Application Phases for Productivity Improvement through Lean Methods Assessments in an Aeronautical Company – Case Study

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Abstract. A well defined manufacturing company focuses on lean practices along the whole product development process, not exclusively during the manufacturing and production phases. This study focuses on the application steps to be adopted for productivity improvement through lean methods assessments in a product development company for the aeronautical industry. It also aims to provide insights for decision makers along the whole lean transformation patch, and to reduce the waste generation by eliminating the non-value-added activities resulted by a bad execution of the lean implementation tools and methods. By deploying the proposed study, the assessed enterprise increased its overall lean engagement level and production outputs.

1. Introduction

The concept of lean manufacturing (LM) was popularized by Womack et al. [1] by extracting the core lean elements from the automotive production benchmarking. LM is regarded as a successor of the Toyota Production System (TPS), a business philosophy that has been in development for over 40 years. Lean production (LP) stems from the Japanese TPS [2] during the hard times of the post-war [3]; that Taiichi Ohno and Eiji Toyoda both Japanese engineers, developed between 1948 and 1975. The essence of TPS is a mindset that embraces continuous improvement (CI) and the capacity to adopt a set of values and culture, as summarized in the TPS house diagram by Liker [4]. The house metaphor is illustrated in the Figure 1 and demonstrates that a house is strong only if the roof, pillars and foundation are also strong. As far as developments may suffer from failures, delays and/or cost overruns [5], the TPS house shows that having a true LM requires adaptations in several sectors [6], moreover it is composed by multiple economic and operational performance dimensions [7] and represents a manufacturing culture of CI and waste reduction through participation of all employees [8], that must abide by a standardized processes [9] in an environment where their attitudes can reflect reactions to change [10]. Nowadays, competitions in manufacturing firms continue to grow [11]. Thus, from the recent years LM has been widely tested in recent literature reviews [12] and practitioners throughout the world by increasing its adoption for the industry 4.0 [13-14]; the implementation of LM emerging from the supply chain processes [15] and management [16-17]; and also by evaluating its motivational influence on the lean way [18-21]. In this paper, the focus is given to the application phases for productivity improvement through lean methods assessments in an aeronautical company. Thus, the case study enterprise was assessed as a complex socio-technical lean system.
2. Background

As product complexity increases, the trade-offs become increasingly complex [22]. Worldwide air traffic has been increasing through the last years, and recent researches indicate that the demand for new aircraft will continue to rise over next few decades [23]. Moreover, the manufacturing industry each time moves towards to products customization [24], while the time-to-market dimension has shrunk [25] in a scenario where aircraft design is largely dependent on previous design experience [26] and different lean strategies are utilized by manufacturing industries to improve its performance [27].

Brazil as an emerging country needs to catch up with technology to extend its international position, especially in the space sector [28]. Thus, the selected case study enterprise emerges from this context, and acts in the aeronautical industry for the aeronautical components supply industry in Brazil. The company was founded on July 4, 1990 at Rio de Janeiro and had around 100 employees by the time the method was deployed. The facility contained manufacturing, laboratory and engineering engaged in the development and production of aeronautical hoses and hydro-mechanical components.

LM plays a critical role in reducing waste when combined with other production resources [29] and do can bring an overall change in a manufacturing plant [30]. To deeply understand the manufacturing process is vital for tracking the bottlenecks and then, the area subject to improvements [31]. In other words, as far as work standardization is part of LM [32] and to save the company’s resources, it is necessary to identify the right set of metrics [33] prior to the method application; thus a plant tour was performed at the facility in order to visually check its ongoing lean processes. The top management and leadership commitment is crucial for the lean adoption [34]; that way the plant tour was followed by all personnel in charge of the lean implementation. A few examples of existing lean approaches resulted from the plant tour in the case study enterprise are shown in the Figure 2 and Figure 3 below:
3. Methodology
The application phases for productivity improvement through lean methods assessments in an aeronautical company are indicated in the Figure 4. The selected lean assessment method for the case study enterprise is the framework proposed by Silvério et al. [35], which includes all mathematics, calculations and roadmap definition for the decision-making process criteria. The activities coordination along the interaction cycle execution was sponsored by the company’s top management along the lean way (LW), including a key–person named “facilitator” or “lean agent,” which is the collaborator responsible to guarantee all adequate resources along the lean implementation patch.

![Interaction Cycle](image)

**Figure 4.** Lean journey method application phases interaction cycle (constructed by authors).

Each phase from the flowchart presented in the Figure 4 has its own pre–defined activities breakdown; later on detailed in the Table 1. For each activity breakdown, a task owner is in charge of its deployment and coordination in all organizational levels. Some of those refereed activities can also have a “multi–task team” defined, by assuming one or more roles according to the following criteria: leader, facilitator (lean agent) or employee. The activities breakdown for each phase is defined below.

**Phase one.** Phase one starts the interaction cycle for the application phases. In the phase one, it is expected to obtain leadership commitment; to define the method implementation schedule; to define the participant’s roles and responsibilities; to allocate resources for the method implementation and application and; to review the progress implementation of current action plans (if applicable). Phase one is considered a key–phase for the productivity improvement through lean methods application and shall have a high involvement from the leadership and the facilitator (lean agent) along its execution.

**Phase two.** In the phase two, it is expected to identify the respondents; and to perform the method introduction and training. Phase two is also considered a strategic–phase for the productivity improvement through lean methods application and shall have a close participation and engagement from all organizational levels directly involved in the lean transformation patch.

**Phase three.** In the phase three, it is expected to conduct the assessment; to collect and process the results; and to discuss, analyze and evaluate the results. Phase three is considered an operational phase, where the strategy defined in the previous phases take place along its deployment and application.
**Phase four.** In the phase four, it is expected to develop the action plan and to prioritize the resources. In the phase four, some results can already emerge and thus, it shall also have a high involvement from the leadership and the facilitator (lean agent) along its execution.

**Phase five.** In the phase five, it is expected to implement the defined action plan, record the results and plan the next assessment application. Phase five closes one interaction cycle for the application phases for productivity improvement through lean methods in an aeronautical company. As per the previous phases, it is also expected a close participation from all organizational levels directly involved in the lean transformation patch along its execution.

Table 1 presents the method application phases interaction cycle responsibilities distribution, where the lean assessment framework from Silvério et al. [35] was deployed and assisted by the leadership for the case study enterprise. As a result, the leanness level was defined, associating its results to a lean roadmap as per the chosen method’s criteria, to be used as guidance for managers to introduce recommended changes on their lean implementation patch, and also to prepare for the next interaction cycle application as per the Figure 4 lean journey method application phases interaction cycle.

| Phases                          | Tasks                                           | Personnel in Charge |
|---------------------------------|-------------------------------------------------|---------------------|
|                                 |                                                | Leader  | Facilitator (Lean Agent) | Employee |
| Phase one: assessment requirements definition | To obtain leadership commitment                  | X       | X                        |          |
|                                 | To define the method implementation schedule    | X       | X                        |          |
|                                 | To define the participant’s roles and responsibilities | X |          |          |
|                                 | To allocate resources for the method implementation and application | X |          |          |
|                                 | To review the progress implementation of current action plans (if applicable) | X | X        |          |
| Phase two: assessment application plan | To identify the respondents                    | X       | X                        |          |
|                                 | To perform the method introduction and training  | X       | X                        | X        |
| Phase three: perform assessment  | To conduct the assessment                       | X       |                           |          |
|                                 | To collect and process the results               | X       |                           |          |
|                                 | To discuss, analyze and evaluate the results     | X       |                           | X        |
| Phase four: develop action plan | To develop the action plan and to prioritize the resources | X | X | X |
| Phase five: implement action plan and plan next assessment application. Follow–up is also necessary. | To implement the defined action plan, record the results and plan the next assessment application | X | X | X |

4. Results and analysis

Adopting lean practices are not easy, particularly, in small and medium–sized enterprises (SMEs) [36-37]; that is also the criteria fulfilled by the case study firm. Moreover, lean solutions bring benefits for companies [38-40] and consequently, to society. That way, during three months after deploying the chosen lean assessment method application in the case study enterprise, the current lean engagement rate was observed and recorded over three full interaction cycles execution as per the Figure 4 flowchart. The trend results observed after each interaction cycles are summarized in the Table 2.
Table 2. Interaction cycles summary for the case study enterprise.

| Interaction Cycle 1* | Interaction Cycle 2* | Interaction Cycle 3* |
|---------------------|---------------------|---------------------|
| 50% (regular)       | 60% (regular)       | 70% (good)          |

* Current lean engagement level (measured rate) compared to an ideal target scenario (100%).

As demonstrated in the Table 2, the case study enterprise improved its overall lean index from 50% (regular) measured in the first interaction cycle to 70% (good) recorded in the last one by deploying the framework proposed by Silvério et al. [35] as per the method application phases interaction cycle presented in the Figure 4, divided according to the phases responsibilities distribution presented in the Table 1. The elements “sponsored” by leadership had a bigger impact on the lean assessment method application results, demonstrating that lean initiatives are closely related to all enterprise’s levels of engagement to succeed on the lean implementation patch. Improvements on the production line were also observed along the interaction cycle’s execution, increasing its production output as far as the chosen framework for the case study application also considers elements such as: process, tools and technology, waste and CI as “key lean elements” on its development and construction.

As an overall result, the application phases for productivity improvement through lean methods assessments in an aeronautical company proposed by this study has supported the efficiency and productivity increase for the case study enterprise on the lean way perspective. Although the resulted efficiency and productivity increment may seem quite small, the refereed overall impact had improved the company’s production output in a sustainable manner, as far as the case study enterprise continued to perform the interactions cycles along its lean journey.

5. Conclusions

Even though having a considerable number of information being delivered by the application phases’ deployment in a real aeronautical company, it is not possible to have a failure–proof lean company for every single process. Lean basis depends on people; and people are not a failure–proof resource. Thus, a failure–proof lean organization is not a feasible, nor a realistic scenario to be considered. In this study, a real problem application demonstrated productivity improvements through lean methods assessments application in an aeronautical company. As a result, the interaction cycle and responsibilities distribution demonstrated to be a useful support tool for decision makers to eliminate the non–value–added activities during the deployment phases of lean implementation practices, methods and processes in companies emerging as true lean organizations.

By applying the proposed method the assessed enterprise presented its real phases and responsibilities distribution for the interaction cycles execution as demonstrated in the Table 1. That way, the acquired data can also serve as reference information for future studies to be developed on the lean field, as far as the same responsibilities and tasks distribution can also be replicated for different industrial segments. Moreover, the method deployment in different industrial sectors, besides the aeronautical one, seems to be a particularly interesting area for further researches in order to perform a benchmarking analysis and comparative approaches on similar tools, methods and processes. A digital platform for each phase application could also be developed in order to provide a real–time key performance indicator (KPI), to be used by decision makers and managers in order to facilitate the data-mining and data-sharing information, among all personnel involved on the company’s lean transformation patch.

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References

[1] Womack JP, Jones DT and Roos D (1991) *The Machine that Changed the World*. New York: Harper Perennial.

[2] Chiarini A, Baccarani C and Mascherpa V (2018) Lean production, Toyota Production System and Kaizen philosophy: A conceptual analysis from the perspective of Zen Buddhism. *The TQM Journal* 30. DOI: doi.org/10.1108/TQM-12-2017-0178.

[3] Shingo S (1981) *Study of the Toyota production system from an industrial engineering viewpoint*. New York: Productivity Press. DOI: doi.org/10.4324/9781315136509.

[4] Liker JK (2004) *The Toyota way 14 management principles from Worlds Greatest Manufacturers*. New York: McGraw–hill.

[5] Wekerle T, Trabasso LG, Loures L, Villeda T, Brandão A and Leonardi R (2017) Design for Autonomy: Integrating Technology Transfer into Product Development Process. *Journal of Industrial Integration and Management* 02. 1750004. DOI: doi.org/10.1142/S242486221750004X.

[6] Pessôa MVP and Trabasso LG (2017) *The Lean Product Design and Development Journey: A Practical View*. Berlin: Springer. DOI: doi.org/10.1007/978-3-319-46792-4.

[7] Shah R and Ward PT (2003) Lean Manufacturing: Context, Practice Bundles, and Performance. *Journal of Operations Management* 21 129–149. DOI: doi.org/10.1016/S0272-6963(02)00108-0.

[8] Suhardi B, Anisa N and Laksono PW (2019) Minimizing waste using lean manufacturing and ECRS principle in Indonesian furniture industry. *Cogent Engineering* 6. DOI: doi.org/10.1080/23311916.2019.1567019.

[9] Alkhoraif AA, McLaughlin P and Rashid H (2019) A framework to improve lean implementation by review leveraging aspects of organisational culture: the case of Saudi Arabia. *International Journal of Agile Systems and Management* 12 124. DOI: doi.org/10.1504/IJASM.2019.10018747.

[10] Mcmackin J and Flood PC (2019) A theoretical framework for the social pillar of lean. *Journal of Organizational Effectiveness: People and Performance* 6. DOI: doi.org/10.1108/JOEPP-06-2018-0039.

[11] Susanto TA and Nur R (2017) Experimental research to investigate the performance of bio coolant when turning of mild carbon steel. In: *International Conference on Manufacturing, Material and Metallurgical Engineering (ICMMME)*. Bangkok, Thailand, 17–19 March 2017. IOP Publishing. DOI: doi.org/10.1088/1757-899X/191/1/012028.

[12] Danese P, Manfè V and Romano P (2017) A Systematic Literature Review on Recent Lean Research: State-of-the-art and Future Directions. *International Journal of Management Reviews*. DOI: doi.org/10.1111/ijmr.12156.

[13] Rossini M, Costa F, Tortorella GL et al. (2019) The interrelation between Industry 4.0 and lean production: an empirical study on European manufacturers. *International Journal of Advanced Manufacturing Technologies* 102 3963–3976. DOI: doi.org/10.1007/s00170-019-04341-7.

[14] Romero D, Gaiardelli P, Powell D, Wuest T and Thurer M (2019) Rethinking Jidoka Systems under Automation & Learning Perspectives in the Digital Lean Manufacturing World. In: *9th IFAC Conference on Manufacturing Modelling, Management and Control*. Berlin, Germany, 28–30 August 2019. IFAC PapersOnLine Series. DOI: doi.org/10.1016/j.ifacol.2019.11.309.

[15] Meng X (2019) Lean management in the context of construction supply chains. *International Journal of Production Research* 57 1–15. DOI: doi.org/10.1080/00207543.2019.1566659.

[16] Sony M (2019) Lean Supply Chain Management and Sustainability. *Advances in Logistics, Operations, and Management Science*. DOI: doi.org/10.4018/978-1-5225-8970-9.ch004.

[17] Tortorella GL, Miorando RF and Marodin GA (2017) Lean Supply Chain Management: Empirical research on practices, contexts and performance. *International Journal of Production Economics* 193. DOI: doi.org/10.1016/j.ijpe.2017.07.006.
[18] Castro F, Figueiredo SP, Pereira–Guizzo C and Passos FU (2019) Effect of the motivational factor on lean manufacturing performance: the case of a multinational consumer goods company. *Gestão & Produção* 26. DOI: doi.org/10.1590/0104-530x4850-19.

[19] Christensen R, Greenhalgh S and Thomassen Anja (2019) When a business case is not enough, Motivation to work with Lean. *Lean Construction Journal (LCJ)* 121–130. DOI: doi.org/10.24928/2019/0146.

[20] Schmidt G (2019) The need for goal–setting theory and motivation constructs in Lean management. *Industrial and Organizational Psychology* 12. DOI: doi.org/10.1017/iop.2019.48.

[21] Herakovic N, Metlikovič P and Debevec M (2014) Motivational Lean Game to Support Decision between Push and Pull Production Strategy. *International Journal of Simulation Modelling* 13. 443–446. DOI: doi.org/10.2507/IJSIMM13(4)4.275.

[22] Borgue O, Panarotto M and Ola I (2019) Modular product design for additive manufacturing of satellite components: Maximizing product value using genetic algorithms. *Concurrent Engineering: Research and Applications*. DOI: doi.org/10.1177/1063293X19883421.

[23] Silva A and Trabasso LG (2019) Design for Automation within the aeronautical domain. *Journal of the Brazilian Society of Mechanical Sciences and Engineering*. DOI: doi.org/10.1007/s40430-019-1791-y.

[24] Anumba CJ, Baldwin AN, Bouchlaghem D, Prasad B, Cutting–Decelle Af, Dufau J and Mommessin M (2000) Integrating Concurrent Engineering Concepts in a Steelwork Construction Project. *Concurrent Engineering: Research and Applications* 8(3): 199–212. DOI: doi.org/10.1177/1063293X0000800304.

[25] Prasad B (1997) Re–engineering life–cycle management of products to achieve global success in the changing marketplace. *Industrial Management & Data Systems* 97(3): 90–98. DOI: doi.org/10.1108/02635579710173158.

[26] Fansuri AFH, Rose ANM, Ab. Rashid MFF, Mohamed Nik NMZ and Ahmad H (2018) Productivity Improvement Through Line Balancing at Electronic Company – Case Study. In: *International Conference on Manufacturing, Material and Metallurgical Engineering (ICMMME)*. Kuala Lumpur, Malaysia, 17–19 March 2018. IOP Publishing. DOI: doi.org/10.1088/1757-899X/409/1/012015.

[27] Singh J, Singh H and Singh G (2018) Productivity Improvement using lean manufacturing in manufacturing Industry of Northern India – A Case Study. *International Journal of Productivity and Performance Management* 67. 00–00. DOI: doi.org/10.1108/IJPPM-02-2017-0037.

[28] Wekerle T, Trabasso LG and Loures L (2019) Technology Nationalization in the Space Sector: The Brazilian Perspective. In: *Systems Engineering in Research and Industrial Practice*. Springer–Cham (Switzerland). Stjepandić J., Wognum N., J. C. Verhagen W. (eds). DOI: doi.org/10.1007/978-3-030-33312-6_12.

[29] Bhasin S (2015) Lean management beyond manufacturing: A holistic approach. Springer–Cham (Switzerland), pp: 149–160. DOI: doi.org/10.1007/978-3-319-17410-5.

[30] Puvanasvaran AP, HuiHui Y and Norazlin N (2014) Managing waste elimination database in Lean manufacturing: Improve problem solving capability. *American Journal of Engineering and Applied Sciences* 7 (2): 271–281 (2014). DOI: doi.org/10.3844/aajassp.2014.271.281.

[31] Badeeb AM, Abdulaal R and Bafail AO (2019) An Application of Lean Manufacturing Techniques in Paint Manufacturing Company: A Case Study. *Journal of King Abdulaziz University* 28(2):51-73. DOI: doi.org/10.4197/Eng.28.2.5.

[32] Liu F, Li Q and Geng H (2019) Correlation Analysis between Gross Parameters and Performance Parameters of the Light Aircraft. In: *International Conference on Manufacturing, Material and Metallurgical Engineering (ICMMME)*. Chengdu, China, 22–25 March. IOP Publishing. DOI: doi.org/10.1088/1757-899X/538/1/012050.

[33] Acosta LMC, Trabasso LG and de Junior CSA (2003) Analysis of the Balanced Scorecard Formulation Process for Setting up Engineering Performance Metrics. In: *14th International Conference on Engineering Design*. Stockholm, Sweden, August 19–21.
[34] Alnajem MN, Garza–Reyes JA and Antony J (2019) Lean readiness within emergency departments: a conceptual framework. *Benchmarking: An International Journal* 26. DOI: doi.org/10.1108/BIJ-10-2018-0337.

[35] Silvério L, Trabasso LG and Pessôa MVP (2019) A Roadmap for a Leanness Company to Emerge as a True Lean Organization. *Concurrent Engineering: Research and Applications*. 28(1), 3–19. DOI: doi.org/10.1177/1063293X19888259.

[36] Cowger G (2016) Half measures gets less than half results. *Mechanical Engineering* 138(1), 30–35. DOI: doi.org/10.1115/1.2016-Jan-1.

[37] Hu Q, Mason R, Williams S and Found P (2015) Lean implementation within SMEs: A literature review. *Journal of Manufacturing Technology Management* 26(7), 980–1012. DOI: doi.org/10.1108/JMTM-02-2014-0013.

[38] Alves AC, Dinis–Carvalho J, Sousa RM, Moreira F and Lima RM (2011) Benefits of lean management: Results from some case studies in Portugal. In: *Proceedings of 6º Congresso Luso–Moçambicano de Engenharia (CLME2011)*. Maputo, Mozambique, South African, 29 August – 2 September 2011. INEGI.

[39] Alves AC, Kahlen FJ, Flumerfelt S and Siriban–Manalang AB (2014) Fostering sustainable development thinking through lean engineering education. In: *Proceedings of the ASME 2014 International Mechanical Engineering Congress and Exposition*. Montreal, Quebec, Canada, 14–20 November 2014. ASME. DOI: doi.org/10.1115/IMECE2014-38192.

[40] Resende V, Alves AC, Batista A and Silva Â (2014) Financial and human benefits of lean production in the plastic injection industry: An action research study. *International Journal of Industrial Engineering and Management* 5(2), 61–75.