Action-research methodology to improve performance using lean production tools

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Abstract

This paper presents a five months Action-Research project developed in the context of a lean production implementation initiative in an elevators company. The project consisted in (i) analysis and diagnosis of two productive areas of the company's production system and (ii) development and implementation of improvement proposals based on lean production tools and techniques. The sectors involved were the metal-mechanic area and the final assembly of the elevators doors. Improvement proposals were developed and implemented, based on SMED, 5S, Visual Management and Standard Work. The main results achieved were the reduction of time spent on setups, work-in-process, defects and distances travelled by operators, along with the standardization of some production processes and the improvement on the production system's organization. The economic impact of these improvements was a gain of approximately 3,143.39 €/year for one sector and about 2,475.66 €/year for the other. These results reinforce the importance of the company's lean initiative.

Key words: Action-Research, Lean Production, SMED, 5S, Visual Management, Standard Work

1. Introduction

With market globalization and customers' ever-growing demand, companies must become more competitive and able to rapidly adapt to new and innovative trends. To achieve this, they need more efficient production paradigms. In this context, Lean Production appears aiming to systematically identify and eliminate all kinds of waste in a continuous improvement process. This organization model has its origin in the TPS – Toyota Production System [1] and allows the creation of value by the manufacture of quality products with minimum lead times, improving the company's flexibility and competitiveness [2-4]. [5] also add that Lean Production is evidenced as a model where people assume a role of thinkers and their involvement promotes the continuous improvement and gives companies the agility they need to face the market demands and environment changes of today and tomorrow. [6] defined five principles that underpin Lean Production: (i) create value for the customer, (ii) identify the value stream, (iii) create flow, (iv) produce only what is pulled by the customer, and (v) pursue perfection by the continuous identification and elimination of waste. When these principles are correctly applied, they can be considered as the "antidote for waste". [1] and [7] identified seven major types of waste that can occur in a production system: (i) overproduction, (ii) inventory, (iii) transportation (materials), (iv) motion (persons), (v) waiting, (vi) over-processing and (vii) defects.

In terms of practical implementation, the Lean Production paradigm provides a vast range of tools and techniques (e.g. Single-Minute Exchange of Die - SMED, 5S, Visual Management and Standard Work) that can be applied by organizations to improve their performance. The SMED methodology is a theory and a set of techniques that make possible the execution of the equipment's setup and changeover operations in less than ten minutes [8]. 5S is a tool that aims to ensure organization and cleanliness of the workspace in order to create a healthy environment and increase productivity [9]. Visual Management is a simple tool where the language used is accessible and easily understood, allowing the operators' autonomy [10] and the assistance of production processes' control, preventing errors and waste. Standard Work consists of a set of work procedures that aims to establish the best methods and work sequences for each process and for each worker [11]. Lean Production is being successfully implemented in many kinds of companies from industry and services all over the world [12-24].

The project described in this paper was developed in an elevators company, that implements lean since 2010, targeting the mechanical transformation sector and the doors' final assembly sector. The main objective for the mechanical transformation sector was the reduction of the setup time of a press machine by applying the SMED methodology, aiming the reduction of lot size, WIP and planning horizon, as well as the standardization of the setup process. For the doors' final assembly sector, the main objective was to increase productivity and flexibility by reducing wastes, involving, among other production organization aspects, the creation of work standards for the manual workstations, rotation plans for the workers and documentation of components and tools. SMED, Standard Work, 5S and Visual Management were the tools applied.

The work developed followed the Action-Research methodology and was undertaken by two researchers, Industrial Engineering master trainees, each one dedicated to one of the referred production sectors.

2. Research methodology

The project was developed using the Action-Research methodology, which is characterized by an active involvement of the investigator [25]. The Action-Research methodology has six characteristics that distinguish it from the others: future-oriented, collaborative, implies system development, generates theory based on action, independent and contextual [26]. It has an iterative five stage-cycle: (i) diagnosis, (ii) action planning, (iii) action taking, (iv) evaluation and (v) learning specification. Thus, following the first stage, the diagnosis of the current status of the production system was conducted. This involved documents' analysis, interviews to workers and managers, gemba observation (including identification of the production flow, operations on each workstation, ergonomic conditions, etc.) and procedures' video-recording. Several tools were used, namely: ABC analysis, sequence diagram, cause-effect diagram, spaghetti diagram and skills' matrix. The conducted analysis led to the identification of problems and wastes, and, evaluation of important indicators such as work-in-process (WIP), takt time, cycle time, setup time, lead time, number of defects, distances traveled by people and materials, productivity, skills of operators, among others.

In the action planning stage improvement proposals were specified, involving the application of the lean tools 5S, Standard Work and SMED. An action plan was created in order to enable the appropriate implementation of each proposal.

In the evaluation stage, the results gathered after the proposals implementations were analyzed and discussed.

Finally, the last stage, aims to identify the main lessons learnt with the project and to reflect about them.

3. Industry application

This section presents a brief characterization of the company, emphasizing the two productive sectors involved in the project. Then, it describes the project developed according the Action-Research methodology (section 2). The company manufactures and assembles standard or customized elevators (approx. 800 elevators/year) and employs 375 workers. An elevator is a complex product composed by more than 10,000 components. The production area occupies two buildings and comprises nine productive sectors (P01, P02, P03, P04.1,

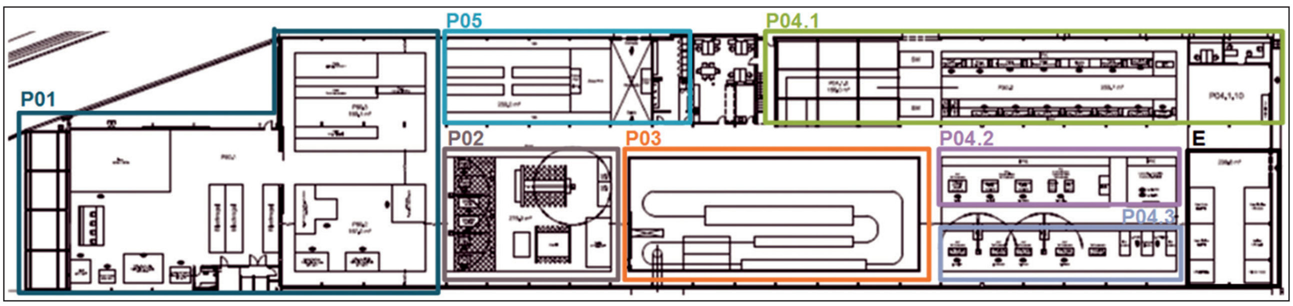


Figure 1. Company layout of building 2

P04.2 and P05 on building 2, and, P04.3, P04.4 and P06 on building 1). After a first lean implementation conducted on building 1, the company has decided to proceed to the sectors of building 2. This paper refers only to the work developed in building 2, whose layout is represented in Figure 1.

The sectors selected by the company for this project were the mechanical transformation sector (P01), due to the machines' high setup times, and the doors assembly sector (P04.1) due to the high irregularity of the operations. The first sector is critical because it supplies components for all the other sectors.

3.1. Diagnosis

3.1.1. Mechanical transformation sector

The mechanical transformation sector of the company occupies about 1/3 of the total shop floor area. It has 24 workers and 14 machines, responsible for multiple processes such as cutting, punching and bending. Figure 2 shows the layout of this sector and the materials flow in a spaghetti chart.

A detailed study of setup processes was conducted on three machines: press machine, punching machine and bending machine, as they presented the higher setup time, but, due to space limitations, only one case will be described. The mechanical press machine (dashed red circle in Figure 2) was chosen because almost all material it supplies goes to the doors assembly sector. The press machine produces small parts and, depending on the type of part, involves different processes (cutting, drilling, stamping and bending). It works one shift, with a single operator, and stays inactive during the second shift. The utilized dies, in a total of 84, are located in nearby shelves and the operator uses a car with a platform to carry them. To select the setup process to be analysed, an ABC analysis was performed. The chosen product was the second in the rank, representing 7% of the company's production, because: (i) it is more complex than the first product in the rank (requires three setups of the press machine) and (ii) it is produced more frequently (smaller lots – 800 units). The average setup time was 22 minutes, ranging from 19 to more than 24 minutes.

The production process of this product starts in this sector and ends in the doors assembly sector (Figure 3).

After the process analysis, following the 5M (Man, Machine, Method, Management and Measurement) technique it was possible to identify some problems and implicit wastes that affected the process quality and efficiency (Table 1).

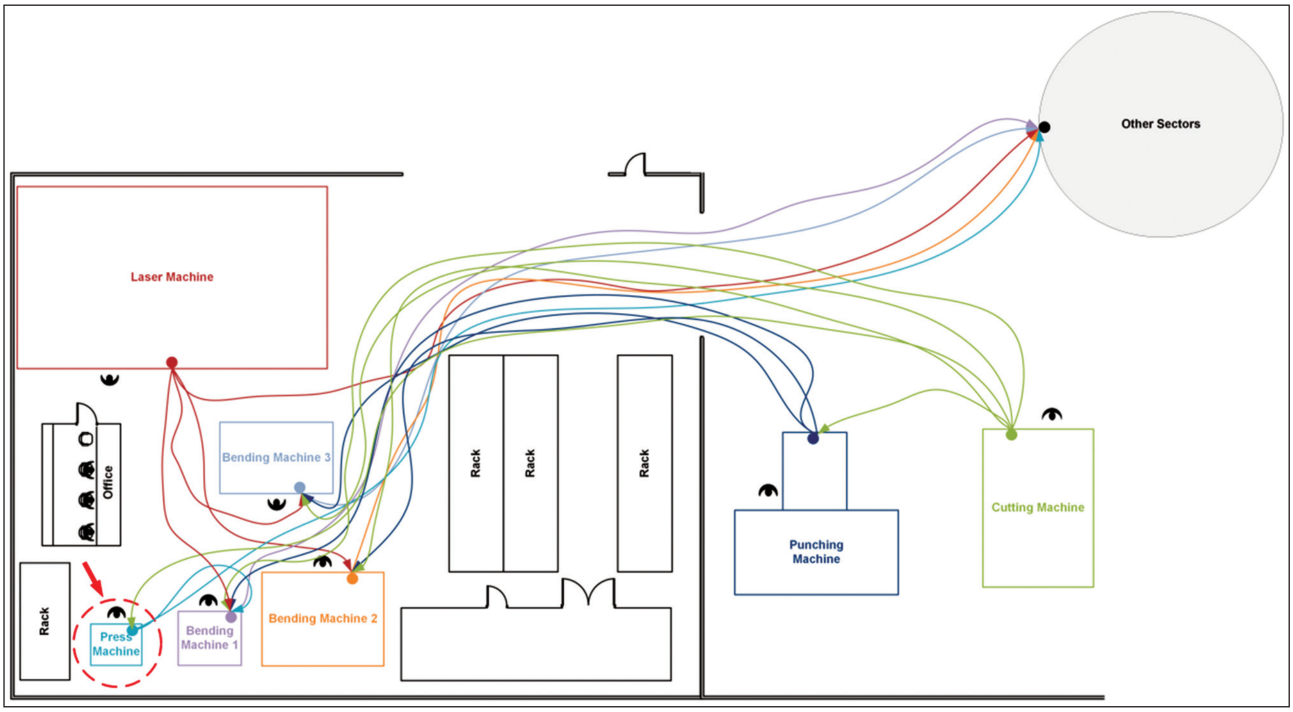


Figure 2. Layout and materials flow of mechanical transformation sector

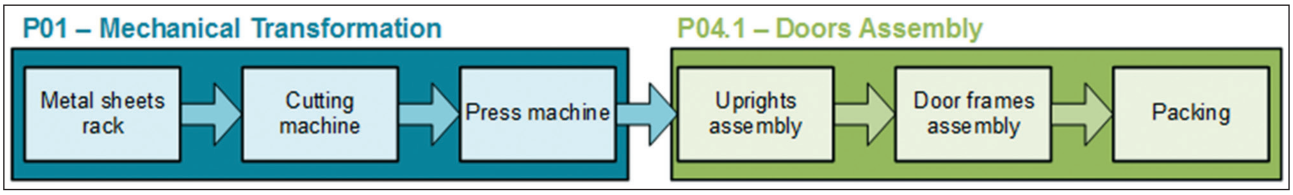


Figure 3. Production process of the selected product

3.1.2. Doors assembly sector

The doors assembly sector receives products not only from the mechanical transformation sector, as already referred, but also from welding and painting sectors, and has 19 workers distributed along 11 manual assembly workstations. A previous tentative of lean implementation was made (some signs are visible) but some practices were not closely adhered to.

This sector assembles two types of doors: landing doors and cabin doors. Each type could have different models and each model different variants. Every model could be produced with different dimensions and particular features. During the design stage, the client may customize the doors' dimensions and opening type. The landing doors are produced in a higher number than the cabin doors (each set has only one cabin door and as many landing doors as the number of floors). The landing door also demands more different subassemblies (5) and components (334) than the cabin door (4 subassemblies and 266 components), including the component selected for analysis in the mechanical transformation sector. So, and due to the space limitations, this paper will diagnose the production process of landing doors (layout and materials flow are represented in Figure 4).

The necessary components come mainly from P0.1 sector (mechanical transformation) or from the central warehouse, and are stored in a supermarket (Figure 4) with a two-bin system. The supply of components to the workstations is carried out by one worker, using small cars.

Production planning is prepared by the respective department that send the orders to each sector.

Table 1. Problems and wastes (mechanical transformation sector)

5M	Problem	Consequence
Men	Lack of knowledge about the setup concept	Incorrect registration of setup times Affects the production planning and control
Machine	High setup time	High quantity of WIP and reduced flexibility High downtime of machines
Method	Large number of movements during the setup	Increased setup time Long distances travelled by the operator
	Long distance travelled to access setup tools	High quantity of movements and transportations
	Long distance travelled to access the car for parts	Time wasted on accessing the car
	The dies' parameters are not recorded in the machine	Time wasted on manual input of the parameters Significant increase in setup time
Management	Setup tools cabinet disorganized	Time wasted on searching for tools
	Lack of space to store dies	To access some dies, other dies must be moved
	Dies cabinet disorganized and positions unidentified	Time wasted on searching for dies
	Some dies have old identification codes and most codes are not placed in a visible location	Time wasted on searching for the die code
	Lack of space to maneuver the transportation car	Time wasted on moving pallets of products
	Setup parameters not identified on dies	Time wasted whenever a new die is loaded
Measurement	Lack of a standardized setup processes	High fluctuations in setup times

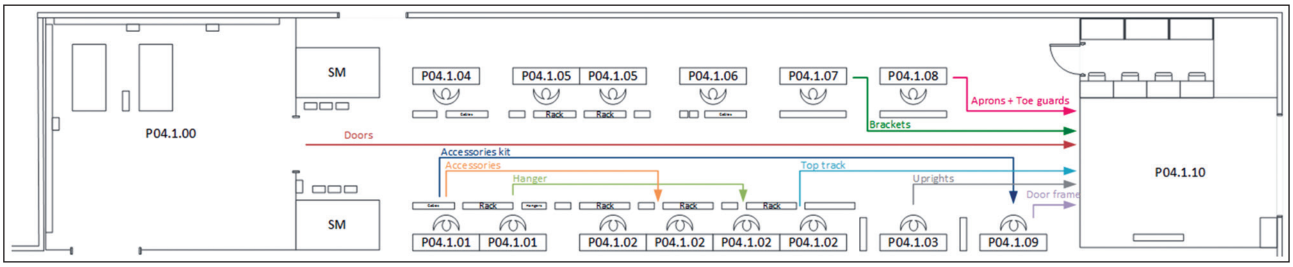


Figure 4. Layout and flow of materials of the doors assembly sector

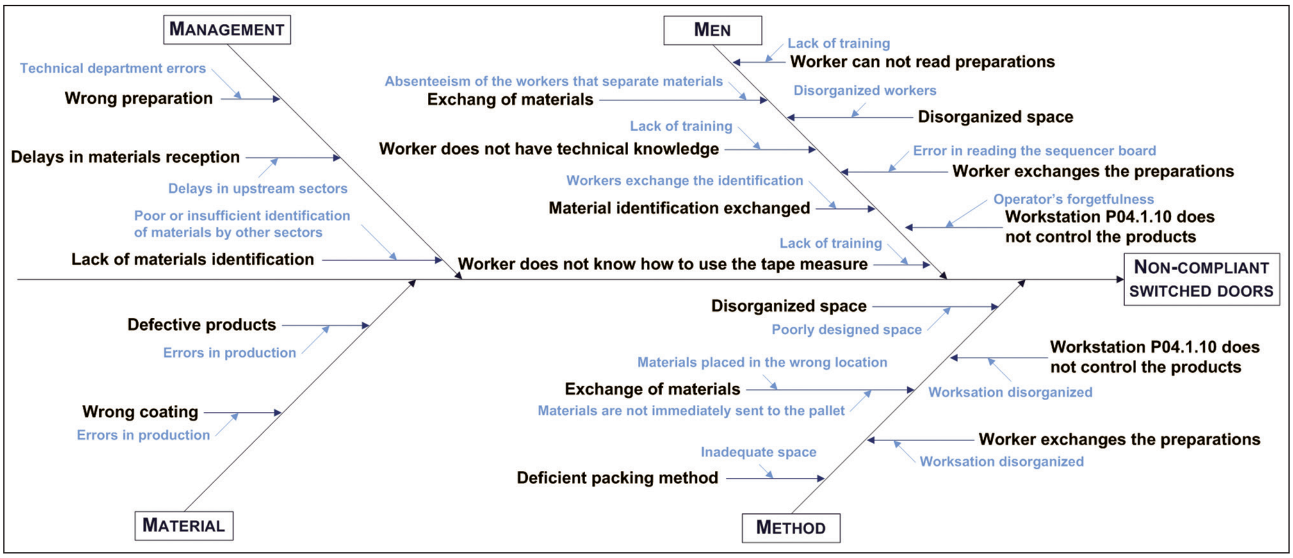


Figure 5. Cause-effect diagram for the non-conformity of "switched doors"

The sector manager provides the scheduling for each final product and displays the daily production goals in a board. This also serves to monitor the production and the quality of the products.

Among the several models of landing doors, the switched door model was selected (ABC analysis) to be studied. The corresponding operations in each workstation throughout the value chain were me-

Table 2. Sequence diagram results

Activity	P04.1. Workstations													
	00	01					02	03		07	08			09
		Access. 1	Access. 2	Access. 3	Access. kit	Hanger		Opposite	Stopper		Upper toe guard	Lower toe guard	Aprons	
Operation	17	21	12	5	5	5	52	4	5	11	4	5	8	11
Transport	8	1	1	1	2	0	0	0	0	4	1	1	2	4
Control	0	2	0	0	0	1	0	2	1	0	0	0	0	3
Waiting	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Storage	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	26	25	16	7	8	7	53	7	7	16	6	7	10	19
VA	65%	84%	75%	71%	63%	71%	98%	57%	71%	69%	67%	71%	80%	58%
NVA	35%	16%	25%	29%	38%	29%	2%	43%	29%	31%	33%	29%	20%	42%
Distance (m)	38.0	9.1	7.6	0.0	28.0	20.0	49.3	1.5	1.5	7.5	3.0	3.0	6.0	66.8
Time (min)	17.2	3.7	3.0	0.5	1.7	6.5	36.2	5.4	5.2	9.8	2.8	2.6	5.2	12.4

ticulously analysed. A sequence-material diagram was developed and its main results are synthetized in Table 2, namely the quantification of value activities (VA) and non-value activities (NVA).

The long distances travelled by the operators affect several workstations, in particular workstations 00, 02 and 09, due to the frequent motions to pick up materials in other places or to grab materials in racks behind the work table (workstation 02). Among other problems identified in the workstations were the disorganization and absence of identification.

Other aspects analyzed were: (i) operations cycle time, (ii) non-conformity causes (cause-effect diagram in Figure 5), (iii) workers skills (a skills matrix was developed) and (iv) workers ergonomic conditions (a questionnaire was applied).

The analysis in this sector allowed the identification of more than 20 problems, which were classified using the 6M1E (includes the Material and the Environment). Table 3 summarizes these problems and wastes.

The main problems in this sector were the variability of the manufacturing processes, the absence of a detailed sequence of work procedures and the complexity of the sector influenced by the huge number of components and subassemblies.

3.2. Action planning

3.2.1. Mechanical transformation sector

The action plan for the mechanical transformation sector was to implement SMED in the press machine, following the nine step methodology presented in [27], which includes setups' video recording and dialogue with the operators.

3.2.2. Doors assembly sector

The action plan for the doors assembly sector followed the 5W2H technique and to each problem (why) a proposal was developed (what), sug-

Table 3. Problems and wastes (doors assembly section)

6M1E	Problem
Men	Lack of polyvalence and rotation plans
	Inexistence of self-control (e.g. operators don't apply 5S)
	Inadequate work posture (8h standing and workstations poorly dimensioned)
Machine	Inadequate cars for placement of materials
Method	Operators unhappy for failing to reach everything they need without moving
	High distances traveled to get materials and during the assembly process
	Discrepancy in cycle times – lack of line balancing
	High transportation effort (weight of materials and distances traveled)
	Quality control is done very late (only happens in the last workstation)
	Complaint from Germany due to poor packing of materials
Material	Many non-conformities assigned to the sector (e.g. switched doors)
Management	Components' racks disorganized and behind the operators
	Components for workstation P04.1.01 occupy the shelf of other operator.
	Disorganization of the supermarket and supply process
	High quantities of WIP
	Inexistence of training actions
	Production halts due to lack of materials
	Poor production planning and control process
	Inexistence of documentation (work procedures, components, tools)
	Information difficult to understand (preparations and technical drawings)
Measurement	Standardized time is different from the time stipulated by the company
	High idle time for the car doors
	Cycle time of the workstation P04.1.02 exceeds the takt time
	There is no measuring or monitoring of the various performance measures
Environment	Inadequate environmental conditions (temperature, air quality and noise)

gesting forms to solve the problem (how) and the person responsible for the implementation (who), many times the action researcher itself, and the place to implement (where) and the moment to do it (when). Table 4 presents this action plan with the main actions developed.

Table 4. Action plan for the assembly doors sector

5M	What	Why	How	Where
Men	Training actions	Lack of polyvalence	Lectures and practical examples	Meeting room and shop floor
		Lack of operators self-control		
		Operators forget to use the 5S		
	Rotation plan	Lack of rotation plans	Rotation plan ABAB	Shop floor
	Reconfiguration of workstations	Operators unhappy with the work posture	New workbench	Workstations P04.1.01; P04.1.06; P04.1.07
Method	Reconfiguration of workstations	Operators fail to reach everything they need without moving	Remove the racks behind the operators; design of new workbenches	Workstations P04.1.01; 04.1.02; P04.1.05
	Line balancing	Lack of line balancing	Balance the value of each workstation cycle time	Shop floor
	Packing standardization	Complaint due to poor packing of materials	Identification of the best way to make the packing	Workstation P04.1.10
Material	Improvement of the workstation P04.1.00	The “switched doors” non-conformity is recurrent	Placement of visual identifications (Visual Management)	Workstation P04.1.00
Management	Reconfiguration of workstations	Racks with components behind the operators	Idealization of a new workbench	Workstations P04.1.01; P04.1.02; P04.1.05
		Components occupy too much space	Delimitation of the space and rack reorganization	Workstation P04.1.01
	Reorganization of racks	Racks and shelves disorganized	Delimitation of the space and rack reorganization of	Workstation P04.1.01
	Reorganization of the supermarket	Disorganization of the sector’s supermarket	Reorganization of boxes; acquisition of new boxes	Sector´s supermarket
	Standard Work-In-Process	High quantities of WIP	Definition of SWIP for each workstation	Sector P04.1
	Training matrix	Inexistence of training actions	Lectures and practical examples	Meeting room and shopfloor
	Document creation	Inexistence of documentation of any kind	BOM; documents for components and tools; stainless steel catalog; std work instructions for each workstation	Shop floor
Measurement	Standardized time	Standardized time different from stipulated	Calculation of the standardized time	Shop floor
	Line balancing	High idle time for the car doors	Balance the value of each workstation cycle time	Shop floor
		Cycle time of the workstation P04.1.02 exceeds the takt time	Divide operations of the workstation for 2 operators	

3.3. Action taking

3.3.1. Mechanical transformation sector

The SMED implementation involved the use of other lean tools, namely 5S, Visual Management and Standard Work, as they were essential to solve some of the identified problems. In the preliminary stage, setup periods of 21.65min, 24.17min and 19.10min were observed for setup 1, setup 2 and setup 3, respectively. It was also realized that all operations were executed as internal setup, since they were performed with the machine stopped. With the separation of the operations into internal and external setup (SMED stage 1) it was possible to significantly improve the entire changeover process. The techniques used were the creation of a checklist, to indicate the information necessary for the setup execution, and the planning of the transportation of tools during the external period. In SMED stage 2 it was used the technique of preparing operating conditions in advance by duplicating the die's upper base. With a single base, the operator was spending time removing that base from one die to another (with the machine stopped). By using two bases, the machine's operator only has to remove the old die and place the new one in (with the upper base already assembled). To rationalize the various aspects of the setups analyzed (SMED stage 3), improvements in internal and external operations were distinguished. The utilization of quick clamps and the elimination of functional adjustments were used as techniques for internal improvements. The die's positioning was greatly improved with the inclusion of an auxiliary jig (metallic plate) in the machine's table (Figure 6).

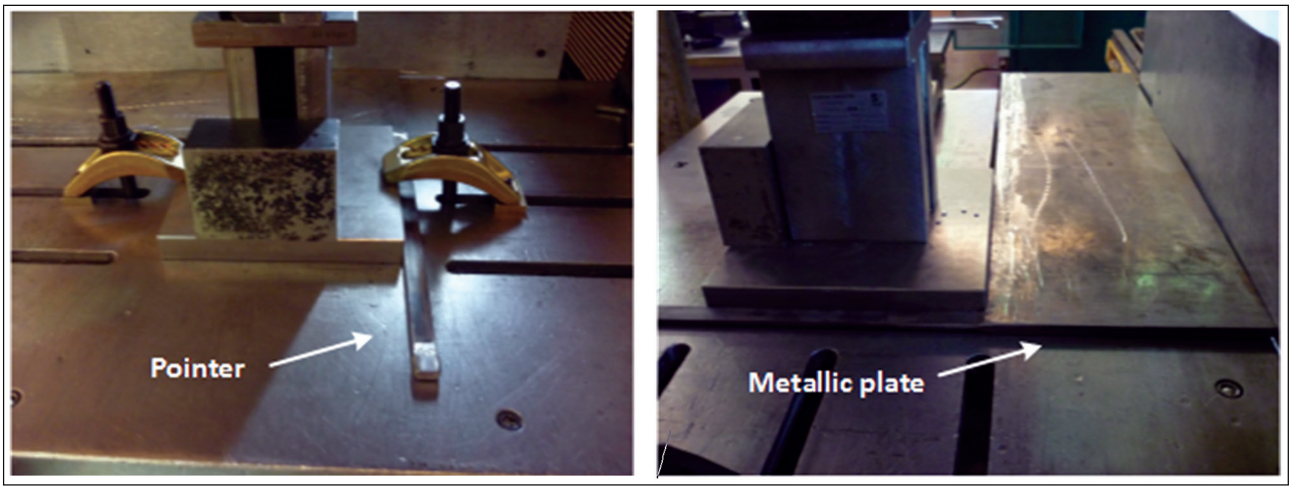
The process of configuring the machine, which was identified as one of the most critical aspects, was improved by predefining in the machine's controller the configuration for each die. Thus, the operator only has to input the die identification in the machine. Visual Management was applied in order to facilitate dies' identification (name plates and color labels were created) and also to avoid physical space obstruction (yellow lines on the floor were defined).

Regarding the external improvements, a new rack was introduced, enabling a better organization and identification of the dies as well as a roller tool cabinet to place the necessary tools for the operator. The lean technique 5S was applied to improve the organization of the workstation, allowing to increase the workspace and reduce unnecessary movements.

Finally, a standard work combination sheet was developed for each one of the three setup processes (section 3.2.1).

3.3.2. Doors assembly sector

The implementation started with the workers training, by providing a training matrix, a rotation program and the work posture improvement. The training matrix was posted in the central sector and was based on the skills matrix previously developed. The rotation program was developed



(a) *(b)*

Figure 6. Solution for centring dies (a) front view (b)

with twofold objectives: prevent musculoskeletal injuries and improve motivation. An ABAB rotation program was developed, i.e., the workers rotate between 2 workstations every 2 hours. A new worktable was proposed to improve work posture. The line balancing with 4 workers was proposed, attending to a takt time of 28 minutes and assuming that workers help each other.

Based on the Visual Management concept, new shelves and a better organization of existing racks were proposed. Different colours were used to identify the different sets of components which prevents problems such as picking wrong components and/or time lost to find the right component. This technique was again applied to improve the supermarket organization, providing a better division of the positions.

Other proposals were related to the creation of bills-of-materials (BOM), documentation for components and tools, material packing standardization and standard manuals. All these documents were posted in the respective workstation to avoid errors and confusion.

The last proposal was about Standard Work implementation, aiming to provide regularity on the manufacturing processes and a detailed sequence of work procedures. The sequence should correspond to the best and safest options, and ensure less waste in the production process. It was defined taking into consideration the opinions of all stakeholders. The sequence was based on predefined standard time and in an amount of WIP allowing that the downstream operator would have sufficient material to work with. The purpose was to achieve a continuous production flow without excessive stock. Figure 7 represents an example of a standard operation combination sheet (Figure 7 (a)) created for the product analysed and the respective work instruction (Figure 7 (b)). Work instructions were created for each workstation, mainly based on visual information (photos and diagrams) so they can transmit the most relevant information in an effective and immediate way.

Additionally, a standard operations chart was created for the sector (Figure 8). This chart identifies the locations with Standard Work-In-Process - SWIP (blue circle with the corresponding quantity) and also the quality control locations (lozenge). The SWIP refers to the WIP between two workstations and is marked in the downstream workstation.

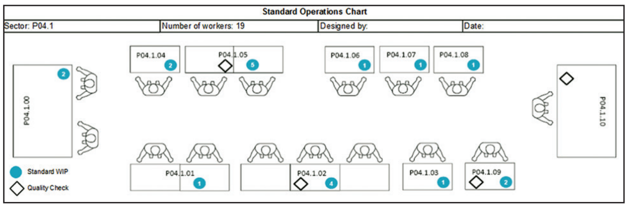
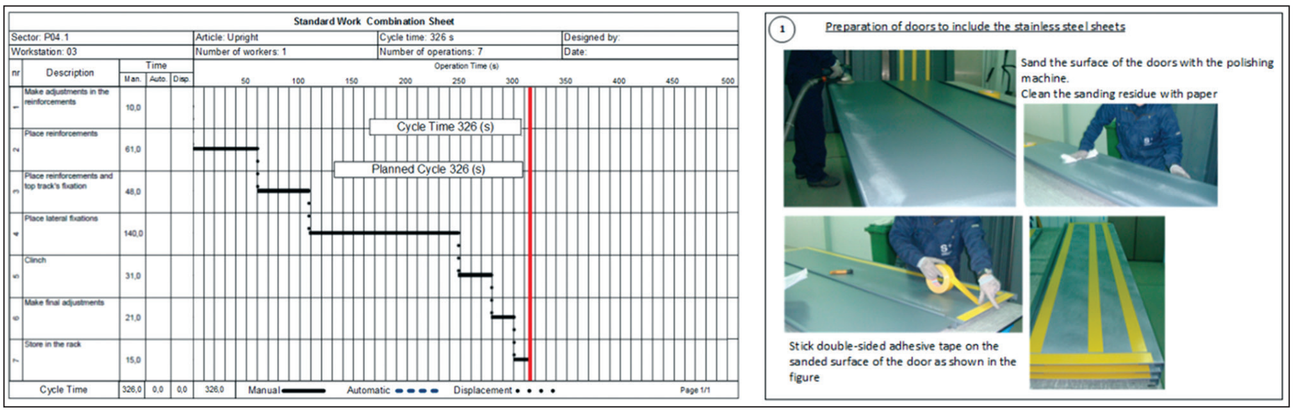


Figure 8. Standard operations chart

To aggregate all documents created to support the operators in the execution of their tasks, it was created a manual for each workstation with the following information: workstation description; operations and times description; components and tools identification; work instructions and standard work combination chart.

3.4. Evaluation

This stage reports the results achieved with the implemented proposals. For those not implemented, the results were estimated. Some proposals



(a) (b)

Figure 7. Example of (a) standard operations combination sheet and (b) work instruction

were implemented after the master dissertations conclusion and others were not applied due to current budget restrictions.

3.4.1. Mechanical transformation sector

In the press machine, the three setup processes inherent to the product referred on section 3.2.1 were improved by applying the SMED methodology. The attained results, in terms of setup time and distances travelled, are indicated for each setup and each SMED stage (Table 5).

In terms of setup time, reductions of 65%, 67% and 53% were attained for setups 1, 2 and 3, respectively. It is interesting to note that the highest improvements were always obtained in the third stage of SMED. Regarding the distance travelled by the operators, the gains were 78% for setup 1, 55% for setup2 and 45% for setup 3. As some of the movements occur during the internal setup period, the correspondent improvement had a direct impact in the reduction of the machine downtime. Operations related to tools and materials gathering are executed during the external period by another operator. The three setup processes were properly standardized and the workspace is better organized, namely in terms of materials and tools positioning and identification. The average reduction of 13.46 min/setup implies a daily gain of 40.38 min (since there is an average of 3 setups/day) or 162.87 h/year (since there are 242 working days/year). Considering the hourly costs inherent to the press machine (approx. 10 €/h) and labour (approx. 9.30 €/h), an annual saving of 3,143.39 € was attained.

Due to the improved setup processes it was possible to reduce the lot size by half (from 800 to 400 units). Consequently, the WIP has suffered a significant reduction (from 12.8 to 6.4 days), which was one of the major goals of the company.

3.4.2. Doors assembly sector

The implementation of the planned actions, involving 5S, Visual Management and Standard Work, brought enormous benefits for the doors' assembly sector. The training sessions started with 5S teaching. The rotation program was postponed and the worktables' modification was not implemented due to budget constraints. Also, the line balancing proposal was not implemented but it would allow a reduction of idle time in about 92% (from 18 minutes to 1.4 minutes). However, significant gains were achieved in three workstations in terms of operations' duration and distances travelled (Table 6) and also regarding shop floor's space occupation (e.g. the capacity of the sector's supermarket was increased by 50%). In the workstations 1 and 4 it was possible to eliminate one operation.

Although not quantified, it was also observed a reduction of errors and, subsequently, non-conformities and rework operations. Even the number of complaints has decreased. Most likely, this was a consequence of the better work environment, more organized and supported by visual information.

Table 5. Main results of SMED intervention

Stage	Setup 1		Setup 2		Setup 3	
	Time [min]	Distance [m]	Time [min]	Distance [m]	Time [min]	Distance [m]
Preliminary Stage	21.65	102.0	24.17	87.30	19.10	95.40
Stage 1	17.50	26.10	18.95	42.50	17.38	54.10
Stage 2	16.28	26.10	17.13	42.50	15.45	54.10
Stage 3	7.57	22.50	7.93	38.90	9.05	52.30
Improvement [%]	65	78	67	55	53	45

Table 6. Gains in operations' duration and distances travelled

Workstation	Gain on Operations' duration [min]	Gain on Distance travelled [m]
0	5	0
1	1	15
4	2.5	75

In fact, the BOM, the lists of tools and the assembly guide created for the workstations resulted in a significant reduction in the number of assistance requests made by the operators, leading thus to a noticeable reduction of the non-productive periods. In the concrete case of workstation 2, the implementation of 5S and Visual Management allowed a reduction of 66 min/day in the time spent by the operator to gather the components and tools. As the cost inherent to an operator is 9.3 €/h, this reduction represents a saving of 10.23 €/day or 2,475.66 €/year. Additionally, the workstation was able to produce more 2 products/day, or 484 products/year.

3.5 Learning specification

A key consequence from this project was the awareness of all stakeholders for the importance of sustaining the practices implemented. This resulted from the involvement of everyone, including the top manager who made a speech at the factory to emphasize the importance of keeping a clean workspace for the comfort and safety of all. After this, it was noticeable the difference in the operators' behaviour. The racks for components used to be full of dust because they were never cleaned but now cleaning is done frequently. Furthermore, the operators had become more careful with waste and scrap (previously dumped into the floor) and now they use the containers available in the workplace.

It was also possible to confirm that large improvements can be often achieved through simple solutions (or apparently simple) without major investments, if those solutions are correctly implemented. The developed proposals followed the key idea of lean production of "doing more with less", so most of them did not require high investment. Essentially, the use of 5S, Visual Management, SMED and Standard Work, resulted in a relevant performance improvement due to better organization of factory space, racks, supermarkets and shelves, and, procedures' documentation.

Another important lesson learnt was related to the interpersonal relations in regard to the existence of natural resistance to change. However, over time and after several explanations about the work objectives, and benefits it could bring, this resistance became weaker. Therefore, it was possible to conclude that the successful implementation of continuous improvement strategies implies open minds, collaboration and commitment from everyone involved.

4. Conclusions

The project was carried out in two sectors of an elevators company (mechanical transformation sector and doors assembly sector), in the context of the company's lean production implementation initiative. Action-Research was the research methodology used, allowing the academy/industry collaboration where both parts benefited from learning from each other. After examining the production system and identifying areas that needed to be improved, the lean tools SMED, 5S, Visual Management and Standard Work were applied. The suggested proposals met the planned objectives.

In the mechanical transformation sector the nine-step methodology to implement SMED (developed during the project) was successfully applied to the mechanical press machine, along with 5S, Visual Management and Standard Work. Important reductions were attained in terms of setup time (53% to 67%), travelled distances (45% to 78%) and WIP (50%). Setup processes were standardized and the workspace was reorganized, leading to a more enjoyable work environment. The SMED intervention resulted in an annual saving of 3,143.39 €.

In the doors assembly sector, most of the suggestions target the overall improvement of the sector's performance using, mainly, 5S, Visual Management and Standard Work. The main results obtained were an increase of 50% in the capacity of the sector's supermarket, a total reduction of 8.5 minutes in the duration of the operations of three workstations and a reduction of 90 minutes in the distances travelled by the operators. In a specific workstation it was possible to save about 2,475.66€ per year and increase 484 products to the annual production.

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