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Standardization and optimization of an automotive components production line

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Abstract

Supported by the concepts and definitions of Standard Work methodology, which underpins Lean Thinking philosophy and Kaizen, the study described in this article was developed at a company in the automotive sector, more specifically directed at a production line manufacturing components for air-conditioning systems. The main objectives were to standardize operations, decrease or eliminate the number of activities those are not generating added-value, enhance productivity and associate continuous improvement actions to the processes at hand in order to eliminate waste. After the implementation of a few simple changes - the standardization of operations, adjustments and allocations of workstations – one was able to tailor the production objectives and cycle times to the line's capacity. The productivity and efficiency of both machines and workers was also increased. Due to the elimination of waste and generation of value, from the customer's perspective, one was able to raise the OEE (Overall Equipment Effectiveness) general average by 16%, from 70% to 86%.

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Keywords: Automotive Parts; Lean Thinking; Kaizen; Standard Work; Optimization; Waste

1. Introduction

The heightened growth of globalization over the last years has clearly intensified the competitive nature of companies worldwide [1]. In this context, and in order to maintain their position in the market, industries in the

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automotive sector have sought alternative measures so as to ensure a position of prominence regarding the competition, and thus gain greater customer share [2]. Within this framework, companies have to consider greater investment in resources as a priority if they wish to enhance competitiveness in such an important business sector [3]. The factors that must be addressed include: greater capacity, innovation in procedures, quality, delivery times and qualified manpower. This set of parameters, as well as a need for rapid delivery of goods to the consumer, tends to influence the requirements of market demand [4]. In this industrial context, it is thus imperative to implement methods whose will boost available capacity, increase the daily production lines productivity, as well as contribute to the greater efficiency of machines and their operators [5]. One of the techniques which are commonly used to address these issues is Standard Work methodology, which forms the basis of the philosophies of Lean Thinking and Kaizen [6, 7]. The study described in this article was undertaken at a company focused on the production of car air-conditioning systems. The main objectives were to standardize operations, increase the number of value-adding activities, enhance productivity and associate continuous improvement actions to the processes involved so that waste can be eliminated. The study consists of five sections. The introduction of the characteristics pertaining to the automotive component sector is defined in section 1. A review of literature, presented in section 2, is related to the description of the concepts inherent to the methodologies of Standard Work, Lean Thinking, Kaizen and OEE. Section 3 deals with the methodology used in the development and application of the study. Section 4 presents the found problems, as well as the proposals for improvements and the results obtained through the implementation of the suggested plans. Finally, section 5 consists of the conclusions and describes how the study contributed favorably to operations at this automotive sector company.

2. Literature review

The expression “Lean Thinking” is described as an extension of the Toyota Production System [8]. This tool associates practices of constant improvement to the process, by eliminating waste from activities whose are considered by the customer to possess no added value [9]. In a more generalized context, the aim of implementing this methodology in the everyday companies’ activities is addressing problems in a quick and efficient manner. However, all the employees should be involved in implementing activities, exchanging information, as well as rapidly identifying problems on the line [10]. In order to support decision-making in the organizations’ production environments, some Lean-Thinking principles were created. These are based on the elimination of waste and on the definition of the “value” concept, as determined by the customer, establishing whose are the most important activities [11]. It is thus possible to organize the system so that it only manufactures what was ordered by the customer, which sidesteps the issue of great quantities of raw material in stock [1]. There is, furthermore, an awareness of the perfection concept, the search for constant improvement in the system, so that the waste that hampers the operation of lines in the productive area must be eliminated [9]. Finally, in addition to these parameters, one can include the importance of standardizing activities; to do so, the worker is required to apply the most suitable method for the execution of the operation at hand [12]. Although this concept is not new, Lean tools have been subjected to profound adaptations in order to meet the real companies’ contexts. As a result, new definitions have emerged to address environmental and ecological responsibilities, which have been included in industrial culture and thus meet the real market, as well as the values those customers consider to be a priority [13]. In this context, and in their search for the achievement of better results, many companies are incorporating Lean tools in their practices as a means to manage processes more suitably [4]. In order to do so, production systems must be evaluated during the process of continuous improvement. This is done through the use of kaizen, a philosophy which implies boosting organizational efficiency and carrying out improvements whose are quick, simple and cost effective [14]. Its purpose is to translate improvement into a benefit by identifying bottlenecks and waste in the system. The most important factors include analyzing the real impact of the change that the applications may cause on the process. These might include issues such as how to motivate workers to implement suggestions, and ways to promote new proposals for the improvement of the environment in context [15]. Another tool in the productive context is the methodology of standard work, which aims to standardize the sequence and execution of activities at each workstation. This ensures that procedures are carried out in the same way, regardless of the employee involved [6]. However, before this can be undertaken, the line must be balanced: operations at each workstation must be distributed to ensure balanced times of availability and smooth productive flow, thus meeting required demand [16].

Standard work is considered to constitute one of the most important aspects of Lean Thinking; it is for this reason that both methodologies have been used very frequently in the area of automotive component manufacture. This sector has gained increasing prominence on the market due to the high quality of its products, which constitute the result of process standardization and applications to ensure continuous improvement [7]. Lastly, and in order to measure the real parameters of the productive environment, Overall Equipment Effectiveness (OEE) was created to identify the real root of the problems. This is applied to each situation where loss or waste is detected, whether related to machines, people or equipment [17]. In order to calculate OEE, one must identify the three main aspects of efficiency that this indicator refers to, through the sum product of availability, performance and quality: availability encompasses equipment operation time; performance relates to the speed of production or the productive rate; and quality indicates the percentage of defective components in total production [18]. Thus, if one is to achieve optimal OEE, the index must reach attain an average value of at least 86%. This concept can aid in the definition of the real available capacity to meet consumer demand [19].

3. Methodology

This study adopted a methodology which was divided into five main stages. In the first stage, one collected information from scientific articles and books published, which pertain to the issues included in the study. A coherent review of literature dealing with analysis tools was thus assembled with the purpose of supporting empirical investigation. The second stage was initiated by means of observation, as well as the mapping of the productive process and definition of the current production objectives. After obtaining an understanding about the system, one then proceeded with the third stage, where one identified the critical points, waste and the difficulties experienced in implementing the Lean Thinking tool. It was also during this stage that one recorded the tasks executed and carried out the measurement of times for each workstation so that the real potential for change could be identified. In the fourth stage – the implementation of continuous improvement tools, Kaizen and Standard Work – one was able to standardize operations and cycle times, reduce waste and increase the system's productivity. Finally, in the fifth stage, and by resorting to the OEE efficiency index, one compared initial data with the data collected after the tools had been applied, aiming by this way to demonstrate the results and benefits of the implementation for the concerned company.

4. Analysis and optimisation of a productive line for the manufacture of air-conditioning tubes

The assembly line on which the study was undertaken is operated by four employees, who work on four shifts (A, B, C e D) for a 12-hour time period. The different stages in the productive process are divided amongst the workers on each shift. The production cell studied transforms raw material into the finished product, and depends directly on the previous processes: metal cutting, inserting components on the tubing top and bottom sections, and material cleaning. Since the production system depends on the placed orders, the air-conditioning tubes only arrive to the line after a customer request, which is executed by an integrated internal program used by the company. Due to a real need for inspection on this line, the process was duly analyzed, and the improvements whose had been identified by the production manager were implemented.

4.1 Processes mapping

In order to begin the application of the stages contemplated by this study, one was required to gain a good grasp of the productive environment and identify some of the process particular features. Initially, the line subjected to study had a production objective of 84 parts/hour, with a total cycle time of approximately 43 seconds when operated by four workers, reaching a weekly production of 12936 parts. One should, however, point out that these values do not represent the real context; they were basically defined by using a reference for another similar production cell and, as such, no specific study had been carried out previously. To this end, a concentrated effort was made to tailor parameters to address the real situation, thus enhancing the efficiency, productivity and capacity of the cell in question. In order to facilitate the visualization of the productive process, one set up Fig. 1 to represent the production stages, during which the raw material is transformed into the finished product.

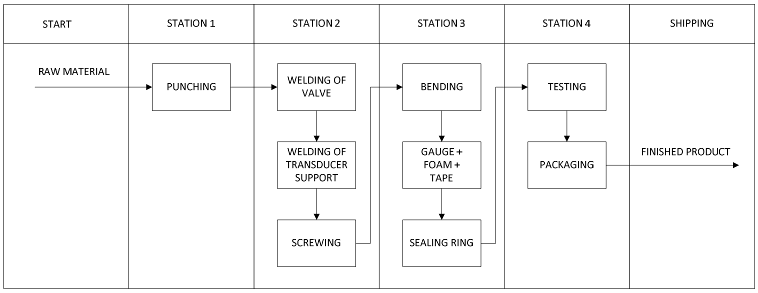

Fig 1. Flowchart of the line's productive process.

The production process is described considering raw material already supplied to the production line. The first station is responsible for the punching of the valve. The second operator welds the components and places the valve mechanism on the screwing machine. The third station then bends the tubes on the bending machine, checks the gauge of each part, places the tape and foam on the spot designated on the tube by the technical sheet, and inserts a sealing ring on the female flange. Finally, the last worker carries out a hydrogen test in the booth to check for leakage and to ensure the overall quality of the part. At the end of the process, the finished product is packaged and shipped to the customer in accordance with the request previously placed.

4.2 Problems Identification/opportunities for improvement

Based on the process analysis presented in Fig. 1, one was able to identify the main difficulties observed during the production flow. This was undertaken through observation and interviews with the workers. Table 1 presents a detailed description of the detected problems on the studied assembly line. It is important to point out that the initially established production objective was higher than the line's available capacity and customer demand, which was only about 9 000 parts per week. After undertaking a survey of the main problems, one proceeded with intervention on the production cell with the purpose of enhancing the system. This involved evaluating which resources were required, standardizing operations and adjusting production flow between workstations. The objective was to reevaluate process times so that activities could be divided in a balanced and uniform manner, thus meeting the objective and addressing customer demands.

Table 1. Description of problems identified.

Problems	Description
Excessive movement	Lack of standardization in operations over the four shifts.
Line balancing	Workstations were not balanced, different times.
Low efficiency	Low efficiency, since the currently established objective is not reached (approximately 70%).
Lack of capacity	Incapable of meeting the current objective.
Demand and Objective	Failure to match the established objective with customer demand.
Displacements	Long and unnecessary distances covered between workstations
Non-cyclical operations	Non-cyclical activities such as line output, supply to the workstation and displacements between stations were not considered when defining the initial objective.
Bottleneck station	Excessively long times required to bend each tube, about 90 seconds.
Gauge + Tape + Foam	The worker must always consult the technical sheet for each part before placing the tape and foam.

4.3 Proposed solution and analysis of results obtained

When the problems had been identified, one was then able to present possible opportunities for improvement, which would increase the productivity and efficiency of the production system being analyzed. Table 2 presents a detailed description of the main suggestions of implementation for the air-conditioning line of a company in the automotive sector.

Table 2. Description of opportunities for improvement.

Problems	Improvement Opportunity
Excessive movement	Standardize operations over the four shifts by using standard work methodology.
Line balancing	Redistribute operations and balance times for each workstation.
Low efficiency	Adjust the objectives and operation times to match the line's actual reality.
Lack of capacity	Calculate capacity in accordance with the line's new real objective.
Demand and Objective	Define an objective to meet customer demand, taking the line's available capacity into account.
Displacements	Bring stations closer and improve the reorganization of activities.
Non-cyclical operations	Consider non-cyclical activities such as line output, supply to the station and displacements between stations.
Bottleneck station	Reallocate another bending machine to speed up times on the line's critical station.
Gauge + Tape + Foam	Mark the verification gauge on the bends where the tape and foam will be inserted to comply with the technical sheet, thus making the operator's checking activity easier.

From the description of the improvement opportunities identified, one drew up Table 3 with a definition of the standard work required for each workstation in the process. This tool was chosen because it helps to reduce the difference in each work shift's operation times. It also contributes to the standardization of methods relating to how parts are inserted, positioned and removed from each machine. This ensures quality and establishes the most suitable sequence in the process, from the initial raw material supply stage to the line where its transformation into a finished product occurs, being then shipped to the end customer. The work methods described in Table 3 considered operations individually. However, during the cycle, the activities were interconnected so that the operator did not have to wait for the machine. This definition made it easier to analyze each workstation so as to better describe the process during the production flow.

In order to analyze the results initially obtained, Table 4 presents a comparison of the times spent for each operation regarding previous situation and after standard work was implemented. The longest time periods for each operation measured on the four work shifts (A, B, C e D), were used as a basis of comparison for the first analysis (previous). The new times were subsequently measured in the second analysis, after standard work was implemented to the activities executed at each work station (after). As can be observed on Table 4, the number of operations remained the same. Yet, in order to analyze the context before and after the application of standard work, one had to consider displacement and supply to the line. This allowed for the calculation of production objectives and process cycle times. In the first analysis, time was defined by using another production cell as a reference, without considering the real context of the system. However, after the operation times were collected, and before any improvements were implemented, the time for the real cycle - representing bottleneck between operations – was observed at station 3 with a total of 64,5 seconds and not 43 seconds (as referred in section 4.1). During the second analysis, cycle time was set at 60 seconds, which represents station 2 with the highest sum for operation times. The difference between the two analyses is that four workers were initially required to carry out operations. After planning, only 3 workers are now necessary to divide activities across the stations. Finally, after defining the standard methods for each station and introducing a second bending machine, one established that the new time was set at 153,8 seconds. There is, thus, a difference of 45,3 seconds when compared to the total time measured in the first analysis.

Table 3. Description of the standard work method for each operation.

Workstation	Standard Work Method Defined
Punching	Take the tube from the box, position it on the gripping devices above and below. Close the clamp in the first tower. Execute the activities of punching, boring and attaching the transducer support. Keep pressing the start button during this process and lower the stopper knob for each of the three operations. Release the clamp in the first tower and simultaneously close the second one. Repeat the process to place the valve. Open the clamp in the second tower. Remove the tube. Check the perpendicularity of the components and place the tube on the rail.
Welding of Valve	Remove the tube from the rail. Place it on the gripping device. Place the valve perpendicularly, lower the welding guide and press the start button to begin the cycle. After completing the required welding time, raise the welding guide. Remove the tube. Check welding quality and place the tube on the rail.
Welding of Transducer Support	Remove the tube from the rail. Press the gripping device. Put the transducer holder at a perpendicular angle, lower the welding guide and press the start button to begin the cycle. After completing the required welding time, raise the welding guide. Remove the tube. Check welding quality and place the tube on the rail.
Screwing	Remove the tube from the rail. Press the gripping device on the screwing machine. Wait for valve lubrication cycle. Take the shell from the case and put it on the clamping device. Wait for the machine to screw the tube on the valve. Remove the tube from the gripping device. Check that the shell is in the right place and put the tube on the rail.
Bending	Remove the tube from the rail. Place it horizontally on the bending machine. Press the button so that the clamp on the machine grips the tube. Press the start button for the machine to begin the cycle. After the tube has been bent, press the button to release the clamp holding the tube. Remove the tube from the machine and place it on the verification gauge.
Gauge + Tape + Foam	Once the tube has been fitted on the gauge towers and the ends closed, remove the transducer from the box, lubricate it and screw it on the transducer holder, aligning the component at a 90-degree angle. Simultaneously, move the valve toggles and transducer to check geometry. Take the foam and insert it on the spot which has now been marked directly on the gauge. Take a strip of tape and set one end on the second spot marked by the gauge. Remove the tube and finish placing the tape.
Sealing Ring	Fit the male flange of the tube on the tip holding the sealing rings. Check the tube diameter and pull the ring up to the groove at the end of the tube.
Testing	Remove the tube from the rail. Place it on the transducer gripping device. Tighten it to torque with the wrench. Fit the tube in the test table towers. Close the two ends of the guiding devices. Close the clamps on the valve, transducer and foam, respectively. Press the start button for the machine to begin the cycle. After completing the test, simultaneously release the clamps on the valve and foam. Release the clamp on the transducer. Remove the tubes from the guides and table tower to proceed with packaging.
Packaging	Take the tube and the first plug, check the fitting on the end of the male flange and insert the plug. Take the second plug and thread it onto the valve. Take the third plug, check the second fitting on the end of the female flange and insert the plug. Remove the label for the tube from the printer and stick it onto the tube, on the right side of the valve. Place the finished and checked tube in the container for shipping.

After implementing the improvement actions proposed by the study, one can then observe (see Table 5) a great increase in OEE in the first 14 weeks of the year 2017. This efficiency indicator considered: planned time and measured time as the basis to calculate availability; the relation between measured time and theoretical time to calculate performance; and, lastly, the quantity of parts produced and rejected to establish quality. Line stoppages were also taken into account, since the value for measured time can be obtained from the difference when comparing this to planned time. With regard to OEE percentages, the first five weeks in the year 2017 (see Table 5) represent the observations undertaken at the beginning of the study. The values were rather low due to line conditions, lack of organization and an inadequate parameters definition. The time period between weeks 6 and 9 was established as the stage when one would carry out an analysis of the suggested improvements implementation, as well as verify the performance of the productive environment. Positive results began to emerge from week 10 onwards, when OEE had already reached a percentage of over 80%. When considering the first 5 weeks, the percentage average for OEE was situated at approximately 70%. This low rate of efficiency is justified by the fact that the line was operating below real average production levels. However, during weeks 10 to 14, and after the period when improvements were implemented and workstations standardized, the average OEE efficiency increased by 16%, reaching an overall average of 86%.

Table 4. Comparison of times before and after the standard work method was applied.

Operations	Workstation	1st Analysis (Before) Longest Operation Times on Shifts A, B, C , D (Seconds)	Workstation	2nd Analysis (After) Standard Operation Times (Seconds)
Punching	1	29,3	1	25,7
Welding of Valve	1	13,6	1	10,2
Welding of Transducer Support	2	13,9	1	10,8
Screwing	2	22,4	2	16,9
Bending	3	17,8	2	10,7
Gauge + Tape + Foam	3	33,7	2	27,8
Sealing Ring	3	4,2	3	2,7
Testing	4	19,6	3	16,8
Packaging	4	18,9	3	17,2
Displacement + Supply	1	4,8 + 1,7	1	3,1 + 1,5
Displacement + Supply	2	4,8 + 1,7	2	3,1 + 1,5
Displacement + Supply	3	7,1 + 1,7	3	4,3 + 1,5
Displacement + Supply	4	2,2 + 1,7	-	0,0
Total	4	199,1	3	153,8
Cycle Time	-	64,5	-	60,0

Table 5. Analysis of the OEE efficiency indicator development.

Weeks	1st Analysis (Before)									2nd Analysis (After)				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Planned time (Seconds)	144	154	154	154	165					155	165	165	163	165
Stoppages (Seconds)	15,7	22,9	16,4	11,7	9,1					4,3	6,3	6,01	5,12	11,9
Measured Time (Seconds)	128,3	131,1	137,6	142,3	155,9					150,7	158,7	158,99	157,88	153,1
Theoretical Time (Seconds)	102,7	108,6	112,2	125,8	114,4					134,7	148,6	147,59	145,86	148,7
Rejected Quantity (Parts)	259	246	223	325	200	Analysis Period: Implementations of Improvement				170	400	185	225	180
Produced Quantity (Parts)	5270	5500	6057	5955	5510					4335	7080	7050	7112	7454
Availability (A)	89%	85%	89%	92%	94%					97%	96%	96%	97%	93%
Performance (P)	80%	83%	82%	88%	73%					89%	94%	93%	92%	97%
Quality (Q)	95%	96%	96%	95%	96%					96%	94%	97%	97%	98%
OEE (%) = A x P x Q	68%	68%	70%	77%	66%					83%	85%	87%	87%	88%
Period Average (%)			70%									86%		

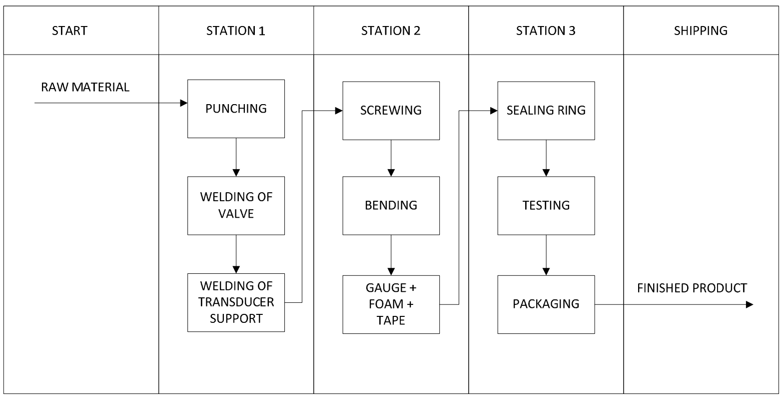

Fig. 2. New flowchart for the process.

Following the changes introduction, the new production flow was reordered, as can be seen in Fig.2. The new activities' division allowed one to improve the production system balance, reduce manpower costs, and speed up the process by acquiring a new bending machine. One also adjusted the objectives, capacity, productivity and efficiency to meet the real context of the process. Once the system was restructured to address real line requirements and customer demand, one was able to define a new production objective of 60 parts/hour, with a total cycle time of 60 seconds (see Table 4). Due to this objective, the number of workers was reduced and production is now set at 9240 parts per week. Operations are currently divided across three workstations, which has allowed for a reduction in manpower costs or the reallocation of the fourth worker to another sector in the company.

5. Conclusions

Focusing on a production line which manufactures components for car air-conditioning systems, the purpose of this study was to optimize the process through the implementation of simple improvement suggestions to hone the system's operation. In order to reach the expected results, one eliminated waste and obstacles. In addition, activities were balanced and levelled out with each other, so that workstations presented similar execution times. The variables for supply and displacement were also considered in the process analysis. The implementation of a new bending machine enabled workstation 2 to manufacture two pieces at a time (one on each machine) during production cycle time. The standardization of the operation methods resulted in a reduction in the number of workers required, from 4 to 3. It also minimized discrepancies in the time needed for activities to be executed over the different shifts. Moreover, displacements were reduced by shortening the distance between operations on the line studied and, lastly, the objectives were adjusted to the real capacity and availability of the production environment in question. By resorting to simple adjustments in the real process, this development project allowed for an OEE increase of 16% in the line's overall efficiency average. Solutions were thus found for the problems encountered on the cell: a correct distribution of line requirements was established in order to meet customer demand; waste was also minimized since there were no longer great quantities of end product stocks in the warehouse. These implementations formed the basis of a transversal application of similar adjustments to other lines at the factory. In general terms, the performance of this Lean tool demonstrated its important role in the achievement of results and contribution to the development of the system.

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