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STUDY APPLICATION OF PRODUCTION SYSTEM TYPICALLY "ENGINEER-TO-ORDER" IN COMMERCIAL VEHICLES SEGMENT

Mota, André Luiz Siqueira
Lins, Romulo Gonçalves
Gaspar, Ricardo
UFABC UNIVERSIDADE FEDERAL DO ABC – Santo André, SP - Brazil
andre.mota@ufabc.edu.br; romulo.lins@ufabc.edu.br; ricardo.gaspar@ufabc.edu.br;

Abstract.

The need to reduce problems and expenses in commercial vehicle operations has led customers to seek technical alternatives together with automakers to provide vehicles adapted to the real context of users' applications. The creation of processes and structures focused on an Engineer-to-Order (ETO) proposal, involving the customers themselves in the development of their customized solutions, is a path of no return, since everyday commercial vehicles recognized as "Equipment for Work". This new reality has forced companies in the sector to reinvent themselves, as the standard product is beginning to be insufficient and the necessary modifications. The main goal of this work is to evaluate alternatives to enhance the delivery of truly customized products, considering that the demand has grown rapidly year after year and having as the main objective, extracting the maximum that Industry 4.0 (serial production line) can contribute in this sense. Identifying, understanding, and categorizing technologies, important elements, and resources that can contribute to the success of this form of custom production. All of it, comparing with a study of a business case. This case example is an important factor in conducting of the material because through them was possibly to collected information that approximate the theoretical concepts to the context found in the real shop floor. The identified articles, on the other hand, serve as a basis for the theoretical foundation of the topic addressed and as a basis for consolidating this content. The result of this study is the evaluation of this new reality and to present some needs and tools, focused on the production process, to make these customizations (ETO) possible in automated production lines, such those using industry 4.0 technologies.

Keywords: *Engineer-to-Order, Design-to-Order e Customization*

1. INTRODUCTION

The scenario of this study is located in the interrelationship between production processes existing in the manufacturing companies of commercial vehicles. More precisely at the dichotomy between a Serial Process and a Customized Process.

A serial product emerge from a preliminary analysis of a market needs, or an interest in a specific niche, segment, or even, into the interest in a specific customer (BASSI, W. di G.; et al.; 2020). Project Management Offices (PMO) and Research & Development Departments (R&D) work as partners in order to develop, test, industrialize and launch those serials products and put them available for sale from who were interested. This type of kind of product has a solid and very deep ballast of technical documentation, with hours of exhaustive tests in bench tests and subject to exhaustive testing in test fields taken to the limit of their capacity.

The most preponderant theme that places greater weight on the development of a new product, is the fact that the responsible engineers does not know exactly where that product will be used and how, by the customers. It is not so rare identify in Brazil that some customers submit their products in a different condition of that which the product was developed. It known by the companies that this situation is passive to refuse the warranty, but the development departments, in fact, input in their selves some responsible for the image of the company if that product present any kind of problem. For this reason, companies usually submit their products to exhaustive and severe tests, taking the products to their mechanical and physical limits, seeking to simulate the worst application case, the most difficult terrain, the most unlikely operation, in order to ensure that everything that happens in the after sales life, are covered by the tests that have been carried out.

For a customized product, which is no less important than the series ones, the approach to do it unfollow the same process be definition, because the product lifecycle is completely different (HUNTI, D. M.; et al. 2013). However, different from serial process, they know exactly whom the customers are, and what ways the products will be used or applied. A customized solution was developed for a specific customer issue and this solution is only applied for them. Having this information is a *sine-qua-non* condition for the business to take effect and for it works.

The speed of the development of a customized product will always be faster than the serial product, as the customer waits for a prior opinion from the company, as to the technical, financial and production feasibility of the requested solution, only after this information be available, the customers decide if they go or not purchase the good. In a serial product, the customer chooses, pays and receives it subject to availability (not always in this sequence).

As some stages of development are suppressed to shorten the deadline for delivery, such as practical, structural and life cycle tests. The alternative generally found in the development process is to compensate in the projects, concepts and materials with an increase of safety-factors. This higher safety-factor brings greater comfort to the engineer responsible for develop the part or concept, as it will not present future risks and problems arising from weaknesses or mechanical failures.

The Engineer-to-Order (HICKS, C.; et al. 2009), or ETO, concept (individualized) is a natural evolution of the Make-to-Order concept (Mass Customization). This new concept brings to light, a new reality of relationship between parties, where customers start looking for partners and not just suppliers of their inputs. Usually, the client has mastery in the execution of his core activity; however, he does not have the resources, structures and expertise to evaluate in a broader way what can be improved, and to potentiate their respective gains, or to mitigate their respective costs or operation problems.

This new reality required the company to adapt processes, empower teams, make quick decisions and, above all, take risks together. As well as the understanding of those involved, aligned objectives and constant synergies between people and departments, as these are the success factors for the sustainability of this Business.

The way that the product is being identified by the customer has also been modified over time. Today, a truck is no longer just a vehicle for transporting goods and inputs; they are now seen as production and logistics equipment, such as an industrial machine or agriculture equipment. Coming from this new way of thinking, adaptations and modifications to improve and extract more efficiency from each one, become fundamental, because even small gains are vital for the success of the operations.

From the customer's point of view, receiving a customized product that was produced within a productive environment brings the benefit of the speed of the beginning of the financial return, as they avoid the need to forward the product to a third party to do it. Another determining factor for choosing an in-house customization (by the manufacturer) is the quality ensured by the company in that question. Imagine if you buy a high value-added car and when you catch that vehicle from the dealer, you are obliged to take it to a armor company that will almost completely dismantle that vehicle, with a very few kilometers traveled to install the armor accessories and shields. Now imagine if the company where you by the car, provides you these service, with quality and a fair price. This is the main reason why customers chosen the service performed under the responsibility of the company that provides the good.

This paper has two goals. First of that, is an evaluation of bibliography research, added to a comparison with a real application in a company that creates a separated structure to allow ETO solutions in their products. This goal is connected to the other one, which has focus in increase the company’s portfolio, adding and offering these creations in different situations.

This paper also brings a batch of lean manufacturing tools that allows to be possible introduce this special products with higher assertively in order to meet the customer feedback.

2. MANUFACTURING PRODUCTION SYSTEMS

With the evolution of production processes over time, added by the current Lean Manufacturing concepts that have permeated the structures, mindsets and operations of several manufacturing companies. Tools such as those described more ahead were and are of central point of the results obtained by each institution where this lean methodology did was implemented. Through them, a new way of managing production is gaining importance and representation, the so-called Engineering-to-Order, or just, Engineer-to-Order.

According to Dalvio Tubino (2000, 37p.), we are currently experiencing a reality quite different from what traditional companies have observed throughout their lifecycle. Today, these same companies are no longer the centerpieces in the competition for the market and customers to become, supporting actors in this scenario. The main actors became the complete production chains, where companies are just one of the members. In this scenario, who has the best set of processes, business partners and service network will have the customer's preference and market leadership.

The evolution of the industry is so dynamic that new technologies appear currently to support the production systems, but only those companies that are truly been open to breaking paradigms will survive in this environment. Those one, that have more skeptical and conservative structures, which do not believe that even the metalworking industry can be constantly renewed, with new ideas, experiences and tools, put an end to its history and also them future.

For a better understanding of what is this new production system, the ETO, we need to give an overview about the others. All they have their importance and in certain moments and situations, they not only can, but also must coexist:

Make-to-Stock (MTS):

It is a form of forecasting market demand, where the company evaluates through studies and research what the trend of desire on the part of customers would be and thus, in advance, starts the production of goods and keeps them in stock

for further commercialization. If the good produced is widely accepted and the market analysis is very accurate, the MTS strategy (HA, A. Y.; 1998) is an efficient way to reduce costs and serve the market. A classic and successful example of this methodology is the company The Lego Group ®, because through a consolidated product, with value and history already established with customers, it has been operating smoothly with this production system for decades.

Assemble-to-Order (ATO):

Through this approach, companies that apply the ATO concept (BATTINI, D.; et al. 2009), pre-produce subsets or sub items already consolidated by the market in advance, leaving the completion of the product to a later step. Upon placing the official order by the customer, the manufacture of the final product are started. In this process, the main driver is agility, as the customer expects to receive something that, to a certain point has been customized for him, with the lead-time of producing an inventory item (MTS). A very common example of this strategy can be found in personal computer assembly companies (e.g. Dell Inc. ®), where several pre-assemblies are ready-made and can be integrated with each other, such as motherboards, graphics cards, processors, monitors, keyboards, etc., upon a specific demand from a customer, a different computer is produced and shipped.

Make-to-Order (MTO):

Make-to-order (TANRISEVER, F.; et al. 2012) or commonly known as Mass Customization or Modularization.

In this type of production system, the product is only produced upon an official order made by the customer, by choosing from a range of options that are presented, at the time of placing this order.

As in the previous process, the ATO, exist the possibility of involve customers in the process of choosing the characteristics of this good, however, it is necessary to explain that these options are actually variables of something that are already pre-developed or pre-chosen from someone of the company itself.

This process is used on a large scale by the passenger's cars industry, they usually offers a chance to adapt the cars previously, including some specials kits or features. For example, the optional could be choose from simples features, as different palette of color or a powerful of engine or a size of tires. Giving the impression to those who choose that there was a decisive participation in the production of that unit, when in fact, he only chose a variant among the several possible and already developed by the areas of Project & Development (R&D) and Marketing.

Engineering-to-Order (ETO) (GOSLING, J.; et al. 2009)**:**

Develop upon a request, is an additional step to the MTO system.

In this process, we can identify a natural evolution of some markets where product adaptation, is more than a desire becoming a necessity.

Upon a special problem that is presented by a customer, companies develop or create alternative solutions, even if is necessary modify completely the standard product. Considering of course, the limits of financial and technical reasonableness, because even though this is a highly customized product, subsequent after-sales services, technical assistance and warranty must be ensured by the company, keeping the relationship between those involved as the most cordial and positive possible. Example of ETO product as shown at figure 1 below.

Fig. 1 – Heavy-duty truck for sugar-cane agriculture, customized by ETO

3. PROCESS DESCRIPTION OF ETO PRODUCTION SYSTEM, IN A COMPANY THAT WAS USED AS A CASE OF SUCCESS

A swarm group reunite itself weekly in order to receive the new inputs brought by Sales department and discuss over the progress of last initiatives. In this discussion, incipient ideas are presented and a multi-disciplinary group start to evaluated tree different perspectives: Technical Feasibility, Cost & Price and Availability. After a regular time that depends of complexity of the initial request, an answer is prepared and sent by the customer to define if the project go ahead or not.

With the green light of them, two parallel process are started: regular production of the basis vehicle and the deep dive of the project solution. After receive both, vehicle and project, the build-up process finally starts and the modification could be realized.

Until the end of customized production, all the documentation concerning the modification is released, giving the robustness needed to support the after-sales and guarantee processes.

After concluded the vehicle, the same is addressed for the customer or for the partner chosen by them.

The complete flowchart could be evaluated through the Fig 2 below:

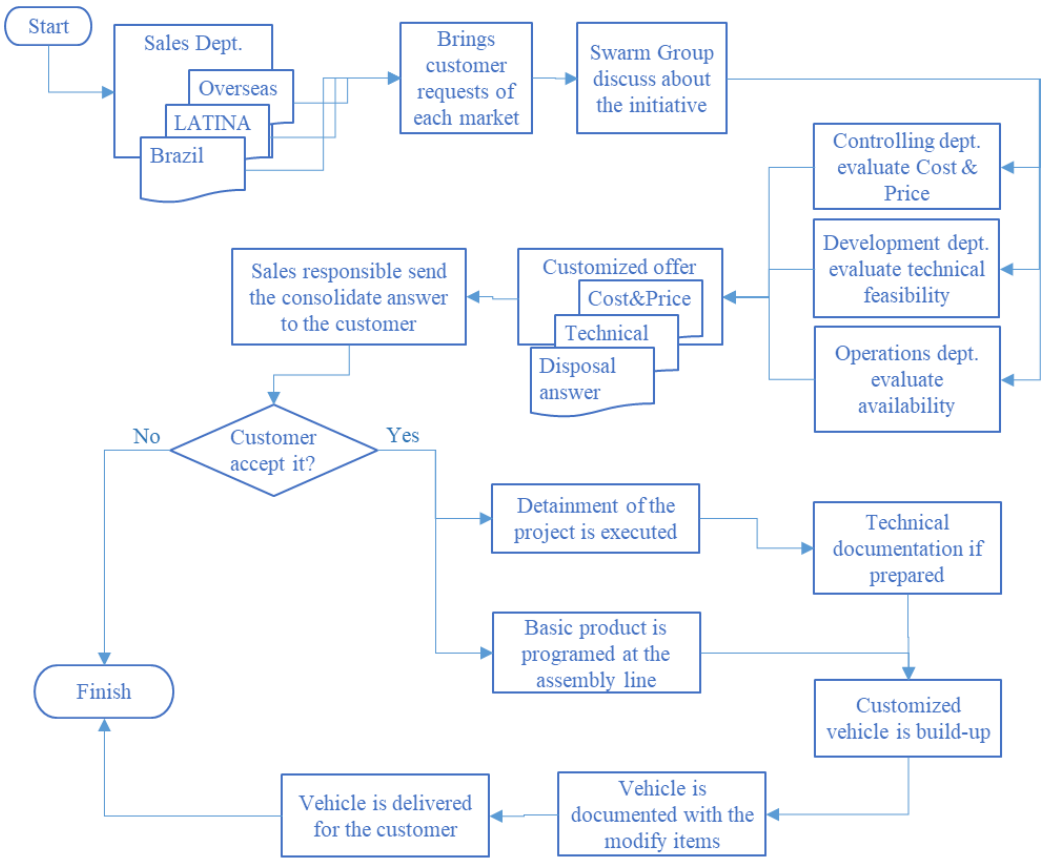

Fig. 2 – Flowchart of ETO process at the case analyzed

4. LEAN MANUFACTURING TOOLS USED TO ALLOW THE ETO IMPLEMENTATION

The success of the application of ETO at assembly lines, it is only be possible, following the consolidated tools existed at the Lean Manufacturing Process (BHASIN, W.; 2015 & CUSUMANO, M.; 1994). Below it is describe some tools used by the company where the study was conducted.

Project Development – Through drawing/modeling construction tools (CAD/NX), projects are developed in order to ensure that the problem identified by the client is solved and that we have a minimum amount of information to repeat the project again, if necessary. At this stage, the Reverse Engineering Strategy was also have enough space, in this strategy, the project is manufactured and after being completed, it is designed in an As-Built manner (BÉNIÈRE, R.; et al. 2013).

Bottleneck analysis – This tool is used to identify whether the specific project can be taken to the production environment (industry 4.0) or whether, given the complexity, it would be better to carry out the modification in a separate and controlled workshop (CHAKRAVORTY, S. S.; et al. 2007).

Poka-Yoke (Zero Error) – Custom pieces can range from small variations of already known pieces, to unique organic shapes, but they all have a common point, they are designed and produced in order to prevent employees who

carry out the activity in that takt-time, have doubts or make mistakes. As these assemblies will rarely be repeated again, because they are normally single batches, the parts have shapes, signs or marks that induce the worker to assemble in the correct position, avoiding assembly errors (MICHALSKA, J.; et al. 2009).

Takt-time – The assemblies that are addressed to the assembly line must always respect a predetermined cycle of time for their execution, called takt. The idea of it, is met the demands made by the customers in a determinate period, by a determinate numbers of stations and workers (ALI, R. M.; et al. 2014).

Kanban – It is a system for pulling parts that are supplied at consumption points, respecting a sequential order of production. Some customizations are sent to the assembly line this way, as it makes the execution of activities much easier if we capture a specific kanban of an item in advance, modify it separately and return it to its place in the production queue. In this way, we will have carried out the necessary customization without the production line becoming aware of or harmed (WAKODE, R. B.; et al. 2015).

Just-in-Time – Another extremely important tool for the ETO process, as it is one of the most used in Industry 4.0, as all parts are fed at the correct time they will be used. Such methodology is not modified for customized and special parts. The providers of these items need to know the process and introduce the modified parts at the right times in the production flow, otherwise the assembly opportunity will be lost (INMAN, R. A.; et al. 2010).

Kaizen – This philosophy and tool, aims to maximize the work performed, seeking improvements in the production environment in order to insert some customizations in a simpler and less traumatic way. Because small changes in workstations or assembly processes are necessary to enable the activity to be carried out. Using the main concept of the tool, we can create new ways to carry out the assemblies and after the specific need is passed, the station and the process can return to the previous form or even absorb that new proposal and continue operating in this way. What is the best for the team at the workstation (BRUNET, A. P.; et al. 2013).

Self-Management Teams - This tool has the objective of incorporating the collaborators a greater autonomy to manner their cells, decision-makers, the work environments and mainly the production process. The use of this approach increases to maturity of the equipment and consequently, an expressive increase in quality and delivery levels will be observed (PARENTE DE SOUZA, C.; 2009).

Gemba - By the use of this philosophical approach, we promote a deeper understanding for the leadership and management about the problems faced by the workers of the real world at production environment. You can talk with them who effectively execute the activities and understand their difficult to do the operations, in terms of tools, processes or even concerning some modifications on the customized products, that will make easier their operations (TRENKNER, M.; 2015).

5. APPLICATION OF CUSTOMERS NEEDS, CUSTOMIZED BY ETO

Follow below a couple of solutions that were brought to meet customer needs, in order to solve or mitigate theirs issues. Both of them has not developed before the start-of-production of that vehicle, being developed after customer request and with their support in order to found the most adequate solution their problems.

Case #1 - Vehicle: Medium Duty Truck for City Construction at Peruvian market

Problem: The standard of Peruvian drivers are being autonomous and due to the market situation, these owners were obligated to seeking for job in different cities and an important part of their earnings had being be deviated by hotel stays. The request made by then, seek for a better solution of accommodation, investing more at the purchasing moment of that unit, but saving latter money with daily costs.

Solution proposed: Exchange de cabin of the truck, including a cabin with bed feature, avoiding the necessity of hotel stays, staying overnight directly at the vehicle. With this new feature, was also necessary correct the wheelbase of the truck, because this new cabin consumed the space behind it over the long members. This extension also provided for the trucker the opportunity to keep with the same truck body.

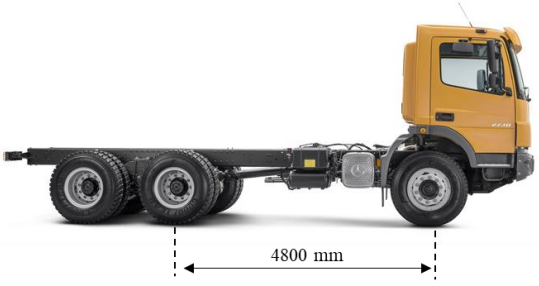

Fig. 3A - Standard product

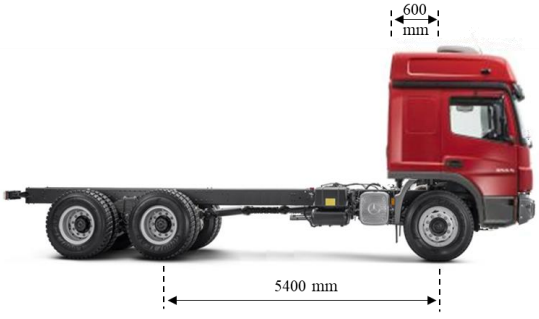

Fig. 3B - Vehicle modified by ETO, with new wheelbase and bigger cabin

Request: Increase the space of the cabin to allow the driver slept at inside it.

Hidden need: increase the space of the cabin, but keeping the payload of the truck and the use of the already available truck body. This is important because the customer did not identify this issue when they made contact the company.

Units sold before the solution: none.

Sales result after the solution: More than 100 units, since the last quarter of 2019.

Case #2 – Vehicle: Extra Heavy Duty Truck for fuel distribution over the Brazilian country

Problem: Transport of fluids is a common problem at Brazilian roads due to the process of weighing the vehicle in movement. Due to the inertia of the liquid, when the driver pass by a balance, the constant movement inside the tanks not allow to assure the weight of the truck. These situation, allow to create misunderstood that could gave the false impression that the composition (truck + body) could be over the weight and this brings a several legal problems for the drivers and for the companies.

Solution proposed: Reducing the weight of the truck and creating a tolerance to absolve this movement.

This solution was build-up together with customer representative, focus on exchange of parts, derivate from different kind of trucks, with same level of quality and robustness, but with a different shape. For example, a lower fuel autonomy, or different air tanks sets, some aerodynamics parts reduction. All of them in accordance with the costumer.

Other solution also used was created alternatives parts, tailor made by this application, as a different exhaust tube or a special ladder of the fifth wheel.

Fig. 4A - Standard product

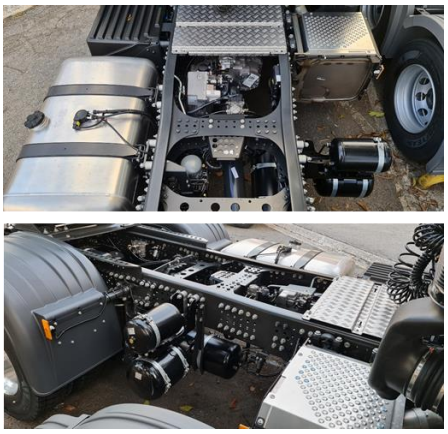

Fig 4B - Vehicle modified by ETO, with weight reduction actions

Request: Total weight reduction of the truck (Tara) in order to create a tolerance over the gross vehicle weight transported by them.

Hidden need: Allow the reduction of the weight, but seeking for opportunities to do it without impact at vehicle quality, robustness, functionality or security. This was important because the impression about the product and about the solution should be the same as a serial vehicle.

Units sold before the solution: none.

Sales result after the solution: more than 1.500 units, since the middle of 2018.

6. ANALYSIS OF THE POINTS THAT LEADS THE CUSTOMERS IN ORDER TO SEEK MODIFICATIONS DONE BY MANUFACTURERS

These are the main reasons that customer that are looked for at ETO process did it directly by manufacturers:

a) Availability of a minimum project and documentation that create a robust technical compliance;
b) After-sales and warranty covered by this project, in order to assure customer support in any necessity at the field;
c) Quality assurance about materials, processes and items used to build-up that solution;
d) After-sales parts reposition, in case of necessity;
e) Assemblies and parts production did it using the same tools, equipment and process as a standard vehicle;
f) Same quality certifications guarantee that a series product, whether in quality, healthy and security standards;
g) Not more necessary sent the vehicle for an external supplier did the modification, because the product is delivered done according to the planning dates.

In both cases presented above, the customers identify a significant gain in their process and the premium price, paid by each unit modified was absorbed by the result of that solution created. At the Case #1, the solution created eliminate the need to separate a part of the shipping cost to pay for accommodation. This modification allowed customer's budget preservation with quality and safety assure by known features, as the extended cabin already tested and applied in other type of trucks. Already at the Case #2, the weight tolerance created brought security at the operation, avoiding problems with inspections on the roads. The focus of the modification was straight at autonomy reduction, and removing some

aerodynamics items, also exchanging some organic parts for others with a much more simple design, but keeping the functionality of each. The parts modified in general were not identified by the customer, which meets what the company would like, that was to prevent the customer from having the perception that something was removed without due care for the whole.

The evolution about the ETO demands, follow the increase of the market over commercial vehicle. Growing in a tax of 63% in average. The abrupt decline of the numbers, shown at 2020 was due to the pandemic situation, but the market was already showing signs of rapid recovery in sales numbers, retuning on track of the increase already at begging of 2021.

Since the start-of-production of this process, this department modified more those seven thousands of trucks according with the information received by them. This evolution could be checked by the sales demands graph at Fig.5 below

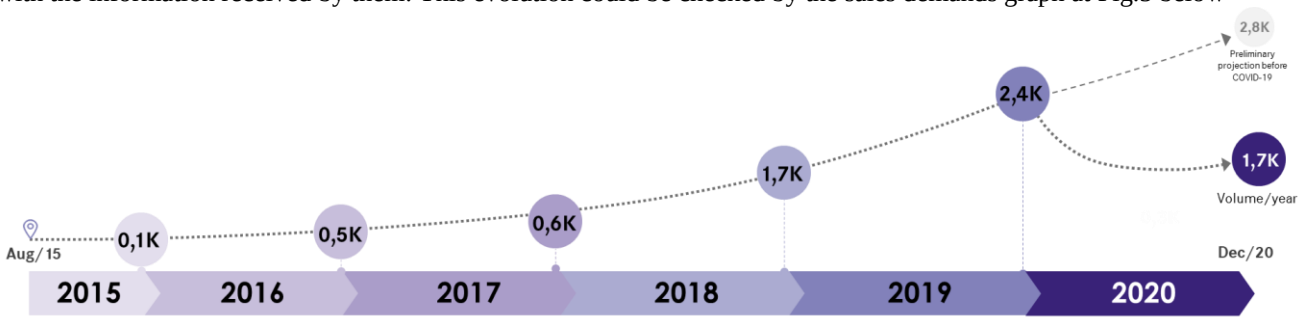

Fig. 5 - Sales ETO evolution demands over the time. 2020 numbers was sensible affect by COVID situation

7. CONCLUSIONS

The continuous seek of costs reduction; pushed the customers to looking for alternatives. One solution identified is modify their equipment in order to improve agility, efficiency and increased the productivity of the operation. All of this, results in a quick return of the money invested.

Through Engineer-to-Order processes, those customers that were seeking for solution found a company that wants to help and become more than just a supplier.

Aligning a multi-disciplinary team, lean manufacturing tools and a new mindset of production and management, created a unique purpose through all. Bringing an additional return over sales and an extra percentage of market share, main due to the volume linked at customer request and the premium cost practice by manufactures to deliver the solution.

This paper does not proposed to identify of what can or cannot be customized, this is responsible of the swarm group chosen by the companies. In addition, the text has no interest in suggest how introduce a special product at the assembly line, but helps to clarify that everything could be made only depending how deep the group are prepared to go to enable this.

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9. RESPONSIBILITY NOTICE

The authors André Luiz Siqueira Mota, Romulo Gonçalves Lins and Ricardo Gaspar are solely responsible for the printed material contained in this article.