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Improving The Order Fulfilment Process At A Metalwork Company

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Abstract

This article describes the 14 measures implemented at a company in the metalwork sector with a view to improving its order fulfilment process. Based on Lean thinking, each of the actions, as well as their potential impact on the process, is explained. Despite the constraints encountered during implementation, and the fact that manufacturing processes are invariably different, the overall results achieved were satisfactory. As a result of the interventions, internal functions were revised and processes simplified. There was also a reduction of 25% in budgeting time, as well as an improvement in communication systems and production management. One additionally was achieved the reorganization of storage spaces, a reduction in logistic operation times of about 20% and a decrease in the time spent accessing tools in near 61%. Far more important than the first results obtained is the company's current commitment to the pursuance of these measures, allowing the different actions to generate synergies and produce improvements, which will undoubtedly set the company on the course of Lean culture.

Keywords: Waste reduction; Process improvement; Lean thinking; Make-to-order production; Metalworking.

1. Introduction

Some of the current challenges relating to competitiveness in industry revolve around two axes – the globalization of the economy and technological innovation [1]. These two factors generate chains of value and global innovation [2] which, in turn, lead to what can be denominated as Globalization 4.0 [3]. In order to address this dynamic reality, companies must focus on overall improvement, as well as on the continuous adaptation of their products, services, resources and processes if they want to survive and evolve. The manner in which this is undertaken varies from company to company, in accordance with the multiple endogenous and exogenous factors involved. As such, the introduction of changes should be tailored to meet each company's requirements. Within this context, the principal objective of this study was to improve the order fulfilment process at a small metalwork company, which operates on

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a production-to-order basis. This was undertaken by resorting to Lean methodology, which constituted the company's first contact with the philosophy, and is rather different from that of traditional management [4]. The overall improvement of this process should result in improvements, which are clearly visible both to the company (reduction in waste and costs) and to the client (better quality in services and products, compliance with requirements and deadlines). This article is divided into seven sections. The first consists of the introduction; the second presents a review of the literature; the third provides an explanation of the methodologies used; the fourth comprises a brief description of the analysis of the process; the fifth section presents an account of the main problems identified; the sixth presents each of the improvement actions undertaken, and the results obtained. Finally, the seventh section consists of a discussion and presentation of the final conclusions.

2. Review of literature

A production process is a system through which products and services are created, It is composed of inputs and outputs, a flow of interrelated activities, resources and an information system [5], producing a result that ensures added value for the client [6], and which can be schematized in various ways, for instance, as a sustainable production process [7]. The term Lean was used in the 1990s to classify methodologies and systems in industrial management which were similar to those of the Toyota Production System [8]. Implemented 40 years ago by Toyota, it enabled the company to increase productivity and reduce costs through the elimination of all types of Muda (the Japanese word for waste) [9]. Toyota's good results arose the curiosity of academics and other companies in the sector [10]. Although it was initially implemented on the shop floor in the automotive industry, this methodology is now used in multiple operations in a company, ranging from product design to the purchase and distribution functions [11]. The model is also used in varied sectors of activity, and systems with different complexity levels [12]. Some of them are rather distinct service providers, for instance in the Health sector, as well as information technologies and public administration [13]. Lean thinking is governed by the principles of Value perceived by the client, value flow, continuous flow, pulled production and the pursuit of perfection [10,14]. This is achieved through the elimination of several types of waste [15,16], which current studies consider to include nine categories [17]. Lean philosophy can be divided into two levels: Strategic and Operational [18]. The first one allows for the definition of plans, based on the strategic concepts of Lean thinking identified by Liker [19]; namely, a long-term perspective and the promotion of continuous flows, Just-in-time, as well as a respect for people and their development [20]. Additional aspects include finding solutions for problems through continuous improvement (Kaizen), which should include the entire organization as well as the supply chain. Operational Lean methodology focuses on the application of tools in processes, with a view to reduce costs, times and improving quality. Of the various Lean tools, one should highlight Value Stream Mapping (VSM), 5S [21], Kanban [22], Overall Equipment Efficiency (OEE) [23], flowcharts and the Ishikawa diagram. The implementation of Lean methodology as a philosophy and as a set of techniques will allow for the achievement of synergies and efficiency in a system which will meet the client's requirements [17]. The motivations for the implementation of Lean methodology have been previously identified by some authors [24]: an increase in market share and flexibility, the need to counter internal limitations, the development of performance indicators, and to implement the best worldwide practices as a result of client or parent company's requirements. Besides this, it is essential to address a set of critical factors, which have been identified as being [25]: the involvement of senior management, sharing a vision of continuous improvement, good communication, sound leadership, a focus on people and on their training, the practicing of improvements, sufficient resources, a coherent system of performance management and closer links with clients and suppliers. Conversely, one should be conscious of the emergence of obstacles when implementing Lean methodologies [26, 27] so that these can be dealt with. The main barriers reside in the preparation of human resources for the change at hand [9, 28]. Indeed, members of senior management are sometimes not sufficiently involved, which may ensue from several factors: they might have no knowledge of this organizational model [29] or do not know how to implement and explain it; the company's hierarchy is not involved entirely; they are unaware of the benefits to be derived from this model, or do not know how to quantify them; there is a resistance to change. In addition to these barriers, others of a financial and operational nature are raised; namely, the high costs of implementation and a reluctance to reduce inventories. It is thus also important to carry out a prior evaluation of the level of implementation of Lean methodology already in existence in each organization [30, 31], so that one might devise a well-structured plan for the use of this method [32]. One has found evidence of the real benefits of the application of Lean principles in several examples. In the case of a company which assembles aircraft components, there was a real reduction of 20% in production time, and a potential decrease of 67% through automation [33]. At a cork-stopper manufacturer, it was possible to reduce downtime for tool changes by approximately 43% [9]

through the use of Lean tools, namely SMED (Single Minute Exchange of Die). An electronic components factory improved the productivity of its assembly line by 10% by means of VSM and Lean Line Design (LLD) [34].

3. Methodology

The methodology used in this study consisted of investigation-action: one integrated both theory and action, combined scientific knowledge with the organizational knowledge already in existence, and addressed problems together with staff at the company [35]. The first phase consisted of an empirical approach, both with regard to the company as well as to the context of the process one intended to study. One then proceeded with a review of related literature and subsequently, through the use of Lean tools, mapped the process, and collected and analyzed data. This allowed for the detection of problems, as well as the selection of the most efficient actions required to enhance the process. With the support of the PDCA methodology, one proceeded with the second phase of action. This comprised implementing actions, monitoring the results achieved, adjusting the measures and actions undertaken, carrying out a final assessment of the state of implementation, and producing suggestions for future studies.

4. Analysis of the order fulfilment process and main problems detected

This process was selected due to the fact that it includes sub-processes which are relevant to the levelling of the order book - such as the quotation process and preparation of work - in the context of a make-to-order company. This ensues from the diversity inherent to the type of production involved and its subsequent production sequence. Figure 1 presents a simplified diagram of the process which was initially in place.

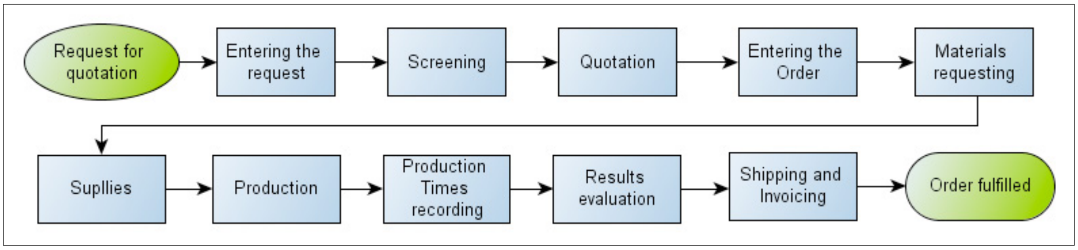

Fig. 1. Summary of the initial order fulfilment process.

A detailed study of the process was undertaken by means of various Lean tools, namely: flowcharts; the mapping of a specific order through an analysis of the Value flow; and an analysis of the creation of value by studying the production times recorded. From the several identified problems, Table 1 presents those which were considered to be a priority. These were thus subjected to improvement actions in order to proceed with their elimination or the reduction of their impact on the performance of the process.

Table 1. Main problems detected.

Main problems	Process Resources						Subprocesses								
	Organization	People	Production Equip.	Logistics Equip.	Layout	Information Systems	Business	Preparation of work	Supplies	Planning of production	Production	Production control	Shipping	Evaluation	Management of non-conformities
Undefined organization chart and functions	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓
Shortage of some middle management staff	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓
Outdated and rundown machine park			✓	✓				✓			✓				
Many machines were unused or damaged			✓	✓	✓						✓		✓		
Undefined circulation and storage areas				✓	✓				✓		✓		✓		
Materials not selected and jumbled									✓				✓		
An incomplete network of the Information system						✓		✓		✓		✓		✓	✓
Slow and limited quotation system							✓								
Delayed and deficient preparation of work								✓		✓	✓	✓			
No Production Management System						✓	✓	✓		✓	✓	✓		✓	
No Quality Management System			✓								✓				✓
Slow and faulty Time Recording						✓						✓			
Badly managed tools and consumable materials	✓							✓	✓		✓				

5. Improvement proposals

Table 2 presents a set of actions chosen for implementation at the company in order to generate the improvement of process components. These measures possess rather different features – some are more strategic and organizational, while others are of a more operational nature and are associated with screening and intervention in the company's resources.

Table 2. Objectives of actions and their impact on the process.

Order fulfilment process		Process Resources						Subprocesses								
Improvement actions	Objectives	Organization	People	Production Equip.	Logistics Equip.	Layout	Information Systems	Business	Preparation of work	Supplies	Planning of production	Production	Production control	Shipping	Evaluation	Management of non-conformities
Awareness for change	Promote continuous improvement	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓
Organization chart	Define tasks and responsibilities	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓
Process Redefinition	Simplify, reduce times and streamline tasks	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓
Improvement of Quotation spreadsheet	Optimize and reduce times							✓							✓	
Planning and control of production	Reduce production times, promote pull and visual management						✓	✓	✓		✓		✓		✓	
Definition of Key performance indicators	Timely monitoring of performance			✓				✓		✓	✓	✓	✓		✓	✓
Internal data network	Improve communication and streamline processes	✓					✓		✓			✓				
Quality management system	Reduce errors and costs, meet quality requirements	✓	✓									✓				✓
Identification tags	Reduce times, errors and defects				✓					✓				✓		
Improvement of storage	Reduce movements, times and improve safety				✓	✓				✓				✓		
Improvement of material handling	Reduce process times and minimize risks				✓	✓				✓		✓		✓		
Implementation of 5S	Eliminate unnecessary equipment and materials; rationalize resources	✓		✓		✓				✓		✓				
Improvement of tool management	Improve control, reduce times and costs						✓		✓	✓	✓	✓				
One operator-two machines cell	Optimize resources and increase productivity		✓									✓				

5.1. Awareness of the need for changes

In order to promote the involvement of company staff in the improvement actions, target groups and different approaches were defined by considering the Lean culture, structure and knowledge already in place at the company. In group 1 (management), one opted for conversations on the shop floor concerning observed waste, possible solutions and the viability of the implementation proposed. In the case of group 2, one drew up a questionnaire for the technical staff relating to their tasks, the problems and waste detection, possible solutions and the promotion of Lean concepts. For group 3, one drafted a questionnaire, which was directed at the operators and related to the tasks executed, the detection of problems and waste, as well as possible solutions.

5.2. Organization chart

The company must have a well-structured team, with someone who is responsible for each of the functions, and where each worker is aware of his/her tasks, responsibilities and duties. An organization chart was determined and proposed, together with a handbook which contains a description of tasks and internal procedures. On drafting this organization chart, one was able to detect a shortage of human resources at the middle management level.

5.3. Process redefinition

A flowchart representation allowed for the identification of gaps and problems in the current state of both the process and sub-processes. New flowcharts were subsequently drawn up to represent the future state of the processes in question, combining the processes with the operation areas.

5.4. Budgeting spreadsheet

Subsequently, a new quotation spreadsheet was drawn up. The one already in existence proved to be inadequate and slowed down the process itself, as well as the quotations for more complex orders. Between February 2017 and February 2018, this spreadsheet was gradually tweaked so that significant improvements were achieved, with a decrease of approximately 692 hours per year in quotation time. On average, the quotation process was reduced from 2,65 to 1,98 hours per item, which corresponds to a 25% reduction in the time required for this process.

5.5. System for the planning and control of production

Since the company did not possess a production management program, there were significant problems in the management of production and the recording of times. The solution proposed was to devise a spreadsheet which would incorporate the registration of Production Orders (PO) as well as production times. The new sheet draws on some Lean concepts, such as: Poka-Yoke (which prevents filling invalid data in empty fields); Yamazumi charts to analyze the performance of machines and staff; visual information of the Andon type, which presents the ongoing PO in colour, as well as finished and overdue products; a panel showing the evolution of some indicators; graphs to visualize Value-adding times and Waste; and the determination of Takt-time for each PO. Although the solution was rather limited, the benefits obtained thereby were considerable. Firstly, one was able to obtain more reliable information regarding the performance of resources, as well as their current and future use. Documents were also issued more quickly, and timely support was provided in the decision-making processes relating to the order book, overtime or subcontracts, the analysis of value generated, as well as the examination of results and deviations in each PO.

5.6. Definition of the Key Performance Indicators (KPI)

In order to monitor the evolution of the order fulfilment process performance, one proposed ten KPI which are associated to sub-processes, such as: Quotations (average time needed to respond to quotation requests and the response rate); preparation of Work (average time between the opening of the work file and the start of production, ratio of hours used for preparation and programming); Supplies (ratio of hours to await supplies); Production (efficiency ratios for workers and machines, ratio of value-adding hours, ratio of hours used for the resolution of non-conformities); and the Recording of times (ratio of hours spent on errors).

5.7. Reorganization of the computer network

A problem was detected in the communication of data from the Work planned to the Numerical Control machinery (CNC). This resulted from the fact that the computers on the shop floor and machines were not linked to the same network. The data was transmitted by means of a pen-drive or by transporting a portable computer to each of the machines individually. This method was slow and potentiated mistakes and loss of data. The solution lay in connecting all the equipment to the company's network and to the CNC machines by using a server, which simultaneously transmits the CAM (Computer Aided Manufacturing) programs to various machines, thus centralizing the data on one single directory. The improvements achieved have led to faster preparation and transmission of data, thus speeding up the start of production. In addition, there was no longer a need for workers and computers to move between machines, and there were also fewer breakdowns and loss of data.

5.8. Quality management system

The company is still not in possession of a Quality Management System (QMS). As such, improvement in this area was imperative, given the clients' strict requirements regarding quality control and traceability. The improvement basically consisted of the creation of a Record of non-conformities and the treatment thereof. One also devised a dimensional control Record, as well as a Record of material certificates. The main advantage of these tools is that they will provide the company with the tools required to respond to the clients' demands regarding dimensional control and the traceability of materials.

5.9. Identification tags

The identification tag created allows for the identification of all types of materials at the company. In this way, time will not be wasted in locating materials; their identification is thus facilitated, preventing errors relating to the source and destination of the materials handled.

5.10. Storage conditions

Several problems were detected regarding the storage of materials. Positioned against a wall, the rack is rather difficult to reach; an excessive amount of material was also placed at the top, which could present a risk hazard; materials were stored randomly; materials placed in the middle of the rack were difficult to handle; access to the rack was restricted by the existence of a saw on one side and a gate on the other; badly packaged material occupied a corridor used by vehicles. It was proposed to eliminate this rack and replacing it with a cantilever rack system, which was positioned next to another wall, as can be observed in Figure 2. The next step was to implement 5S methodology when placing material on the new rack, separating scrap and organizing the material needed in groups. This solution allowed for easier access to materials, and increased the area of vertical storage from 25m^2 to 38m^2, thus providing more space for production.

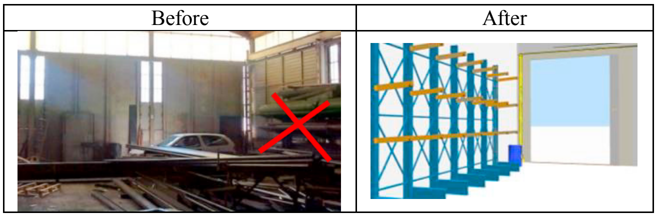

Fig. 2. Storage solution proposal.

5.11. Internal transport

Intervention in this area targeted the welding area where the movement of materials presented several problems. One observed that there was only one overhead crane and no runway for the circular stacker. It was estimated that six workers would spend 2.070 hours per year on material transport. The solution proposed for the problem consisted of defining runways for the stacker, as can be observed in Figure 3. One also established a location for the storage of the machinery used to move cargo. These measures are expected to produce a 20% reduction in the time spent on transport.

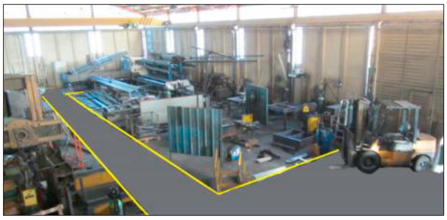

Fig. 3. Proposal for the location of one of the runways.

5.12. Implementation of 5S

The 5S methodology was implemented in the company's machine park. A considerable quantity of this equipment is seldom or never used, which can be observed in Table 3.

Table 3. Implementation of 5S in the machine park.

Stages	Description
1stS Sort	Of the thirteen machines which are rarely used, eight of them can be dispensed. This measure will free up an area of approximately 35 m^2, thus reducing maintenance costs and possibly generating a financial return if this equipment is sold.
2ndS Straighten	This consists of redefining the layout of the production area after the machines are removed, with a suitable use attributed to the space now available.
3rdS Shine	Undertake cleaning and general repair of the machines to be kept for use.
4thS Sustain	Establishing cleaning procedures and minor maintenance activities for each machine. Every operator must assume responsibility for the state of each machine operated.
5thS Discipline	Consolidation of these routines by each operator at his/her workstation.

5.13. Tool management

Given the considerable cost of tools, their management process should be revised for three reasons – the use of tools must be controlled and rationalized; allow them to be allocated to cost centres; a faster provision of tools to the operators must be ensured. Due to the various problems observed, it was estimated that an operator spends 272 hours/year to obtain tools. Future measures must consider making someone responsible for tool supplies and defining the procedures for the management of this process. The implementation of the 5S methodology will address issues such as: the elimination of unused tools and organization of space; creation of an inventory of existing items; a computerized record of tool movements; definition of tools to remain at each station and those which will be kept by the tool supplier. Besides the impact on tool consumption produced by these measures, one estimates that there will be a reduction of 166 hours/year in the time each operator will need to obtain tools. Namely, since some of the tools will already be in the worker's possession, he/she will make fewer trips to the tool warehouse, thus minimizing the time spent on this activity. This will allow for a reduction in time of approximately 61% when compared to the current situation.

5.14. A cell consisting of one operator and two machines

It was concluded that in 2017, the FM1 milling machine operated for 1183 hours, whereas a similar machine (FM2) was practically inactive because there was no operator. Since these machines do not require human intervention during the relatively long periods of the metal grinding and trimming processes, one proposed allotting two machines to each operator. By changing the layout of machines, and selecting a motivated worker who would be able to operate both machines, the hours of machine activity can be levelled out. As such, one could point to a reduction in the working hours for each machine of approximately 10% (from 1183 h to 1065 h/machine) due to the increase in setup times. It is expected that the adoption of this cell solution will allow for an improvement in the overall number of machine occupancy hours on both machines, from 1297 hours to 2130 hours, which is translated into an increase of 65%. When compared to the previous situation of two machines and two operators, the second scenario is expected to be more cost effective, so that this type of cell could generate a profit margin which is three times higher than beforehand (from 3000 € to 9000 €/year).

6. Conclusions and suggestion for future studies

As this was the first scientific and systematic study relating to Lean-based process improvements to be undertaken at this company, the implementation of some of the actions was slower than others, due to the expected resistance to change. Even so, the improvements which were achieved produced a significant impact on the performance of the process. In this particular case, the implementation of Lean methodology led to improvements those are reflected in the management's awareness of the need for change; it also pointed to a clear demand for human resources and the simplification of processes. The methodology adopted also allowed for complex and simultaneous quotations to be drawn up in less time; there was, in fact, a 25% reduction in the time required for this task. Also enabled was the creation of a tool to control production, as well as a proposal of indicators to evaluate performance. Furthermore, the methodology promoted improvements in the logistics operations(a 20% reduction in the time required for internal transport, a larger area, and better storage conditions), reduced the time needed to find tools by 61% and, even though eight production machines were removed, it achieved an increase in production by devising the one operator-two machines cell solution. It is suggested that future action at the company should include the hiring of technicians to address the gaps in some of the company's activities. In addition, the implemented measures must be consolidated to enhance their contribution to the performance of processes and ensure that they are adopted permanently. Subsequent action should encompass the promotion of activities to improve the production process. Finally, one must highlight the importance of some factors which ought to be considered when drawing up and implementing a Lean plan. The first of these consists of an assessment of the company's capacity to assimilate certain Lean concepts or technologies which will foster improvements. An analysis must also be undertaken to determine how the company manages and transmits knowledge internally. Lastly, one should identify the informal structure of the company and its staff. These measures constitute the key to the successful implementation of future changes, which must be complemented by initiative and attitude on the part of senior management.

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