Operations Improvement in a Manufacturing Business of Make-to-order Special Vehicles

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Abstract

Build to Order or Make to Order is 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 special ambulances as well as vehicles adapted for the support and transport of passengers with less mobility. In this type of business, operations are scheduled in response to a confirmed order received from a final customer. Thus, the variability and the uncertainty characterizing what is project based, generate a complexity that requires specifically tailored managerial approaches to handle all the involved processes - from design and engineering to production and delivery. Hence, in this accentuated complexity, it is extremely important to guarantee that both the material and information flows are efficient and effective. The present study, framed in a program of operational improvement in a manufacturer of special vehicles, 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. In fact, 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.

Keywords
Process Improvement, Process Standardization, Make to Order, Raw Materials Management

1. Introduction

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 (BTO), make-to-order (MTO) and assembly-to-order (ATO) to react to the growing individualization of demand. In fact, customized 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.

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. In particular, in this research 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 decrease the overall efficiency and effectiveness. Strategies to address all these matters are to be identified and applied. Having in consideration these objectives, 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?

The methodology adopted for this study has its grounds on both qualitative and quantitative techniques employed in the perspective of a deductive method. The following stages were considered: (a) acquire general awareness of the case; (b) in-depth analysis of the operating mode and clear identification of the existing problems as far as raw materials sourcing is concerned as well as the process related to product configuration; (c) definition of the roadmap to follow in order to solve the problems identified and prioritized; (d) implementation and follow-up of the tools proposed; (e) detail lessons learned and future work.

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 (Project No. 1) and improving the proposal to customer process (Project No. 2).

Raw Materials Management in a customer-centered 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. Furthermore, one of the most frequent reasons for difficulties in orders planning is the fact that a great number of the confirmed orders suffer changes. The process 'proposal to customer' has to do essentially with the interaction between the sales force and the customer when he intends to acquire a 'taylor-made' special vehicle.

The remaining of the paper is organized as follows. Section 2 includes a review on topics related to customer-oriented production systems. Then, the next section presents the case in study considered. Section 4 presents the analysis of potential improvement opportunities. Finally, section 5 provides the most important conclusions and the future potential developments to be considered.

2. Customer-oriented production systems

Nowadays 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. In fact, 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. The main challenge is how a company can differentiate itself in the marketplace while still creating products at a relatively low cost.

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).

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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.

3. Case Study

3.1 Business Model

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.

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 wide 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 total lead-time. 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. 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.

Based on Osterwalder and Pigneur (2010) business model framework, Figure 1 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.

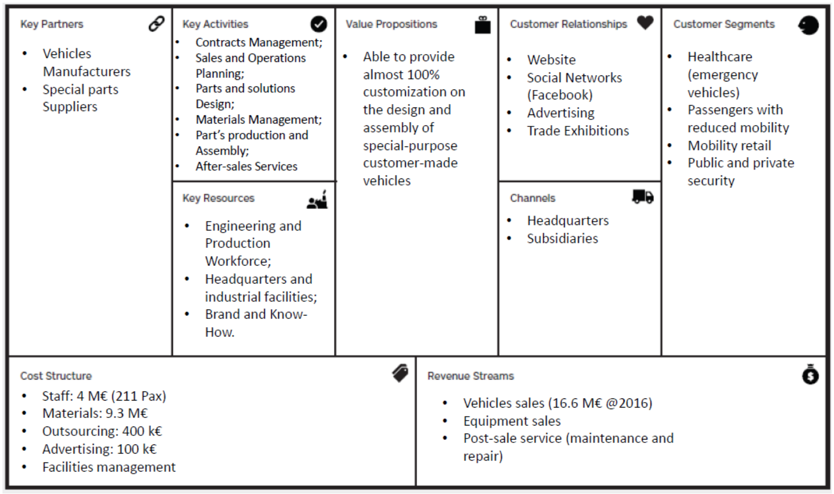

Figure 1. The Business Model Canvas of the company in study

The different building blocks presented in Figure 1 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 block the different cost components involved are presented.

3.2 General Production Process Flow

In Figure 2, 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 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.

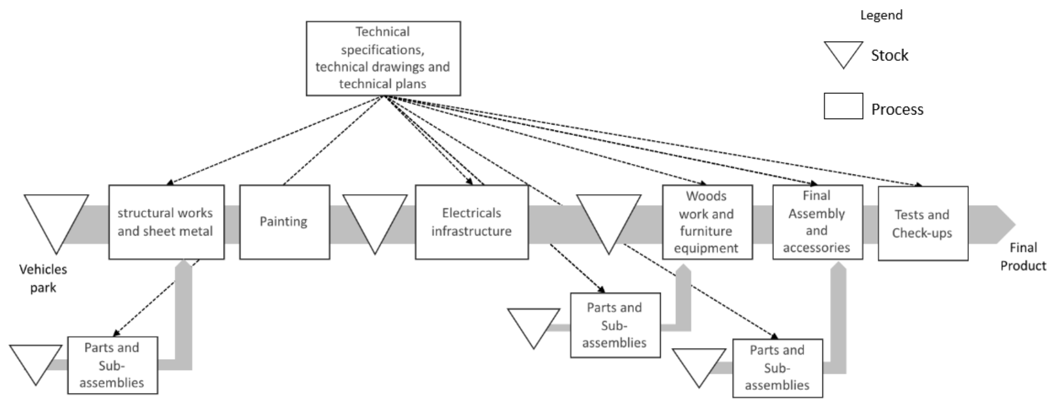

Figure 2. Overview of the production process flow

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.

Currently, the monthly production is centered 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, vehicles dedicated to the transport of people with reduced mobility, vehicles dedicated to the transport of values, among others. 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 color 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 vehicles stated by law).

3.3 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 hunting) was completed (following employees and observing them perform their daily operations in order to collect improvement opportunities). For instance, 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%). On the other hand, after analyzing 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.
A brainstorming workshop that was made with key people regarding improvement opportunities raised several potential ones. 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.
As far as Service Level is concerned, two different indicators were considered. The first one, Lateness, was 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 processed and it was approximately 22 days. The second one was the number of customer complaints. Our analysis identified a total value of 85 complaints along 5 months. Furthermore, during the same time period, there were 292 vehicles produced, of which 94 suffered alterations, i.e. 32% of the produced vehicles suffer changes. These changes generate entropy in each one of the sections which ends up affecting production planning.
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.

4. Analysis of Improvement Actions

4.1 Improving Raw Materials Management

Raw Materials Management in a customer-centered 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.
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 vehicles transformations 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 3 presents an extract of the said table.

T	Article Code	Description	Quantity	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 2. 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 4, while the number of articles per type can be observed in Table 1.

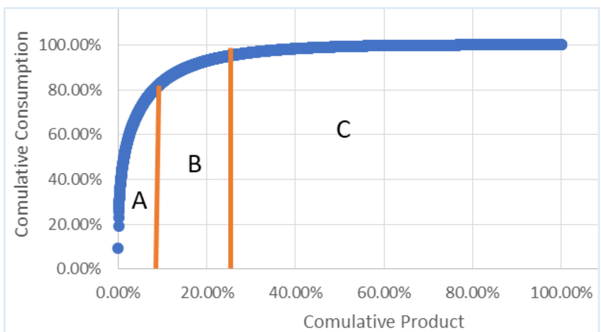

Figure 3. Pareto Chart (ABC analysis)

Table 1. Number of articles per type

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

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.
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%). 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 5.

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 5. Screenshot 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).

After observation, the following recurring causes for a high number of stockouts 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 bills of materials were incomplete or had outdated references.

In order to design a solution, it was necessary to structure the decision-making process as far as purchasing is concerned. For each reference category, criteria were defined concerning visibility, price limit and consumption frequency. 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 regarding stocks management. Until then, stock management was being made without any particular criteria. 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.

Weekly, in order to analyze which articles should be ordered in the present week, it would be necessary to extract three different types of data from the ERP of the company: the Stock History, the Consumption History and the Orders History. After the stocks, consumption and orders sheets were updated, the "Analysis" sheet made to ease management would be possible be analyzed. In this sheet it can be obtained: the average of consumption, consumption in frequency, security stock and maximum stock. Then, it can be obtained a result: necessities and suggestion of order.

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.
In Figure 6, the evolution of the KPI per week over the past weeks can be seen. Although the target value of 0% was not reached, it consistently diminished, being currently at 15%.

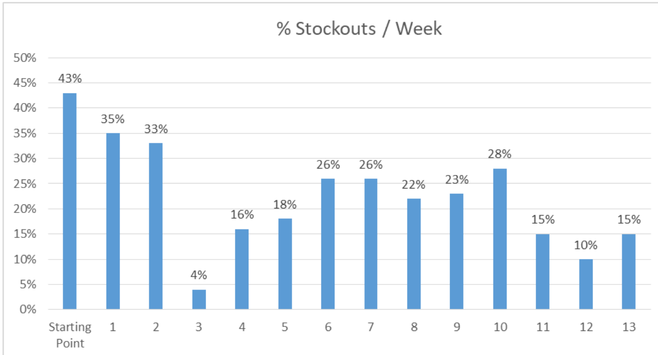

Figure 6. Evolution of the KPI during the project

In Table 2, 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 2 - 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 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 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.
By then, there were four people in the commercial office. In order to understand the process, observations were conducted 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.
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:

$$\% \, Changes \; = \frac{(Number \; of \; Changes/Week)}{(Number \; of \; Ambulances \; Produced/Week)}$$

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. With the creation of the configurator, references with quantities are automatic and generated at the same time of the commercial proposal. After this development, a mockup was done and it was observed that it would take a total of 45 minutes to perform the tasks that lasted for 3h15 before.

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).
Between the period of May 7th and June 24th, the number of changes per department were registered, as can be observed in Figure 7. 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 7. Number of changes per department

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.
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 8.

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 8. % Changes index calculation

5. Conclusions and Future Developments

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%. 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.
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 continue 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.

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