Factors influencing the implementation of Lean Production (LP) in the company are widely studied; however, the literature does not present the most relevant factors from the perspective of individual parts of the manufacturing system, such as Manufacturing cells (MC). Four case studies were conducted to identify and understand the factors that affect the implementation of LP in MC and results suggested that those factors are: (a) the reason for adopting LP, (b) the experience of the company lean, (c) the involvement of supporting areas, (d) the interdependence of some practices, (e) the variety of product models, (f) the synergy between the LP and MC, and (g) the equipment’s size.

KEYWORDS: Lean Production, Manufacturing cells, Lean assessment

INTRODUCTION

Cellular manufacturing is widely known as a mechanism to reduce lead times, improve quality and provide flexibility for changes in the mix and volume. Since these features are prioritized in lean production (LP) environments, manufacturing cells (MC) are often used in this context (Hyer & Wemmerlov, 2002). Moreover, the fact that a MC is a small unit of the manufacturing system tends to reduce the complexity of implementation of LP principles and practices. In particular, many companies adopting LP have deployed the MC to replace functional job shop layouts (Womack & Jones, 1998; Rother & Harris, 2001), whose characteristics (large intermediate stocks and large batches) conflict with LP goals.

Although many factors are known to influence the LP implementation within the company as a whole, such as organizational culture (Mann, 2005), the existence of infrastructure to support manufacturing (Soriano-Meier & Forrester, 2002), the process type and size of the company (White & Prybutok, 2001); the literature has not emphasized the most relevant factors from the perspective of individual parts of the manufacturing system, either in cells or other forms of
manufacturing organization. Several studies that evaluate and discuss factors that affect LP implementation (Sim & Rogers, 2009; Taylor et al., 2013) do not stress the understanding of LP implementation at a MC level. Companies often have different processes and productive sectors that may be experiencing various difficulties in LP implementation due to their specific characteristics. For example, factors affecting the implementation of lean practices in an assembly cell may differ from those that affect a machining cell, even if they are part of the same company, due to the characteristics of their environment, such as the differences between operators, machines, materials, equipment, procedures, requirements and product quality.

In this context, the main objective of this paper is to identify and understand the factors that affect the implementation of lean practices in MC. The existence of different perspectives around the fundamental characteristics of a lean enterprise (Maskell & Baggaley, 2004) requires an assessment of the lean implementation at the studied companies. Thus, it was applied the LP assessment method from Saurin et al. (2011), because this was the only one found in the literature that evaluates the implementation of lean practices in MC. It is important to notice that the implementation of lean practices does not assure that the underlying principles are in place (Spear & Bowen, 1999). In relation to that, Mann (2005) recommends that companies begin LP implementation with the adoption of practices, because the absorption of the principles by organizational culture is a slow process. Thus, the assessment of lean practices makes more sense in businesses that are starting their lean journey. The method of Saurin et al. (2011) also emphasizes the integrated application of lean practices from a systemic perspective, which is essential to understanding general socio-technical environments systems (Clegg, 2000).

LITERATURE REVIEW

The application of the method for LP practices assessment in MC (Marodin, 2008; Saurin et al., 2011) is divided into four phases: (i) phase 0, preparation phase, (ii) phase 1, preliminary information, (iii) phase 2, collection of evidence and evaluation of the use of lean practices and (iv) phase 3, feedback meeting and validation of results.

The preparation phase consists on training the person who is about to assess the system. A key requirement of the evaluator is that he knows the concepts of LP and MC addressed in the assessment. This phase also includes the introduction of the method in the company, which comprises three necessary steps: (i) present the assessment tools to company members involved in the work in order to facilitate data collection, (ii) select the cell which will be evaluated, and (iii) set the agenda for data collection. The presentation must contain at least the purpose, method, activities and expected results from the assessment.

Phase 1 aim to comprehending the MC functioning and identifying its characteristics. A questionnaire is proposed to guide the data collection at this phase. It consists of four main sections designed to characterize the company and the cell: (i) questions about the company, such as market segment, business, products, customers and LP implementation efforts, (ii) questions about the number of employees, equipment, products, and the organizational attribute of the cell, (iii) development of a products and processes matrix for the cell in order to assess the presence of the group technology attribute and (iv) cell evaluation according to the attributes of time, space and information.

Phase 2 consists of collecting and analyzing evidences of the use of LP practices in the cell. Analogously to phase 1, there are specific questionnaires structured as checklists for each source of evidence. There are three sources of evidence at this phase that allows the data analysis: (i) observation of the MC, (ii) interviews with operators and (iii) interviews with leaders or supervisors. Table 1 shows the pre-selected qualifying attributes for each of the 18 LP practices assessed in MC. They are divided into three subsystems: (i) human resources, (ii) planning and production control and (iii) process technology.
Phase 3 of the method is the feedback meeting. This meeting includes a discussion of the results and identification of improvement opportunities, which are resultant from the gap between cell current state and what would be missing for the attribute be fully achieved.

Table 1: Qualifying attributes for LP practices in MC

<table>
<thead>
<tr>
<th>Practices</th>
<th>Attributes</th>
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<tbody>
<tr>
<td>1. Teamwork and leadership (TWL)</td>
<td>Team leader supports workers in continuous improvement activities, such as problem solving and implementation of improvements. Team leader substitutes missing workers. Performance assessment of workers is made on a team basis, rather than on an individual basis.</td>
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<tr>
<td>2. Continuous improvement (CI)</td>
<td>Workers are trained in problem solving methods, including root cause analysis. Workers are involved in continuous improvement initiatives, whether formal or informal ones. Continuous improvement groups are coordinated either by workers or team leaders.</td>
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<tr>
<td>3. Multifunctionality and cross-training (MCT)</td>
<td>All workers are able to carry out all cell operations (i.e. cross-training is fully implemented). There is a skills matrix that documents every worker’s skills. Job rotation among cell workstations is undertaken on a daily basis.</td>
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<tr>
<td>4. Workers’ autonomy (WAU)</td>
<td>Workers have autonomy both to identify and to control process and product variability. Workers have autonomy to stop production if abnormalities occur. There are visual devices for calling the team leader or support areas, such as maintenance.</td>
</tr>
<tr>
<td>5. Standardized work (STW)</td>
<td>There are documented work standards. Work standards are visible to the team leader. Standards include information on takt time, cycle times, manual and automatic time, production sequence, standard inventories, and cell layout. Standards are updated on a regular basis. There are audits to check compliance with work standards on a regular basis.</td>
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<tr>
<td>6. Workplace housekeeping (WHK)</td>
<td>The cell is clean and equipped with only the necessary objects. Every object has a standard place, which is easily identified by visual devices. There is a 5S program, which is audited on a regular basis. Results of 5S audits are posted in the cell.</td>
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<tr>
<td>7. Pull production (PULL)</td>
<td>All inventories (raw materials, work-in-process, and end products) have visually defined maximum caps. There are visual devices informing both production sequencing and materials loading sequences. There are standard routes for loading raw materials and removing end products, including standard picking times. The above attributes exist for all components, whether manufactured in the plant or purchased from external suppliers.</td>
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<tr>
<td>8. Smoothed production (SPR)</td>
<td>All product models are produced every day. Consumption of raw materials from the preceding processes occurs at constant intervals and volumes.</td>
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<tr>
<td>9. Quick setups (QST)</td>
<td>There are no setups among different models. If there is setup, its tasks are standardized and separated into internal and external tasks.</td>
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</table>
10. Total Productive Maintenance (TPM)
Workers carry out routine maintenance on all equipment (e.g., cleanliness, lubrication and small repairs) following standardized procedures. There is either preventive or predictive maintenance of all equipment.

11. Lean performance metrics (LME)
Cell performance is assessed based on metrics linked to lean production principles, such as lead time, rework and scrap rates, standard inventory versus actual inventory, overall equipment effectiveness (OEE).

12. Visual management of production control (VPC)
There is a production control board visible to all cell workers, showing production schedule either on an hourly or shift basis. The following information is presented on the board: planned; undertaken; difference pending; reasons for failing to comply with schedule; corrective actions.

13. Visual management of quality control (VQC)
There are quality control boards, which are visible to all cell workers. The boards display quality related metrics, root causes of defects, and respective action plans.

14. Equipment autonomation (EQA)
Machinery carries out value adding operations without either workers monitoring them or manual intervention. All pieces of equipment have devices either for preventing or detecting abnormalities. These devices stop production or provide warning of abnormalities.

15. One-piece-flow (ONE)
Single pieces of material are produced and moved between operations. There is no piece of material waiting between adjacent workstations.

16. Visibility and information exchange (VIS)
All workers can easily see their cell counterparts, equipment and materials. All workers can talk with each other in a normal tone of voice.

17. Layout size and shape (LSS)
All workers can exchange materials without walking more than 1 m (this distance was arbitrarily established). Cell design allows changing the amount of workers and production capacity.

18. Organization by the dominant flow (ODF)
All products pass through the same processes in the same sequence.

RESEARCH METHOD

The research method was divided into three steps: i) selection of participating companies, (ii) case studies in MC and (iii) integrated analysis of case studies. The case study is used for an in-depth understanding of the characteristics of a specific object, which can be a single event or phenomenon or one of its aspects (Eisenhart, 1989). According to Yin (2003), the case study is an empirical investigation in which combines different methods of data collection to examine real-life phenomena. By studying a company in its natural environment, the theory generated by the case study can provide an explanation why the phenomenon occurred (Meredith, 1998). Among the reasons for choosing case study, it highlights the fact that the identification of factors affecting LP implementation does not require direct action of company members or any kind of intervention with them. Furthermore, multiple case studies were carried out with the intention of investigating different types of MC in different organizational contexts to achieve greater validity generalization.

Three companies were selected for case studies called Alpha, Beta and Gama. In Gama, two cells were evaluated while only one cell was evaluated in Alpha and Beta. The Alpha and Gama companies belong to the automotive industry, which is one of the reasons for choosing them, since this kind of industry is recognized as one of the most experienced in terms of LP practices. Alfa is a tier two supplier in the automotive sector and Gama is a tier one. Moreover,
Alpha and Gama are implementing LP as corporate policy. On the other hand, Beta provides electronic components and is its starting lean implementation. Throughout the four case studies (case 1 in Alpha, case 2 in Beta and cases 3 and 4 in Gama) there were some differences in the way evaluations were conducted. The choice for investigated MC in each company was based on different criteria. In Alpha, the cell was chosen due to its simplicity, since there were only two operators and three operations. However, in Beta the criterion of choice was the opposite, since the selected cell presents the largest products and machines in the plant. Cases 3 and 4 represent all MC in Gama’s plant and present a customer-supplier relationship between them. The results of the four individual analysis were used as input for the integrated analysis, organized into two activities: (i) a comparison of the number of LP practices distributed in each of the three categories in order to analyze the characteristics related to such impacts, (ii) an analysis of the classification of each practice in each case, with the goal of raising the presence of factors that affect the LP implementation in MC.

RESULTS

Case Study 1

Alfa has 150 employees and produces components for automotive companies. Regarding LP, its implementation began in 2002, with some training initiatives conducted by a consultancy. After 10 months of training, the implementation became responsibility of the company’s employees under the guidance of the production supervisor. Moreover, LP implementation was reinforced when the company participated, in 2005, of a supplier development program performed by one of its largest customers. The plant presents a typical job-shop layout combined with a few downstream cellular processes. The creation of MC occurred within the first LP deployment efforts in 2003, aiming at reducing process lead-time. Previously, the entire plant had functional physical arrangements. Although the sequence of operations may change, all cells are similar to MC 1, which operates in two shifts with three operators each, performing identical cycles, characterizing the existence of multifunctional type operation of multiple processes (Shingo, 1989). In MC 1, among the eighteen practices, seven were fully used (3, 6, 12, 15, 16, 17 and 18) three were partly used (4, 5, and 11) and eight were not used (1, 2, 7, 8, 9, 10, 13 and 14).

Case study 2

The company Beta presents two plants and about 1,600 direct employees. The main customers are the automotive and electrical sectors. From a strategic standpoint, the company had never done a project or formal effort to implement LP. However, some isolated improvement actions were driven over the past 10 years, such as 5S projects, search for root causes and incentives to suggestions for improvements. The physical arrangement of the visited plant is composed almost exclusively of highly automated MC. Products do not undergo more than one cell to become finished products. Most of the cells comprise one or two operators that perform only the activities of feed, product removal and maintenance of the equipment s. Case 2 cell operates with 9 operators and three shifts. In total, it was identified full presence of only one practice (18), nine others were classified as partially used (1, 2, 3, 4, 10, 11, 13, 14 and 16) and the remaining eight (5, 6, 7, 8, 9, 12, 15 and 17) were absent.

Case study 3 and 4
Gama is a subsidiary company of a multinational company that is located in an industrial condominium and exclusively supplies to one automaker. This plant presents 39 employees and two MC. Production volumes are about 800 units per day, and the first cell operates in two shifts and the second in three. According to the interviews, both cells were developed with the participation and suggestions from operators.

The company has a program that evaluates and scores industrial units according to various performance indicators. Although this is not a specific lean approach, 8 of the 20 indicators are related to lean practices. There is no responsible for implementing LP concepts.

MC 3 operates with one operator and produces three different products that are used in the MC 4, which has six operators per shift.

**General analysis on LP practices implementation**

Regarding the practices implementation, practice of Lean performance metrics (number 11) had a partial application in all cases, which may be explained due the following reasons: (a) in Gama, where LP implementation is more mature, both cases use three out of four pre-determined indicators; (b) OEE indicator was used in all cases, even in companies that are not undergoing a lean implementation, which reinforcing the ambiguous nature of this indicator, which reflects both the mass production and LP principles. Figure 6 shows the consolidated results for all MC.

The practice Pull production was categorized as not applied in all cases. The assessment of this practice is quite difficult, since it is necessary to consider interactions with elements outside the cell (purchasing, warehouse and sectors that supply or are customers of the cell). This fact may be explained due to the need of support and participation of other sectors for its implementation (Smalley, 2004). Case studies were differentiated in relation to number and application of LP practices, as shown in Figure 1.

<table>
<thead>
<tr>
<th>Subsystems</th>
<th>LP practices / Cases</th>
<th>Case 1 (Alfa)</th>
<th>Case 2 (Beta)</th>
<th>Case 3 (Gama)</th>
<th>Case 4 (Gama)</th>
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<tr>
<td>Human resources</td>
<td>1. Teamwork and leadership</td>
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<td>2. Continuous improvement</td>
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<td>6. Workplace housekeeping</td>
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<td>Production planning and control</td>
<td>7. Pull production</td>
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<td>8. Smoothened production</td>
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<td>9. Quick setups</td>
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<td></td>
<td>10. Total Productive Maintenance</td>
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<td>11. Lean performance metrics</td>
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<td>12. Visual management of production control</td>
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<tr>
<td>Process technology</td>
<td>13. Visual management of quality control</td>
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<td>17. Layout size and shape</td>
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<td>18. Organization by the dominant flow</td>
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</table>
MC 3 and 4 presented the highest levels of LP practices implementation. This result may be due to some existent characteristics of the company, such as: (a) existence of formal initiatives to implement the LP; (b) company supplies to automakers within an industrial condominium, which reinforces LP implementation in the company; and (c) there is only one customer for these cells, which facilitates information flow and reduces variation in customer requirements. Indeed, the impact of the diversity of product mix is evident when comparing MC 4 (manufactures two models of products throughout the plant) and MC 2, which manufacture 83 different models in the cell. Experience with LP implementation among employees may also have influenced the results of practices implementation. On the other hand, results for MC 2 (Beta) demonstrate that some LP practices can be applied in MC even if companies do not have a previous knowledge or effort in this direction. However, many practices have not been fully adopted. In a first analysis, comparing MC 1 and 2, it is identified that both have the same results. However, the adoption level may change according to the practices.

DISCUSSION

Reason for adopting the LP

The motivation for the implementation of lean at Case 1 was a corporate policy, without any technical or financial support coming from the firm’s headquarters. As a result, there was an inefficient structure for the coordination and implementation practices and a lack of commitment from the support areas and top management. Case 3 and 4 had the company located in an industrial condominium of a car assembly company that is strongly imbued in LP principles. In fact, the car assembler creates a strong interdependence between firms that are located in the facility, suggesting that they should adopt LP. The lower level of adoption of LP practices on Case 2 was influenced by the firm’s lack of any policy or plan to implement LP, where they had only a few and isolated lean practices implementing initiatives. Although the reason for adopting lean is not frequently presented as strong factor for hindering the LP implementation at the literature, this factor may impact on the support of top and senior management and the belief of the importance of lean to the company (Bhasin, 2012). Nevertheless, top management support is generally considered as a crucial to LP implementation (Boyle et al., 2011; Moyano-Fuentes & Sacristan-Diaz, 2012), although there is still a lack of knowledge in what makes a top management supportive or not to the LP implementation (Marodin & Saurin, 2014).

Experience of the company with LP

How long the company was implementing lean and the age of the MC was appeared to positively influence the presence of the LP practice of PE at the cells. While the company Alpha (case 1) started their training on lean in 2002, the company Gama (Cases 3 and 4) started the LP implementation with training and kaizen events four years earlier 1998. The people that worked on production, support areas and the managerial team of this company had a higher knowledge of the use and implementation of lean practices because of the longer experience with the subject. At the same firm, Case 3 showed a lower level of implementation of the lean practices than Case 4 due to the fact that it was 2 years younger than the other that has running
for 4 years. The factor of the age of the cell had a more impact on the LP practices that had a need for a higher involvement of the operators, such as Continuous improvement (2), Multifunctionality and cross-training (3), Workers’ autonomy (4) and Quick setups (9). In fact, a certain amount of time is needed for the workers to feel comfortable to accept the use of lean practices (Taylor et al., 2013).

Involvement of the supporting areas in some LP practices

Some of the lean practices appeared to be more difficult to implement because they required a higher involvement of areas that support the production at the shop floor, such as Production planning and control, maintenance, sales and purchase. Teamwork (that was fully used at three cases) and Multifunctionality (fully used in two cases and partially used on the other two) are examples of practices that could be implemented only by the involvement of the people from the shop floor, such as workers, leaders and production supervisors. On the other hand, in Case 1, the lack of human resources in some areas such as quality and maintenance made it very hard to implement practices such as Total productive maintenance (10) and Visual management of quality control (13).

The Pull production, for example, was not used in all cases. The implementation of a full pulled production system requires a broad and high involvement and effort of areas such sales (e.g. leveling sales), purchasing (e.g. long term negotiation and supplier development), logistics (just-in-time deliveries) and production planning and control (e.g. planning and controlling the kanban cards) (Smalley, 2004). In fact, the implementation of lean is often lower in other areas rather than production because those areas typically have managerial practices and metrics that are that are guided by mass production principles (Hodge et al., 2011)

Interdependence of some practices

Saurin et al. (2011) identified 46 direct relationships between the 18 LM practices at a MC. These relationships were used to classify the practices into three groups, the Basic practices (depends on fewer practices), Intermediate practices (depends on an average number of practices) and End practices (depends on a higher number of practices). The case studies suggested that a higher number of relationships between the lean practices increase the difficulty of implementing the some of those practices. For example, in Case 1, the MC was not able to implement pull production because of a lack of production stability. This stability could be achieved if the company had implemented the Quick setup and Total productive maintenance before trying to apply a pull system. Other relationships were found within practice 1 (Teamwork and leadership) and practice 2 (Continuous improvement) in Case 1.

It is worth pointing out that this assumption could also be supported by the fact that a Basic practice can be implemented without any other practices. That was presented on Case 2, in which the Organization by the dominant flow (18) was the only practice fully implemented. The relationships between LP practices at the company level were largely tested in empirical studies with large samples (Cue et al., 2001; Shah and Ward, 2007). However, the fully systemic nature of the LP does not seem to be yet fully understood (Saurin et al., 2013).

High variety of models produced by cell

The higher number of product models that are made at the cell tends to negatively influence the use of the lean practices. It happens because this higher number usually different requirements for each product, for example, frequency of deliveries, production volumes, cycle times, setup times and other technical differences. This factor was highlighted comparing Cases 1 (23
different products) and 2 (83 different models). The differences at the products made the setup
time to vary from 20 minutes to two and a half hours at Case 2 and, because of that, the
batches were made to last for at least one month which made all the waste reductions and
implementing other practices more difficult.
Meanwhile, the lower number of product models (only two) and the frequent deliveries (16 times
a day) at Case 4 made it easier to: (a) Organize in a dominant flow because the was only one
flow between the two models; (b) the Quick setup tool, because there was only one setup
needed; (c) the Smoothed production with only two products. Meade et al. (2010) found that a
high number of models manufactured by the company increases the variety of different
sequences flows at the factory and generates higher inventories and hindering the use of LP
practices.

Synergy between the LP and MC

The LP practices and the MC attributes presented a series of synergies that complements each
other. For example, a group technology of 100%, a MC attribute that was assessed at the
Phase 1 of the Saurin et al. (2011) framework, was presented at Cases 1 and 4. This high group
technology has positively influenced in practices 16 (visibility and information exchange) and 18
(organization by the dominant flow), because it does not made it necessary to have alternative
flows which would need additional equipment’s at the MC.
The lack of the Organizational attribute of the MC was also cause a negative influence at the
implementation of some practices, such as Teamwork and leadership and Continuous
improvement at Case 1. The fact that the workers at the cells were not managed as a team and
had metrics that assessed the individual performance rather than team performance had a
negative impact on the use of those two practices.
Regarding the attributes of time, space and information between workstations, a few lean
practices also demonstrated that they had a positive impact on those connections. For example,
the use of visual devices to request assistance, the organization of the workplace and visibility
in case 4 clearly contributed to the connections of information. Similarly, the single piece flow,
multifunctionality and the size and shape of the layout contributed to the connections of time
and space in case 1.
In fact, many authors suggested that the use of MC is a crucial for implementing a lean system.
Marodin and Saurin (2013), in a systematic review with 102 papers on LP implementation,
found out that the MC is one of the most common practice used in lean assessment methods,
which corroborates with the results of the case studies.

Size of the equipment

Larger equipment’s seems to have a negative influence on some of the LP practices of and MC
attributes. For example, there were two machines occupy about 25 to 10 square meters each at
Case 2 and there were two machines occupying about 4 square meters each in Case 4. In such
cases, large equipment hindered the practice 15 (One-piece-flow), 16 (Visibility and information
exchange) and 17 (Layout size and shape) because it represents a longer distance for the
worker and the parts to move and visual barriers for the information and product flow within the
cell. Moreover, large equipments, such as presses or forges, require also great tools that hinder
other practices of LP, such as Quick setup (practice 9) and, by direct causal relationships a
negative impact on Smoothed production (practice 8) and Pull production (practice 7).

CONCLUSIONS
This study suggests that seven factors influence LP practices implementation in MC: (i) the reason for adopting the LP, (ii) the experience of the company with LP, (iii) the need for involvement of the supporting areas in some LP practices, (iv) the interdependence of some practices, (v) the variety of models produced by cell, (vi) the synergy between the LP and MC, and (vii) the size of the equipment.

First, despite the fact that literature does not emphasize the reasons for adopting LP, this factor is easily evidenced based on the level of support provided by senior management to lean implementation (Bhasin, 2012). Several authors consider fundamental this level of support for successful lean implementation (Moyano-Fuentes; Sacristán-Díaz, 2012; Boyle et al., 2011). Our findings support these empirical evidences, since cells that presented highest levels of LP practices implementation belong to a company placed inside an industrial condominium, in which LP is part of its business mission. This kind of reinforcement is noticed when comparing the level of practices adoption among MC 3 and 4 with others.

Finally, conducting multiple case studies provides a greater degree of external validity for the results (Meredith, 1998). Nonetheless, it is suggested that the results may be tested with a larger amount of MC, which enables a statistical analysis regarding the presence and impact of factors on LP practices implementation. Therefore, future research could be driven to develop mathematical models that explain the relationships among those factors based on statistical procedures, such as structural equation modeling. Moreover, future studies could verify the impact effectiveness of management actions that abrogate the presence of one factor in a long term.

REFERENCES


Marodin et al., 2014  Factors that affect lean production in manufacturing cells


