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Simulator Training for Employees in the Field of Production: A Robert Bosch Gasoline Systems Case*

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As a result of market globalization and increasing demand of products, companies have to improve their production processes and modify their operations to adjust to changes and be competent. This context is being steadily accentuated in the manufacturing sector, where many companies are conducting research on formative methods that allow engineers and operators, whether newly hired or transferred from other plants of the company, reach the standard production level quickly, thereby achieving and maintaining the necessary level of market competitiveness.

In this paper, we introduce a case of formative software development at the Robert Bosch Gasoline Systems Company (Aranjuez, Spain) that has just begun the implementation of a Lean Transformation project, performed in order to standardise production according to their global benchmarks and thereby improve the productivity of the filter manufacturing lines. During a previous evaluation of production lines, we decided that cultivating employees based on parameters of machine management and the knowledge of their influence on the final product is the key area of concern since it significantly influences production losses and the productivity indicator of each line. In order to achieve this, we focused on the production of diesel filters; a master's student at the company was designated to analyse various formative methods. Finally, we developed a decision-making simulator of the manufacturing parameters. The resultant software was implemented in Visual Basic and Excel, which allowed the integration of the tool in the company's work culture. The simulator was then tested with plant employees, observing the general improvement of knowledge about the production processes of diesel filters. Finally, it was implemented at the factory. We realised that time reduction on technical and on organizational losses led to an increase in the productivity.

Keywords: decision-making; simulator; employee training; manufacturing; filters

1. Introduction

In the industrial environment, it has become increasingly important to improve the socio-economic issues that affect production along with the technical aspects to increase the productivity ratios of the company [1].

A majority of the production activities based on social issues focus on employee training and result in cost reduction of the final product, for example, the learning curve applied by manufacturing industries, such as the automotive industry [2]. In this sector, when operators gain a better understanding of the process, they can contribute their ideas to improve the value stream or react better to unforeseen circumstances such as machine breakdowns or unplanned changes in the production process.

Nowadays, companies do not provide sufficient specific knowledge of their industrial activities to recent graduates who have been recruited. Therefore, in this paper, we propose an improvement in the level of training given on the production of diesel fuel filters to new hires at Robert Bosch Aranjuez (Spain) by means of a simulator, and analyse the impact of the proposed training on productivity [3].

In order to realise the proposed improvement, we formulated a number of working hypotheses to limit the subject matter. First, since the factory is ready to make products such as plastic parts, brush holders, spare fuel injectors and filters, we decided to focus on the production of diesel filters, as they have the highest demand, and thus, it was possible to conduct a better analysis of the cost improvements. Second, to standardise the study approach according to the production parameters, we used the parameters recommended by the International Labor Organization (ILO). On the other hand, to assess the effect of training through reducing job losses, which affect the number of valid parts and in turn the productivity index, we considered the Overall Equipment Effectiveness (OEE), Eq. (1).

$$OEE = \frac{Valid \cdot parts \times Part \cdot Takt}{Work \cdot time - \sum Planned \cdot outages} \quad (1)$$

Here, Part·Takt is the time between one part and the next one on the production line, total work time is an 8-h work shift and Planned outages include breaks, Total Productive Maintenance (TPM), assemblies and training among others.

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Finally, at the experimentation and validation stage, we selected a representative group of the new employees at the plant considering the following two criteria:

- The group would include university graduates (in this case, recently qualified engineers) and students in practical training courses.
- Due to the importance of job rotation in manufacturing lines, it was considered useful to train employees of two similar filters lines, diesel and oil.

2. Background and initial situation

The present study is placed in the context of market globalization and increasing product demands, which have led companies to modify their operations to adapt to these changes.

Many companies have conducted Lean Transformation projects with the aim of standardizing work procedures among various sister plants to achieve efficient production that allows them to be more competitive in terms of price and customer service. Robert Bosch Gasoline Systems, in Aranjuez-Madrid (Spain), was asked to implement a Lean Transformation project to improve productivity and quality, thereby reducing its significantly large losses [4].

After an evaluation audit of the plant and several meetings, it was decided that the company was sufficiently qualified to implement Lean Transformation projects, which will be carried out in the next two years. Fig. 1 shows the Value Stream Mapping (VSM) for the production of diesel filters in order to check the production aspects to be improved [5].

From all these aspects (see Fig. 1), it was felt that the most relevant to the productivity ratio of the company were 5, 6, 9 and 13 factors related to the improvement of the OEE of the automatic station dedicated to the manufacture of the filter paper components. OEE is a performance indicator, as explained in the previous section, Eq. (1).

Over several working sessions, various stages of production were evaluated and problems in each line were detected; thus, the correct Lean Transformation project for every stage was implemented.

We detected a considerable lack of operator knowledge on the importance of the control parameters of the line and its influence on the end product because of the company's policy of transferring employees to another line in case of non-working lines coupled with the unclear documentation of the stages of the production process; the effect was particularly pronounced in two assembly lines. Then, the losses shown in terms of the number of pieces produced during the month of January 2012 in one of the mounting strips were found to be problematic [6]. Fig. 2 shows the losses of parts during January 2012 in one of the studied lines [7].

As shown in Fig. 2, many of the parts not produced in the shift deal with technical problems such as problems in the parameter control during machinery breakdowns and starting line, and most of these problems are a result of a lack of process training received by operators and the lack of knowledge regarding how these parameters affect the final product [8].

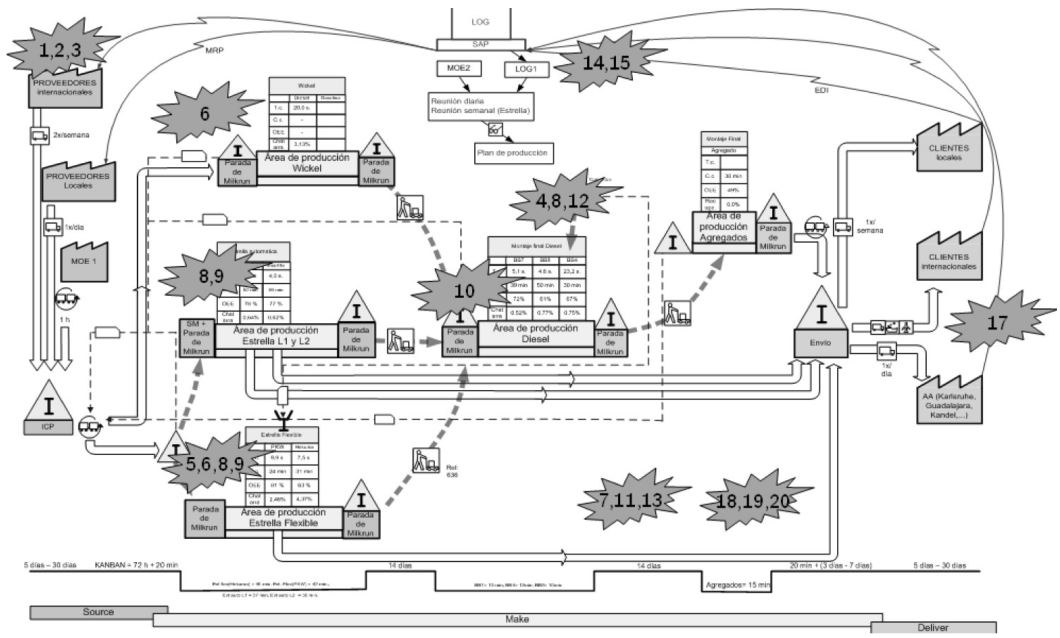

Fig. 1. VSM lines (diesel).

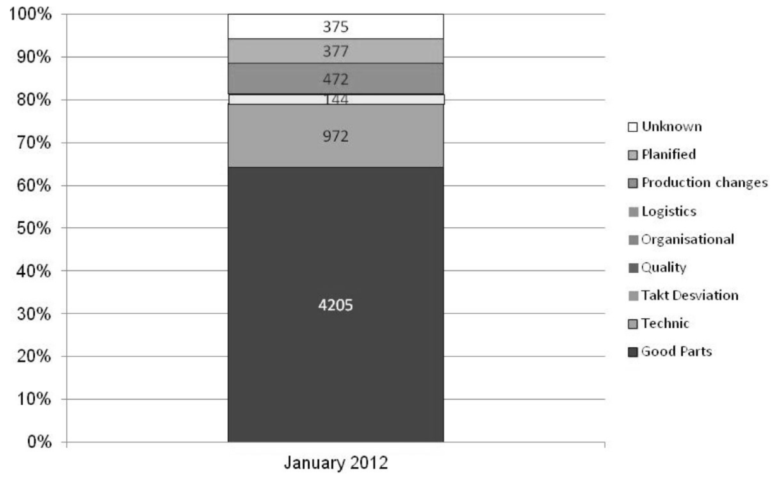

Fig. 2. Lost parts diagram, January 2012.

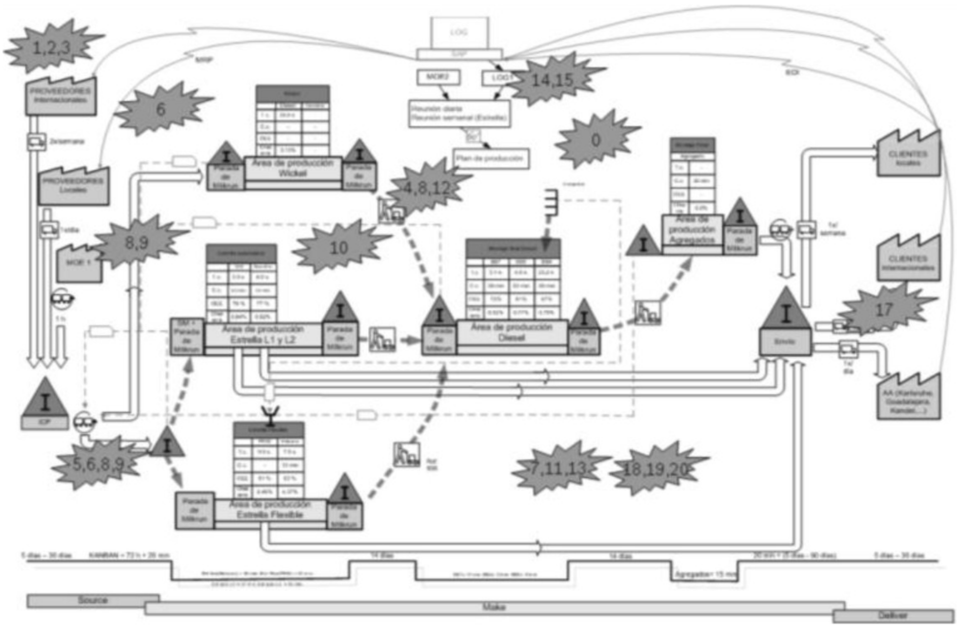

Fig. 3. Modified VSM lines (diesel).

By scanning each of the lines, we found that the training of new employees is critical for achieving high productivity ratios and for correctly implementing the Lean Transformations projects in the company; hence, the VSM was modified as shown in Fig. 3.

3. Software development

Before introducing the training software, it is important to know the process of manufacturing diesel filters. This process begins with the winding of paper rolls to facilitate the subsequent cutting. For this purpose, a series of rollers are used to smooth the product and lead it to the automatic fold machine, where two blades perform the paper folding. The paper is conveyed to a furnace which provides it the required filtering properties. Upon leaving the furnace, the paper is segmented into more manageable work packages. Then, the paper is welded by means of ultrasound which generates a cylindrical form for the positioning of the filter covers. When the filter is received in the assembly line, it waits to be mounted while the trap is mounted in the casing cap in order to allow the filtered water to leave the fuel filter assembly. The filtered element is inserted and sealed within the assembly by positioning a top felt and curling the set. To ensure the seal, the set is tested with an air-helium mixture. Finally, the filter is packaged.

According to the method proposed by Rezg et al. [9], simulation programs are designed in the following five stages:

1. Construction of a model that reflects the requirements of the system with the desired accuracy.
2. Establishment of the rules of operation/treatment products.
3. Description of the manufacturing process through the production line.
4. Generation of possible decisions regarding the simulated environment.
5. Development of production scenarios and optimization.

For the simulation program to faithfully represent the reality of the filter factory, it should have control parameters and reflect the different variables which influence the production process. The production processes always tends to have:

- the lowest delivery and manufacturing times,
- a level of quality that meets customer expectations,
- and a relatively low cost, derived from the previous two and from the newest technologies, processes and materials that result in cheap production and commodity management [10].

These aspects will be controlled by the program; thus, users will be able to check the effects of their own decisions on the production. After defining the control parameters, we developed a measurement system for each of them in order to achieve a realistic representation.

Controlled information in the filter plant is classified into three main groups: cycle times of machines and lines (Takt Time), documentation focused on analysing the junk production (wrong filters), and cost per unit produced (€/unit).

To have a scale that is easy to use for the employee, we uses a whole scale of '–3' to '+3', where '0' was the average rating for the current target of business productivity, which was OEE of 85%. Thus, in order to establish a rating scale, we used the following averages of an assembly line, see Table 1.

The costs showed in the table were calculated on the basis of the available minutes planned on the line (460 min/shifts) and €/h of work, both of man and of machine; and the possible levels of scrap were compiled from the letters of the annotation of faults of several months. If the information of the table is translated into percentages of improvement with respect to the initial situation '0':

Once the simulation flow was known, which coincided with the productive process explained earlier, and the decision evaluation method, one could establish a few rules of 'behaviour' of the product that could be included later in the process training manual and explained to the users for an appropriate understanding of the program. The general rules established for the simulation were as follows:

1. The diesel production of filters has a wide range of issues/series, and hence, for an entire simulation, one will work with the same product.
2. The simulation will measure first in terms of weeks in order to explain the concepts related to the parameters of work in the lines, and it is not necessary to have a wide temporary horizon.
3. Since the factory works in lots, and in one week approximately 180.000 filtering sets are produced (12.000 filters/shifts and 15 shifts/week), the weekly calculations of benefits will be calculated on the basis of the delivery of a weekly lot of 180.000 products.

With a view to the capture of decisions related to the production parameters, we established the following procedures:

1. A filtering set can never return to a previous stage. Therefore, the decisions within a period of simulation must have a consecutive form: stage after stage.
2. Every decision taken in the production (that is, the choice of a value for a parameter of work) will have a few consequences in terms of time, cost, and product quality.

Table 1. Scale of valuation on the assembly line

Parameter	**–3**	**–2**	**–1**	**0**	**1**	**2**	**3**
Time (Takt Time)	7.45 s	7.3 s	7.15 s	7 s	6.95 s	6.9 s	6.85 s
Cost (€/unit)	0.133	0.13	0.127	0.125	0.124	0.123	0.122
Quality (% Scrap)	1.50%	1.40%	1.30%	1.20%	1.15%	1.12%	1.08%

Table 2. Scale of valuation on the assembly line in percentage with respect to the initial situation '0'

Parameter	**–3**	**–2**	**–1**	**0**	**1**	**2**	**3**
Time (Takt Time)	0.06%	0.04%	0.02%	0%	–0.007%	–0.015%	–0.021%
Cost (€/unit)	0.064%	0.043%	0.016%	0%	–0.008%	–0.016%	–0.024%
Quality (% Scrap)	0.25%	0.16%	0.083%	0%	–0.042%	–0.066%	–0.10%

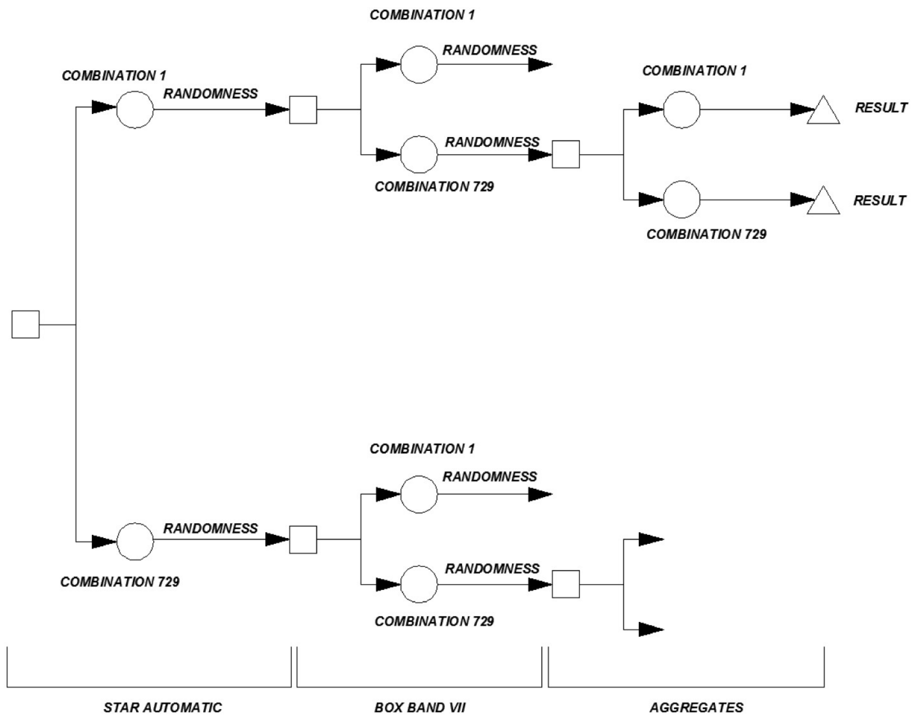

Fig. 4. Decision tree for the algorithm of work.

3. From one week to another, all the decisions taken on the parameters of work will be changeable since this is possible in real-life scenarios.
4. These consequences will be evaluated according to the scale previously indicated for Takt Time, percentage of scrap, and variation of the unit price.
5. There may be parameters of work that interact with some other parameters (that is, directly influence other parameter values).

A considerable part of the project was dedicated to seeing how each of the variables influenced time, cost, and product quality; here, this part is omitted because of space limitations. For more information, refer to [6].

It is important nevertheless to indicate the double relation that exists among the diverse stages. On one hand, all the stages shape a line of production and his order inside the same one is invariable. He carries it to that a good management of a previous stage, he will carry benefits for later stages and for the final result.

On the other hand, if every stage is analysed closely, it is possible to observe that the partial decisions taking during every phase do not affect the other partial decisions of the same stage (except decisions related to the speed of court and the depth of spent. In other words, some of the decisions taken at every stage of production do not affect the following stages, while the others affect the following stages and the product.

Hence, we consider the following algorithm of work based on a decision tree (see Fig. 4).

With all this there was elaborated software of simulation which functioning remains reflected in the low graph: the user introduces his personal information and realises a series of decisions for the diverse parameters of work that affect production. Further, during four cycles, every cycle simulates one week and the program shows the user a few results and a series of advice in order to improve the process with his future decisions (see Fig 5).

4. Validation and experimentation

To validate the user, his level of representation was studied with respect to the reality of the factory. For this, 18 complete simulations were realised; they represented the information of partial benefits of each one of the 70 weeks simulated in a histogram. In turn, with the average values taken in the problematic assembly lines during January, February, March and April 2012, we calculated the weekly royal benefit and showed it in the histogram, Fig. 6.

Apart from checking that the software is necessary since high places of benefit are not obtained levels, the simulation is representative of the situation of the company, and its results are trustworthy.

In order to see the usefulness of the software in the company's own factory, a group of new employees was selected, including as many graduates of engi-

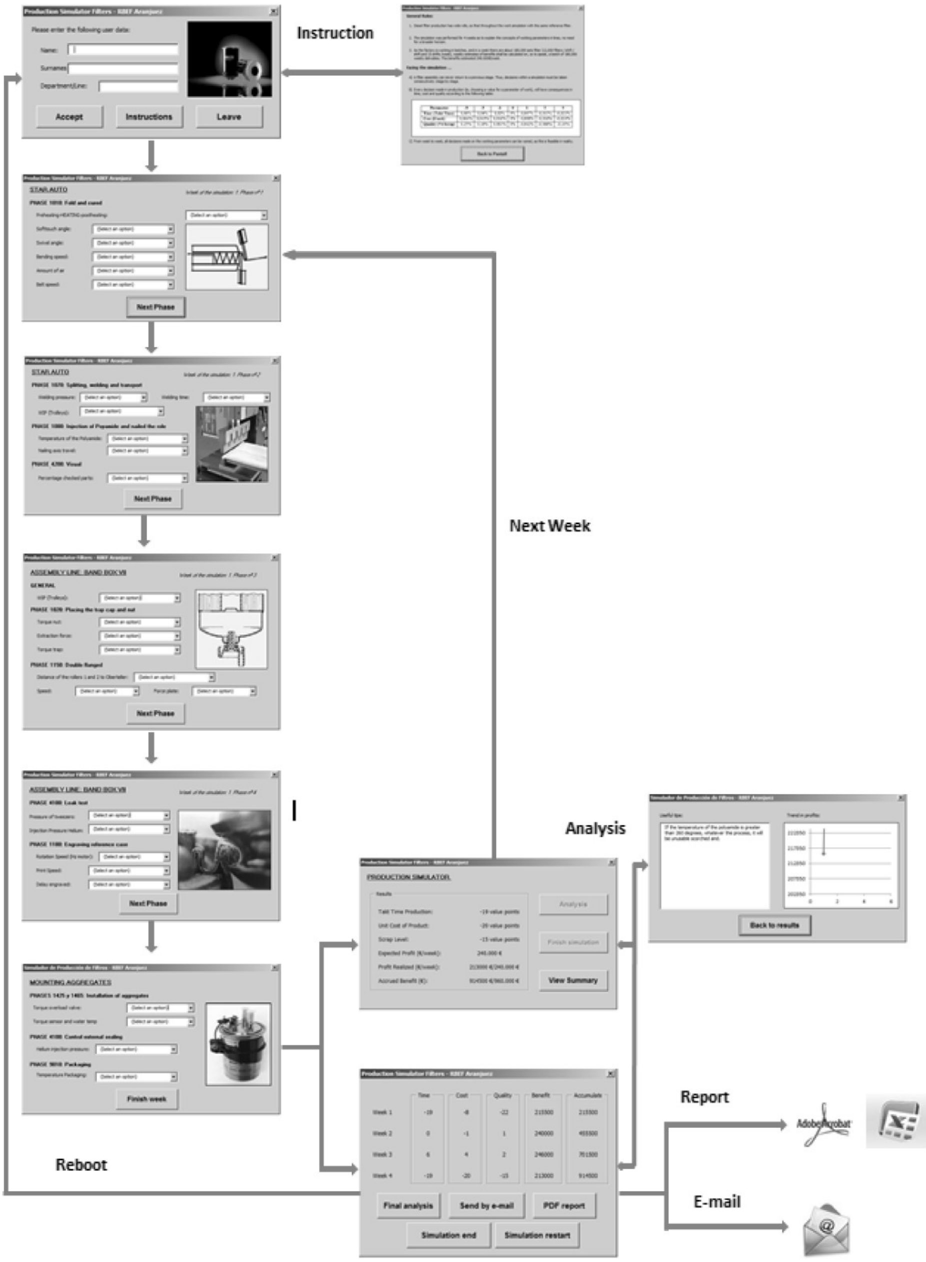

Fig. 5. Functioning of the simulation program.

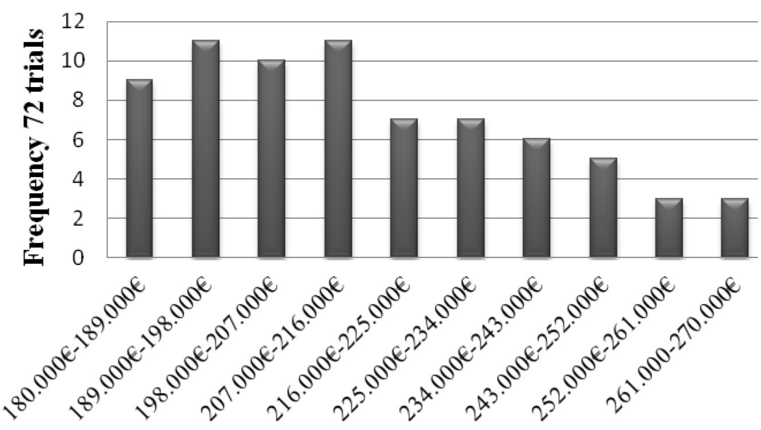

Fig. 6. Histogram of weekly results.

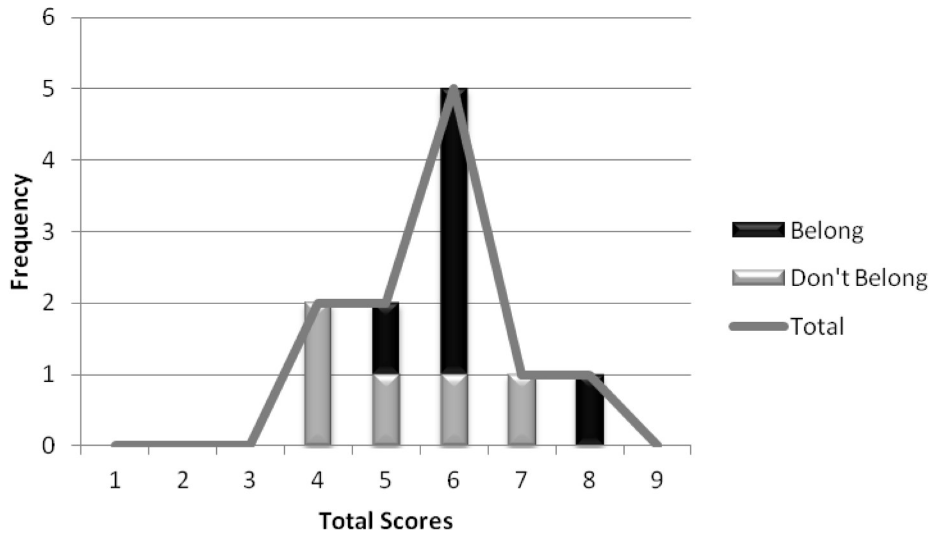

Fig. 7. Scores depending on whether the participants belonged to the group of simulated lines (1st phase).

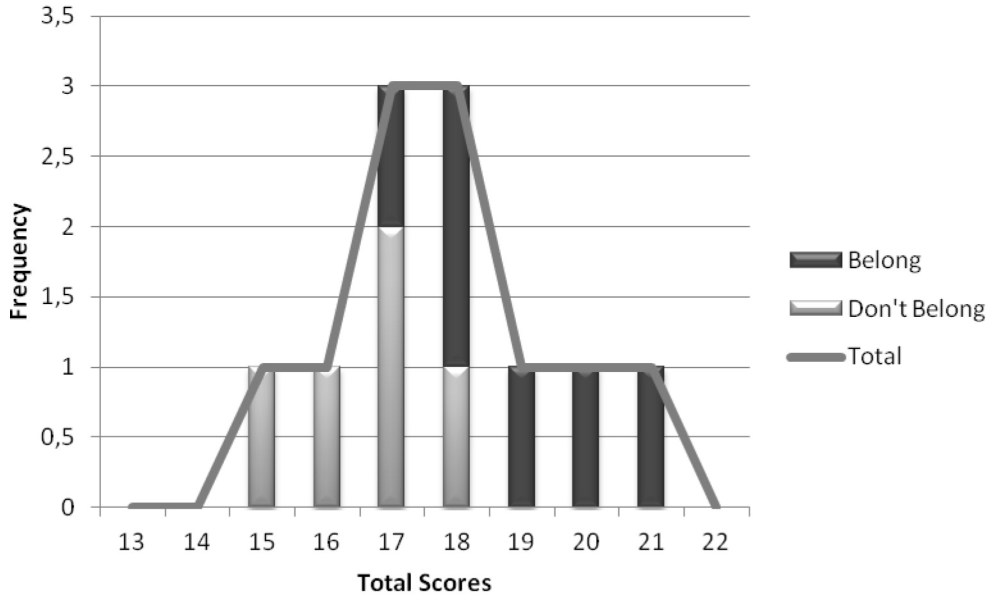

Fig. 8. Scores depending on whether the participants belonged to the group of simulated lines (2nd phase)

neering as of the cycles of formation, and those holding the following diverse production-related positions: (practicing) Azubis, OP (operatives), and OP2 (operatives chief) of diverse lines.

In the first instance, all the selected employees were asked to fill out a questionnaire to check their process knowledge process and the variables that affect production before introducing them to the simulation software.

Later, a graph of the results of the first test was plotted; the green lines in the graph indicate the lines of manufacture or assembly included in the test. The orange ones denote the lines excluded from the simulation but whose operatives were moved often to the abovementioned green lines in order to cover positions or because in their lines, there was a low demand for production.

The analysis of the current situation indicates that the selected employees have basic knowledge in all the lines of work, with more detailed information on their habitual line of work; also, OP2, the managers responsible for solving machinery-related problems, exhibited more process knowledge than the others. However, this level of knowledge is not sufficient, and this lack of knowledge leads to considerable losses at the technical level in the production process.

After this preliminary test of knowledge, the participants were showed the results and asked to conduct the simulation. After the simulation, they were asked to complete a second questionnaire in order to check whether their knowledge improved because of the developed program.

The results again revealed that the operatives who belonged to the lines included in the simulation had better process knowledge than the others. This could be attributed to the fact that the operatives of the Automatic Star and BBVII could in some cases rely more on intuition developed by being employed in the production environment; the operatives of the other lines could only answer as much in case of the questions of the Attachés' line.

5. Conclusions

After normalizing the responses to a scale of ten points and representing the results for every group of study before and after the use of the software, we plotted a few comparative graphs as the ones shown below. These graphs reveal that the tool of formation has had a major impact on the operatives' chiefs of the lines that were not included in the simulation, improving their responses by more than 3 points (which is equivalent to an increase of 76% in the knowledge of the other lines). This extent of improvement could be attributed primarily to the fact that a majority of OP2 are not rotated between lines since they are experts at solving the problems of a particular line. Further, the normal operatives, who are rotated between lines, had in the first phase of the experiment slightly more knowledge of the simulated lines.

On the other hand, it is necessary to indicate that all the gone away university students and of formative cycles they have improved his knowledge on the productive processes and the parameters that

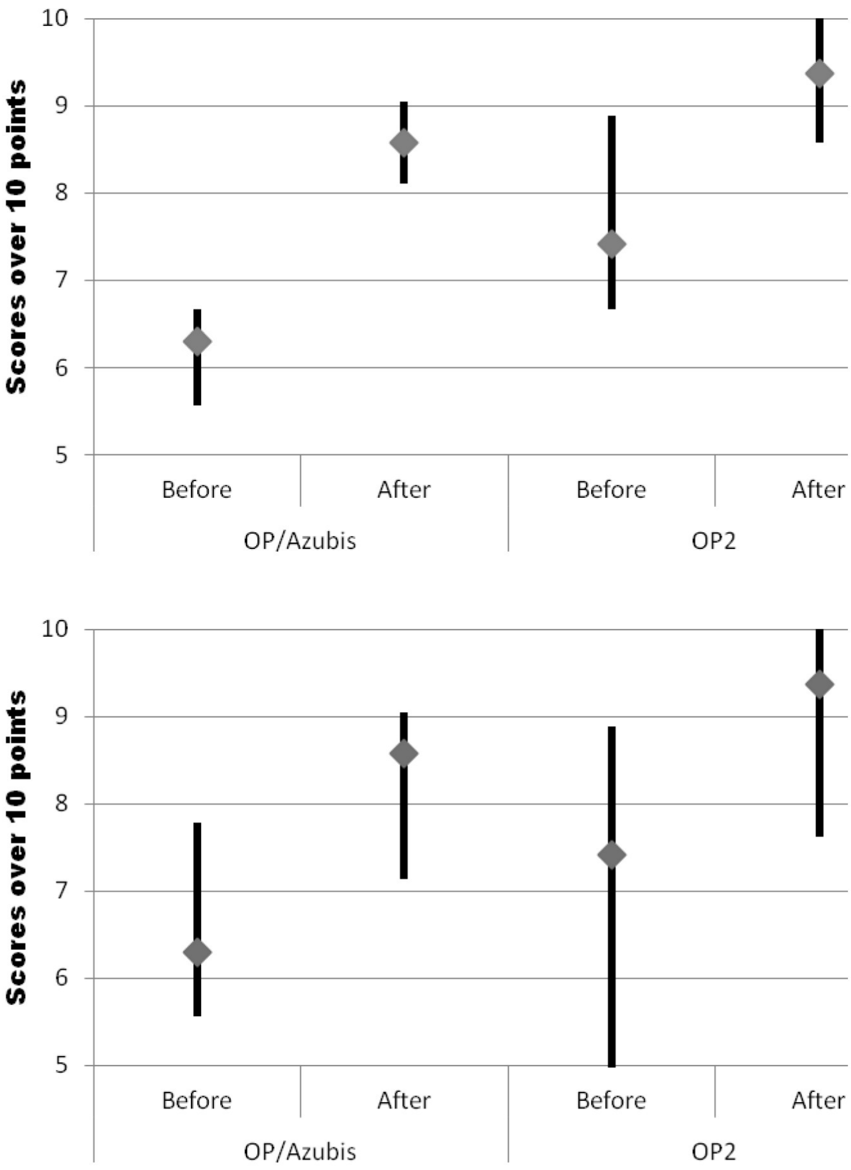

Fig. 9. Impact of the training on the employees of the simulated lines.

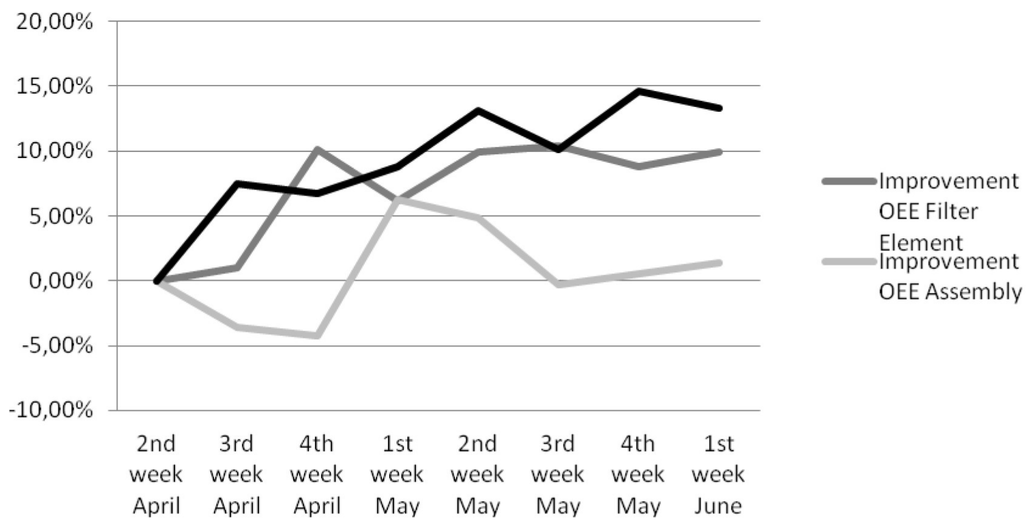

Fig. 10. Improvement of OEE from the Second Week of April.

the influence (spending of an average total punctuation the from 6, 21 to one of 8, 43 with what the increase is 35, 7%), for what the aim of the tool of formation is covered.

On the other hand, it was necessary to indicate that all the gone away university students and of formative cycles they have improved his knowledge on the productive processes and the parameters that the influence (spending of an average total punctuation the from 6.21 to one of 8.43 with what the increase is 35, 7%), for what the aim of the tool of formation is covered.

In order to know the impact of this formation on the percentage of diesel filtering sets lost because of technical and/or organizational problems in terms of the produced quantity, we analysed the weekly data of the technical and organizational losses for each of the simulated lines. Further, by considering the reduction of losses since March, which is when the experiment with the employees was begun, we obtained the following improvement in OEE:

Therefore, the software expires with the intention of formation of the new income in the company, and this has an impact in terms of productivity improvement. Likewise, according to the responses of the surveyed operatives, the tool is useful as it explains the aims and rules of simulation and is easy to use.

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