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The impact of training and *ad hoc* teams in industrial settings

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Abstract. This paper aims to reflect the use of training via ad hoc teams to adopt lean production practices. In our research, eleven automobile manufacturer suppliers implement training interventions to achieve better results through lean production, concluding that training helps companies to develop lean production systems and to improve performance indicators.

Keywords: training, industrial performance, automobile industry, teamworking

1 Introduction

Training is undoubtedly an important factor in business management and particularly when organizations face a change in how they operate. Training is useful for consolidating the new vision that change brings with it[2] and for identifying necessary activities[10]. This paper will focus on the effects of training in companies that try to implement a lean production system. It is important to note from the beginning that we do not aim to study the goodness of lean production, but to discuss how to achieve a higher degree of lean production features through training.

Knowledge may be acquired by using what are traditionally known as training systems or self-study, via personnel turnover to gain experience, attending conferences, visiting other plants, benchmarking, etc.[11]. In this case, we will focus specifically on know-how acquired via ad hoc teams which we will discuss further on. This type of intervention is based on the classic concept of temporary committees or ad hoc teams[6]. These teams do not make up a permanent part of the organizational structure and have a limited duration. They represent a second job for members and superimpose their regular obligations within the organization[29].

Furthermore, these are teams that are managed externally[21], since their sole responsibility is to carry out the task they have been assigned. Management sets up the team as a work unit (it designs the team task, chooses its members, sets out the basic rules for attaining goals, $\cdots$). It also orients team performance and supervises how they carry out their duties, in addition to designing the organizational context in which the team is going to work (establishing the rewarding, training, and information systems).

In this research, groups' main task is, then, to implement training interventions to improve performance, which is one of the most common topics assigned to group work[17]. Although the results of group work and its effect on effectiveness improvements is not sufficiently demonstrated, there seems to be certain consensus regarding the utility of more participative practices in employee motivation[7]. That would be enough reason for introducing training through group work, since one of the main recommendations for training activities' success is that they should motivate and involve employees.

So, the main objective of our work is to analyze the effect of training based on ad hoc work teams in industrial companies implementing a lean production system. In order to address this aim, we will begin by

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taking a brief look at the basic aspects of lean production. Following this, we will define the basic indicators that will enable us to pinpoint the improvements that are expected in companies after training activities are implemented. We will go on by explaining fieldwork, its methodology and the final results obtained from analyzing the cases studied. We will conclude this paper by discussing the data and drawing some conclusions.

2 Basic dimensions of lean production

Lean production is the term given to production systems used by Japanese companies in the 90s[33]. It was especially relevant in the automobile manufacturing industry[5, 20], in fact, the term arose from the International Motor Vehicle Program's study of certain automotive assembly plants[23]. The concept of lean production can be defined as the degree to which high quality articles are produced with labor-costs, space investment and development time all being kept to a minimum. It attempts to take advantage of mass production while at the same time avoiding its lack of flexibility and the cost of socio-technical systems. Lean production could be therefore situated somewhere between mass-production and socio-technical systems[2, 3, 5, 25]. Moreover, it does not negate some of the traditional correlates with high productivity, such as economies of scale[23].

Although 'lean defendants' claim that manufacturing performance (especially labour productivity and product quality) is dramatically improved by the synergistic pursuit of lean production practices, and that such system should be considered a universal set of best practices yielding performance benefits at the establishment level, some researchers state that the combination of certain factors, such as scale (volumes), capacity utilization and automation, play a key role in performance achievements, too[23]. However, the judgement of lean production as an ideal system is not the aim of our study, and thus we will focus only on how to achieve a better lean production system using training activities in ad hoc teams.

Lean production applies to a whole series of techniques that attempt to optimize the use of resources, resulting in a group of inherent key factors or features[2, 8, 12, 16, 24, 31, 33]. We will begin by listing the basic features of lean production, linking them later to the training interventions that are associated with their implementation.

(1) Organizational Culture that Supports Processes and Employee Participation.

An organizational culture that supports lean production is one where its employees are aware of the organization's goals and how their work contributes to achieving them; communication channels are open between production workers and top and middle managers; employees are able to identify and eliminate waste, and solve problems; moreover the management team is committed to fostering all these features.

(2) Industrial Housekeeping and the "Visual Factory".

A workplace in line with lean production techniques is one where materials and tools are correctly organized, labeled and arranged according to their use. The job is efficient, safe, clean and organized. The visual factory is a management system based on the rapid assimilation of data in order to make quick decisions. This system uses visual aids that convey important information in the form of labels, maps and worksheets, etc. Moreover, the visual factory also consists of applying monitoring that enables any person to immediately recognize the standard and any deviation with respect to it. Its aims are to promote safety, zero defects, information sharing, warn about errors, how to correct them if applicable, promote waste elimination, encourage worker autonomy, and support continuous improvement[15].

(3) Standardized Work.

This dimension aims at reducing the variability of the process, manufacturing with quality, maximizing the productivity of the workforce and of the equipment used in the manufacturing process. It also determines the order or sequence of the tasks a multi-skilled worker must carry out when operating different machines.

(4) Continuous Process Flow.

This feature assesses whether production operations have been designed to meet changes in demand without producing waste or reducing productivity. In order to implement a synchronized flow of materials it is necessary to use the pull system and the level production that are discussed further on as dimensions[30].

(5) Continuous Improvement.

Continuous improvement is an ongoing effort to identify and remove wasteful elements in the manufacturing process. To this end, it is necessary to have a clear internal communication strategy and to designate an on-site person in charge. A system of improvement suggestions should also be in place, and employees must be trained in methods of continuous improvement.

(6) Error Proofing Processes.

This dimension assesses the existence of error proofing devices in the process that enable quality manufacturing, eliminating defects before they occur. Furthermore, it detects errors that have already occurred in order to prevent them from occurring again later on in downstream process[14]. Depending on its regulating function, its purpose and the techniques used, two types of system may be identified: monitoring-prevention methods that turn the machine off when errors happen in order to prevent the same defect from reoccurring; and warning methods that tell the worker when errors occur. As monitoring methods are more effective in any scenario, they should be used as often as possible.

(7) Quick Changeover Capability.

This dimension assesses whether the organization is using a systematic method to reduce changeover times with the aim of maximizing how long the production process is in operation. Reducing changeover times is achieved by applying the Single Minute Exchange of Die system (SMED)[1]. This is a tool that endeavors to improve the machine setup time, reducing to the maximum how long is needed for equipment changeover.

(8) Total Productive Maintenance.

A total productive maintenance system is one that increases the availability of machines that favor the manufacture of zero defect products in optimal times and at the minimum possible cost[22]. By involving the whole organization, this system identifies the prevention and prediction of breakdowns so that these do not cause production downtime.

(9) Pull System.

KANBAN is a tool that contains information enabling us to trigger work orders, specifying what is going to be produced, the quantity, the means and how it is to be transported. Its main functions are production monitoring, process improvements, the movement of materials, and information transferal.

(10) Level Production.

This dimension analyzes whether the organization carries out a level production process that enables a constant volume and mix of manufacturing to be maintained over a certain period. In this way, the following is achieved: a fit between production and demand; a stable workforce is maintained with few staff changes; the inventory of raw material and the finished product is reduced; and manufacturing flexibility is boosted.

There are certain training actions which aim to develop one or several of the ten features/dimensions described above. The researched companies have, in fact, implemented several of these interventions, in order to increase their level of lean production. In the following Tab. 1 a comparison is made between the main features of lean production and the most suitable interventions for improving it.

Table 1. Features of lean production and training interventions

• Features of Lean Production	Training Interventions
• Cultural Awareness	Measures implementation, group problem solving, continuous improvement, internal communication, waste elimination
• Industrial house keeping	5'S, visual factory
• Standardized Work	Line balancing, Standard Operations Procedure (SOP)
• Continuous Process Flow	Multi-skilled workforce, process layout (U-Cells)
• Continuous Improvement	Waste elimination, continuous improvement, group problem solving, suggestion systems, Value Stream Mapping (VSM.)
• Error Proofing	Error proofing[25]
• Quick Changeover Capability	SMED
• Total Productive Maintenance	TPM
• Material Control	Pull/push system, Value Stream Mapping
• Level Production	Just in Time

3 Description of performance indicators

Once we have described lean production and exposed the main training interventions used for improving it, we will now describe what we understand by effectiveness and performance, so that we can later analyze the effects of training on performance indicators.

In reference to the concept and measurement of the effectiveness of the company, faced with the absence of a universally accepted theory, many authors have tried to clarify the basic criteria necessary for evaluating the performance for a company. From the classic goal-based models[4] through resources or systems models[13, 18, 34] or process models (Steers 1977), right up to multiple component models or competitive values[9, 19, 26–28, 32]. We found especially interesting the indicators used by Lowe et al.[23], since their study dealt with a close industrial setting, namely automotive component plants. These researchers followed the International Motor Vehicle Program, defining performance in terms of physical productivity and quality at plant level rather than through financial measures of organizational performance. They argued that physical performance indicators provide more robust comparisons, because they are less influenced by short-term fluctuations (e.g. in exchange rates) and the differing accounting procedures which affect financial indicators. Therefore, in our work we have chosen several indicators based on different studies:

(1) Quality (First-Time-Through Capability): FTT.

This represents the percentage of components that complete a production process and meet quality specifications adequately without having to be rechecked, repaired off the production line, returned or thrown away as scrap.

$$\text{FTT} = \frac{\text{No. units entering process} - (\text{reprocesses} + \text{retests} + \text{repairs offline} + \text{scrap})}{\text{No. units entering process}}$$

(2) Overall Equipment Effectiveness: OEE.

Measures a machine's ability to perform an operation in accordance with quality standards, at the desired frequency and without stoppages.

Measures the availability, efficiency and quality ratio of a piece of equipment for a specific product.

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{FTT}$$

where:

$$\text{Availability} = \frac{\text{Production Time}}{\text{Net Time Available}}$$
$$\text{Performance} = \frac{\text{Ideal Cycle Time} \cdot \text{Total Pieces Produced}}{\text{Production Time}}$$
$$\text{FTT} = \text{quality ratio defined in point 1}$$

(3) Dock to Dock Time: DTD.

An indicator of the mean time elapsed from the delivery of raw materials up to the shipment of finished products.

$$\text{DTD} = \text{RM} + \text{WIP} + \text{FP} + \text{Manufacturing Time}$$

where:

RM is the raw material inventory. WIP is the work in progress inventory, and FP is the finished products inventory.

All of these quantities are adapted to production days using the following formula:

$$\text{Inventory (days)} = \frac{\text{No. Pieces Inventory (units)}}{\text{Average Volume of Daily Production}^{\text{(units/days)}}}$$

"Manufacturing time" is the sum total of operations' time in the processes a component goes through.

(4) Workforce Productivity.

Measures the number of units produced per workforce hour worked.

$$\text{Productivity WF (Processes)} = \frac{\text{N° Units Produced}}{\text{N° WF Hours Worked}}$$

(5) Changeover Time.

Total time a manufacturing process is stopped to perform a model changeover. It begins when the last correct component model is produced, and finishes when the first correct component of the following model is produced and the line is ready to manufacture the next product.

Changeover Time should include: setup time for tools, materials and matrices, etc. for the next process; the necessary time to perform gauging and adjustments, and the time necessary to begin producing correct components once the changeover is completed.

$$\text{Changeover Time} = \text{Preparation Time} + \text{Adjustements Time} + \text{New Stable Process Time}$$

(6) Value Added Ratio (VAR).

Represents the time used to perform operations on the product that add value to it, with respect to the total time invested in manufacturing the product (waits, inspections, movements and operations).

$$\text{VAR} = \frac{\text{Value Added Operations' Time}}{\text{Waiting Time} + \text{Inspections Time} + \text{Movements Time} + \text{Manufacturing Time}}$$

4 Methodology

According to our goal, we have already specified the main features of lean production, linked them with the corresponding training actions, and defined the selected performance indicators. Now we will explain how did we run our fieldwork.

For our empirical research we collected data from 11 automobile manufacturer suppliers. These companies were chosen because of their significant volume of purchases, because they had carried out cost reductions over the last few years, or because problems have been detected recently in the quality of their deliveries.

The companies, located in Spain's major cities, belong to different industries (plastics, metal-mechanical, electrical products, chemical products $\cdots$). They also manufacture a wide range of products including paneling, sound proofing, padding, metal mechanizing, metal pressing, welded components, nuts, plastics (injection and molded), mechanical assembly pieces and electrical products (see Tab. 2).

Table 2. Description of the companies studied

	Processes	Turnover (mill e)	No. employees	Sector
Case 1	Injection and assembly	28	250	Plastics
Case 2	Pressing, mechanizing, injection and welding	29	250	Metal-mechanical
Case 3	Pressing and welding	80	400	Metal-mechanical
Case 4	Mechanizing, pressing and injection	27	250	Metal-mechanical
Case 5	Injection	24	250	Plastics
Case 6	Mechanizing and assembly	60	600	Assembly
Case 7	Assembly	85	250	Assembly
Case 8	Injection and assembly	178	450	Chemistry
Case 9	Injection	125	900	Chemistry
Case 10	Injection and assembly	166	1000	Plastics
Case 11	Injection and assembly	85	900	Electronical products

Depending on the company, data was obtained over a 9-12 month period and was structured in the following way:

(1) Initial diagnosis of the company's situation and assessment of the degree of implementation of "lean production". This generally takes two days and involves working with a group of four to five managers from different departments. The aim of the diagnosis is to pinpoint the company's strengths and weaknesses and to gauge the main manufacturing indicators explained in the previous section.

For each lean production feature, a form is filled in based on a check list of the best practices, and their degree of use is assessed.

(2) Development of training and intervention activities. A system of workshops lasting four to five full days is used. The necessary theoretical concepts, adapted to each case, are presented and a detailed study of the production line is made. Groups of 5-14 people take part in these workshops, which include at least 50% of workers or team leaders. The subjects to be taught are chosen according to the needs detected during diagnosis. At the end of the week the activities to be carried out over the following three months by the team members are put forward to management. Lastly, a date is set to carry out follow up on how the productive efficiency indicators have progressed. This process is repeated two or three times in each of the companies until the objectives specified in the initial diagnosis are completed.

(3) Closing session: the team provides management with a summary of the activities and the results achieved.

5 Results

In this section we will show the overall results of the companies studied. We will firstly describe the companies' current situation with regard to production indicators (Tab. 3) and to the use of the lean production system (Tab. 4). If we look at the last row in Tab. 4— showing the mean value of the ten features of lean

Table 3. Current situation in the production indicators

Indicator	Measure	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Mean
FTT	%	91.2	82	78.3	93.2	97			76	55	71	90	81.5
OEE	%	53	67	66	59	70			61	77.2	79	60	65.8
DTD	days	6.9	13	8.2	23	14.5	9		17.8	10.6	39	37.6	19.2
WP	Units/ WF hrs worked	6.4	19.6	69	4166	43.7	29.0	3.5	16.7		4.3	13	437.0
BCT	minutes	18	35.5		357	89	40			75	17	180	101.0
Added	%	0.1	0.004	0.032		0.01	0.01		0.1	0.29	0.21	0.004	0.084

Note: FTT—Quality; OEE—Overall Equipment Efficiency; DTD—Dock to Dock Time; WP—Workforce Productivity; Batch Changeover Time—BCT; Added Value Rate.

production — we can see that with the exception of company 10, the remaining companies are at an early stage, possibly in line with a traditional mass-production approach (cases 2, 3, 6, 8 and 11, where the mean of the features is under 4,0), or an intermediate manufacturing stage on the way to lean production (cases 1, 4, 5 and 9, where the mean of the features is equal or over 4,0).

In companies where the implementation of lean production is more advanced, the features that are most developed are organizational culture, visual management and continuous improvement, followed closely by the other dimensions. The least developed features are the reduction of "quick changeover times" and "pull systems".

In companies whose production systems are close to mass production, the most developed dimensions are continuous flow of components and error proofing systems. Once again, and somewhat behind the first features this time, the last positions are taken up by "quick changeover times" and "pull systems".

We want to highlight the fact that in both cases "continuous flow" means that the components are processed one-piece, since they are moved along a continuous assembly line. However, with the exception of companies 5, 8 and 10 – where the flow comes closer to the actual concept of one-piece – components are processed within a rather large batch. The main reason for this is that the true JIT one-piece flow requires,

Table 4. Current situation in the implementation of lean production

Indicator	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Mean
Culture	7	4	3	5	5	2		5	5	8	4	4.8
VM	5	3	3	5	3	2		4	6	8	4	4.3
SW	4	4	4	2	4	3		3	5	8	4	4.1
CF	3	5	5	5	6	5		6	4	6	3	4.8
CI	7	5	3	5	3	1		3	4	7	4	4.2
EP	5	5	4	5	5	5		4	3	5	5	4.6
QC	4	2	1	4	5	2		1	1	8	2	3
TPM	4	1	4	6	3	4		1	4	5	3	3.5
PS	5	2	1	2	3	1		3	4	6	2	2.9
LP	4	4	1	3	5	3		7	4	8	2	4.1
Mean of the 10 features	4.8	3.5	2.9	4.2	4.2	2.8		3.7	4	6.9	3.3	4.03

Note: The points refer to a scale of 1–10 representing to what degree lean production is used.
VM—Visual Management; SW—Standardized Work; CF—Continuous Flow;
CI—Continuous Improvement; EP—Error Proofing; QC—Quick Changeover;
TPM—Total Productive Maintenance; PS—Pull Systems; LP—Level Production.

among other things, considerably reduced changeover times. And, as we will see later on, this is one of the main activities that has been included in training companies.

Another aspect to be taken into account is that in companies where lean production is less developed, activities aimed at attaining standardized procedures or error proofing processes are mainly performed by engineers or specialized personnel. Meanwhile, companies where a "lean" culture has been promoted try to involve first-line workers in the process.

It is also logical that the pull systems are in last position, since their implementation is impossible until the other features have been developed. They require considerably stable production systems with high quality ratios, and where information is transferred in an extremely visual and intuitive manner.

In Tab. 5 we show the training activities included in the workshops. These activities endeavor to prioritize the companies' problems. Such problems will vary depending on the extent to which lean production has been implemented.

As a general rule, companies with a less developed lean production system (cases 2, 3, 6, 8 and 11) initially focus on developing awareness aspects to create a culture oriented to lean production. This is carried out by introducing continuous improvement via "waste elimination" programs developed in groups where first-line workers play an active part. "Standardized Work" is also used as a tool for cultural awareness and involves the participation of those workers affected.

As we can see, companies where the above aspects are more advanced (cases 1, 4 5, 9 and 10) begin by developing the most technical tools (SMED). After initial workshops, the other activities tend to focus on tools that enable the stabilization and backup of the system. These activities are basically those for maintaining a "visual factory" environment, for defining certain indicators that enable constant updating on how the system works, and preventive/productive maintenance in companies with automated processes. Lastly, the concept of "pull systems" is implemented in those cases where the simplicity of the process or the degree of progress towards lean production makes it possible.

Once we know the starting point (Tab. 3) and the training interventions followed (Tab. 5), Tab. 6 shows us how the production indicators have improved in the cases under study. The information gathered indicates that manufacturing indicators have benefited from the "mini projects" developed in the workshops.

Summarizing the main results obtained in the eleven cases studied, we should point out the following: a notable improvement was achieved in machine efficiency (approximately 10%) – this was basically due to radical improvements in changeover times (reductions close to 50% the original time); improvements of close to 5% in the quality ratio (based on levels above 80%); an almost 50% reduction in inventory levels and an increase in productivity of between 8% and 60%. In addition, we also observed considerable improvements in the use of space in the factory plant, a reduction in the number of containers, and in the distance covered by products.

Table 5. Training interventions in the companies

Indicator	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
1^{st} Workshop, Date and contents	Jun 99 SMED	Jul 99 WE PL LB Kanban	March 99 SMED	July 00 SMED	June 00 SMED	June 99 GPS WE LB PL CPF	July 00 WE LB QPS Measu	June 99 GPS WE LB PL CPF	Jan 01 SMED	Jun 99 GPS WE LB PL CPF	May 01 SMED
2^{nd} Workshop, Date and contents	Sept 99 WE PL LB	Sept 99 VF Measu	May 99 WE PL LB Kanban	Oct 00 VF QPS Measu	Jul 00 VF QPS Measu	Oct 99 Kanban	—	Oct 99 VF QPS	Apr 01 CPF	Sept 99 Kanban	July 01 TPM
3^{rd} Workshop, Date and contents	Dec 99 VF QPS Measu	Nov 99 SMED	June 99 VF QPS Kanban Measu	Dec 00 TPM	Sept 00 TPM	Jan 00 VF QPS Measu	—	Nov 99 Kanban	July 01 TPM	Nov 99 VF QPS Measu	—

Legend:
Code—Intervention; CPF—Multi-skilled Workforce; GPS—Group Problem Solving
Kanban—Push/Pull Systems: Kanban; LB—Line Balancing; Measu—Measures Implementation
PL—ProcessLayout; QPS—Standardized Work; SMED—SMED
TPM—Total Productive Maintenance; VF—5'S,Visual Factory; WE—Waste Elimination

Table 6. Improvement in efficiency indicators. (original format)

Indicator	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
FTT	8%	5%	11	6%	1%			1%			5.6%
OEE	36%	13%	30%	6%	11%			4%			25%
DTD		-41%	-48%	-22%	-7%	-64%		-21%			-60%
WP	11%	14%$^{+}$	17%$^{+}$	8%		34%	60%	23%	9%$^{+}$	21%	14%$^{+}$
BCT	-33%	-72%	-75%	-40%	-71%			-54%	-48%		-87%
AVR	8%		72%			160%		20%			126%

Note: Note: FTT—Quality; OEE—Overall Equipment Efficiency; DTD—Dock to Dock Time;
WP—Workforce Productivity; Batch Changeover Time—BCT; Added Value Rate.
The percentage of improvement was calculated as: (value at end-value at start)/value at start.
$^{+}$: measured as direct workforce variation for a specific production instead of components' variation per worker.

Lastly, we should bear in mind that these measurements are not independent. An improvement in quality will affect the efficiency of machines. Efficiency is also affected by a reduction in changeover time – as this decreases, more manufacturing time for a machine may be achieved. Nevertheless, this measurement is not direct – if the company exploits the fact that the changeover is faster to make more model changes, the machine will not be put to better use. In this last case, however, it is the DTD indicator that will be improved, since the work in progress is reduced because smaller batches are being processed. An example of this can be seen in company 4 (Table 6). The 6% improvement in OEE is due to the optimized quality of the products, while the 40% reduction in changeover times did not help to improve efficiency, since the company's policy has been the reduction of batch sizes. This has improved DTD[17] and allowed customers, on average, to be supplied with products a week earlier (going from 23 days to 18 days).

6 Discussion and conclusions

We will start this part by trying to reflect on the most outstanding results shown before. The first observation to discuss refers to the quality performance indicator, where just minor effects are recorded. We should point out, however, that all of the companies had already engaged in activities to improve manufacturing with the aim of ensuring acceptable quality levels. These activities were initiated because their clients obliged them to become ISO-9000 certified companies. They also set up their own certification with auditors from the client company purchase department in order to continue supplying them. Therefore, our research does not conclude that training has a low impact on quality indicators, since the starting point of the studied companies regarding quality was already high.

Another discussion point should be the fact that those companies closer to a mass production approach are the ones that experienced the highest reduction in Dock to Dock time and in Batch Changeover time. We should bear in mind that their traditional approach fostered a high use of training activities (e.g. see cases 3, 6 and 8). Assuming such training interventions were correctly recommended to each company, according to its individual situation, these results suggest that DTD and BCT are the easiest indicators to improve. Therefore, we could suppose a relationship between training activities and reduction of Dock to Dock and Batch Changeover times.

It is also outstanding that company 11 faced just two training interventions (SMED and TPM) and it gained significant good results in most performance indicators. This fact is specially remarkable, since the company's initial situation regarding lean production is always under the average.

Interesting is the comparison of companies 1 and 3. Both present similar levels of initial production indicators, almost identical training interventions, and both experience high improvements in quality and efficiency. However, there is an important difference between their starting point in lean production. While company 1 has a much higher punctuation in lean production culture and in continuous improvement — and general higher degrees in almost all the lean production features —, company 3 is one of the cases closest to a traditional mass production approach. By comparing both cases, we could conclude that quality and efficiency improvements could be linked to certain training interventions followed by these companies. But, a new concern arises from our research, namely, how previous lean production situation affects quality and efficiency indicators. That would be a highly interesting research line for further studies.

Regarding the before mentioned concern, it is a pity that we do not have enough performance indicators about case 10. That company is highly relevant, because it shows the highest level of lean production and it is also one of the companies that applies more training initiatives. Therefore, it would have been interesting to check its results.

Actually, one of the restrictions of this study can be seen in the fact that 23 (34.8%) of the boxes in Table 6 are blank. The main reason for this was that providing data for calculating indicators represented a considerable cost for some companies or, as it happened with company number 7, data confidential politics did not allow us to access them. We must also bear in mind that most of the companies did not have a reliable information system to provide data rapidly. In those cases where an information system was in place, the data offered were incongruous depending on the source that supplied it (production, quality or maintenance department). Alternatively, the information stored did not always coincide with the data that were required. This last factor is because the companies used different formulae to gauge their manufacturing efficiency.

On the other hand, in some cases the way data were interpreted in the plant did not coincide with the definitions used in this study. This was particularly critical in the indicators for efficiency and machine availability.

Because of all these reasons, we were obliged to trace the necessary data in each company, contrasting them with various sources, or recording them directly in-plant when discrepancies emerged. This process took us close to two working days to conduct and involved several key staff, generally those who held important positions in maintenance, quality and production. Most of them had little time available and involving them in our research proved to be costly for the company. Thus to avoid problems, in each factory we limited ourselves to obtaining measurements of indicators that were of immediate practical use to them. This meant taking into account the requirements detected in the initial diagnosis, the training activities carried out, and the changes implemented in the production lines.

With regard to the generalization of our results, it should be stressed that all the companies studied have the common feature of being suppliers for automobile manufacturers and operate in accordance with the philosophy of lean production. Nevertheless, they represent various sectors which use different manufacturing processes where the implementation of lean production varies (some, such as companies 3, 6 or 11, are more like the prototype of mass production). For all these reasons, we believe that this experience may be very beneficial to other companies that wish to conduct these activities although they are not in the lean scenario/automobile industry.

In conclusion, the results obtained in our research highlight the importance of training activities and how effective team work is. We are confident that this study provides evidence that will encourage other companies to implement similar processes that facilitate improvements in their working performance and efficiency.

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