based only on subjective estimates and heuristics. This method can be used when the other two approaches are not directly applicable due to difficulties related to availability and quality of data.

It should be pointed out that regardless of the techniques chosen, the coordination of the physical flow of material with the information flow (e.g. information related to production plan and control) is the core challenge of an effective production planning and scheduling. In fact, a lack of coordination between materials management and production and assembly scheduling will result in a disturbance of the production even though high stock levels are available. These disturbances increase with an increase of variety and complexity of the products in combination with variation of demand.

2.4 Service Level

One of the parameters included in the concept of customer service (the speed of delivery and delivery accuracy) is service level: a measure of the degree to which a company meets customer requirements. Service level is often measured differently for make to stock (MTS) and make to order (MTO) business environments.

Service level metrics for make to stock (MTS) business environments – retailers, distributors, and manufacturers that make and or sell products from inventory (from stock) need a service level measure that reflects the availability of inventory for customers. Thus, the service level is usually measured as a fill rate metric. The unit fill rate is the percentage of units filled immediately from stock; the line fill rate is the percentage of lines filled immediately from stock; and the order fill rate is the percentage of orders filled immediately from stock. The terms "fill rate" and "service level" are often used synonymously in MTS business environments. The essential issue in satisfying customers in the MTS environment is to balance the level of finished inventory against the level of the service to the customer (Jacobs and Chase, 2013).

Service level metrics for make to order (MTO) business environments (where, order products are built, assembled, configured and packaged in response to a customer's request (order)) are usually defined as the percentage of orders that are filled on time, otherwise known as on-time delivery (OTD), which is the percent of orders shipped (or received) complete within the promise date (or request date).

An agreement between a supplier or service provider and a customer that specifies the type and quality of services that will be provided is usually established through a contract called SLA (Service Level Agreement). The SLA is an effective means for the customer and supplier to determine what is important and clearly specify expectations concerning delivery conditions and related performance concerning due dates satisfaction.

2.5 Customer Order Decoupling Point

As mentioned before, all production and inventory control systems deal with two fundamental decision variables: (1) when to order, and (2) how much to order. The different types of the order triggering require different mechanisms of operations control. Basically two main approaches are considered: Pull and Push control.

With a push system, usually the planner decides when and how much to produce/order based on forecasted demand and inventory position information. Thus, it is driven by long-term projections based on a market forecast rather than actual customer demand. With a pull system, the main goal is to decide when and how much to produce/order based on the real needs, thus, existent customer demand drives the process.

The application of the Push control principle means that a high inventory is usually necessary to make a custom-designed final assembly possible. This inventory grows with the increase of the diversity of variants since all variants must be on stock to meet the customer requirements. Since the planned inventory depends strongly on the quality of the forecast of the customer demand, an overestimation of the demand causes a very high inventory level. If the forecast values are below the actual demand, a low inventory leads to low material availability.

In a pull system, the manufacturing plan is based on actual customer demand. It is a system that guarantees the manufacturing flow along the process. According to Srinivasan and Mandyam (2012), a pull system can lead to advantages in product quality, reduced production costs through lower levels of WIP, shorter lead times, lower inventory levels, smoother production flow, improved quality (short queues reduce the time between creation and detection of a defect) and overall reduced cost. Furthermore, when pull is used, the bullwhip effect along the manufacturing chain can be reduced. The reason is that costumer demand is known in the pull strategy and forecasts are not needed.

Hopp and Spearman (2004) provide a different perspective when comparing push and pull systems. They consider a pull system as one that limits the amount of work in process that can be in the system and a push system as one that has no limit on the amount of work in process that can be in the system. They argue further that the definition of push and pull is largely independent of the make to order/make to stock decision.

It is important to refer that there are no pure push or pull systems in practice, but rather an association or coexistence of the two models. Lysons and Farrington (2012) argue that the interface between the push and pull based stages in a manufacturing chain are known as the push-pull boundary. In fact, the push-pull boundary is the point at which a manufacturing company (or supply chain) switches from a push system (involving a strategy of planning based on forecasts) to a pull system (building to an actual customer order); this push-pull boundary usually is called customer order decoupling point (CODP) or order penetration point (is the point at which the customer order enters the system). Thus, CODP is the point between forecast and customer order and after this point the product is bound to a certain customer. For example, with an Assemble to order (ATO) system, the CODP is just before the final assembly.

Figure 3 illustrates the different positioning of the CODP. Associated to CODP is the concept of the P:D ratio, introduced by Shingo (1981). In the P:D ratio, both P and D are lengths of time, where P represents the production lead time and D represents the delivery lead time (the time from order to delivery). Based on the ratio of P divided by D one can determine the amount of planning and production that needs to be based on forecasts/speculation, and the amount that can be based on customer orders. Typically, four CODPs are defined, i.e. engineer-to-order (ETO), make-to-order (MTO), assemble-to-order (ATO), and make-to-stock (MTS). The further downstream the CODP is positioned, the more of the value-adding activities must be carried out under uncertainty, while the further upstream the CODP is positioned, the more activities can be based on actual customer orders, i.e. certain information (Wikner and Rudberg, 2005). The triangles pictured in Figure 3 represent the point where push couples with pull (push-pull boundary).

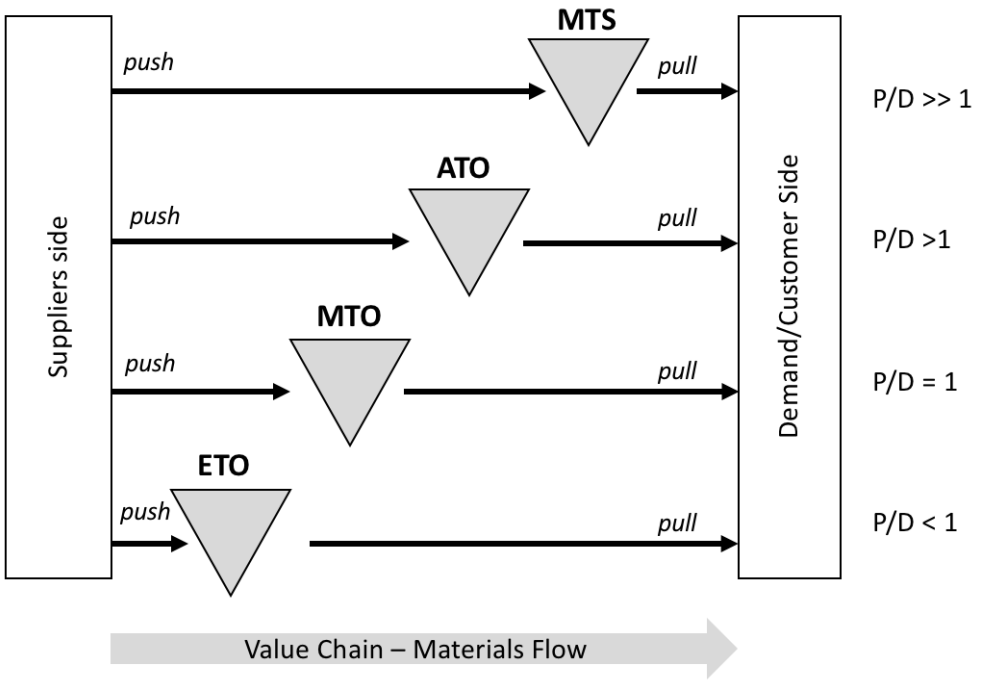


Figure 3 - Customer Order Decoupling Point *in* Wikner and Rudberg, 2005

Figure 4 presents the role of this decoupling point in a customer oriented production system. A push production strategy (push system) is followed in the first stages in manufacturing (i.e. precedent to the decoupling point) in which raw materials and components are transformed into semi-finished products. Up to the decoupling point, achieving economies of scale is the main objective. After the decoupling point, the production stages follow a pull strategy, i.e., the involved production and assembly activities are bound to specific customer orders. In fact, the customer "pulls" the order through these stages (Blecker and Abdelkafi, 2006).

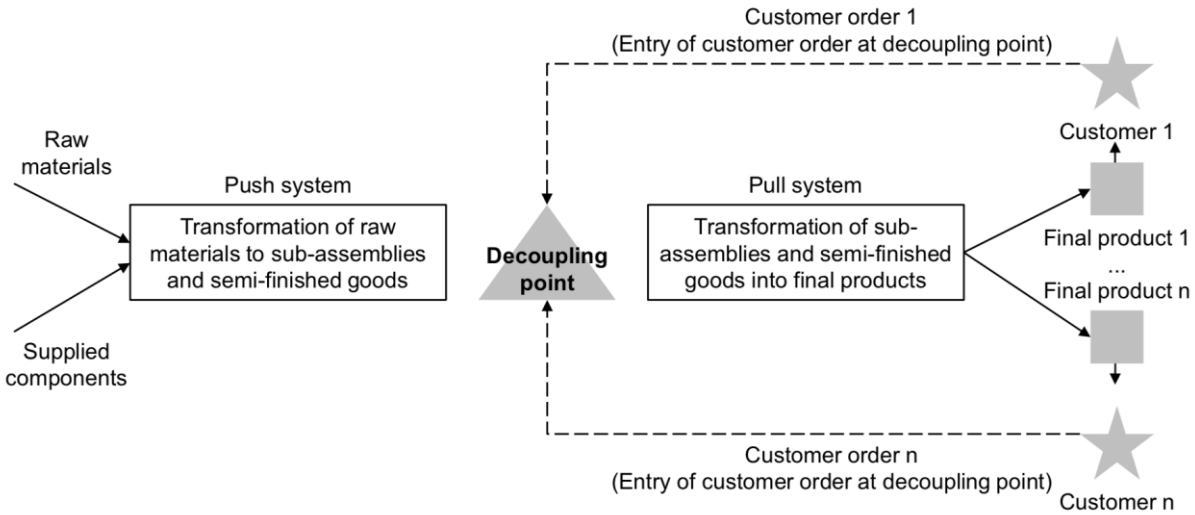


Figure 4 - Push-pull production system *in* Gotzfried, 2013 and adapted from Blecker and Abdelkafi, 2006

The push-pull boundary is closely related to postponement (postponed differentiation) and has strategic implications. Moving the push-pull boundary to a point earlier in the process allows firms to be more responsive to customer demand and avoid mismatches in supply and demand. However, the customer lead time will usually get longer.

Another interrelated concept in the context of customization is the one of postponement. Van Hoek (2001) gives the following definition: "Postponement means delaying activities in the supply chain until customer orders are received with the intention of customizing products, as opposed to performing those activities in anticipation of future orders."

The goal of the postponement is to delay the customization as late as possible in the supply chain. Postponement refers to the situation when the production or assembly starts after an order has been confirmed. It can be understood as a technique used to provide a wide range of variety but still maintain low inventory, transportation and processing cost. Standardized products are used to maintain a neutral state as long as possible and only customize the products in the last steps of the manufacturing processes (Lysons and Farrington, 2006). Because the products are manufactured after a customer places an order, the risk of overproduction will be reduced, which makes it efficient concerning unpredictable customers and markets.

Mainly three types of postponement strategies are mentioned in supply chains: time postponement, place postponement and form postponement (Van Hoek, 2001). Time postponement means delaying the forward movement of goods until customer orders are received (delaying the determination of the time utility); place postponement involves the storage of goods at central locations in the channel until customer orders are received (delaying the determination of the place utility) and form postponement considers delaying product finalization until customer orders are received (delaying the determination of the form / function utility).

To develop and implement a postponement strategy, the company needs to have a robust inventory control in order to keep track of where all the products are and by that keep track of all the value adding processes. Furthermore, postponement requires process modularity, and it moves the customer order decoupling point downstream in the value-added material flow. It contributes to mass customization by increasing both the leanness and agility.

2.6 One-of-a-kind Products and Mass Customization

Nowadays, the continuous evolution of order qualifying and order winning factors are driving companies to offer an ever-increasing variety of product's options. Also, they are more and more seeking differentiation through an offer of customized products in order to keep up with the trends and survive in the current business environment. In fact, the main challenge is how a company can differentiate itself in the marketplace while still creating products at a relatively low cost.

Products designed, manufactured and assembled based on specific customer requirements are customized products usually referred as OKP (one-of-a-kind products). In this type of business environment, the variability and the uncertainty characterizing what is project based, generate a complexity that requires specifically tailored managerial approaches to handle all the processes, from design and engineering to production and delivery (Rahim and Baksh, 2003).

In industries where increasing customization is becoming a qualifying factor towards a true mass customization business environment, a key point is the necessary realignment of operations strategies, namely concerning key decisions associated to resources, processes and competencies. Thus, one of the main questions can be raised as: how can a production company optimize its operations capabilities, resources and processes in an environment where the market demand is shifting towards mass customization? Adopting a mass customization strategy, suitable for highly customized, usually non-repetitive products, usually involve adapting business models and managerial paradigms, operations and productions strategies and Information and Communication Technology (ICT) supporting mainly the operations.

The concept of mass customization was introduced by Davis (1987) who explained that "the same large number of customers can be reached as in mass markets of the industrial economy,

and simultaneously treated individually as in the customized markets of pre-industrial economies". In literature several research works around different taxonomies and strategies around the concept of mass customization can be found (e.g., Pine, 1993; Gilmore, 1997; Duray, 2000).

An interesting taxonomy has been introduced by Lampel and Mintzberg (1996) who differentiate between five strategies by considering a simplified view of the value-chain. Figure 5 presents the strategies framework proposed by these authors.

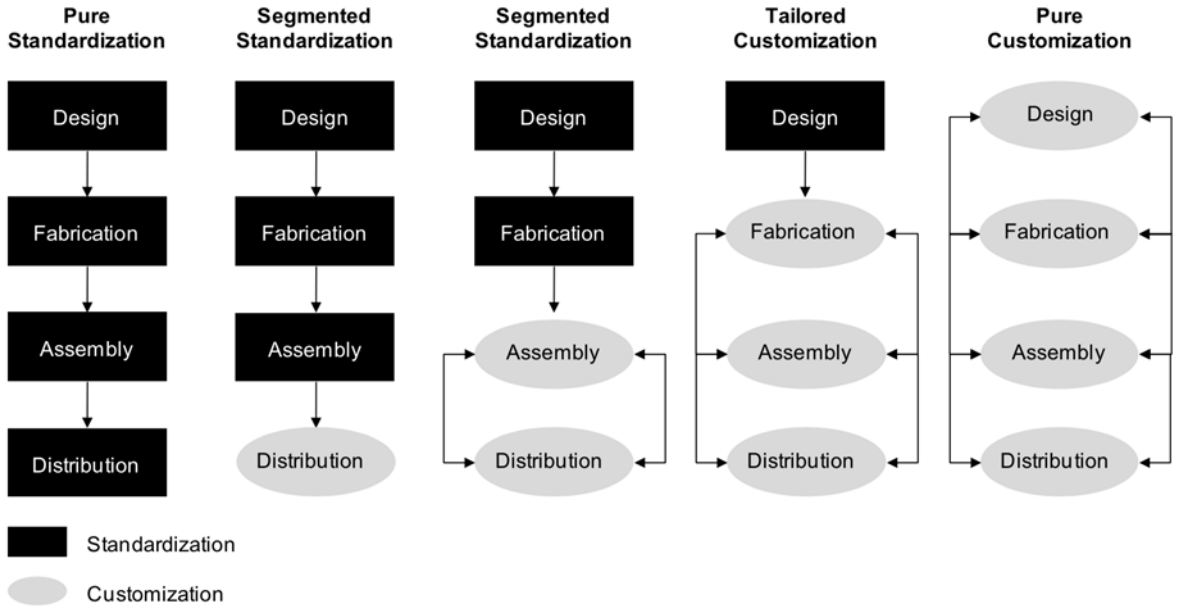


Figure 5 - Mass customization strategies proposed by Lampel and Mintzberg *in* Gotzfried, 2013

Da Silveira (2001) identifies eight different levels of mass customization: 'design', 'fabrication', 'assembly', 'standardization', 'additional custom work', 'additional services', 'packaging and distribution', and 'usage'. The first level, design, is the stage where the customer enters the production cycle before manufacturing has begun, making it an Engineer to Order (ETO) strategy. The fabrication strategy is custom tailored products, produced from a predefined design, thus making it a MTO production. The assembly strategy is mainly focused on configuring modular components into many different kinds of products, in accordance with the customer orders, and is as such considered an ATO strategy. The three levels, 'additional custom work', 'additional services', and 'usage', all have the customization at, or after, the point of sale. The 'package and distribution' level customizes at the packaging level, by for example differentiating the packaging for different regions and customers.

Optimizing the order processing of customized products using techniques of product configuration is a common strategy towards mass customization. In fact, product configuration with the integration of modular product structure and product family architecture has been recognized as an effective means for implementing mass customization (Duray, 2000). Modular approaches can provide advantages in various areas along the product life-cycle. It is recognizable that modular systems reduce costs (economies of scale) and processing time of an order. In addition, changing the function of modules, as well as an extension of the product range, is possible. Furthermore, modular design allows to increase reusing and remanufacturing, as well as lowering separation costs for recycling. However, adopting a modular products approach requires balancing the requirements for the overall performance and costs of the total product family and the sub-optimization of each product parts.

Figure 6 presents the relation between lead time, cost, complexity and the level of customization.

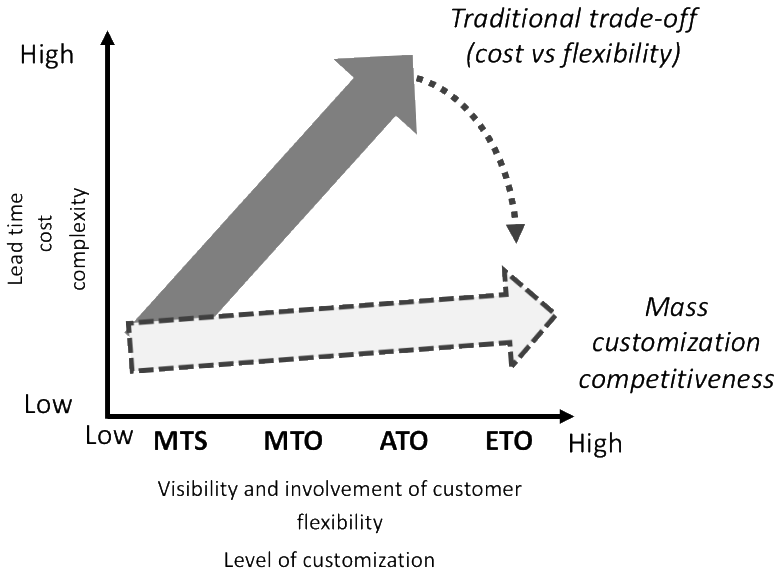


Figure 6 - Adopting a mass customization strategy implies overcoming the challenge inherent to traditional trade-off cost vs flexibility

Adopting a mass customization strategy raises several challenges. From a competitiveness point of view, the main question is related to the identified trade-off of cost efficiency and flexibility (as illustrated in Figure 6). In fact, to overcome this trade-off, there are several organization-based factors that should addressed, namely:

- The global value chain must be ready, as mass customization requires its supply chains willingness and readiness to be able to provide raw materials and components efficiently;
- The information must be available and propagated in real-time along the value chain, where it is needed to support the decisions to be taken;
- The processes and involved resources should be configurable and adaptable according to the demand needs;
- Knowledge must be shared and reused, as the company should be able to pick up on new customer trends and demands and be able to translate them into new products.

3 Problem Characterization

In this chapter, it is intended to characterize the problem considered in this dissertation project. Firstly, the company's business model and operation mode are described. Secondly, several potential improvement opportunities regarding organizational and operational practices are highlighted and characterized.

3.1 Case Study

The Company considered in this case study was founded in the seventies and operates within the manufacturing industry, offering special-purpose custom-made vehicles upon specific customer requests. The business is centered around the transformation of vehicles of various types, for target segments, such as emergency vehicles (e.g ambulances), armored vehicles, wheelchair transport, mini buses, school children transport, workshops mobile vehicles, among others.

Nowadays, the company's product mix as far as vehicles are concerned falls essentially in four categories:

1. Emergency vehicles: Vehicles equipped for transport of patients and the delivery of health care (e.g. ambulances) – four main categories are currently offered (type A1, A2, B and C);
2. Mobility vehicles: vehicles adapted for the support of passengers with reduced mobility – three main categories are currently offered (VDTD, TE and TPMR);
3. Business mobility: vehicles adapted for retail trade or service delivery – eight main categories are offered (mobile office, mini-bus, workshop, home support, transport of dogs, etc);
4. Security vehicles: vehicles adapted for public security and armored vehicles for the transport of valuables - four main categories are currently offered (cellular transport, anti-riot, assistance of shipwrecks, transport of valuables).

Figure 7 presents the segmentation of 2016 sales. Apart from selling vehicles, the company also sells separately the equipment they produce like stretchers, wheelchairs, etc (Equipment) and offers post-sale service (Services Porto and Services Lisboa).

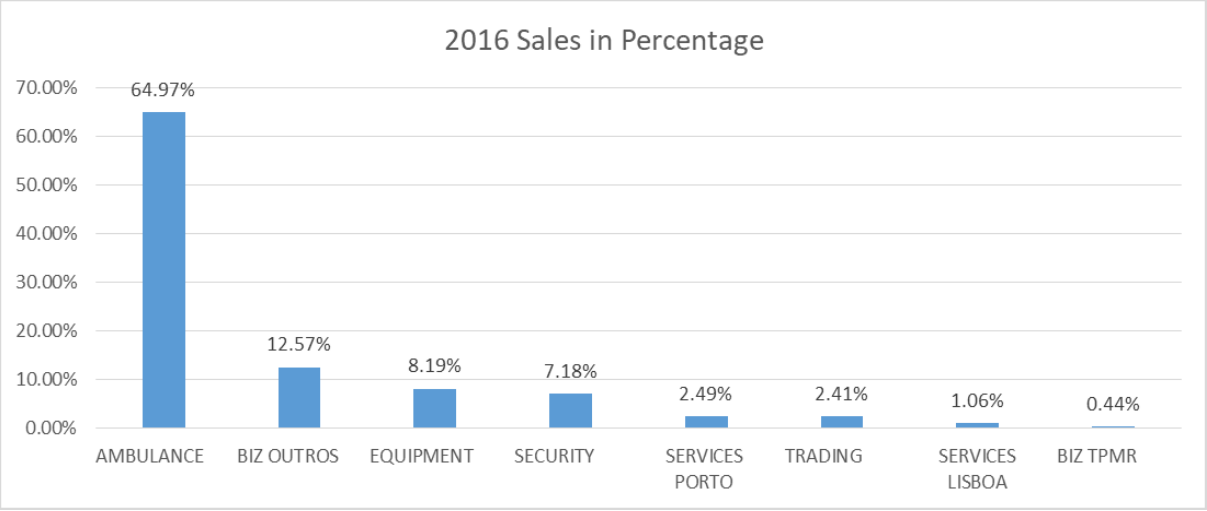


Figure 7 - 2016 Sales in Percentage of Turnover

Today, operating with almost 300 employees and with about 30.000 square meters of industrial area, with production and assembly facilities, the company is able to match customers' requirements in the best possible way by adapting and designing solutions according to their specific needs; hence all final products are unique and customer adapted. Presently, the company's base portfolio is vast and the products offered are complex, involving several elaborate subsystems as well as several standard and non-standard parts. Furthermore, the involved processes are also complex due to the high number of operations and workstations involved.

Whether large-scale or low volume productions or single vehicles for national and international markets are being created, developers, technicians, electricians and other specialists work hand in hand so that base vehicles get turned into very special ones. Transforming around 73 special-purpose vehicles a month on which 63 are sophisticated ambulances, they manage to generate an annual revenue of more than 16 million euros (resulting from business at national and international level).

Due to a continuously increase of international competitiveness pressure, the company needs to be more efficient and improve productivity concerning the business operating model in order to increase the overall profitability and guarantee future business sustainability.

In general terms, the company follows mainly a Make-to-Order and Assembly-to-Order business operating model strategy in order to manage the trade-off concerning customization level and customer order lead-time fulfilment.

Although the product development is considered relevant to the company, the key business processes are the contracts management, the sales and operations planning, and the manufacture and assembly of the actual products based upon customer orders. Processing and translating the customer order into detailed specification information (parts and solution design, technical specifications, drawings and technical plans) typically involves a significant value of the total lead-time.

Based on Osterwalder and Pigneur (2010) business model framework, Figure 8 presents the company's business model as a simplified representation of the company's business logic and the rationale of how a firm creates, delivers and captures value.

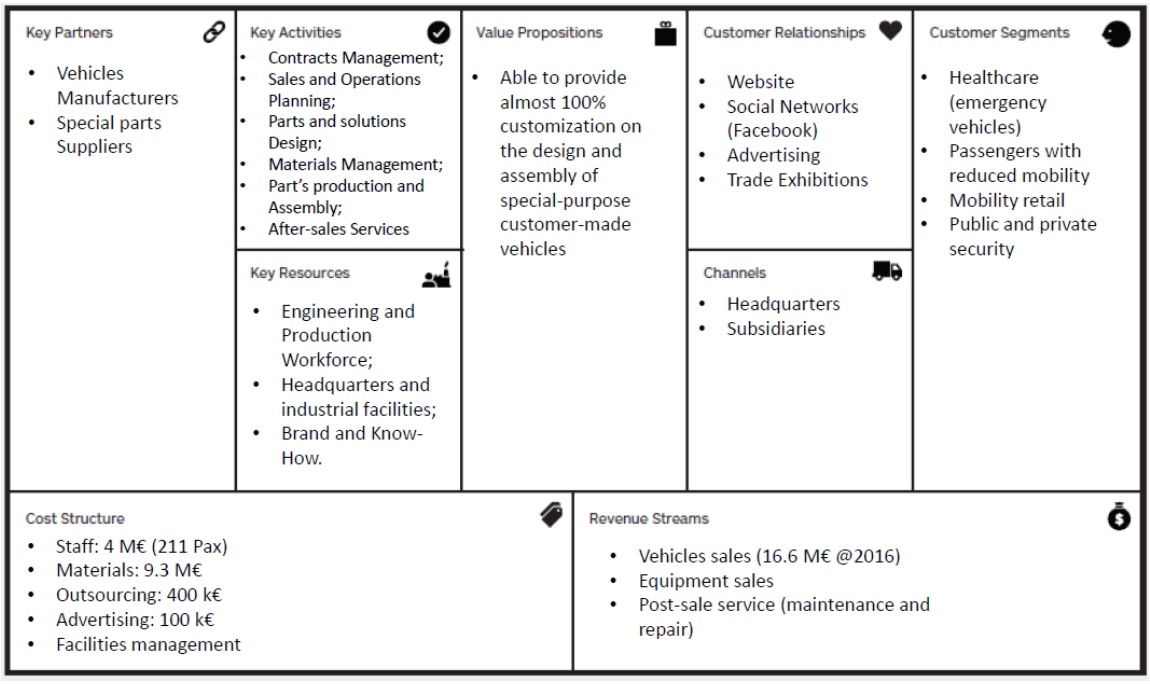


Figure 8 - The Business Model Canvas of the company in study

The different building blocks presented in Figure 8 describe the most critical points related to the company business model. Nine building blocks are considered, namely:

1. Customer segments, related to the different groups of customers that the organization serves, which in this case ranges from fire brigades to the INEM (the Portuguese National Institute of Medical Emergency), security firms, among others;
2. Value proposition as the offer of products and services that the company promises to satisfy customer needs. In this case, the company proposes to customize up to a level of 100% all customer needs regarding special vehicles;
3. Distribution channels as the different types of channels through which the firm communicates and delivers the offer to the customers. Currently, the company sells directly from its headquarters, as well as its four subsidiaries: one in Spain, one in France, one in Dubai and one in Senegal;
4. Customer relationships define the instruments developed to communicate and manage relationships with its various customer segments with the objective to retain the existing customer base and to acquire new ones. The company actively participates in a number of national and international trade exhibitions and also engages with customers through its social networks;
5. Revenue flows in the present business model: the revenue streams are coming mainly from vehicles sales to the different customer's segments;
6. Key resources are the assets required in the different activities that create and deliver the firm's products and services are mainly the skilled engineering, production and assembly workforce and the owned facilities;
7. Key activities as the most relevant activities required to guarantee the promised value proposition. They are the set of key business processes of the company, namely the ones related to contract management, sales and planning, design, production and assembly and after-sales services;
8. Partner network contains the company's most relevant partners and suppliers: the vehicles Original Equipment Manufacturers (OEM) and key suppliers involved in the outsourcing of some special parts, in this case;
9. Cost structure, in this bloc the different cost components involved are presented.

3.1.1 Organisational Chart

From an organisational perspective, the company here considered follows a traditional functional organisational approach. Essentially, concerning vertical differentiation the organizational chart considers three main authorization levels: CEO, directors of departments and functional areas supervisors. Concerning horizontal differentiation design, the company is structured in seven main departments, namely:

- Administrative and Financial department
- Purchasing department
- Marketing department
- Technical and design department
- Production and assembly department
- Quality department
- Applications and IT department.

In figure 9, the functional organizational chart of the company can be observed. This chart is valuable because it enables one to visualize a complete organization, by means of the picture

it presents. A clear distinction is made between administrative, commercial, purchasing, production, technical and IT departments.

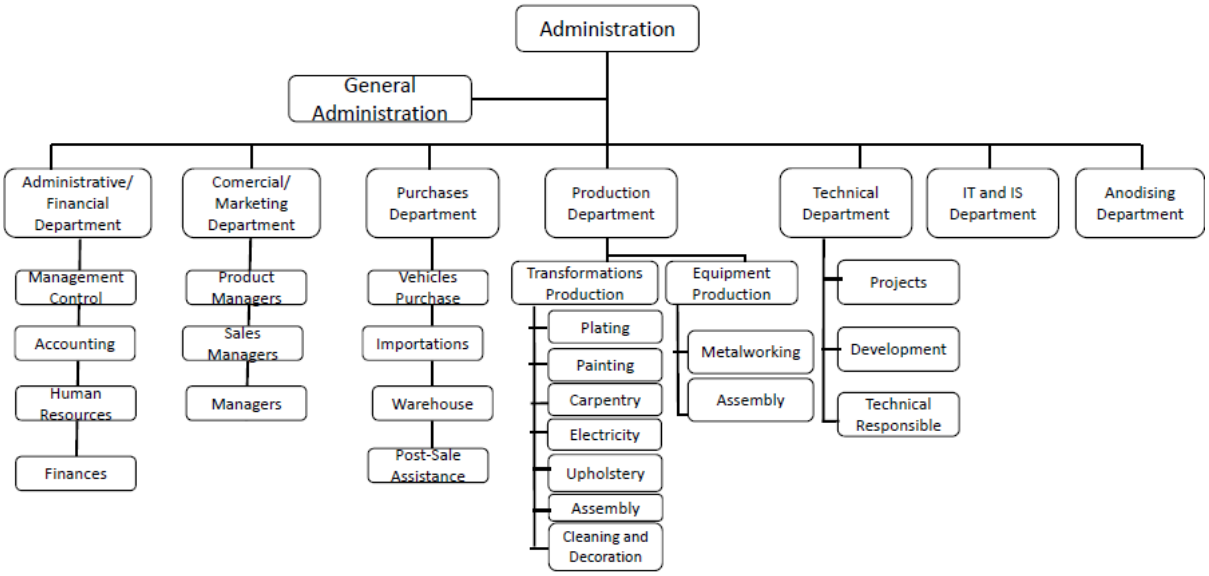


Figure 9 - Functional organizational chart of the company

3.1.2 Information Flow

Figure 10 constitutes a process mapping, which intends to illustrate the flow of processes in the company, from the most macro perspective to the level of detail necessary to identify opportunities for improvement. This figure presents the main sequence of events in a swimlane as far as information flow is concerned.

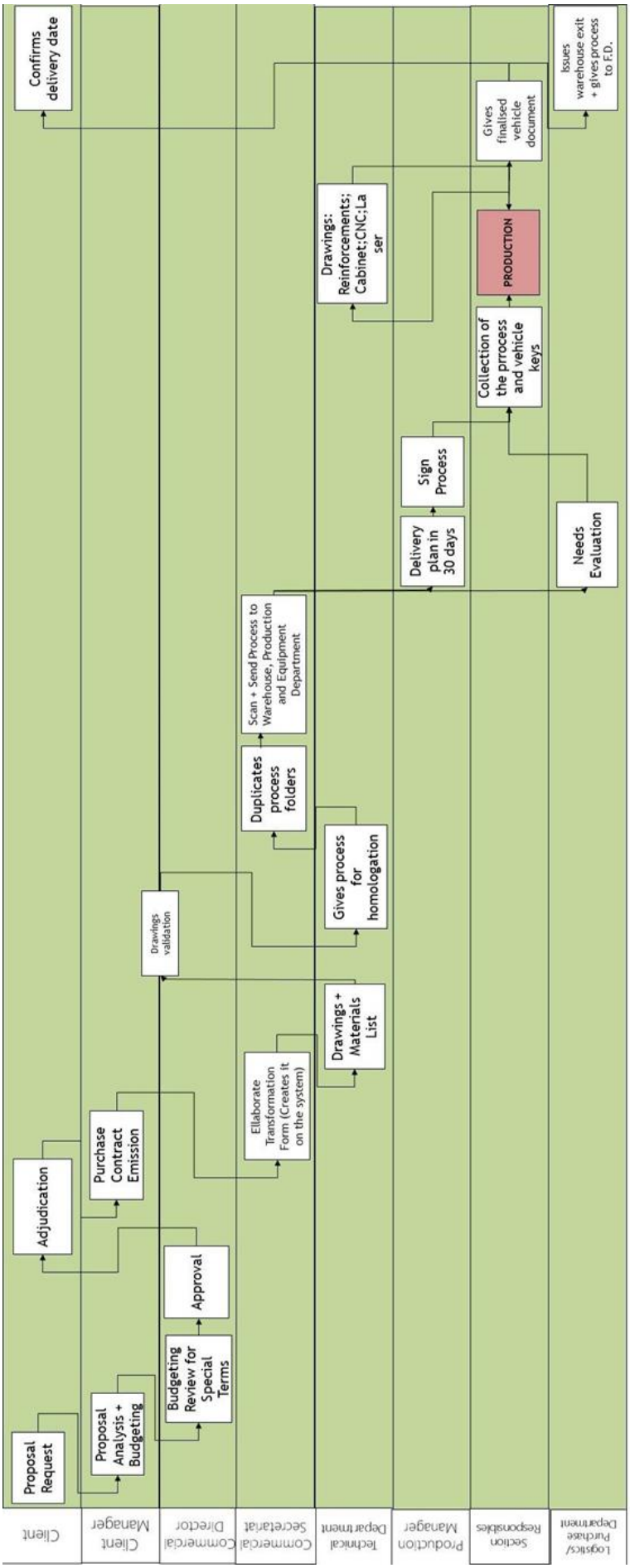


Figure 10 - Swimlane of the Information Flow

3.2 General Production Process Flow

As previously stated, in order to build any special-purpose vehicle, the effort from different departments needs to be combined. In Figure 11, an overview of the production process flow can be observed.

Firstly, the vehicles wait in the parking area until it is time for them to be transformed. Inside, the shop floor is divided in different areas. In the first section (Structural Works and Sheet Metal), it is necessary to add several plates to the interior of the car, to form the skeleton in which everything will be attached to subsequently. Following that, the car moves to the Painting Section, where irregularities due to the addition of sheet metal are treated. Depending if there is or not an available slot in the following area, which is electricity, the vehicle may have to wait again in the vehicle parking area, outside of the building. Then, in the electricity area, it is proceeded to the installation of the internal wiring and all of the exterior emergency lights. After that, the vehicle is moved to the carpentry section (if it has an area available, otherwise it may have to go outside again as it was already mentioned) and everything from the floor, to the roof and cabinets is assembled. It is important to notice that all these different wood and PVC parts are internally designed and produced, which requires coordination between sections. Afterwards, electricity and air conditioning sections both intervene to make their final installations.

Later, the car moves again to the Assembly section, where everything from chairs, stretchers, wheelchairs, oxygen system, defibrillators and other medical equipment is assembled and put inside the vehicle. After this last phase, the vehicle has to be inspected by the quality responsible, in order to ensure that all the standards and requirements are fulfilled. Apart from general quality inspection, electricity and air conditioning tests are also performed before the vehicle proceeds to the last area: Cleaning and Decoration. The car has to be thoroughly cleaned both inside and outside. Various decorations in vinyl and stickers are applied and the vehicle gets its final appearance. When it is ready, if it coincides with the occasion when clients are supposed to pick up the vehicle, it is handed out in that moment. However, most of the times the vehicle goes to the parking area again and awaits to be picked up by its future owners.

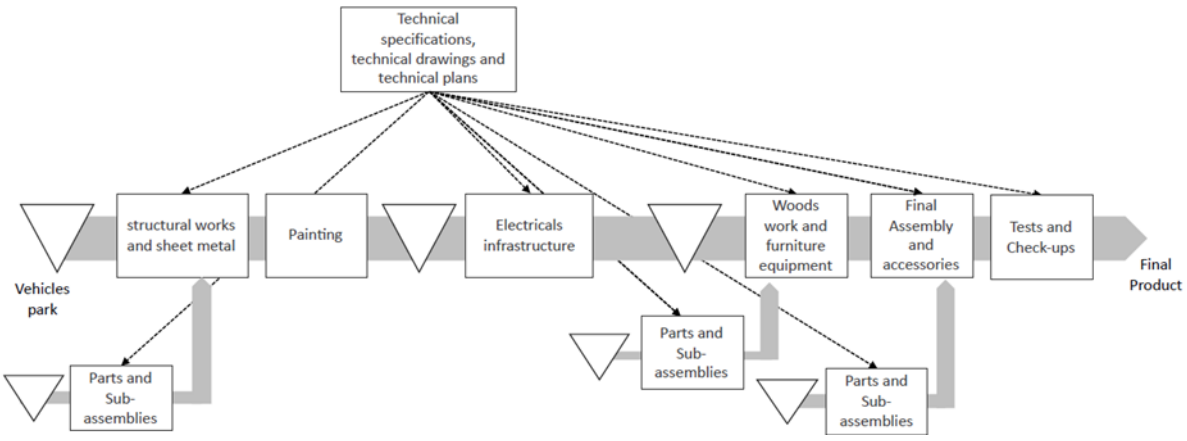


Figure 11 - Overview of the production process flow

Now that the general process has been described, it is important to add a brief description of each type of the company's core product: ambulances. There are different types of ambulances approved in Portugal and legislation which establishes and defines each type: its characteristics and respective equipment, as well as the requirements for its crew (Diário da República, 2014).

Type A: Ambulance of patients transport. It is an ambulance conceived and equipped to transport patients whose clinical situation does not foresee any associated risk of collapse of life functions. A Type A Ambulance is either a Type A1 or Type A2.

Type A1: Ambulance of individual transport. It is destined to the transport of one patient at the time, either in a stretcher, bench or wheelchair, and a companion. In Figure 12 some possible configurations for this type of ambulance can be seen.

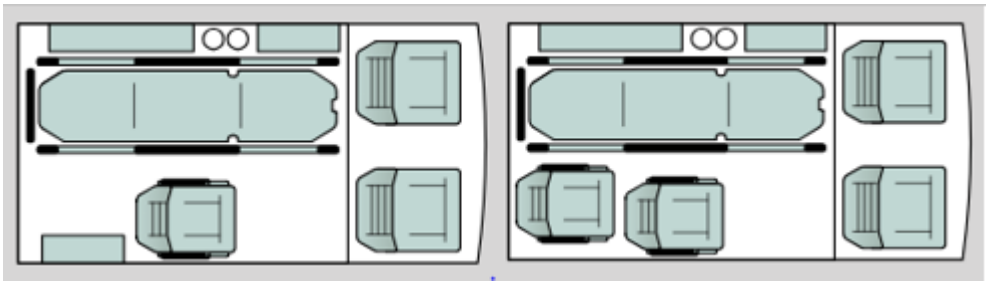


Figure 12 - Examples of possible configurations for a Type A1 Ambulance

Type A2: Ambulance of multiple transport. It is destined to the transport of one or more patients in stretchers, benches and/ or wheelchairs, and their respective companions. In Figure 13 some possible configurations for this type of ambulance can be seen.

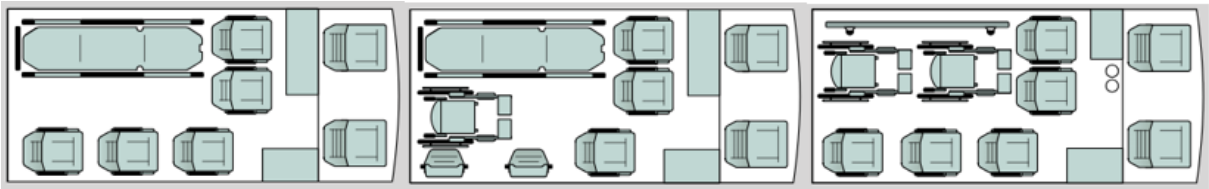


Figure 13 - Examples of possible configurations for a Type A2 Ambulance

Type B: Emergency ambulance. It is an ambulance conceived and equipped to transport and provide an urgent healthcare service to urgent patients. In Figure 14 some possible configurations for this type of ambulance can be seen.

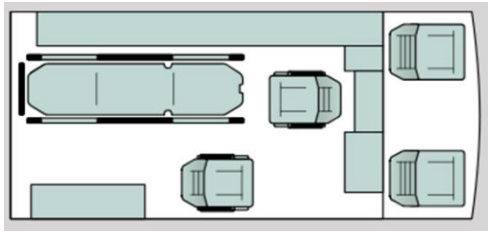


Figure 14 - Example of a possible configuration for a B Type Ambulance

Type C: Intensive care ambulance. It is an ambulance conceived and equipped to the non-urgent transport while providing an advanced healthcare service to patients who depend on more advance means of therapies and supervision. This type of ambulance is not as common as the other ones previously mentioned.

In order to produce the complex vehicles aforementioned, different sections have to intervene, in a specific order, performing diverse operations. These operations lead to very long and variable lead times: 32 days is the average calculated based on data from eleven samples extracted from SEGIN (the company's information system), which can be observed in Table 3.

Table 3 - Lead time based on 11 samples

	Beginning	End	Lead time (Days)	Working Days
Sample 1	03/03/2017 14:27	28/03/2017 17:30	25.13	18
Sample 2	27/02/2017 08:02	31/03/2017 10:00	32.08	24
Sample 3	06/03/2017 10:32	06/04/2017 12:50	31.10	24
Sample 4	03/03/2017 15:22	07/04/2017 12:08	34.86	26
Sample 5	08/03/2017 09:27	06/04/2017 17:30	29.34	22
Sample 6	02/03/2017 16:01	11/04/2017 19:42	40.15	29
Sample 7	22/02/2017 22:27	03/04/2017 14:47	39.68	28
Sample 8	23/02/2017 16:11	10/04/2017 17:30	46.05	32
Sample 9	23/03/2017 08:15	13/04/2017 09:50	21.07	16
Sample 10	07/03/2017 16:42	04/04/2017 11:58	27.80	21
Sample 11	06/03/2017 18:03	04/04/2017 13:46	28.82	22

Up to this date, the monthly production is centred around seventy-three vehicles, sixty-three of which are ambulances and the remaining vehicles belong to a "special category", for example vehicles dedicated to the transport of the ill (VDTD), vehicles dedicated to the transport of people with reduced mobility (TE and TPMR), vehicles dedicated to the transport of values, among others.

Because the business is growing, future monthly demand is predicted to be around 130 vehicles, and the division between the categories mentioned before as far as the expected demand is concerned can be seen in Figure 15.

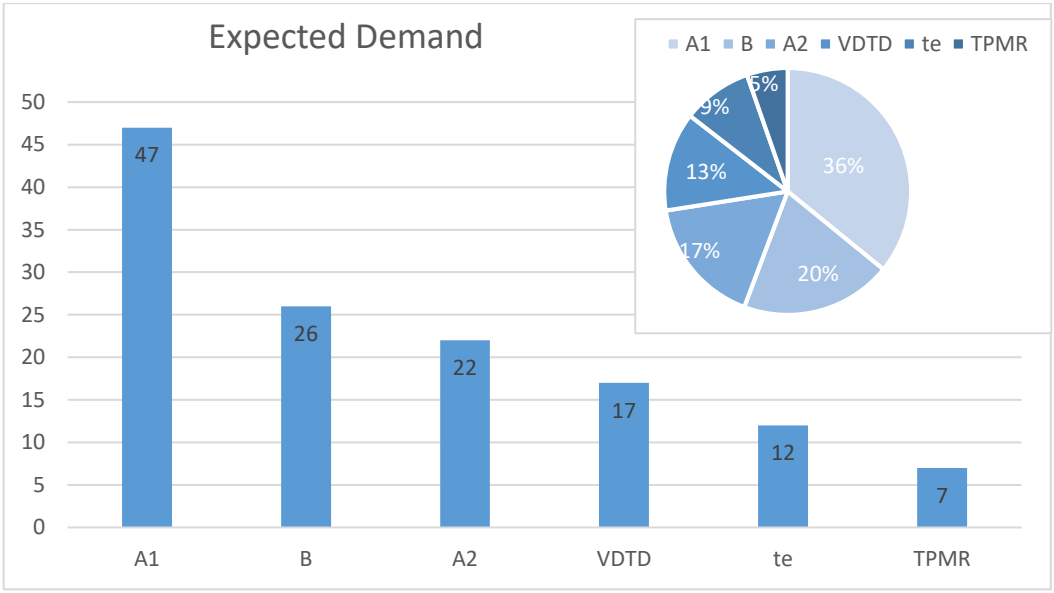


Figure 15 - Expected demand in number of units per month per vehicle category

It is important to highlight that for each type of vehicle it is possible to have a significant number of different configurations, going further than the number/position of chairs and stretchers. Almost 100% customization is what differentiates this company from others in the market: the client can choose the colour palette of the interiors, the number and position of seats, the exterior lights and decoration, among many other features and extras (as long as it complies with the norms for ambulances stated by law).

3.2.1 Operating Difficulties and Opportunities Found

This company grew at an enormous pace in the last few years. That led to increasing difficulties when dealing with the ever-growing diverse information and data.

This being said, many opportunities with great chance for improvement arose when MUDA hunting (non-value activities elimination) was completed (following employees and observing them perform their daily operations in order to collect improvement opportunities).

In the warehouse, diversified inefficiencies were observed, of which it can be highlighted the following:

- Reception without a purchase order, which is a document that indicates the quantity and description of the goods being bought, the conditions of delivery and payment as well as tax data;
- Scarcity of information about procedures;
- Lack of clarity concerning obsolete materials;
- Unnecessary movement;
- Unorganized spaces;
- Work launch without a complete project verification.

Also, a comparison was made between the materials in stock and the necessities of an ambulance going into Production. A total of 187 references in stockout (43%) and 248 references in stock (57%), as it can be observed in Figure 16. This analysis was made for the beginning of production for an ambulance on the 23rd of F, 2018.

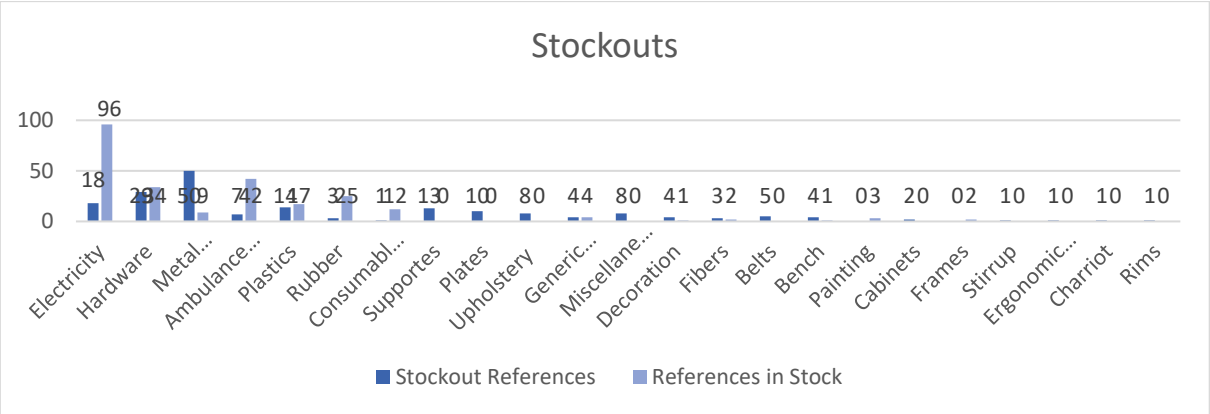


Figure 16 - Number of stockouts per area when initiating production

On the other hand, after analysing the Information Flow, it was realized that:

- An approval is made by the Commercial Director after client's confirmation;
- There is no joint verification of technical drawings;
- There is no delivery plan of load/ capacity per vehicle type;
- There are no complete information details from the technical department when unlocking order.

Regarding Orders Planning, the following inefficiencies were acknowledged:

- Unexpected vehicles which leads to delays in the planned ones;
- Definition of priorities (urgencies);
- Simultaneous teams working in the same vehicle;
- Production launch without the necessary material;
- Numerous changes within Production.

The Brainstorming that was made with key people regarding improvement opportunities can be found in Appendix A. All these inefficiencies aforementioned provide space for process improvement and optimization.

3.2.2 Service Level

As far as Service Level is concerned, two different indicators can be considered. The first one, Lateness, can be defined as the difference between the expected date for the vehicle to be ready and the date it got actually ready. For a number of 140 samples, lateness was calculated and it was approximately 22 days. The second one are Customer Complaints. In Figure 17, the number of Customer Complaints for the months between January and May of 2018 are depicted.

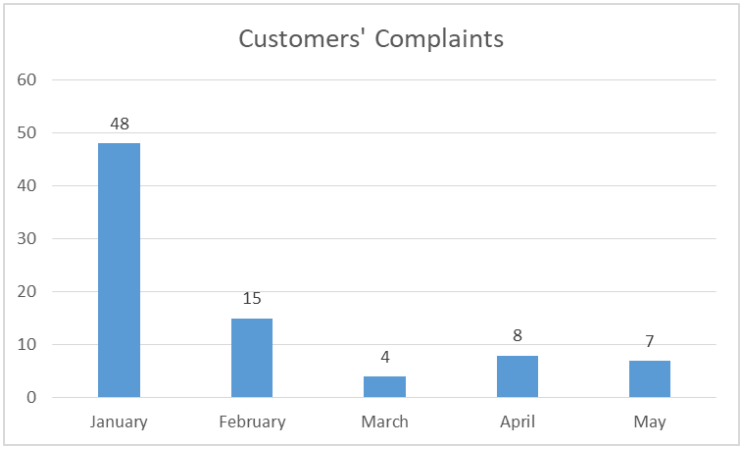


Figure 17 – Number of customers' complaints between January and May of 2018

Between January and April of 2018 there were 292 vehicles produced, of which 94 suffered alterations, as it can be observed in Figure 18. 32% of the produced vehicles suffer changes. These changes generate entropy in each one of the sections which ends up affecting production planning.

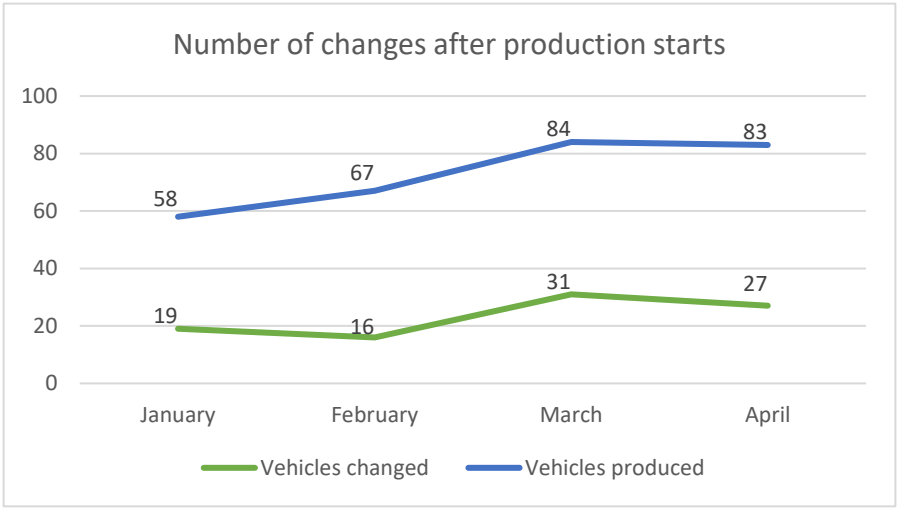


Figure 18 - Number of changes after production starts

To better understand the nature of these changes, Figure 19 presents the different occurring motives when clients propose changes and Figure 20 presents the different existing motives when the Commercial Department proposes changes.

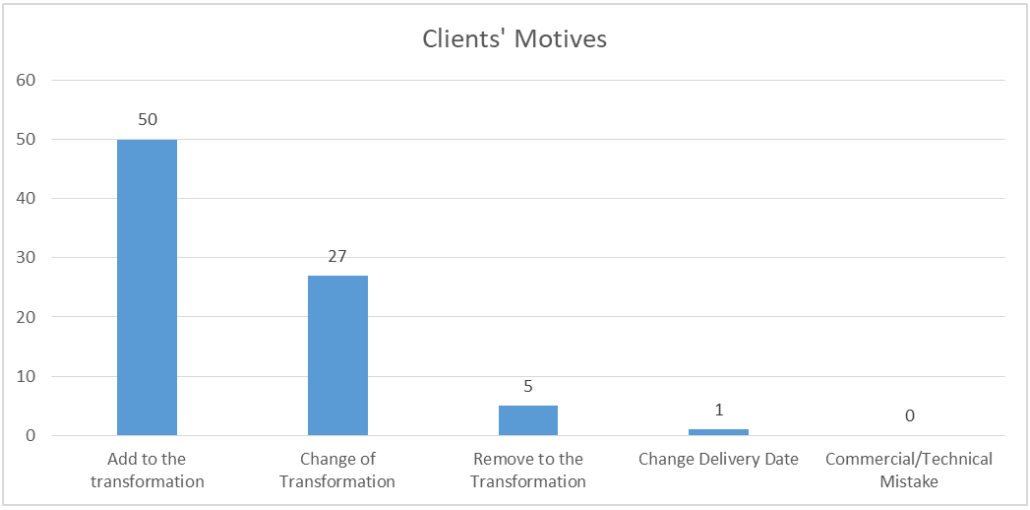


Figure 19 - Motives for changes after production starts by the client in the months of January, February and March of 2018

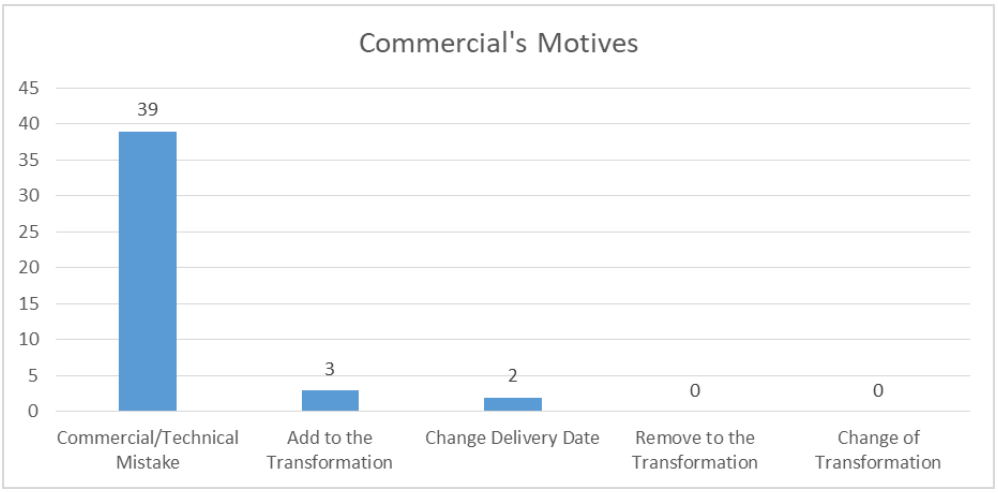


Figure 20 - Motives for changes after production starts by the Commercial Department in the months of January, February and March of 2018

3.3 Manufacturing Operations Management Platform

Information technology (IT) plays a key role in the operations management of the case study's company. In fact, customer-order business environments raise specific requirements for IT systems, which distinguish them from systems designed for make-to-sock environments.

The company here considered has implemented an ERP that covers all administrative, financial and human resources related activities integrated with a specific software platform to support mainly the shop-flor operations (MOM – Manufacturing Operations Management/ MES – Manufacturing Execution System). This MOM/MES platform has a high level of customization in order to cope with the specific requirements of the current business model.

Basically, in the current situation, the MOM/MES platform covers the following main functionalities:

- Customer orders and contracts management, supporting the activities of the commercial department in the generation of specific customer-order proposals and the subsequent revisions that emerge in the context of a negotiation phase between customer and company;

- Product documentation, comprising the maintenance of technical information such as the bill of materials and bill of operations;
- Materials management, scoping the activities around inventory planning and control of standard components and parts;
- Planning and scheduling, comprising materials requirements planning (work orders and purchase orders) and control of orders execution;
- Resources management, involving the activities around planning and control of tools and production equipment as well as production and assembly operators.

Although the vendor of the MOM/MES platform claims that the software has a high level of adaptability to different operation's needs, in fact several specific functional limitations have been identified. Also, the frequent users of the platform in the company complain about it being rather slow and with old-fashioned visuals.

Previously, the company had tried to implement standard commercial software at the manufacturing level. However, several commercial difficulties emerged, namely the ones related to quality and availability of information (usually on these solutions lead times are assumed to be known and constant as well as it is assumed that products have fixed routes).

4 Analysis and Proposed Solutions

In this chapter, the work developed will be presented, along with the proposed solutions to solve the aforementioned problems.

It is important to underline that despite the existence of a generalized perception of a number of operational problems concerning materials management, orders planning and processing, among others, relevant quantitative evaluations of those problems did not exist. Furthermore, there were no structured methods to perform any kind of analysis. Therefore, priority was given to the development of practical solutions that could be timely implemented generating quick wins in order to solve what was considered to be critical.

Among several improvement initiatives implemented, in which the author has been deeply involved, there were two main subprojects selected in the context of this dissertation project:

- Subproject No. 1: Improving raw materials management (Section 4.1);
- Subproject No. 2: Improving the process of proposal to customer (Section 4.2).

To better structure the problems approached and conduct people involved in the different project activities, the named A3 methodology was adopted. This is a structured problem solving and continuous improvement approach, first employed at Toyota and typically used by lean manufacturing experts. It provides a simple and focused approach systematically leading towards problem solving over structured approaches, since the idea is to systematize all the work in a single A3 sheet of paper.

The A3 methodology covers the following nine steps:

1. Goal Description: a clear and objective description of the challenge or problem to be addressed;
2. Analysis of the Current Situation: it is a statement based on facts and figures that quantifies the AS-IS state;
3. Target Definition: it is the objective envisaged.
4. Analysis of Root Causes: it is the investigation of the sources of causes relevant for the problem;
5. Solutions Design: the definition of the TO-BE state;
6. Solutions Test: a brief description of how to check the efficiency and effectiveness of the envisaged solution;
7. Action Plan Update;
8. Target Confirmation;
9. Lessons Learned: Sharing the successfully implemented actions.

Each of these steps will be approached in this section for the two projects, apart from Step 7: Action Plan Update and Step 9: Lessons Learned, which will be addressed in the following and last chapter, Conclusions and Future Developments.

4.1 Subproject No. 1: Improving Raw Materials Management

Raw Materials Management in a customer-centred production is a key point at operational level. When starting production, it is very important to ensure that all the necessary raw materials are in stock. If a stockout happens, production can be delayed for a considerable period of time. As a result of this, it is essential to ensure a correct raw materials management. At the time of this analysis, raw materials orders were made without any type of logical support of the kind, only based on personal judgement and experience. This evokes two problems: lack of sustainability of the process since it is highly dependent on a human and also lack of confirmation, since there is no way to confirm if the orders for the week are the most correct ones.

First of all, it is fundamental to understand how are components structured and organised in the company. Each component, from the smallest to the biggest, has a reference composed by a letter and nine numbers. The letter designates the major category to which the component belongs. In Appendix B a table with the different existing categories can be seen.

The first three numbers after the letter indicate the more specific category inside the general one, represented by the letter aforementioned. The different specific categories can be seen in a table in Appendix C.

Since the scope of this project is the raw materials management, a table was made in Excel with the list of all the "M" references (raw materials) – approximately 4000 – with additional data such as its supplier, average consumption, price, lead time, among others. In Appendix D, the table is partially represented (information that is not currently available is displayed in red).

To better comprehend the importance of each specific category in raw materials, a Pareto chart was made, which can be visualized in Figure 21. By observing it, one realizes that metal fittings represent 18% of all the raw materials, with consumables representing also 18% and electricity raw materials 17%. These three categories totalize 53% of all the raw materials in number of SKUs.

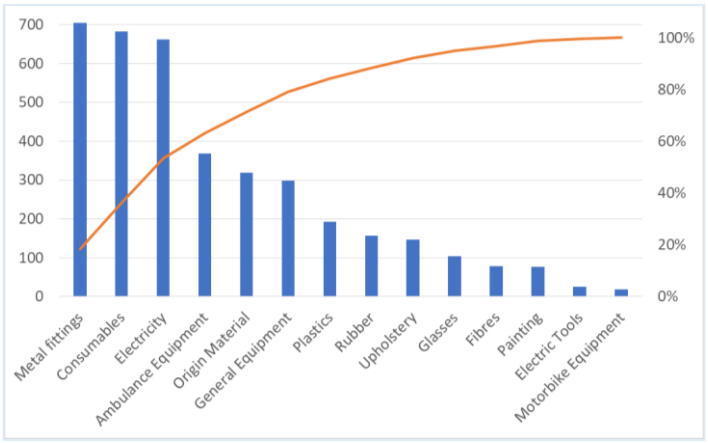


Figure 21 - Pareto chart of the number of SKUs of the specific categories in raw materials

Each type of ambulance/vehicle (A1, A2, B, etc) has an associated "T" (the "T" stands for "Transformation"). There are different possible Ts for the same type of vehicle, depending on the number of chairs or cabinets, for example, among other things. In Figure 22 it is depicted a list with a sample of vehicles with the respective current adjusted volume and future adjusted volume.

Code	Type	Quantity	Weight T	Adjusted Weight	Current Adjusted Volume	Future Adjusted Volume
T009010006	A1	25	5%	8%	70	124
T404010001	A1	22	5%	7%	61	109
T101010002	A1	18	4%	6%	50	89
T362010017	A1	15	3%	5%	42	74
T362010018	A1	14	3%	5%	39	69
T101010003	A1	11	2%	4%	31	54
T354025001	A2	12	3%	4%	33	59
T004025002	A2	12	3%	4%	33	59
T354025002	A2	9	2%	3%	25	45
T353025001	A2	6	1%	2%	17	30
T004025003	A2	5	1%	2%	14	25
T107026002	A2	5	1%	2%	14	25
T106025001	A2	4	1%	1%	11	20
T405057001	A2	3	1%	1%	8	15
T353026001	A2	3	1%	1%	8	15
T004025001	A2	3	1%	1%	8	15
T353100015	B	18	4%	6%	50	89
T004100014	B	13	3%	4%	36	64
T354100003	B	10	2%	3%	28	50
T004100013	B	10	2%	3%	28	50
T453100001	B	8	2%	3%	22	40
T106100004	B	6	1%	2%	17	30
T353100016	B	4	1%	1%	11	20
T353100012	B	4	1%	1%	11	20
T353100013	B	4	1%	1%	11	20
T353030004	VDTD-RM	17	4%	6%	47	84
T106030005	VDTD-RM	6	1%	2%	17	30
T004030004	VDTD-RM	4	1%	1%	11	20
T106060001	VETE-RM	11	2%	4%	31	54
T106060002	VETE-RM	7	2%	2%	19	35
T353060002	VETE-RM	3	1%	1%	8	15
T402120016	9L	10	2%	3%	28	50

Figure 22- Volume per Transformation

The “Weight T” for each line was calculated by dividing the quantity by the total quantity of 458 (the sample volume). As the sum of the “Weight T” is 65%, the “Adjusted Weight” had to be calculated. It was calculated by dividing each “Weight T” by 65%. Finally, the Current Adjusted Volume was calculated by multiplying the adjusted weight by 840, which is the current annual volume of ambulances produced. The Future Adjusted Volume was calculated by multiplying the adjusted weight by 1495, which is the expected future volume of the company in terms of ambulances produced. This value was calculated by multiplying 130, which is the expected monthly production of ambulances by 11.5 (eleven months and a half of production).

4.1.1 Raw materials Segmentation

Raw materials were classified using the ABC analysis. In order to perform it, it was necessary to have information about raw materials consumption quantity and its unit value (price per item). To acquire this data, the Bill of Materials (BOMs) of all the transformations mentioned before were accessed. It is relevant to refer that at the time there were very few BOMs completed, and some were not updated or had some mistakes, so collections of data were made to complete the Bill of Materials together with the responsible of each section and the warehouse responsible.

It was built a table with all the articles per transformation, accompanied by its description, quantity used in the transformation, total quantity (calculated by multiplying the quantity used in the transformation per the current adjusted volume of the transformation) and the total future quantity (when the volume rises to the number of 1495 ambulances). Figure 23 presents an extract of the said table.

T	Article Code	Description	Quantit	Total Quantit	Total Qty 840AB	Total Qty 1495AB	U.M	Vehicles
T004025001	M002011001	CHAPA ZINCOR 1MM DC01 ZE25/25	19.13	153.04	153.04	286.95	KG	3
T004025001	M002002024	BARRA FERRO 70X6MM	5.14	41.12	41.12	77.1	M	3
T004025001	M002002001	BARRA FERRO 100X6MM	3.68	29.44	29.44	55.2	M	3
T004025001	M002004004	CHAPA ACO DECAPADA 5MM DD11	23.3	186.4	186.4	349.5	KG	3
T004025001	M002004009	CHAPA ACO DECAPADA 8MM S235JR ST37	12.26	98.08	98.08	183.9	KG	3
T004025001	M002011001	CHAPA ZINCOR 1MM DC01 ZE25/25	7.24	57.92	57.92	108.6	KG	3
T004025001	M999021003	DESPERDICIOS	2	16	16	30	KG	3
T004025001	M003013007	TUBO GUEN DE ISOLAMENTO 6X7MM	0.2	1.6	1.6	3	M	3
T004025001	M003013006	TUBO GUEN DE ISOLAMENTO 5X6MM	0.1	0.8	0.8	1.5	M	3
T004025001	M003011004	TUBO DE CRISTAL MEDIO 10X13MM	0.1	0.8	0.8	1.5	M	3
T004025001	M003011004	TUBO DE CRISTAL MEDIO 10X13MM	0.2	1.6	1.6	3	M	3
T004025001	M003011003	TUBO DE CRISTAL GROSSO 19X24MM	0.1	0.8	0.8	1.5	M	3
T004025001	M002012003	PERFIL DE ALUMINIO BRUTO CA-26-03	1.1	8.8	8.8	16.5	M	3

Figure 23 - Screenshot of articles per transformation table

By reordering every article through its consumption quantity (in a year), each reference was classified in “A”, “B” or “C”. It was decided that the articles responsible for 80% of the total consumption value per year would be marked as “A”, the articles responsible for 15% of the total consumption value per year would be marked as “B” and the rest, responsible for 5%, would be “C”.

The Pareto Chart corresponding to the ABC Analysis can be seen in Figure 24, while the number of articles per type can be observed in Figure 25.

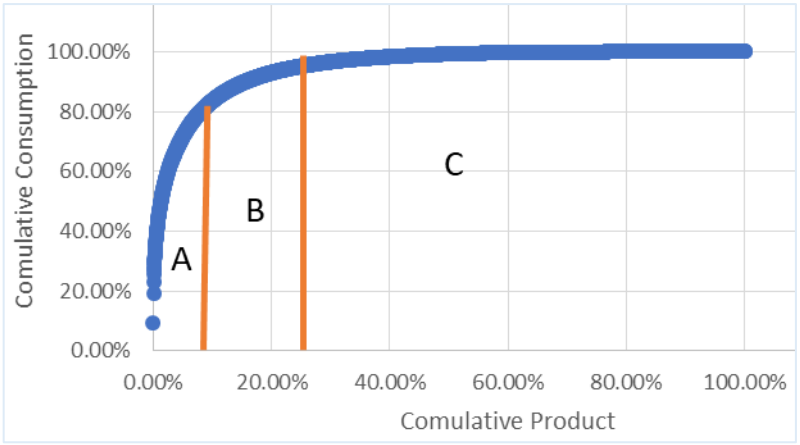


Figure 24 - Pareto Chart (ABC analysis)

Type	Number	Percentage
A	307	8.01%
B	636	16.63%
C	2888	75.36%

Figure 25 - Number of articles per type

Although the standard ABC analysis here made only considers one criteria (consumption), different criteria could have been chosen in parallel to make the analysis more complete. For example, an analysis could have been made regarding the annual consumption (which was here considered), consumption value and the lead time. However, the unit price, lead time or demand at the time was not immediately available for every reference. Therefore, it was decided to perform an empirical qualitative analysis as well. It was asked the Purchasing Department to select from the almost 4000 references those which, by using their tacit knowledge, were more

relevant to carry out a more careful weekly management according to the variability of demand and importance regarding consumption.

From the list they elaborated, the references were crossed. From the 307 A references, only 186 were chosen by the purchasers, from the 636 B references, only 276 were chosen and, finally, from the 2888 C references, 734 were chosen. This reveals the limitation of the ABC analysis.

4.1.2 A3 Step 1: Goal Description

The goal is to standardize the supply process and achieve 0% of stockouts in purchased material every time a new vehicle starts being produced. This will be achieved by defining the purchasing strategy, until here inexistent.

4.1.3 A3 Step 2: Analysis of the Current Situation (AS-IS)

As mentioned in the previous chapter, a comparison was made between the materials in stock and the necessities of an ambulance going into Production. It was concluded that there were a total of 187 references in stockout (43%) and 248 references in stock (57%). This analysis was made for the beginning of production for an ambulance on the 23rd of February of 2018. In Table 4 the starting point for the project can be observed. Detailed information about the calculation of the KPIs is found in Section 4.1.4.

Table 4 - Starting Values of KPIs

KPI	Starting Point
% Stockouts	43%
Stock Value (€)	1,540,000€

4.1.4 A3 Step 3: Target Definition

It was decided to establish the goal of achieving 0% of stockouts in purchasing material every time a new vehicle starts being produced, by improving the purchasing strategy.

The percentage of stockouts is calculated as follows:

$$\%\ Stockouts = \frac{Components\ with\ stockouts}{Total\ Components\ (per\ BOM)}$$

In order to measure this KPI and also to calculate the current stock value, an Excel File was created to be used weekly by the Purchasing Department. A screenshot of the said file can be seen in Figure 26.

Artigo	M

Código	Série	Artigo1	Descrição	Soma de Falt	Qtd. Stock	Stock OK/NOK
M001001002	0218:77540	M	ABRACADEIRA METAL	2	26.1	OK
M001001003	0318:04650	M	ABRACADEIRA METAL	1	46.05	OK
M001001003	0218:69847	M	ABRACADEIRA METAL	1	46.05	OK
M001001003	0218:77540	M	ABRACADEIRA METAL	1	46.05	OK
M001001003	0218:83715	M	ABRACADEIRA METAL	1	46.05	OK
M001001008	1117:60385	M	ABRACADEIRA METAL	4	44	OK
M001001010	0218:77540	M	ABRACADEIRA METAL	1	0	NOK
M001001011	0318:04650	M	ABRACADEIRA METAL	1	107.91	OK
M001001011	0218:77540	M	ABRACADEIRA METAL	1	107.91	OK
M001002008	0318:04650	M	ABRACADEIRA PLASTI	1	281.28	OK

Total Refs	1440
NOK	223
% Roturas	15%
Valor Inventário	1,077,417.62 €
Data	22/06/2018

Figure 26 - Screeenshot of the Stockout Analysis Excel

In this file, the percentage of stockouts is calculated by dividing the number of "NOKs" by the number of total references. The stock is "NOK" if the quantity of stock is inferior to the "Soma de Falta" which is the quantity needed for that reference in a particular series. The inventory value is calculated by adding the stock quantity of each reference that is located in either the Main Warehouse or Kardex, which is a flexible solution for storing and retrieving small-volume goods which need to be kept in particular good conditions (for instance medical equipment).

4.1.5 A3 Step 4: Analysis of Roots and Causes

After observation, the following recurring causes were identified:

- Suppliers' delays: some products had just one supplier, so if the supplier did not deliver the product on time, a stockout would happen for a certain period of time;
- Order process without any type of strategy or routine: as it was already mentioned, the ordering process was made without any defined strategy;
- System does not correspond to reality, portraying wrong information: it was verified for a number of random products that the number in stock was not correct;
- Lack of Bill of Materials: for some vehicles transformations a bill of materials did not exist at all;
- Wrong existent Bill of Materials: it was verified that many bill of materials were incomplete or had outdated references.

4.1.6 A3 Step 5: Solution Design

Firstly, it was necessary to structure the decision-making process as far as purchasing is concerned so a decision flowchart was created, which can be seen in Figure 27. This flowchart portrays the decisions that have to be done to see what the most suitable strategy is: either Stock Control, Order When Needed, or Keep in Stock.

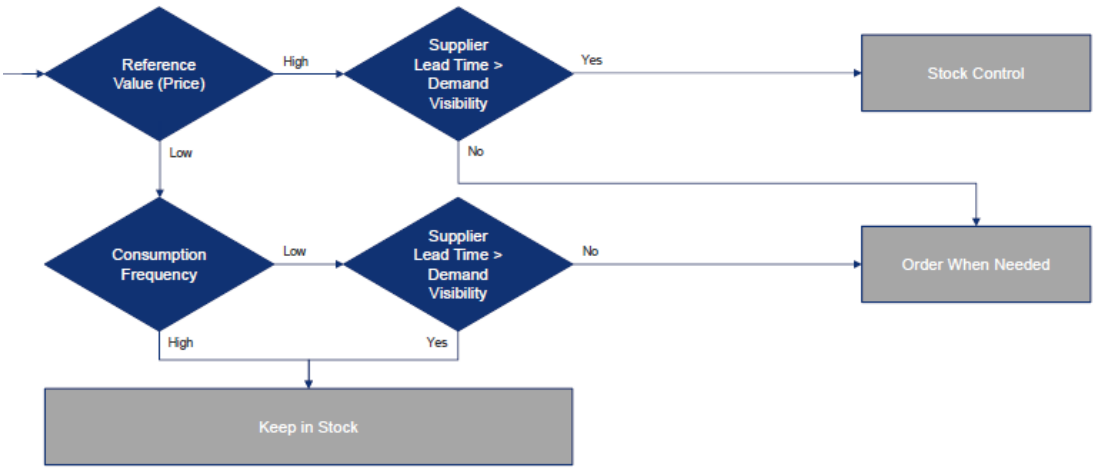


Figure 27 - Decision Flowchart

For each reference category, criteria was defined concerning visibility, price limit and consumption frequency (already previously mentioned). This criteria is summarized in Figure 28.

Code	Category	Visibility (in days)	Limit Price	Consumption Frequency (ABC)
001	METAL FITTING	30	10	Verify each reference
999	CONSUMABLES		30	
050	ELECTRICITY		100	
200	AMBULANCE EQUIPMENT		100	
009	ORIGINAL EQUIPMENT		10	
100	GENERAL EQUIPMENT		-	
004	PLASTICS		10	
003	RUBBER		20	
051	UPHOLSTERY		20	
007	GLASSES		Order	
006	FIBRES		Order	
053	PAINTING		35	
300	ELECTRIC TOOLS		Order	
210	MOTORBIKE EQUIPMENT		Order	

Figure 28 - Criteria defined per category

After structuring the decision-process for purchasing, it was necessary to define concrete tasks and routines to be performed by the collaborators of the Purchasing Department. These routines can be observed in Figure 29.

Frequency	Type of Supply	Method	Responsible	When
Daily	Raw materials supply with high consumption and/ or low cost (permanent stock)	Stocks Management File (compares quantity in stock with order point)	Ricardo and Manuela	Beginning of the morning and beginning of the afternoon
Daily	Sections Requests	Requests Managementt through the ERP	Sections Responsibles and Purchasing Department	End of the morning and end of the afternoon
Weekly	Low consumption material and/ or with a high cost, with no demand visibility	Stocks Management File (verifies references that are not in stock)	Commercial and Purchasing Department	Monday, Wednesday and Friday
Weekly	Low consumption material and/ or with a high cost, with no demand visibility	Define method with Commercial and Technical Departments (Stock Control)	Commercial, Technical and Purchasing Department	Monday

Figure 29 - Supply Routines Defined

In Figure 30 the schedule for the routines mentioned previously is defined.

Time	Monday	Tuesday	Wednesday	Thursday	Friday
08:00	Permanent Raw Materials	Permanent Raw Materials	Permanent Raw Materials	Permanent Raw Materials	Permanent Raw Materials
09:00					
10:00	With no demand visibility (define routine)				
11:00					
12:00	Sections Requests	Sections Requests	Sections Requests	Sections Requests	Sections Requests
13:00					
14:00	Permanent Raw Materials	Permanent Raw Materials	Permanent Raw Materials	Permanent Raw Materials	Permanent Raw Materials
15:00	Low consumption material (by order)	Low consumption material (by order)	Low consumption material (by order)	Low consumption material (by order)	Low consumption material (by order)
16:00					
17:00	Sections Requests	Sections Requests	Sections Requests	Sections Requests	Sections Requests

Figure 30 - Weekly schedule for provisioning routines

An excel file was developed to help the Purchasing Department with the orders.

The cover of the document with its sections can be seen in Figure 31. Section 0.2 presents the standard to fill in the document. Section 0.3 has information on all the approximately 1200 references that were selected by the team: description, reference code, supplier, minimum quantity to order, cost and delivery frequency.

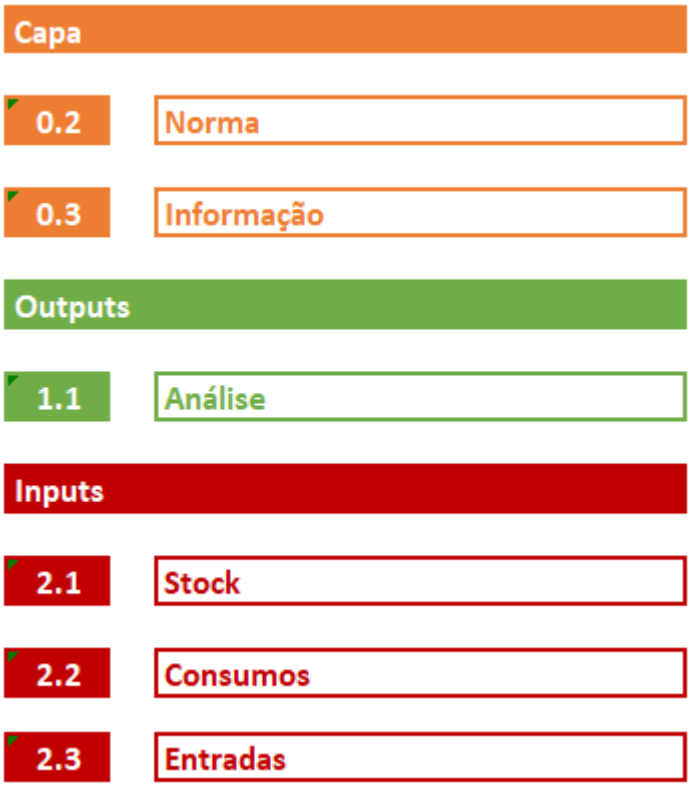


Figure 31 - Screenshot of the document cover

For the 1200 references that were considered the most important, some properties were gathered, namely: the minimum quantity to order, the unitary price and the delivery frequency in weeks and in days. An extract of the file with such information can be seen in Figure 32.

0.3 Informação

Informação das Referências em Stock (aprox. 1200 seleccionadas pela equipa)

TIPO MATERIAL			Propriedades			
Descrição	Código	Fornecedor	Quant. Min.	Custo	Freq. Entrega (semanas)	Freq. Entrega (dias corridos)
A.C. KIT FALKOM KOMBI SEM ADAPTADOR REF. 7	M100001079	KALORI (SAS)	16	313	2.9	20
A.C. KIT KOOL KOMBI EG SEM ADAPTADOR REF. 7	M100001051	KALORI (SAS)	15	282	2.9	20
A.C. RENAULT TRAFFIC KIT MK1 700.15.863	M100001127	KALORI (SAS)	10	331	2.9	20
ABRACADEIRA C/ BORRACHA 0542 20 15 REF. 101	M001077007	MULTIBORRACHA, LDA.	100	0.29	1.7	12
ABRACADEIRA C/ BORRACHA 12MM 542 12 15	M001077017	MULTIBORRACHA, LDA.	100	0.44	1.7	12
ABRACADEIRA C/ BORRACHA 15MM 0542 15 15 R	M001077013	MULTIBORRACHA, LDA.	50	0.25	1.7	12
ABRACADEIRA C/ BORRACHA 20MM	M001077018	MULTIBORRACHA, LDA.	50	0.308	1.7	12
ABRACADEIRA C/ BORRACHA 22MM B-15	M001077003	MULTIBORRACHA, LDA.	100	0.54	1.7	12
ABRACADEIRA C/ BORRACHA 25MM	M001077011	MULTIBORRACHA, LDA.	100	0.22	1.7	12
ABRACADEIRA C/ BORRACHA 30MM 054230 15 00	M001077008	PLASTIBORRACHA, LDA	100	0.4	0.9	6
ABRACADEIRA C/ BORRACHA 6/15 W1	M001077014	MULTIBORRACHA, LDA.	100	0.34	1.7	12
ABRACADEIRA C/ BORRACHA 8MM	M001077020	PLASTIBORRACHA, LDA	200	0.25	0.9	6
ABRACADEIRA C/ BORRACHA REF. 128	M001077015	MULTIBORRACHA, LDA.	200	0.25	0.9	6

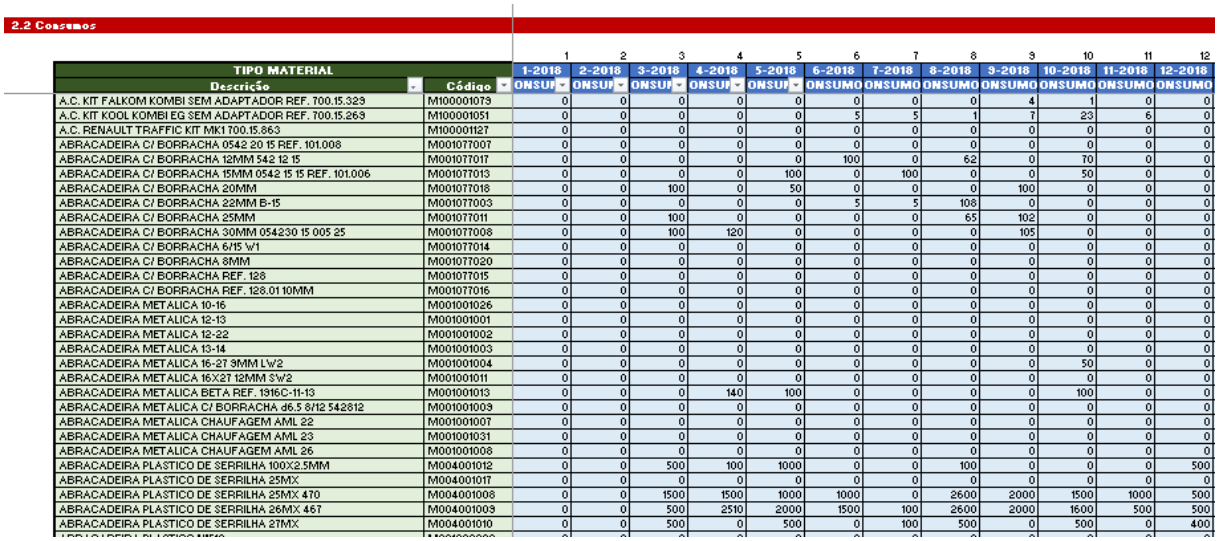
Figure 32 - Screenshot of the Information section

Weekly, in order to analyse which articles should be ordered in the present week, it is necessary to extract three different types of data from SEGIN, the ERP of the company: the Stock History, the Consumption History and the Orders History. The data has to be put in separate Excel sheets – screenshots can be seen in Figure 33, 34 and 35, respectively.

2.1 Stock

		1	2	3	4	5	6	7	8	9	10	11	12
TIPO MATERIAL		1-2018	2-2018	3-2018	4-2018	5-2018	6-2018	7-2018	8-2018	9-2018	10-2018	11-2018	12-2018
Descrição	Código	STOCK	STOCK	STOCK	STOCK	STOCK	STOCK	STOCK	STOCK	STOCK	STOCK	STOCK	STOCK
A.C. KIT FALKOM KOMBI SEM ADAPTADOR REF. 7	M100001079	0	0	0	0	0	120	0	60	60	0	0	0
A.C. KIT KOOL KOMBI EG SEM ADAPTADOR REF. 7	M100001051	0	0	0	0	0	99	0	39	39	0	0	0
A.C. RENAULT TRAFFIC KIT MK1 700.15.863	M100001127	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA 0542 20 15 REF. 101	M001077007	0	0	0	0	0	514	0	257	257	257	0	0
ABRACADEIRA C/ BORRACHA 12MM 542 12 15	M001077017	0	0	0	0	0	324	0	62	200	200	0	0
ABRACADEIRA C/ BORRACHA 15MM 0542 15 15 R	M001077013	0	0	0	0	0	308	0	54	154	154	0	0
ABRACADEIRA C/ BORRACHA 20MM	M001077018	0	0	0	0	0	520	0	310	310	210	0	0
ABRACADEIRA C/ BORRACHA 22MM B-15	M001077003	0	0	0	0	0	248	0	109	106	106	0	0
ABRACADEIRA C/ BORRACHA 25MM	M001077011	0	0	0	0	0	206	0	103	138	36	0	0
ABRACADEIRA C/ BORRACHA 30MM 054230 15 00	M001077008	0	0	0	0	0	1160	0	605	605	500	0	0
ABRACADEIRA C/ BORRACHA 6/15 W1	M001077014	0	0	0	0	0	186	0	93	93	93	0	0
ABRACADEIRA C/ BORRACHA 8MM	M001077020	0	0	0	0	0	130	0	65	65	65	0	0
ABRACADEIRA C/ BORRACHA REF. 128	M001077015	0	0	0	0	0	626	0	313	313	313	0	0
ABRACADEIRA C/ BORRACHA REF. 128.01 10MM	M001077016	0	0	0	0	0	536	0	268	268	268	0	0
ABRACADEIRA METALICA 10-16	M001001026	0	0	0	0	0	308	0	154	154	154	0	0
ABRACADEIRA METALICA 12-13	M001001001	0	0	0	0	0	576	0	288	288	288	0	0

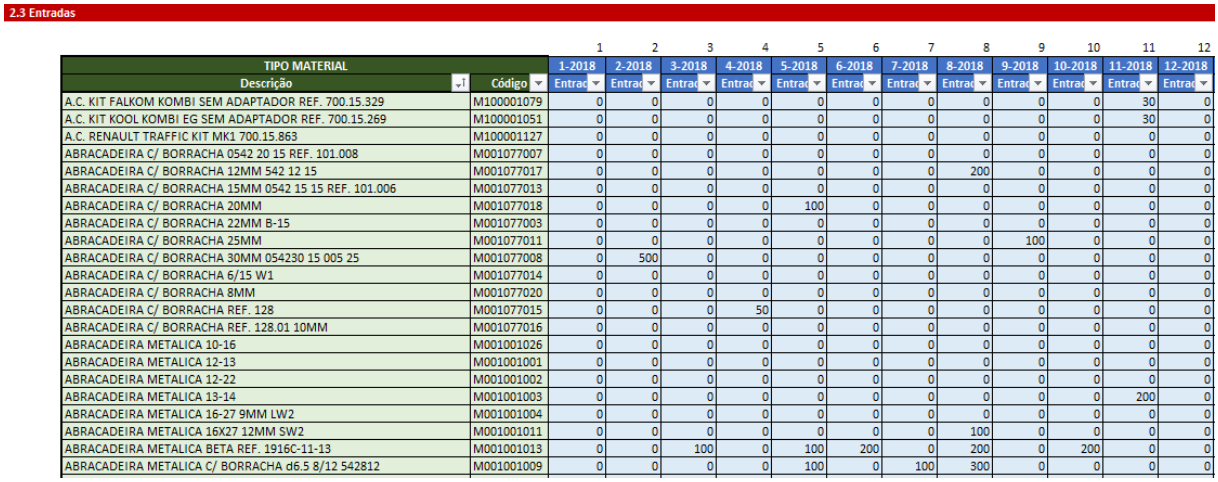
Figure 33 - Screenshot of the "2.1 Stock"



2.2 Consumos

		1	2	3	4	5	6	7	8	9	10	11	12
TIPO MATERIAL		1-2018	2-2018	3-2018	4-2018	5-2018	6-2018	7-2018	8-2018	9-2018	10-2018	11-2018	12-2018
Descrição	Código	ONSUMO	ONSUMO	ONSUMO	ONSUMO	ONSUMO	ONSUMO	ONSUMO	ONSUMO	ONSUMO	ONSUMO	ONSUMO	ONSUMO
A.C. KIT FALKOM KOMBI SEM ADAPTADOR REF. 700.15.329	M100001073	0	0	0	0	0	0	0	0	4	1	0	0
A.C. KIT KOOL KOMBI EG SEM ADAPTADOR REF. 700.15.269	M100001051	0	0	0	0	0	5	5	1	7	23	6	0
A.C. RENAULT TRAFFIC KIT MK1 700.15.863	M100001127	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA 0542 20 15 REF. 101.008	M001077007	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA 12MM 542 12 15	M001077017	0	0	0	0	0	100	0	62	0	70	0	0
ABRACADEIRA C/ BORRACHA 15MM 0542 15 15 REF. 101.006	M001077013	0	0	0	0	100	0	100	0	0	50	0	0
ABRACADEIRA C/ BORRACHA 20MM	M001077018	0	0	100	0	50	0	0	0	100	0	0	0
ABRACADEIRA C/ BORRACHA 22MM B-15	M001077003	0	0	0	0	0	5	5	108	0	0	0	0
ABRACADEIRA C/ BORRACHA 25MM	M001077011	0	0	100	0	0	0	0	65	102	0	0	0
ABRACADEIRA C/ BORRACHA 30MM 054230 15 005 25	M001077008	0	0	100	120	0	0	0	0	105	0	0	0
ABRACADEIRA C/ BORRACHA 6/15 W1	M001077014	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA 8MM	M001077020	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA REF. 128	M001077015	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA REF. 128.01 10MM	M001077016	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA 10-16	M001001026	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA 12-13	M001001001	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA 12-22	M001001002	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA 13-14	M001001003	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA 16-27 9MM LW2	M001001004	0	0	0	0	0	0	0	0	0	50	0	0
ABRACADEIRA METALICA 16X27 12MM SW2	M001001011	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA BETA REF. 1916C-11-13	M001001013	0	0	0	140	100	0	0	0	0	100	0	0
ABRACADEIRA METALICA C/ BORRACHA d6.5 8/12 542812	M001001009	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA CHAUFAGEM AML 22	M001001007	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA CHAUFAGEM AML 23	M001001031	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA CHAUFAGEM AML 26	M001001008	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA PLASTICO DE SERRILHA 100X2.5MM	M004001012	0	0	500	100	1000	0	0	100	0	0	0	500
ABRACADEIRA PLASTICO DE SERRILHA 25MX	M004001017	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA PLASTICO DE SERRILHA 25MX 470	M004001008	0	0	1500	1500	1000	1000	0	2600	2000	1500	1000	500
ABRACADEIRA PLASTICO DE SERRILHA 26MX 467	M004001009	0	0	500	2510	2000	1500	100	2600	2000	1600	500	500
ABRACADEIRA PLASTICO DE SERRILHA 27MX	M004001010	0	0	500	0	500	0	100	500	0	500	0	400

Figure 34 - Screenshot of the "2.2 Consumption"



2.3 Entradas

		1	2	3	4	5	6	7	8	9	10	11	12
TIPO MATERIAL		1-2018	2-2018	3-2018	4-2018	5-2018	6-2018	7-2018	8-2018	9-2018	10-2018	11-2018	12-2018
Descrição	Código	Entrad	Entrad	Entrad	Entrad	Entrad	Entrad	Entrad	Entrad	Entrad	Entrad	Entrad	Entrad
A.C. KIT FALKOM KOMBI SEM ADAPTADOR REF. 700.15.329	M100001079	0	0	0	0	0	0	0	0	0	0	30	0
A.C. KIT KOOL KOMBI EG SEM ADAPTADOR REF. 700.15.269	M100001051	0	0	0	0	0	0	0	0	0	0	30	0
A.C. RENAULT TRAFFIC KIT MK1 700.15.863	M100001127	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA 0542 20 15 REF. 101.008	M001077007	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA 12MM 542 12 15	M001077017	0	0	0	0	0	0	0	200	0	0	0	0
ABRACADEIRA C/ BORRACHA 15MM 0542 15 15 REF. 101.006	M001077013	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA 20MM	M001077018	0	0	0	0	100	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA 22MM B-15	M001077003	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA 25MM	M001077011	0	0	0	0	0	0	0	0	100	0	0	0
ABRACADEIRA C/ BORRACHA 30MM 054230 15 005 25	M001077008	0	500	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA 6/15 W1	M001077014	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA 8MM	M001077020	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA REF. 128	M001077015	0	0	0	50	0	0	0	0	0	0	0	0
ABRACADEIRA C/ BORRACHA REF. 128.01 10MM	M001077016	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA 10-16	M001001026	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA 12-13	M001001001	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA 12-22	M001001002	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA 13-14	M001001003	0	0	0	0	0	0	0	0	0	0	200	0
ABRACADEIRA METALICA 16-27 9MM LW2	M001001004	0	0	0	0	0	0	0	0	0	0	0	0
ABRACADEIRA METALICA 16X27 12MM SW2	M001001011	0	0	0	0	0	0	0	100	0	0	0	0
ABRACADEIRA METALICA BETA REF. 1916C-11-13	M001001013	0	0	100	0	100	200	0	200	0	200	0	0
ABRACADEIRA METALICA C/ BORRACHA d6.5 8/12 542812	M001001009	0	0	0	0	100	0	100	300	0	0	0	0

Figure 35 - Screenshot of the "2.3 Orders"

After the stocks, consumption and orders sheets are updated, the “Analysis” sheet can be analysed. In this sheet (an extract of the file can be seen in Figure 36), it can be obtained: the average of consumption, consumption in frequency, security stock, maximum. Then, it can be obtained a result: necessities and suggestion of order.

Análise					Situação Atual		Resultado	
Média de Consumo	Consumo na Frequenci	Stock de Segurança	Nível de Reposiçã	Máximo	Stock Atu	Entradas	Necessidad	Sugestão de Encomend
0	0	0	0	6	234	0		
21	76	36	112	113	102	50		
22	80	38	118	119	109	50		
17	62	28	90	92	119	50		
17	62	28	90	91	115	50		
19	70	32	102	103	107	50		
12	46	19	65	67	117	50		
0	0	0	0	50	54	100		
0	0	1	1	7	8	8		
0	0	1	1	11	82	0		
144	288	282	570	670	535	0	135	200
2	3	5	8	21	0	0	21	26
9	34	19	53	63	32	0	31	40
2,063	4,125	3,710	7,835	9,485	29,700	0		
1,182	2,363	2,017	4,380	6,630	26,546	0		

Figure 36 – Screenshot of the “Analysis”

Average of Consumption: the average is calculated according to the previous track record (four weeks).

Consumption in Frequency: it is calculated by multiplying the Delivery Frequency by the Average of Consumption.

Safety Stock: It is calculated by multiplying the estimated standard deviation of demand during the replenishment lead time by the service coefficient (1.28).

Replenishment Level: it is equivalent to the sum of the consumption during the lead time with the safety stock.

Maximum: the maximum is equivalent to the sum of the minimum quantity with the replenishment stock.

Necessities: if either the replenishment level equals zero or the replenishment level is smaller than the sum of the current stock with the entries, the necessities are none. If not, the necessities are equal to the maximum minus the current stock minus the entries.

Order Suggestion: it is the same logic as with the necessities, but "the maximum minus the current stock minus the entries" has to be rounded to the quantity per package and above the minimum order quantity.

4.1.7 A3 Step 6: Solution Test

In Figure 37, the evolution of the KPI per week over the past weeks can be seen. Although the target value of 5% was not reached, it can be seen that it consistently diminished, being currently at 15%.

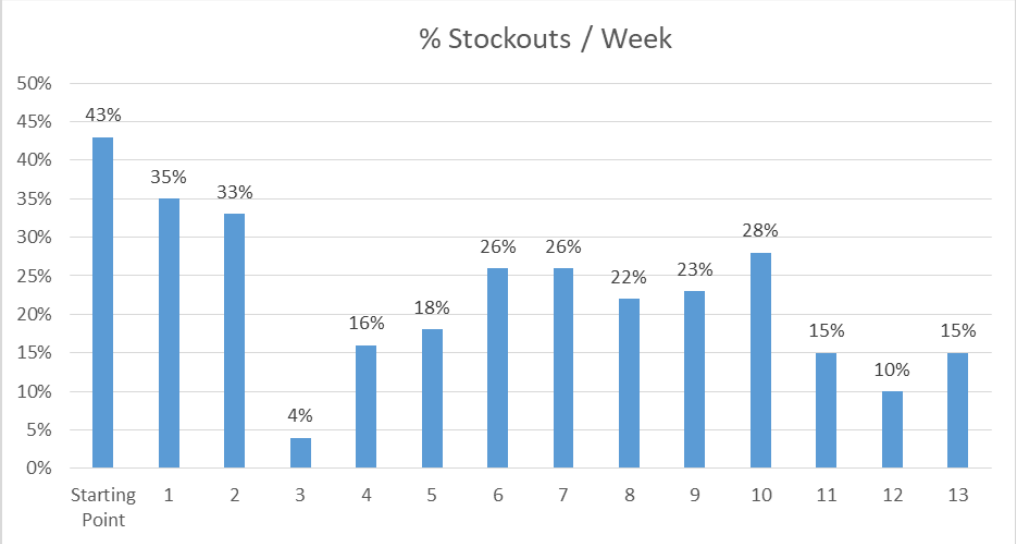


Figure 37 - Evolution of the KPI during the project

In Table 5 a comparison between the Starting Point values and the values at the moment can be seen. The stockouts reduced 28% comparing to its original value and the overall stock value reduced in 462,584€.

Table 5 - KPI value at the moment

KPI	Starting Point	At the moment
% Stockouts	43%	15%
Stock Value (€)	1,540,000€	1,077,417.62 €

4.2 Subproject No. 2: Improving the Process 'Proposal to Customer'

One of the most frequent reasons for difficulties in orders planning is the fact that a great number of the vehicles produced suffer changes. Between January and April of 2018, there were 160 changes requests for a total of 94 different vehicles. This totalized 254 alterations in the shop floor. Therefore, in average there were 2.7 affected sections per altered vehicle. In Figure 38 the number of changes per section in these months can be seen.

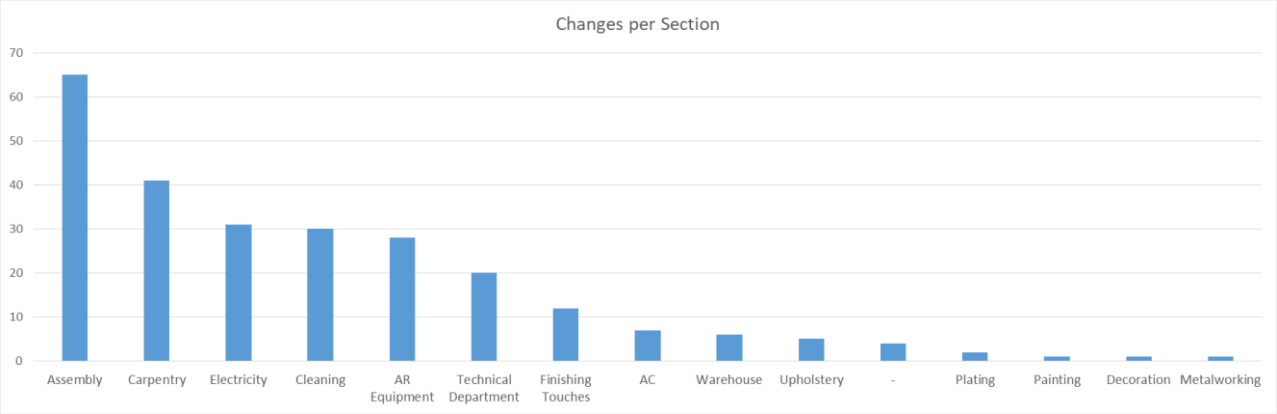


Figure 38 - Changes per section between January and April of 2018

In a complex supply chain, wrong decisions and choices can compromise the effortless flow of the rest of the chain. Thus, it is important to ensure that the process starts correctly from the first link in the chain. In this case, one of the first phases in the process is the proposal to customer.

The process 'proposal to customer' has to do essentially with the interaction between the Commercials and the Client when he intends to acquire, in this case, a special vehicle.

At the moment, there are four people in the commercial office. In order to understand the process, observations were done and times registered. It was concluded that it takes approximately 1h30 to prepare a budget plus 1h45 to generate the descriptive memory of the vehicle and its respective bill of materials, totalizing 3h15 for the entire operation.

As already mentioned in Chapter 3 (Information Flow), firstly the Commercial elaborates a draft of the proposal and sends it to the Commercial Assistant. Then, the Commercial Assistant prepares the descriptive memory to attach to the proposal. If the proposal is accepted, the Assistant references each material belonging to the Transformation with the help of a dossier. The project file with all the references (susceptible to mistakes) is then sent to all the intervening departments: Production, Equipment and Warehouse.

Examples of the descriptive memory can be consulted in Appendix E.

4.2.1 A3 Step 1: Goal Description

The goal is to standardize the process of budgeting, thus simplifying commercial work and reducing the amount of time currently existing in the information flow.

It was decided that in the final Situation (TO-BE) 5% of the produced vehicles would suffer changes.

4.2.2 A3 Step 2: Analysis of the Current Situation (AS-IS)

As already stated in Chapter 3, in the initial situation (AS-IS) 32% of the produced vehicles suffer changes.

The transformation sheet is volatile. It is easy to occur a mistake while elaborating the form. Furthermore, it is allowed for the client to change his request during production, which raises numerous constraints for the many sections. Currently, the flow is neither standardized nor optimized.

4.2.3 A3 Step 3: Target Definition

In order to proper identify if the solutions proposed and implemented are having effect, it is important to establish a Performance Index since the beginning, so that it is possible to quantify improvements due. Thus, as the standardization of the process will ease and clarify the information flow, it was decided that the percentage of changes in Production would be measured.

$$\%\ Changes = \frac{Number\ of\ Changes/\ Week}{Number\ of\ Ambulances\ Produced/\ Week}$$

In order to weekly measure this index, it was created an Excel file where, for each change, it has to be filled in the serial number of the vehicle, the date of the end of production, the date it started production and the date of the change, the responsible for the communication of the change (commercial or technical departments), the name of the person responsible, the detail of the alteration and the affected areas (up to six).

In that Excel File it is possible to analyse, apart from the % of Changes, several other data. An extract of the file can be seen in Figure 39.

Listagem das Alterações de Viaturas (Já em Produção)							Análise % Alterações /	Responsável pela Alteração	
Nº Série Viatura	Data Fim Produção	Data Entrada Produção	Data Alteração	Responsável pela Comunicação da Alteração	Nome Responsável	Detalhe da Alteração	Áreas Afetadas 1	Áreas Afetadas 2	Áreas Afetadas 3
0003032001	13/04/2018	05/04/2018	10/04/2018	Cliente	Hilma	Acrescentar à Transformação	Armazém	Montagem	
0003032002	13/04/2018	05/04/2018	10/04/2018	Cliente	Hilma	Acrescentar à Transformação	Armazém	Montagem	
0003001103	24/04/2018	18/01/2018	12/04/2018	Técnico	João	Erro Técnico	Montagem	Carpintaria	
0003001117	27/04/2018	09/02/2018	12/04/2018	Técnico	João	Erro Técnico	Montagem	Carpintaria	
0003001128	24/04/2018	06/03/2018	12/04/2018	Técnico	João	Erro Técnico	Montagem	Carpintaria	
0003001132		14/06/2018	12/04/2018	Técnico	João	Erro Técnico	Montagem	Carpintaria	
0003001116	01/05/2018	19/02/2018	12/04/2018	Comercial	Amalia	Alteração de transformação	Armazém	Eletricidade	
0003001116	01/05/2018	19/02/2018	12/04/2018	Técnico	Bruno	Alteração de transformação	Eletricidade		
0003004069	11/05/2018	24/01/2018	11/04/2018	Comercial	Liliana	Alteração de transformação	Carpintaria	Estofador	Montagem
0003004070	11/05/2018	24/01/2018	11/04/2018	Comercial	Liliana	Alteração de transformação	Carpintaria	Estofador	Montagem
0003004071	11/05/2018	24/01/2018	11/04/2018	Comercial	Liliana	Alteração de transformação	Carpintaria	Estofador	Montagem
0003004072	11/05/2018	24/01/2018	11/04/2018	Comercial	Liliana	Alteração de transformação	Carpintaria	Estofador	Montagem
0003004073	11/05/2018	24/01/2018	11/04/2018	Comercial	Liliana	Alteração de transformação	Carpintaria	Estofador	Montagem
0003004074	11/05/2018	24/01/2018	11/04/2018	Comercial	Liliana	Alteração de transformação	Carpintaria	Estofador	Montagem
0003004075	11/05/2018	24/01/2018	11/04/2018	Comercial	Liliana	Alteração de transformação	Carpintaria	Estofador	Montagem

Figure 39 - Screenshot of the Excel file with alterations in vehicles

4.2.4 A4 Step 4: Analysis of Roots and Causes

Between the period of May 7th and June 24th, the number of changes per department were registered, as can be observed in Figure 40. 60% of changes have its origin in the Technical Department and 20% of changes have its origin in the Commercial Department.

Count of vehicle serial number	Responsible for the Change					
Weeks	Warehouse	Client	Commercial	Production	Technical	Global Total
19			1		36	37
20		2	23		6	31
21	2		6	1	20	29
22	5	4	1		26	36
23	1	12	2		28	43
24	3	1	4	10	10	28
25			5			5
Global Total	11	19	42	11	126	209

Figure 40 - Number of changes per department

4.2.5 A3 Step 5: Solution Design

The goal is to standardize the main Transformation types (B, A2 and A1-FR) with quantification and referencing of materials and vehicles pre-assembled components like stretchers.

A configurator was created using Microsoft Excel for each standard Ambulance Type (B, A2 and A1-FR). For that reason, it is possible to automate and standardize Budgeting, the Descriptive Memory to be sent to the client and the Bill of Materials to be sent to the Technical Department and Purchasing Department.

Furthermore, some internal deadlines for modifications after the contract agreement were defined:

• The process must reach the Technical Department until the seventh day of the month prior to the month it enters Production;

•The process will have to enter the Production Department until the fifteenth day of the month before the month it enters Production – with no opportunity for modifications, unless there is availability.

In Figure 41, a screenshot of the Configurator for the B Transformation can be seen.

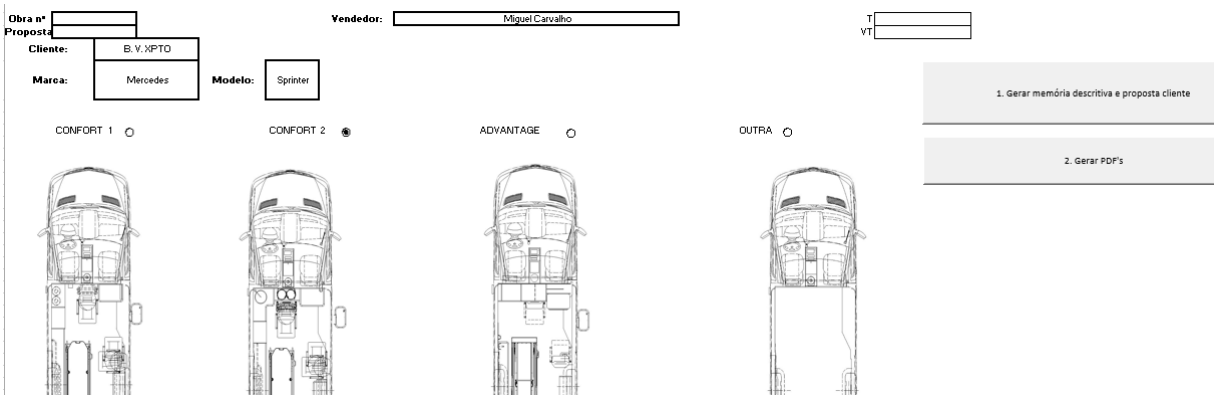


Figure 41 - Configurator for the B Transformation

Standards that were defined for the utilization of the configurator can be consulted in Appendix G and Appendix H.

4.2.6 A3 Step 6: Solution Test

With the creation of the configurator, references with quantities are automatic and generated at the same time of the commercial proposal. Thus, a mockup was done and it was observed that it would take a total of 45 minutes to perform the following tasks:

- 00h30 - Budgeting + Descriptive Memory + Bill of Materials)
- 00h15 - Verifying BOM and sending files to the technical department + purchasing department

It is therefore possible to calculate the following benefits:

- Number of work predicted for 2018: 880
- Hours saved/ year: (195 min – 45 min) x 880: 132.000 min./year = 2.200 hours/year
- There are in average 222 working days per year. Considering that a person works eight years per day, in one year that person will work 1776 hours.

Therefore, one person is not necessary anymore and can be given other functions.

Furthermore, the weekly percentage of changes diminished, reaching a value of 3%, which can be seen in Figure 42.

Week	Vehicles with changes	Vehicles in Production	%Changes/Week
19	37	177	21%
20	31	196	16%
21	29	186	16%
22	36	196	18%
23	43	194	22%
24	28	144	19%
25	5	144	3%

Figure 42 - % Changes index calculation

In this chapter, only two main projects were described. However, in the context of this project other improvement actions were developed in which the author has participated. In particular, initiatives related to the development of a daily continuous improvement culture grounded on Kaizen concepts, methodologies and tools. The main goal was to involve all operators in order to change their mind-set towards more efficient work practices.

5 Conclusions and Future Developments

Nowadays, manufacturing companies compete on multiple performance objectives, namely concerning quality, flexibility and responsiveness. At the same time, operational efficiency remains of capital importance in order to reduce non-added value activities and consequently diminish the operating costs. Furthermore, companies are more customer centric, that is, they are trying to adopt more and more a demand-driven manufacturing approach, in which the products are planned and built against customers confirmed orders. Thus, the ability to fulfil these orders at the required time and with an effective cost determines the competitive advantage in today's low volume and high variety competitive business environment. To meet this challenge, mass customization and personalization are key strategies that companies are exploring.

In that context, companies are changing product development strategies and manufacturing processes in order to efficiently implement adequate operating models, such as build-to-order, make-to-order and assembly-to-order to react to the growing individualization of demand. This is the case of the special vehicles industry, where there is a high level of complexity, not only in the process itself of transforming the vehicle but also to remain competitive by offering highly-customized products. The project carried out arises from a necessity for a company in this sector to grow and improve its processes in order to be more efficient and responsive. That way, the company could be more prepared to remain competitive in such a complex environment.

After a diagnosis was performed to the firm, many different projects emerged. In this research project, two main challenges were selected among the pool of improvement opportunities: improving raw materials management (Subproject No. 1) and improving the proposal to customer process (Subproject No. 2).

As stated in Chapter 1, the following research questions were raised:

1. How to classify raw materials, components and parts?
2. What are the most suitable replenishment policies and strategies in this context?
3. When to apply those policies?
4. What factors affect orders planning?

The first question proposed was answered while developing Subproject No. 1. Raw materials were classified through the ABC Analysis. However, Key People also made their value judgements, which were not necessarily compatible with the ABC Analysis. In the end, a compromise was made between the two.

The second research question was also answered in the context of Subproject No. 1. The most suitable replenishment policies and strategies in this context are Stock Control, Order When Needed, Keep in Stock. They shall be applied weekly or daily, depending on the reference value, consumption frequency and if the supplier lead time is higher than demand visibility or not, which answers the third question.

Finally, to answer the fourth question, a brainstorming session was executed in order to identify the different causes and factors that disturb orders planning. These were the:

- Unexpected vehicles which lead to delays in the production of the already planned ones:

Often there are "urgent" vehicles that enter production last-minute and therefore make the other ones be finished later.

- Simultaneous teams working in the same vehicle:

Frequently there are many operators belonging to different sections (for instance, two carpenters, an electrician and one assembler) working at the same time in a vehicle, which creates entropy in the work environment and generates waste.

- Production launch without the necessary material:

Many times a car starts being transformed in Gemba and important components needed at the time are still not available in the warehouse, for example the car headlights, among others.

- Numerous changes within Production:

Often a vehicle is being transformed, and it suffers changes in its configuration that affects planning and production. This last factor served as the scope for Subproject No. 2.

5.1 Main Conclusions

The results obtained throughout the project envisage the company improving as far as raw materials management is concerned, being presented a new purchasing model capable of reducing stock levels without compromising production needs.

In the AS-IS situation, there were 43% of stockouts and 32% of changes in production. When writing this document, the indicators were 15% and 3%, respectively. Thus, comparatively to the starting values, it was possible to reduce the level of stockouts in 28% and the inventory value (in 462,583€). Furthermore, it was possible to reduce the number of changes in 29%, improving one of the factors that was most contributing to the difficulties in production planning. Due to a time restriction to carry out this project, it was not possible to achieve the target proposed of 0% of stockouts, but it was possible to reach the target of 5% for the percentage of changes.

There were some adversities in the project development. The lack of initial data necessary to establish a baseline required that a great amount of time was spent gathering data rather than developing the tools.

Furthermore, the project implementation suffered from the effect of resistance to change. Implementing a continuous improvement culture is not easy most of the times, since people do not recognize the benefits of it from the beginning.

5.2 Future Developments

Although the positive results achieved, that had a great impact in the performance of the company, there are still some aspects to develop.

For instance, regarding raw materials management, the purchasing team shall continuing validating and making some adjustments to the quantities being ordered.

Furthermore, a new configurator, more user-friendly, shall be developed by the IT department of the company, since the one developed in this context was significantly slow when processing. Moreover, a more exhaustive data collection regarding bills of materials will have to be done, as well as corrections and updates to the existing ones.

On the whole, each research question defined for this project was answered. For that reason, in the future it will be possible to tackle other projects in the company, as there were many improvement opportunities that were recognized but not approached within the scope of this project.

One research question that was not considered, but would be interesting to approach in the future, would be the following:

1. What are the principles and standards that must be defined in order to ensure a correct production planning?

It would be interesting to review the existent paradigm of "vehicles per month". Instead of having a month planning, a number of processes per week to enter the Technical Department should be defined.

Another relevant theme would be to evaluate the current production model (per section) and perform a line design in order to improve the production flow.

The path towards operational excellence will depend not only on the improvement opportunities already referred but also on the technological infrastructure structures, namely information systems. In particular, this dimension will be relevant to guarantee the effectiveness and responsiveness requested in a quite challenging mass-customization environment.

Finally, people dimension is a key stone to guarantee the overall success of an improvement program as described. Therefore, it will be particular important to design, launch and deploy suitable operators-oriented programs grounded on quality and improvement concepts.

References

Adrodegari, F., Bacchetti, A., Pinto, R., Pirola, F., and Zanardini, M. (2015). *Engineer-to-order (ETO) production planning and control: An empirical framework for machinery-building companies*. Production Planning & Control, 26(11), 910-932.

Du, S., Bhattacharya, C. B., and Sen, S. (2007). *Remaping relational rewards from corporate social responsibility: The role of competitive positioning*. International journal of research in marketing, 24(3), 224-241.

Blecker, T., and Abdelkafi, N. (2006). *Complexity and variety in mass customization systems: analysis and recommendations*. Management Decision, 44(7), 908-929.

Christensen, K. H., BScB, I. M., and Nielsen, E. H. (2012). *Mass Customization*.

Chu, C., Gin-Shuh L., and Chien-Tseng L. (2008). *Controlling inventory by combining ABC analysis and fuzzy classification*. Computers & Industrial Engineering 55.4: 841-851.

Da Silveira, G., Borenstein, D., and Fogliatto, F. S. (2001). *Mass customization: Literature review and research directions*. International journal of production economics, 72(1), 1-13.

Davis, S. M. (1987). *Future Perfect: A Startling Vision of the Future We Should Be Managing Now*.

Diário da República, (2014). *Portaria n.º 260/2014*. Available at: https://dre.pt/home/-/dre/64797338/details/maximized?p_auth=0mVYI8Wb [last accessed: 01/07/2018].

Dovetail, 2018. *The difference between qualitative and quantitative research*. Available at: "https://dovetailapp.com/guides/qual-quant" [last accessed: 01/07/2018].

Duray, R., Ward, P. T., Milligan, G. W., and Berry, W. L. (2000). *Approaches to mass customization: configurations and empirical validation. Journal of operations management*, 18(6), 605-625.

Erlenkotter, D. (1990). *Ford Whitman Harris and the economic order quantity model. Operations Research*, 38(6), 937-946. Gilmore, J. H. (1997). The four faces of mass customization. Harvard business review, 75(1), 91-101.

Gilmore, J. H. (1997). *The four faces of mass customization*. Harvard business review, 75(1), 91-101.

Götzfried, M. (2013). *Managing Complexity Induced by Product Variety in Manufacturing Companies: Complexity Evaluation and Integration in Decision-Making* (Doctoral dissertation).

Gunasekaran, A., and Ngai, E. W. (2005). *Build-to-order supply chain management: a literature review and framework for development*. Journal of operations management, 23(5), 423-451.

Flores, B. E., and Whybark, D. C. (1987). *Implementing multiple criteria ABC analysis*. Journal of Operations Management, 7(1-2), 79-85.

Heizer, J. H., and Render, B. (2008). Operations management (Vol. 1). Pearson Education India. Hill, Arthur V. The encyclopedia of operations management. Eden Prairie, MN: Clamshell Beach Press.

Hopp, W. J., and Spearman, M. L. (2004). *To pull or not to pull: what is the question?*. Manufacturing & service operations management, 6(2), 133-148.

Jacobs, R., and Chase, R. (2013). *Operations and supply chain management*. McGraw-Hill Higher Education.

Lampel, J., and Mintzberg, H. (1996). *Customizing customization*. Sloan management review, 38(1), 21.

Lysons, K., and Farrington, B. (2012). *Purchasing and supply chain management*. Pearson Education. Lumsden.

NC State University (2017), *What is Supply Chain Management (SCM)?* Available at:" https://scm.ncsu.edu/scm-articles/article/what-is-supply-chain-management-scm" [last accessed: 01/07/2018].

Ng, W. L. (2007). *A simple classifier for multiple criteria ABC analysis*. European Journal of Operational Research, 177(1), 344-353.

Osterwalder, A., & Pigneur, Y. (2010). *Business model generation: a handbook for visionaries, game changers, and challengers*. John Wiley & Sons.

Pine, B. J. (1993). *Making mass customization happen: strategies for the new competitive realities*. Planning Review, 21(5), 23-24.

Powell, D., & Arica, E. (2015). *To Pull or Not to Pull: A Concept Lost in Translation?*. American Journal of Management, 15(2), 64.

Rahman Abdul Rahim, A., & Shariff Nabi Baksh, M. (2003). *Case study method for new product development in engineer-to-order organizations*. Work Study, 52(1), 25-36.

Ramanathan, R. (2006). *ABC inventory classification with multiple-criteria using weighted linear optimization*. Computers & Operations Research, 33(3), 695-700.

Sauro, Jeff. (2015). *5 Types of Qualitative Methods.* Measuring U Available at: "https://measuringu.com/qual-methods"/ [last accessed: 01/07/2018]

Scholz-Reiter, B., Heger, J., Meinecke, C., and Bergmann, J. (2012). *Integration of demand forecasts in ABC-XYZ analysis: practical investigation at an industrial company*. International Journal of Productivity and Performance Management, 61(4), 445-451.

Schönsleben, P., (2007). *Integral Logistics Management*, third ed. Auerbach Publications.

Shingo, S. (1981). *Study of Toyota Production System from Industrial Engineering View-Point*,"Japan Management Association". Business & Economics.

Simão, J. M.., P. C. Stadzisz, and Morel G. (2006). *Manufacturing execution systems for customized production Lean*. Journal of Materials Processing Technology 179: 268-275.

Srinivasan, M. M., and Mandyam, S. (2012). Building lean supply chains with the theory of constraints. New York, NY: McGraw-Hill

Tsai, C. Y., & Yeh, S. W. (2008). *A multiple objective particle swarm optimization approach for inventory classification*. International journal of production Economics, 114(2), 656-666.

University of Pretoria, (n.d.). Chapter 5: Defining the Problem and Development of Propositions. Available at: " https://repository.up.ac.za/bitstream/handle/2263/27665/04chapters5-6.pdf?sequence=5&isAllowed=y" [last accessed: 01/07/2018]

Van Hoek, R. I. (2001). *The rediscovery of postponement a literature review and directions for research*. Journal of operations management, 19(2), 161-184.

Wikner, J., and Rudberg, M. (2005). *Integrating production and engineering perspectives on the customer order decoupling point*. International Journal of Operations & Production Management, 25(7), 623-641.

Yang, W., & Fung, R. Y. (2014). *An available-to-promise decision support system for a multi-site make-to-order production system*. International Journal of Production Research, 52(14), 4253-4266.

Appendix A: Improvement Opportunities Brainstoming

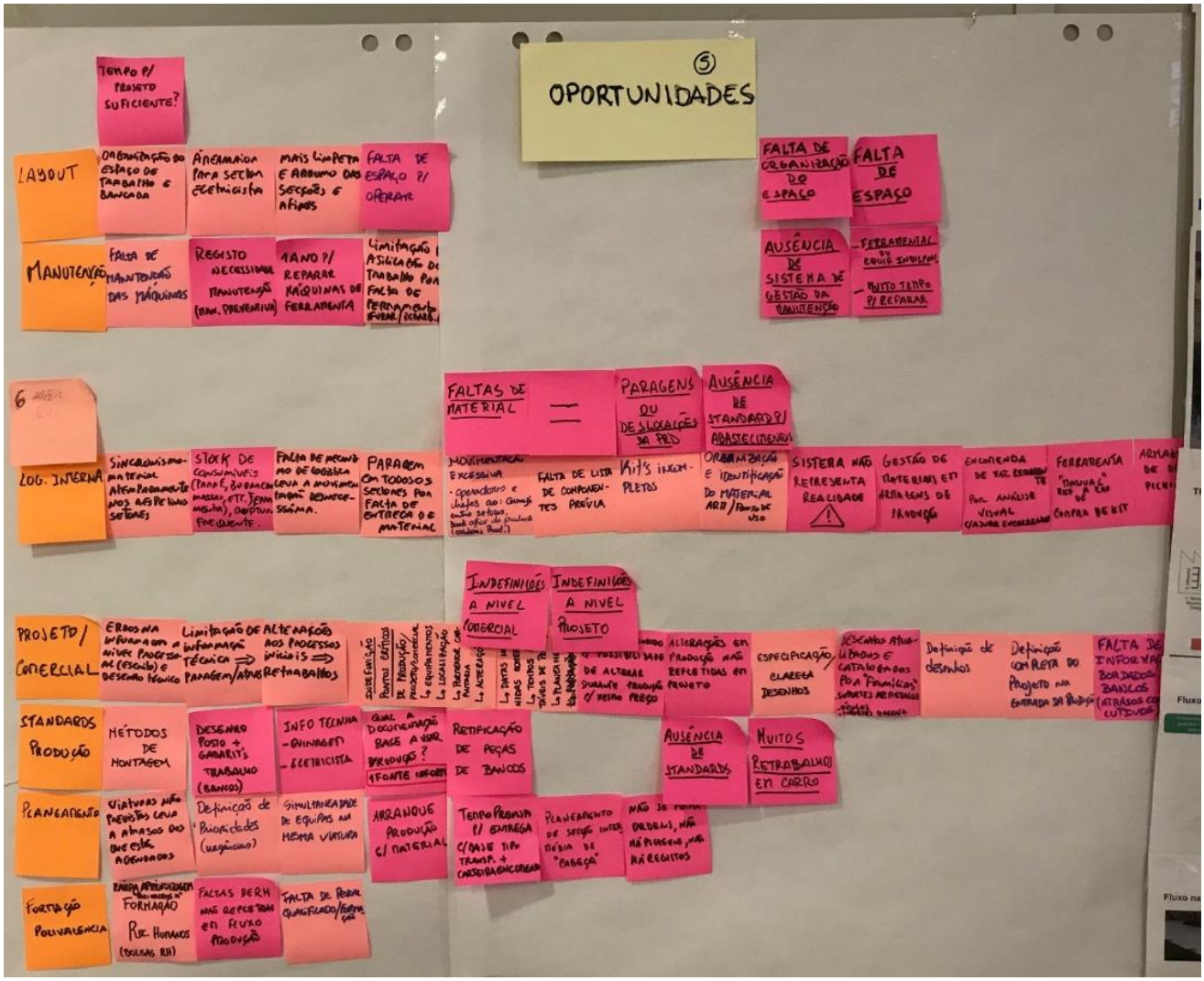


Figure 43 - Improvement opportunities brainstorming

Appendix B: Categories of References

Table 6 - Categories of References

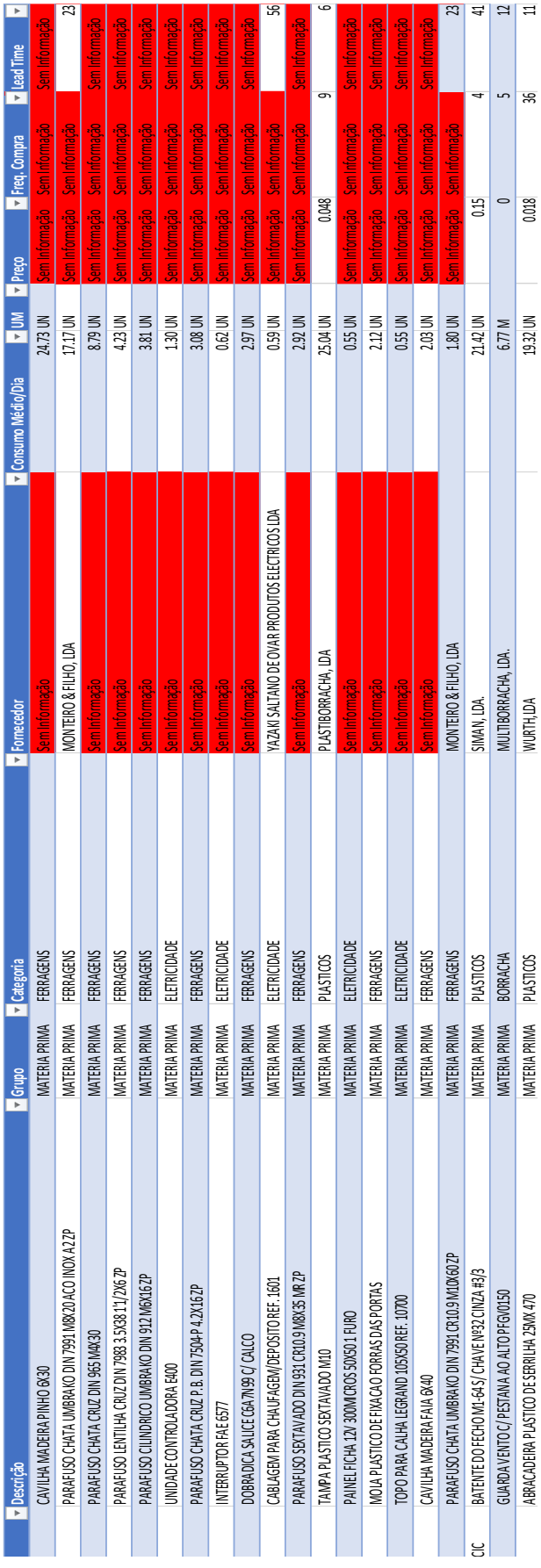
Code	Designation
X	Tests Vehicles
W	WYIPI Metrics
V	Vehicles
T	Transformations
S	Subkit Warehouse
R	Equipments Repairs / Tools Acquisition
P	Transformed Product
O	Work
M	Raw Material
K	Kit
I	Undifferentiated
G	General
F	Finished Product
C	CNC Cuts
A	Alterations

Appendix C: Specific Categories of References

Table 7 - Specific Categories of References

Code	Designation
999	Consumables
800	Mechanics
700	Tools for Sale
300	Electric Tools
210	Motorbike Equipment
200	Ambulance Equipment
100	General Equipment
056	Bodywork
055	Hearse Equipment
054	Anodising
053	Painting
052	Decoration
051	Upholstery
050	Electricity
010	Diverse Raw Material
009	Origin Material
008	Plates
007	Glasses
006	Fibres
005	Aluminium
004	Plastics
003	Rubber
002	Metallic Structures
001	Metal fittings

Appendix D: Extract of the list with M References



	Descrição	Grupo	Categoria	Fornecedor	Consumo Médio/Dia	UM	Preço	Freq. Compra	Lead Time	
	CAVILHA MADEIRA PINHO 6X30	MATERIA PRIMA	FERRAGENS	Sem Informação	24.73	UN	Sem Informação	Sem Informação	Sem Informação	
	PARAFUSO CHATA UMBRAKO DIN 7991 M8X20 ACO INOX A2 2P	MATERIA PRIMA	FERRAGENS	MONTEIRO & FILHO, LDA	17.17	UN	Sem Informação	Sem Informação		23
	PARAFUSO CHATA CRUZ DIN 965 M4X30	MATERIA PRIMA	FERRAGENS	Sem Informação	8.79	UN	Sem Informação	Sem Informação	Sem Informação	
	PARAFUSO LENTILHA CRUZ DIN 7988 3.5X38 1'1/2X6 ZP	MATERIA PRIMA	FERRAGENS	Sem Informação	4.23	UN	Sem Informação	Sem Informação	Sem Informação	
	PARAFUSO CILINDRICO UMBRAKO DIN 912 M6X16 ZP	MATERIA PRIMA	FERRAGENS	Sem Informação	3.81	UN	Sem Informação	Sem Informação	Sem Informação	
	UNIDADE CONTROLADORA E400	MATERIA PRIMA	ELETRICIDADE	Sem Informação	1.30	UN	Sem Informação	Sem Informação	Sem Informação	
	PARAFUSO CHATA CRUZ P. B. DIN 7504-P 4.2X16 ZP	MATERIA PRIMA	FERRAGENS	Sem Informação	3.08	UN	Sem Informação	Sem Informação	Sem Informação	
	INTERRUPTOR FAE 6577	MATERIA PRIMA	ELETRICIDADE	Sem Informação	0.62	UN	Sem Informação	Sem Informação	Sem Informação	
	DOBRADICA SALICE CGA7N 99 C/ CALCO	MATERIA PRIMA	FERRAGENS	Sem Informação	2.97	UN	Sem Informação	Sem Informação	Sem Informação	
	CABLAGEM PARA CHAUFAGEM/DEPOSITO REF. 1601	MATERIA PRIMA	ELETRICIDADE	YAZAKI SALTANO DE OVAR PRODUTOS ELECTRICOS LDA	0.59	UN	Sem Informação	Sem Informação		56
	PARAFUSO SEXTAVADO DIN 931 CR10.9 M8X35 MR ZP	MATERIA PRIMA	FERRAGENS	Sem Informação	2.92	UN	Sem Informação	Sem Informação	Sem Informação	
	TAMPA PLASTICO SEXTAVADO M10	MATERIA PRIMA	PLASTICOS	PLASTIBORRACHA, LDA	25.04	UN	0.048	9		6
	PAINEL FICHA 12V 300MICROS 50X50 1 FURO	MATERIA PRIMA	ELETRICIDADE	Sem Informação	0.55	UN	Sem Informação	Sem Informação	Sem Informação	
	MOLA PLASTICO DE FIXACAO FORRAS DAS PORTAS	MATERIA PRIMA	FERRAGENS	Sem Informação	2.12	UN	Sem Informação	Sem Informação	Sem Informação	
	TOPO PARA CALHA LEGRAND 105X50 REF. 10700	MATERIA PRIMA	ELETRICIDADE	Sem Informação	0.55	UN	Sem Informação	Sem Informação	Sem Informação	
	CAVILHA MADEIRA FAIA 6X40	MATERIA PRIMA	FERRAGENS	Sem Informação	2.03	UN	Sem Informação	Sem Informação	Sem Informação	
	PARAFUSO CHATA UMBRAKO DIN 7991 CR10.9 M10X60 ZP	MATERIA PRIMA	FERRAGENS	MONTEIRO & FILHO, LDA	1.80	UN	Sem Informação	Sem Informação		23
CIC	BATENTE DO FECHO M1-64 S/ CHAVE Nº32 CINZA #3/3	MATERIA PRIMA	PLASTICOS	SIMAN, LDA.	21.42	UN	0.15	4		41
	GUARDA VENTO C/ PESTANA AO ALTO PFGV0150	MATERIA PRIMA	BORRACHA	MULTIBORRACHA, LDA.	6.77	M	0	5		12
	ABRACADEIRA PLASTICO DE SERRILHA 25MX 470	MATERIA PRIMA	PLASTICOS	WURTH,LDA	19.32	UN	0.018	36		11

Figure 44 - Extract of the list with all the M References

Appendix E: Examples of Descriptive Memories

TRANSFORMAÇÃO AMBULÂNCIA TIPO B

CABINE DE CONDUÇÃO:

- Dois lugares individuais.
- Painel táctil de comando de sinalização e equipamentos da célula sanitária.
- Comandos de sinalização acústica.
- Disjuntor unipolar de protecção (220 V).
- Tomada de 12 V.
- Luz de leitura de mapas.
- Intercomunicador entre a cabine e a célula sanitária
- Suporte para um extintor.

CÉLULA SANITARIA:

- Estrutura Interior reforçada com tratamento anti-corrosão.
- Divisória rígida de separação entre cabine e célula sanitária, equipada com dois vidros móveis que permitem a comunicação.
- Piso e painéis revestidos térmico e acusticamente, com material lavável de excelente qualidade.
- **Uma maca** colocada no lado esquerdo da célula sanitária, de concepção **ãre,** fabricada em alumínio, com elevação da cabeceira e elevação de membros inferiores, resguardos laterais, colchão forrado a material lavável, não absorvente, cintos de segurança, porta soros amovível e certificada em conformidade com a norma NP EN 1865:2002
- **Um Carrinho de Transporte** de concepção **ãre**, fabricado em alumínio, com pernas articuladas, posições intermédias, certificado em conformidade com a norma NP EN 1865:2002
- **Um Charriot** de concepção **ãre**, fabricado em alumínio, que permite a deslocação do conjunto maca/carrinho lateralmente e no sentido eflec/posterior, acrescido de sistema **TRENDLEMBURG** e com suporte para aplicação de maca "Redimax".
- **Dois Bancos** individuais, equipados com apoios de braço e cintos de segurança de 3 pontos, forrados a napa ignífuga, laváveis e com características anti-fungos e anti-bactérias, homologados de acordo com a EN1789, sendo um colocado à cabeceira da maca e outro rotativo e rebatível na parte lateral direita.
- Suporte para duas garrafas de oxigénio.
- Suportes para oxigénio portátil.
- Dois suportes para soro.
- Dois Varões de apoio longitudinais no teto da célula.
- Três pontos de luz tecnologia lead na célula sanitária.
- Dois focos de luz de intensidade variável.
- Ventilador elétrico com sistema de extração/introdução de ar aplicado no teto da célula.
- Vários armários para primeiros socorros.
- Quatro gavetas para acondicionamento do respetivo material nas cores: amarelo, verde, vermelha e azul.
- Suporte para cadeira de transporte.
- Suporte para Plano duro e tala de tração.
- Armário com prateleiras para colocação de sacos de 1º socorros, á entrada da porta lateral.
- Lavatório com água fornecida por bomba eléctrica.
- Armário com gavetas colocado do lado direito da célula à entrada da porta traseira.

ãreAmbulance ãreEquipment ãreSecurity ãreBus

Figure 45 - Example of part of a Descriptive Memory of a vehicle

Ambulância Tipo A1 ☐ **Ambulância Tipo B** [X] **Ambulância Tipo C** ☐

	Descrição				Referência
Cor dos painéis laterais (laminite)	BRANCO				
Cor forras dos pilares	AZUL ESCURO				MTENAP 0102
Cor do chão	CINZENTO CLARO EM FIBRA				MTTAPCHAVIA
Cor dos bancos	AZUL ESCURO				MTENAP 0102
Cor dos perfis / orlas	AZUL				
Cor dos acrílicos (armários)	AZUL TRANSPARENTE (10 mm)				MTPLAACRI0014
Cor dos varões	CINZA ACETINADO				
Frente das gavetas	METÁLICAS		ACRILICO	X	4 cores
Bancos com pesponto	SIM	X	NÃO		CINZA PRATA
Bancos com logótipo AR BORDADO	SIM		NÃO	x	----------
Bancos com logótipo CLIENTE	SIM	x	NÃO		Logo (ver 2ª folha
Cor da linha para os logótipos					Conforme logo.
Cor conjunto carrinho/maca/charriot	MACA M764 4 SW preto e cinza, CHARRIOT A150 PRETO/CINZA				
Cor colchão para maca	AZUL ESCURO				MTENAP 0102
Rotativos	QTD.	2 + PONTE	LEDS		Fornecido pelo cliente
			STROBS		
Cadeira de Transporte (tipo e cor)	C600 preto com lona azul				
Disposição do Interior	1 MACA E 2 BANCOS (NORMAL)				Desenho:
Decoração Exterior	CONFORME LEGISLAÇÃO (1133 ABSC 06) LISTAS REFLET. NAS EMBALADEIRAS				
Equipamento de rádio	Banda Alta	NÃO	Banda Baixa	NÃO	

Cliente: BOMBEIROS VOLUNTÁRIOS DE MAFRA

Marca / Modelo: MERCEDES-BENZ SPRINTER 316 CDI 37 RAL 3000

Chassis: 288932

Figure 44 - Example of part of a Descriptive Memory of a vehicle

Appendix F: Macros for Configurator

```
Sub gerarPDF()

Fname1 = InputBox("Insira nome de documento:", "Grave os seus documentos", "insira nome da proposta")
Fname = ActiveWorkbook.Path & "\" & Fname1 & ".pdf"

Worksheets("Relatório").Activate

ActiveSheet.ExportAsFixedFormat Type:=xlTypePDF, Filename:= _
            Fname, Quality:=xlQualityStandard, _
      IncludeDocProperties:=True, IgnorePrintAreas:=False, OpenAfterPublish:= _
            True

 Dim aOutlook As Object
     Dim aEmail As Object
     Dim rngeAddresses As Range, rngeCell As Range, strRecipients As String

Fname3 = ActiveWorkbook.Path & "\" & Fname1 & ".xls"

Dim wb As Workbook
Set wb = Workbooks.Add
ThisWorkbook.Sheets("Ficha B_C").Copy Before:=wb.Sheets(1)
wb.SaveAs Fname3

Set aOutlook = CreateObject("Outlook.Application")
Set aEmail = aOutlook.CreateItem(0)
aEmail.Importance = 1
aEmail.Subject = "Memória descritiva"
aEmail.HTMLBody = "<p>Bom dia,</p>" & vbCrLf & _
"<p>Segue em anexo a memória descritiva e a proposta cliente.</p>" & vbCrLf & _
"<p>Cumprimentos Inês Azevedo  </p>"

    aEmail.CC = "iazevedo@kaizen.com;"
       aEmail.To = "iazevedo@kaizen.com;"
       aEmail.Attachments.Add Fname
       aEmail.Display

End Sub
```

Figure 45 - Extract of the macros for the configurator

Appendix G: Standards to Update the Data Base

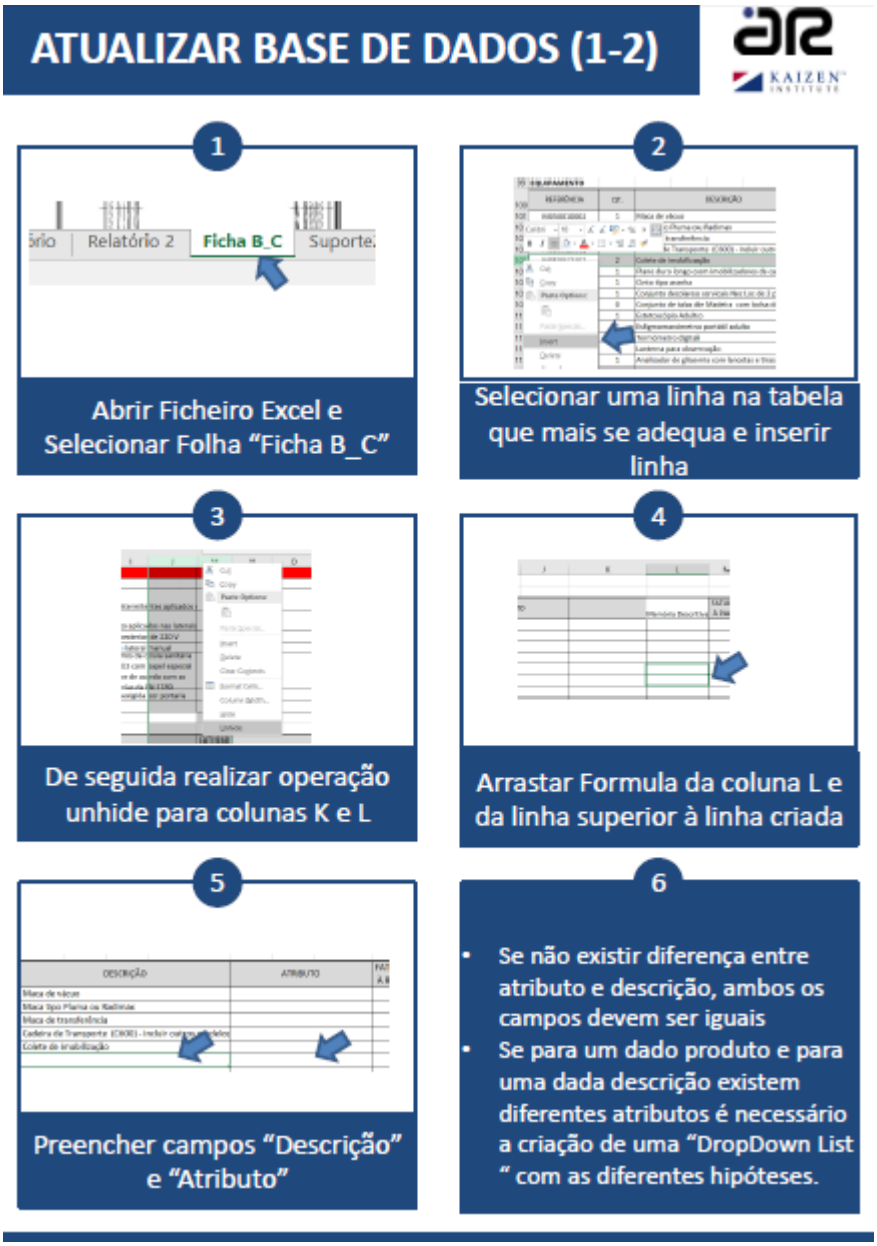


Figure 46 - Standards to update the data base (part 1)

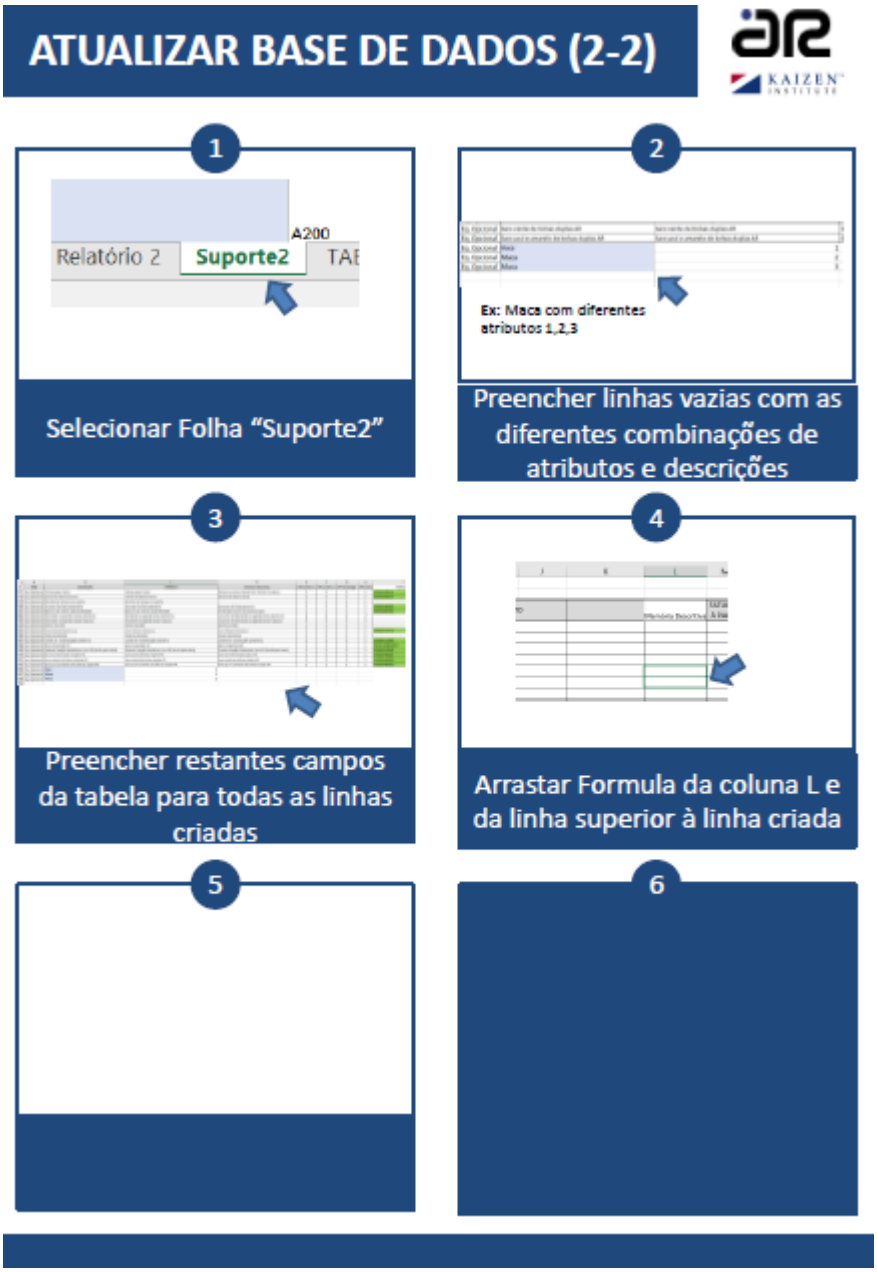


Figure 47 - Standards to update the data base (part 2)

Appendix H: Standards for Commercials



Figure 48 - Standards to generate proposal and report