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Order fulfilment process improvement in a ceramic industry

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Abstract

In the current business landscape, customers' orders compliance with the established delivery dates and the efficient use of resources are two relevant topics on the agenda. In this context, order fulfilment (OF) is a key business process dealing with all the activities needed to define customer requirements, design the production and logistics processes, and fill customer orders.
In this paper, a case study developed in a ceramic company is presented. Its aim was to analyse and improve the company order fulfilment process that had been deteriorating after the introduction of a new product line that implied a new production process. Due to the change in the usual paradigm, there were several challenges that hindered customer service. The DMAIC cycle was applied. At the end of the study an improvement in the process capacity, as well as a 30% reduction in the percentage of delayed orders was achieved, amongst other improvements.

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Keywords: Order fulfilment process; DMAIC cycle; production planning and control; theory of constraints; production levelling; information management

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1. Introduction

Every single day companies are challenged to meet commitments regarding customers delivery agreed dates at the risk of losing their trust and hence their business if they fail. The introduction of a new product line in the case study company – new collections of stoneware table products - forced the introduction of new production processes with which the company was not familiarized, and the restructuring of some of the existing ones. The new product line greatly increased the number of references to produce and required the introduction of new workstations. Consequently, new operations were introduced, as well as new production route sheets (PRS) with a higher level of complexity and new raw materials with a much higher level of variety. Furthermore, the production planning process became more complex. Prior to this change, the production planning was essentially focused on the first production process, the forming process, and all the succeeding production steps flowed continuously until the shipment of the packaged product. Furthermore, although the company information system, the SAP system, was adapted to the new reality, it had not been tested and validated in the new context.

Due to the new product line, during the initial production stage, multiple problems occurred in the OF process leading to the deterioration of the company customer service. This was the main motivation to the development of this project that intends to identify the main problems occurring in the order fulfilment (OF) process due to the change of the production processes and to solve them to increase the customer service to an adequate level. Specifically, we seek to improve the efficiency of the process, while at the same time to reorganize the production planning process and provide reliable delivery dates to customers.

The project followed the DMAIC cycle and was greatly supported by data collection and measurement. The process improvement was evaluated through two main measures: the process capacity, following the Six-Sigma approach, and the percentage of late orders. The Six-Sigma approach (6σ) is usually used to improve the efficiency and effectiveness of processes by increasing their productivity, reducing costs and improving quality, following the DMAIC (Define, Measure, Analyse, Improve and Control) improvement methodology [1] that seeks to find and reduce processes variation [2]. During the project two main improvement alternatives were identified: the improvement of the short-term production planning and control (PPC) process, related with the definition of a production schedule that determines the sequence, dimension and delivery dates to a set of production lots, resulting in an efficient use of the available resources [3]; and the improvement of the quality of the data used to support the PPC and OF processes. The PPC process was tackled through the Theory of Constraints that is an operation management philosophy focused on the identification of capacity constraints along the value stream chain, and execution of the required changes to remove them [4], [5]. This philosophy uses the Drum-Buffer-Rope methodology to support the short-term PPC [1], [4], [5], [6]. In our case study, the production levelling concept was embedded within the Drum-Buffer-Rope methodology, materialised through a heijunka box. The production levelling is a lean manufacturing practice that levels the mix and volume of production over a fixed period of time [7] aiming to avoid fluctuations in a production schedule [8] while the heijunka box is a visual management tool used to operationalise the production levelling by distributing a set of kanbans within a facility at fixed intervals [7]. The quality of the information used during the PPC greatly impacts its quality. Factors such as the resources to perform each operation, technical data such as the production route sheets, processing times and setup times, among others, are of great importance [1]. Moreover, Courtois et al. [9] argue that the PPC process will only be efficient if the technical data maintained in the information systems are accurate, because these technical data are the basis of the production management system. For this, it is mandatory to guarantee that these data are correct when they are created and to update them whenever changes are introduced.

Several examples of application of the Six Sigma approach to several processes and sectors are reported in the literature [10,11,12,13].

This paper is organized into four sections. In section 2 a macro view of the stoneware table products production process is outlined; section 3 is dedicated to the description of the company OF process and to the project presentation; while in section 4 the main conclusions of the project are highlighted as well as some possible future developments.

2. Production process

The company new product line offer includes three types of segments: Line products (products that must be satisfied within 48 hours and that are not subject to minimum order quantities; these products are produced in a make to stock policy whenever their level is below the minimum stock level size); Replenishment products (products produced in a make to order policy, subject to minimum order quantities and that have an order lead time equal to one month); and Customer products (customized products by request, produced in a make to order policy, with agreed due dates with customers and subject to minimum and maximum order quantities). The general process flow is presented in Figure 1.

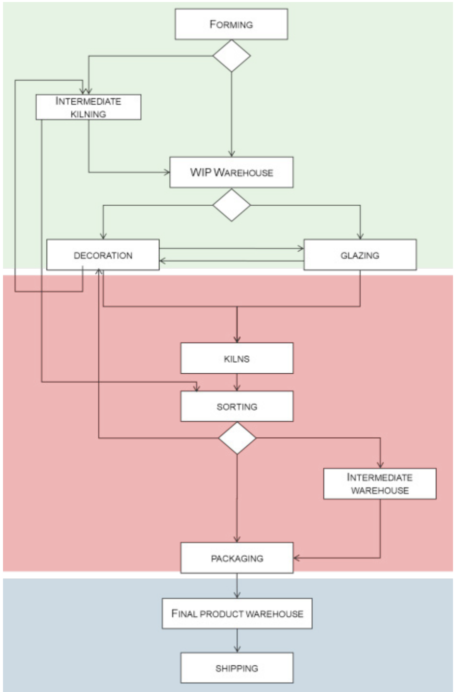

Fig. 1. New products line general process flow.

3. Order fulfilment process improvement

In this section, the study aimed at reducing the variability associated with the OF process of the case study company will be described following the five phases of the DMAIC cycle.

3.1. Phase 1 - Define

The creation of a new product line in the company portfolio leads to the introduction of several new production processes with higher complexity in comparison with the existing ones as well as to a greater variety of PRS. As a consequence, the company service level started deteriorating. Customer satisfaction is a priority for the company, so it becomes urgent to understand the main causes contributing to the problem to solve them. The OF process is briefly explained below.

The process begins with the order placing in the SAP system by the Customer Service department, which will trigger needs throughout the production process of each of the products ordered, as well as of the raw materials that compose them, whose production is planned by the logistics department. In the logistics department, the production planning function will analyse in SAP the available stock levels of the required products and will place a new order to the final product warehouse if all the required products are available in the required quantities. Otherwise, a new production order will be placed.

The production phase is organized as follows: the forming process (presented in Figure 1) is planned on a weekly basis, taking into account some rules and priorities, such as the delivery dates, customer class, PRS, products families ordered, raw materials available, and setups minimization; thereafter, the production planning function will also devise a schedule for the glazing and decoration processes aggregating the products in family batches to minimize setups;

after the glazing and/or decoration, the products are cooked according to the order in which they are received from the glazing and/or decoration section; afterwards, the products are sorted and packaged, following the priorities established by the production planning function; finally, the OF process ends with the shipment of the order. Along the production process the products spend some time stored in warehouses. Moreover, all the production process, as well as the different warehouses, are managed through the SAP system.

3.2. Phase 2 - Measure

This phase started with the identification, observation and measurement of relevant data to characterize the OF process. The data were collected during November 2017 and a total number of 201 orders were analysed, of which 96 have had some kind of problem. The collected data was then organised in generalist types of problems, presented in Table 1. It is quite evident that the due date delivery failure is the most expressive problem type, with a 91.7% representativeness in the OF process problems.

Table 1. Types of problems associated with the order fulfilment process.

PROBLEM TYPE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY
Due date delivery failure	88	91,7%
Wrong product	4	4,2%
Defective product	2	2,1%
Damaged product	2	2,1%
TOTAL NUMBER OF ORDERS WITH PROBLEMS	96	100%

Furthermore, the process capacity was measured through the calculation of the number of Defects Per Million Opportunities (DPMO), followed by the determination of the correspondent sigma level. The variables considered for the DPMO calculation can be observed in Table 2.

Table 2. Variables used in the DPMO calculation.

Number of defects	Number of late orders
Number of defects opportunities per unit	Number of alternative problem types that may occur during the order fulfilment process
Number of units	Number of orders during November 2017

DPMO = (Nº of defects ×1 000 000)/(Nº of defects opportunities per unit ×Nº of units)

$DPMO = \frac{88\times 1\ 000\ 000}{4\times 201} = 109452{,}7\ DPMO$, corresponding to a Sigma level of the OF process of approximately 2,73.

3.3. Phase 3 - Analyse

During the analyse phase the aim was to gain the deepest knowledge about the problems identified in the previous phase, and to ascertain the root causes. The analysis was focused on the most relevant problem identified previously, i.e., in the due date delivery failure. Firstly, an analysis was made to identify the most critical collections to the due date delivery failure, to investigate the type of relationship between the products families and the constraints experienced in the workplace, i.e. to identify possible system constraints (or bottleneck resources). The results are presented in Figure 2. The collections represented in green are the ones that according to the PRS are processed in the decoration cell. The remaining ones are represented in blue. It can be observed that about 50% of the delays are due to collection A, that represents 11.7% of the total number of units ordered during November 2017. However, the remaining 50% is mostly associated with the collections represented in green, having a representativeness of about 18% in the total number of units ordered during November 2017.

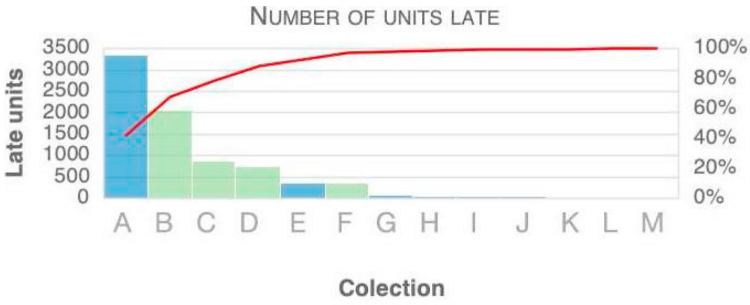

Fig. 2. Pareto diagram for the final product units late during November 2017.

According to Courtois et al. [9], two possible ways to identify a bottleneck resource are: the existence of systematic delays in the delivery of the products manufactured in that resource and a high stock level upstream of the resource. So, possibly the decoration cell is a bottleneck. Additionally, the forming and glazing processes capacity is equal to 20 thousand parts per day while the capacity of the decoration process is approximately 1050 parts. Moreover, on average 24% of the references go through this operation meaning that a capacity of approximately 4800 parts per day would be needed in the decoration process to be aligned with the level of available capacity in the forming and glazing processes. Thus, the decoration process has a much lower cadence than the other production processes, being this another symptom of the existence of a bottleneck.

In order to analyse the root causes that contribute to the due date delivery failure, an Ishikawa Diagram was elaborated (Figure 3). To that end, several causes were identified throughout the production process, organized in six categories: environment, material, machine, manpower, method and measurement. The causes were identified during a brainstorm session with the participation of the several managers of the departments involved, namely the Industrial Engineering department, the Production Planning department, the Logistics department, and the Technology and Quality department.

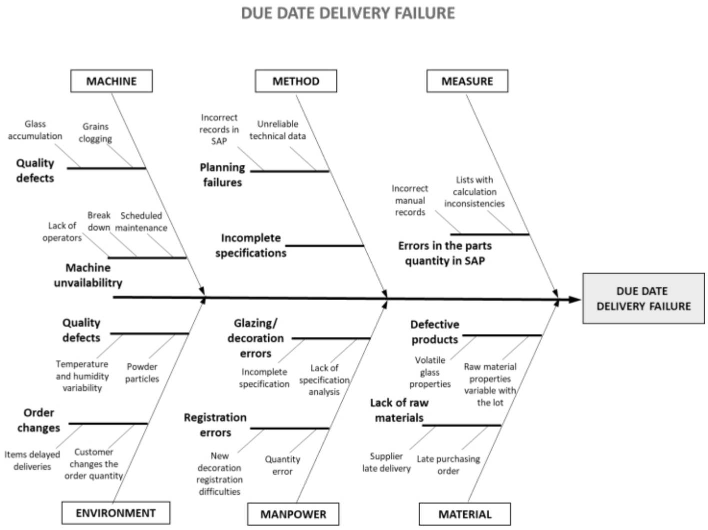

Fig. 3. Ishikawa diagram – causes for due date delivery failure.

After the analysis of the root causes, it was decided to focus the improvement in the manpower, material, method and measurement categories because they are causes most easily controllable internally. Thus, they can be more easily improved through changes in the internal procedures and the implementation of new tools. Two main streams of improvements were considered: the PPC of the decoration process, and the improvement of the information that supports the PPC in the SAP system.

The main inefficiencies identified in the decoration process were lack of planning considering a given planning horizon, non-consideration of the setup times during product exchanges, workload variation (with days with no production and days with workload excess). Regarding the information that supports the PPC, several errors were identified in the SAP system, such as unreliable technical data and records with errors, leading to unreliable planning and to errors in the stock levels. To identify the most relevant problems a survey was carried out over a period of two months. The results are outlined in Table 3.

Table 3. Survey of the error types in SAP.

Error types in SAP	Frequency
Records with errors	30
Production route sheet	18
Denomination inconsistency	10
Information omission	9
Formula error	5
Quantity	1

3.4. Phase 4 - Improve

The improve phase was focused on the enhancement of the problems identified previously. Thus, to standardise and organise the codification of the new and existent products in SAP, a set of new rules were created. 632 new codes were created, from which 41 correspond to final products and the remaining ones to the intermediate products integrating them. Amongst the several advantages of this improvement, the following ones can be emphasized: reduction in the number of errors during the glazing operation, increase in the visibility of the need to perform the changeover of glasses, the scheduling of references that do not need a changeover become more intuitive, improvement of the communication amongst the several departments, reduction in the probability of errors occurrence during the production process, easiness in the information analysis and use of filters. The PRS and the technical lists information maintained in SAP were also subject to improvements. A set of 300 PRS were analysed, with a focus on the production sequence. 83.3% of the analysed PRS were considered correct. The remaining ones were rectified in the SAP system after the development of production tests to establish the most appropriate operations' sequence. The technical lists were corrected iteratively whenever an inconsistency was detected. Furthermore, to reduce the errors in the future, a new procedure for their creation was outlined. Several enhancements were also devised to the SAP requirements list sheet, to better reflect the company production system and to support the PPC, namely the inclusion of new fields in the sheet and the reformulation of other ones. Another improvement related to the information maintenance was the reduction of the number of manual records in the forms used along the production process.

To improve the PPC of the decoration process the Theory of Constraints principles [4] were put into practice. The Drum-Buffer-Rope approach was applied to the products that include the decoration operation on the production route sheet. To establish the system rhythm in the Drum, the production levelling concept was applied through the creation of a heijunka box, as seen in Figure 4. By using the production levelling concept, the aim was to diminish the production lots dimension and to increase the variety of products produced per unit of time, thus, better satisfying the customers while maintaining a smooth flow in the system [14].

Ideally, the references scheduled for each day should allow the quick creation of lots for the glazing process, achieving a higher variety of products and simultaneously guaranteeing the efficiency of the glazing process, by batching references belonging to the same family that does not require setup or have very small setup times. So, the PPC considers all the open orders and distribute them levelly along the week, guaranteeing that in the same week are produced references belonging to all the collections ordered. The schedule is visible to the operators through a heijunka box, in which each time slot corresponds to 20 minutes. 23 kanbans are programmed daily, corresponding each to 20 minutes. Moreover, the quantity per Kanban was determined through the following equation: Kanban quantity = (20 (minutes))/(Part processing time (minutes))×5 (people)×75%.

The decoration schedule is aligned with the glazing process, feeding it. So, when a given lot of a given collection is finished in the decoration it goes to a storage area from which it is moved to the glazing process. In the glazing department, this lot will be scheduled taking into consideration the expected delivery date of the decoration, when the decoration precedes the glazing process, or the customer delivery date, when the glazing precedes the decoration.

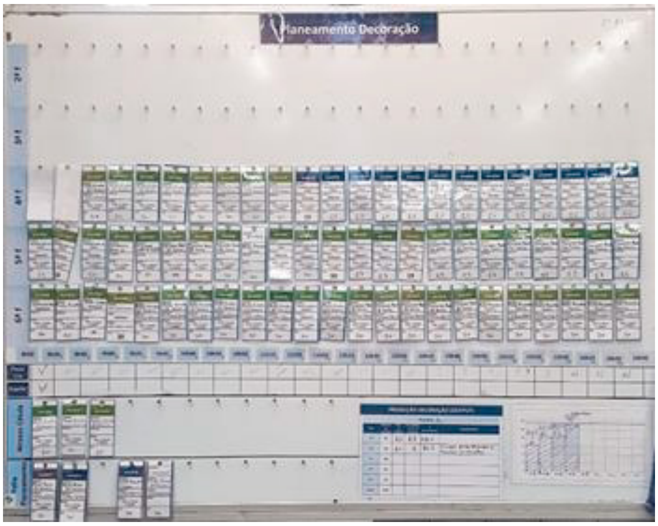

Fig. 4. Production scheduling heijunka box introduced in the decoration process.

According to Chase et al. [15] the bottleneck resource management should ensure that an upstream stock or buffer stock is maintained to guarantee the feeding of the bottleneck, and that what is produced in the bottleneck is communicated to the upstream operations to release only that amount of stock – a communication process known as rope. So, a buffer area to the raw materials planned to be produced in the near future in the decoration process was created near it. Chase et al. [15] suggest that initially about ¼ of the total system lead time should be maintained for buffering, and that this value should be adjusted over time to a smaller or higher value according to the needs. Being the total lead time of the system about four days, it was decided to consider a buffer equivalent to one working day in the decoration process. To determine the references that should constitute the buffer, an analysis of the sales of decorated products was made, considering the year 2017 and the first quarter of 2018. The results showed that about 60% of sales is due to four references. So, the buffer will be constituted by a combination of these four references, or even by only one of them, depending on the schedule. The buffer size was established assuming that only one reference will be kept in a given day (meaning that only that reference will be produced in that day) and is given by the number of parts per kanban of a given reference multiplied by the number of kanbans produced in a given day. Furthermore, this value may be adjusted according to the planned references to be produced in a given day and the corresponding quantities to be produced.

The rope mechanism of the Drum-Buffer-Rope approach is aimed to link the decoration process (bottleneck resource) with the previous one, the forming process. This is achieved through the heijunka box, that shows continuously information about the quantity and references already produced and under production. Consequently, the person responsible for the PPC of the forming process can check the kanbans and knows immediately when he/she should produce each of the references. In addition, a daily meeting is run with the attendance of the heads of each productive department to discuss the plan and results achieved.

3.5. Phase 5 - Control

In the control phase some KPIs and factors analysed in the previous phases of the DMAIC cycle will be presented to show the results achieved with the improvement of the OF process. The data was collected during March 2018. The decoration process came to work five days a week, with a better-balanced workload than previously. Moreover, initially, in 201 orders analysed, 88 did not meet the delivery date, meaning that 43,8% of orders were late. Analysing the open orders at the end of March 2018, in a similar way to the analysis made for November 2017, there were 37 late orders, in a total of 292 orders. Thus, 12,7% of the orders were late, in which only one of the collections processed in the decoration was included. To evaluate the process capacity after the improvements, the DPMO measure was calculated again, resulting in a value equal to 31678,08 defects per million opportunities, which is converted to a Sigma level equal to 3,36 (DPMO = (37×1 000 000)/(4×292)=31678,08 DPMO). Also, the majority of the delays is no longer due to the references that are processed in the decoration. Table 4 summarises the several KPIs that were analysed at the beginning and at the end of the project, allowing a quick and intuitive comparison, which confirms the improvement of the process capacity and the reduction of the incidence of the main defect (due date delivery failure).

Table 4. KPIs comparison of order fulfilment process before and after improvement.

KPI		November 2017	March 2018
DPMO		109452,7	31678,08
Sigma Level		2,73	3,36
Percentage of late orders		43,8%	12,7%
Quality of technical data	$\frac{Nº\ of\ correct\ production\ route\ sheets}{Nº\ of\ production\ route\ sheets\ analysed} \times 100$	83,3%	98,7%

4. Conclusions

This work has demonstrated the applicability of the DMAIC cycle in a different way from the traditional one. Typically, this methodology is focused on the elimination of defects, being usually related to the quality of the product. In this project it was adapted to help to diminish the order fulfilment process problems of a ceramic company, namely, to reduce their level of due date delivery failures. Through the adaptation of each phase of the methodology to the process under analysis, it was possible to achieve the goal, using the tools commonly applied in the analysis and elimination of quality defects. Despite the improvement achieved in the process capacity, there is still potential for improvements throughout the entire OF process. Having this project been associated with a new range of products of the company offers, several processes still need to be studied and standardised in order to reduce the probability of errors occurrence. Additionally, as a future improvement, it could also be interesting to develop a SMED project in the glazing and decoration processes. The reduction of the setup times will bring agility to the processes, namely through the lots dimension reduction, and consequently would allow to improve the production levelling.

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