Analyzing the Lean Manufacturing Challenges to Sustain Flexible Aeronautic Industry

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Abstract
These last two decades, many companies have grabbed the benefits of lean manufacturing in order to ease the flexibility of production workshops and enhance the global performance. However, when attempted to be implemented, the lean issue becomes less straightforward due to a lack of a clear understanding of the undertaken steps for achieving successful improvement.

The main objective of this paper is to lead an analysis on the main inducers implying the aeronautic industry to commit in lean manufacturing practices, following by a first attempt to build up a strategic model providing gradual and relevant Lean implementation starting from VSM converging towards the Leanness achievement. A Leanness degree measuring the progression of Lean could provide a significant indicator to position the company in its global strategy and help evaluating the remaining efforts. Our findings are called to be applied in aeronautic companies to state their usefulness and get feedbacks from the direct practitioners.

Keywords: Lean management, Flexible manufacturing, Aeronautic industry.

1. Introduction
Many companies are struggling to establish reliable manufacturing system able to face a complex context, full of disruptions, by answering various customer demands with high level of flexibility. This flexibility can be ensured only if the overall manufacturing system is accordingly built up: relevant workspace, adapted production lines, well thought workshops alignment, quick changeovers times, synchronized cycle times, JIT supply… All these elements belong to the Lean management, a very widespread managerial model. Fernando [1] in their historical analysis of Lean found that moving to Lean philosophy enables the flexibility of manufacturing systems by "offering a wide variety of products in a sequence that reflected more closely the market’s demands, reducing lead times and eliminating the need for large volumes of inventory, reducing the space constraints for manufacturing and warehousing facilities". The paper is organized as follows: in the section 2 a literature background is presented. The section 3 details the lean inducers in the aeronautic industry justifying the interest to develop a thoughtful approach of lean implementation. Section 4 shows the lean implementation challenges in a strategic model and the idea of leanness effectiveness measurement. Conclusion and further works are evoked in section 5.

2. Literature review
The Lean manufacturing becomes these last few decades an interesting managerial approach increasingly adopted by different companies in all segments of manufacturing systems: The Lean impact in Food Industry is analyzed in [2], in Steel Mill [3] in Automotive [4],[5],[6],[7],[8] in Aerospace [9],[10],[11]. Beyond the
manufacturing operations, the service operations also have received interesting Lean issues [12],[13],[14]. The Lean manufacturing intends to enhance the productivity by reducing the non-value added activities. Directing the efforts toward the core activities (value added activities) and get rid of non-value added activities [15] permits the company to thrive in current competitive context. An activity is considered as value-added according to Fiore in [16] when customer is willing to pay for the activity, when there is a transformation of the physical shape of the object or product, when it is done correctly first time. Nonetheless, the Lean management is often confronted to significant barriers that may lead to failures of Lean practices, such as organizational culture [9] change resistance [18],[19] and size of organization [20]. For implementing successful Lean management, it is fundamental to go beyond the technicalities by adopting relevant organizational culture. In this direction, the main objective of this paper is to counter these possible failures of Lean implementation by investigating a conceptual model helping the deciders to build their Lean strategies and choose relevant lean tools accordingly.

The literature dealing with the various Lean practices (JIT, TQM, TPM, VSM, SS, SMED, Cells Manufacturing, Kaizen, OEE, Pareto, Pull System, Line balancing… ) issued from Toyota Production System is very abundant. It would be useless to investigate these tools or define them again. The main idea through this literature analysis is to depict the different streams of Lean field researches to position our current contribution and the objective of our research. Three main streams of Lean management literature were identified. Stream.1 Lean models & simulations [21], [22] where authors tested through simulation the effect of different Lean tools in different workshops configuration ; Stream.2 Lean surveys & influence factors [20], [23],[18],[1] where the authors gathered different testimonies of practitioners concerning the factors influencing lean implementation (culture, organization,…); Stream.3 Lean implementation & performance [24],[1],[25],[10] where the authors focused on the impact on business performance after leading a lean conversions. According to the previous analysis, very few works focused on measurement and Lean performance evaluation [26]. The works related to Stream.3 deal with the performance evaluation once one or several Lean bundles practices are adopted. This performance may be split on different categories (financial, environmental, business, storages,…). Rare are the papers dealing with the Leanness assessment beyond the operational performance improvement. Among those fewest works, let us quote [27] in which the authors treat the degree of Leanness implementation, suggesting a fuzzy model to assess it because of its multidimensional character and subjective appreciation. The authors underline the difficulty of dealing with subjective appreciation. In [17] the authors also mention the global subjective appreciation of Lean implementation success. The Lean manufacturing practices are measured in qualitative way on a three-point scale: no implementation, some implementations, extensive implementations. However, [23] the authors highlight the still missing straightforward approach “There is no clear, standardized, easy-to-use framework for a lean manufacturing practice implementation available which also considers sector specific barriers”. Building a structured approach for Lean implementation is not sufficient; the specificities of the sector, the success of Leanness effectiveness implementation are useful as well.
3. Lean inducers in aeronautic industry

While the previous aeronautic projects were led under classical project management features, including the Lean management philosophy becomes obvious today, even if it is difficult to implement and tough to sustain. The summarized analysis highlights the characteristics of the sector which allow the emergence of important managerial insights directly linked with Lean management philosophy (speed up the production flow, reduce the variability and increase quality, improve the OTD - On Time Delivery, increase the coordination with suppliers to avoid missing parts., etc.).

Table 1: Lean inducers in aeronautics

<table>
<thead>
<tr>
<th>Lean Inducers</th>
<th>Main characteristics of the sector</th>
<th>Managerial insights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Competition</td>
<td>New Competitors: China with COMAC 919, Russia and Brazil.</td>
<td>Improve the Time To Market TTM, Quality, Costs to maintain a competitive positioning.</td>
</tr>
<tr>
<td>Market Demand</td>
<td>Growth in Air traffic: The ageing of the aircraft fleet, new low costs company arrivals, the opening of aviation area, Demand diversification: Final product presents too many requirements to so different clients.</td>
<td>Perform rapidly the increasing orders book. Create flexible manufacturing system to absorb the diversity of requirements, components and supplies respecting the schedule. Example*: A350 was developed with modularity concept 3 versions, 5 variants to reduce the diversity impacts on production and assembly lines.</td>
</tr>
<tr>
<td>Innovation &amp; Design</td>
<td>New savings issues: economical savings due to the energy costs and environmental sustainability are the new critical drivers in innovation. Example*: innovation LEAP Engine challenging the lightweight, energy storage and nitrogen oxide emissions. Dedicated to the next-generation single-aisle aircraft. Intended to be used in A320neo; Partners &amp; Suppliers increase: in charge of developing and/or delivering sub-final products.</td>
<td>Make an evolution in technologies: Constant need of innovation Build up a solid partner’s network and collaboration framework. Create an adapted production system to handle this complexity of products and operations realization.</td>
</tr>
<tr>
<td>Product complexity</td>
<td>High data volume: Generated by various bill of materials for design, for production. Multitude of operations Complex context exists where each data should be traced and each operation should be ensured in the best manufacturing conditions. Example*: 10 000 components constitute the Dauphin-Civil Helicopters (from Eurocopter) with more than 800 operations required.</td>
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Figure 1: Main Lean Inducers in Aeronautics
| Quality Focus                                                                 | Advanced required technicality of the final product, sub-assemblies and components: |
|                                                                              | Dependence to the first tier suppliers increases the risk of defect rate.             |
|                                                                              | Safety of the human lives issue.                                                     |
|                                                                              | Risk of clients and contracts loose in case of defects. Example*: the incident of Lithium-ion Battery and Conflagration in Boeing 787 of Japanese airlines in 2014. The entire fleet was grounded due to undergo the control. Boeing brand was altered. |
|                                                                              | Improve the model of the supply chain collaboration to achieve the defect free final product. |
|                                                                              | Keep a 1st tier reduced number of suppliers: reliability and quality is the argument. | |
|                                                                              | Ensure solid quality control tests.                                                  |
|                                                                              | Adopt a penalty costs to ensure defects free products delivery.                     |
| Missing parts                                                                | Delegate to a supply chain service the coordination among the suppliers.             |
|                                                                              | Reinforce the multi sourcing strategy.                                               |
|                                                                              | Disruptions in internal production lines and external missing parts.                |
|                                                                              | Adopt a relevant production system internally and coordinate with supplier JIT deliveries |

(*): Extracted from Public Documentations (Airbus, Boeing, Zodiac Aerospace)

This analysis reveals gradually the obvious involvement of aeronautic industry in Lean management conversions, mainly due to (Market competition Market demand, Innovation &Design, Product Complexity, Quality Focus and Missing parts on FAL (Final Assembly Lines).

The emphasized Lean inducers definitely convince the aeronautic industry to the need of using Lean management practices. Nevertheless, comparing to the automotive industry where the Lean practices achieve a mature level, the aeronautic industry is willing to improve and catch up the backwardness. Large scale Lean projects are currently deployed in French industry, such as AEROLEANK project initiated in 2011, driven by SPACE (Supply Chain Progress towards Aeronautical Community Excellence)-Toulouse: The directive is to create working groups where each OEM manages fifteen SMEs to initiate them to the Lean practices. The project "Industrial Performance" where 400 SMEs and 60 OEMs are working together, initiated by GIFAS (Industrial groupmate in aeronautic field), 3 years unfolding (2014-2017), is aiming to lead the global supply chain to the excellence of operational level through the process and production flow improvement. Relating to this growing interest of implementing Lean management practices in aeronautic industry, the challenging idea is to move toward new approaches helping the deciders in building a correlated Lean deployment regarding the evoked specificities of aeronautic market, in order to bring the applicability of Lean as close as possible to the sector’s concern.

4. Lean Implementation Model

Lean implementation, whatever business it concerns, is generally structured through the well-known project approaches DMAIC (Define Measure Analyse Improve Control) or PDCA (Plan Do Check Act). This way of splitting project allows structured steps with defined milestones to go through, and internally identified action plan. This freedom the managers have in building their Lean approach may be
beneficial in some cases (for large-size companies, very long projects, transverse departments, various partners,...). But the lack of a structured Lean implementation approach becomes a disability for some other companies (willing to commit in Lean conversion but missing a clear approach for it).

As no documented methodology is clearly provided for Lean managers, the challenge in this research is to build up a model helping the managers to implement the lean approach according to operational analysis starting by VSM to avoid the vagueness of the improvement axis often appearing in the phase DEFINE of DMAIC approach (see Figure.2). The distinctive point of our approach lies on the sequential analysis of the Lean implementation according to a bottom up approach: from the ground (operational level) to the strategic level. Unlike existing models in the literature requiring high level of formalization with time consuming procedures to find out the performance measures values, the suggested model herein, lies in the development of strategic dimensions influencing the analysis, diagnosis and solutions of Lean implementation process.

**Challenge 1: From VSM deployment to relevant Lean tools**

It is ultimately interesting for each company willing to pursue Lean conversion to start the Lean implementation with Value Stream Mapping Deployment VSM [22] that is a visual graphic captured from the state of production. When thoroughly addressed it constitutes a solid basis of diagnosis to bring the corrective actions. The main operational dysfunctions revealed by the VSM deployment are: Important set up times, Long global leadtimes, High level of work in progress, Bottleneck processes, Defect rate, Unbalanced cycle times.

These operational dysfunctions indubitably enclose different wastes in the workshops. Called Muda in Japanese, the existing wastes can easily be identified through a quick
gemba-walk throughout the production shops. Qualified as being of 7 types linked to: over processing, over production, inventory, defects, expectations, transportation or motion, these wastes are the causes of operational dysfunctions and are tightly linked to them (example: W4 Defect, W5 Waiting, W7 Motion are 3 Wastes constituting the issue of High set-up times appearing in VSM).

At this step, relevant Lean tools should be assigned to the identified operational dysfunctions. Any tool cannot be used for any dysfunction. Through this step, we study the relevancy of Lean tool practices according to the undergone disruptions. The objective here is to provide a first attempt of an overview of adaptability of practices (example: Defect rate requires the implementation of 5S, PokaYoke, 6Sigma, visual management. High Work In Progress (WIP) requires: line flexibility that allows several outputs with low batch sizes in order to produce the just required quantities, cross training to make the resource versatile and be able to produce other references and Pull system producing exactly the quantities required by the downstream shops).

The relevant Lean practices significantly contribute to reduce operational dysfunctions extracted from VSM analysis and obviously drive down the seven types of wastes identified in Toyota systems.

Challenge 2: From Lean tools to Leanness degree

Once the company has chosen different Lean tools to implement, the ultimate objective will be to assess the level of success of achieving Lean. Called Leanness degree: the idea hereafter is to suggest an assessment of Leanness achievement. We argue that, to be qualified as being Lean a system should ensure three main aspects of achievements. Leanness achieved degree is split into three main aspects checking: Structural degree, Organizational degree and Involvement degree.

Structural Leanness degree: It relates to the physical configuration of the workshops. This dimension reflects the degree to which the static state is in accordance with Lean philosophy. This indicator is independent from the quantity of demand and can be considered as the static dimension of Lean deployment success.

Organizational Leanness degree: It relates to the dynamic order execution in the workshops. This dimension indicates the ability of the organization to provide the compliant product with on time delivery. This indicator depends on the quantity of demand and can be considered as the dynamic dimension of Lean realization.

Involvement Leanness degree: It relates to the Leanness induced by the agility provided by the different technical and human resources. It can be considered as an inherent dynamic dimension of the company.

All these three Key Leanness Indicators (KLI) are measured in percentage regarding the different influencing elements described in the table.1 below. The different partial KLI when lined up together provide a global Leanness measure. In fact, thinking that a company achieving a good level of Lean management is the one achieving a good organization of the flow of production is misleading. The organization alone may be efficient for a short time but quickly the dysfunctions may come back again if the structuration of the workshops is not thoroughly arranged, if the involvement of the facilities (human and technical resources) is not correctly perceived and in that cases the Lean project may easily fail (even if it seems promising for a while).
Table 2 – Leanness Measurement: Key Leanness Indicators (KLI)

<table>
<thead>
<tr>
<th>Strategic KLI</th>
<th>Partial indicators</th>
<th>Objectives</th>
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<tbody>
<tr>
<td>$\theta^o_{Str}$ Structural degree of Leanness</td>
<td>• Proximity of equipments</td>
<td>Evaluate the transportation and interprocesses time</td>
</tr>
<tr>
<td></td>
<td>• Flow crossflow</td>
<td>Evaluate the risk of defective products and order mixtures</td>
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<tr>
<td></td>
<td>• Coverage Lean pilote project</td>
<td>Evaluate the coverage of lean practices inside the entire plant</td>
</tr>
<tr>
<td>$\theta^o_{Org}$ Organizational degree of Leanness</td>
<td>• Durations of process</td>
<td>Evaluate the added value leadtime</td>
</tr>
<tr>
<td></td>
<td>• Conformity of products</td>
<td>Evaluate the degree of quality rate</td>
</tr>
<tr>
<td></td>
<td>• Storage turnover</td>
<td>Evaluate the duration of storage in the plants (work in progress, raw materials and final products).</td>
</tr>
<tr>
<td>$\theta^o_{Res}$ Involvement degree of Leanness</td>
<td>• Availability of flexible production lines</td>
<td>Evaluate the reactivity to respond efficiently to diversified demands.</td>
</tr>
<tr>
<td></td>
<td>• Number of multifunctional operators</td>
<td>Evaluate the reactivity of the team to manufacture different/urgent orders.</td>
</tr>
<tr>
<td></td>
<td>• Direction involvement in Lean projects</td>
<td>Evaluate the willingness of the direction to support Lean projects.</td>
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Hence, the Leanness degree (noted: LM) is the key lean indicator considered as an achievement of the different partial indicator’s influence (noted: $\theta^o$). The more the Leanness Measure LM is high the more the company’s Lean integration approach is reliable and sustainable over the time. This contribution reinforces the idea of combined parameters to ensure the Lean success implementation.

5. Further developments & conclusion

The aim of this paper is to analyze the context of Lean literature revealing the consistent gap in Leanness measure. Moreover, the critical aeronautic context in France is worthwhile and definitely requiring new approaches to deal with the actual increasingly demand market. The main Lean inducers are released forcing the aeronautic industry to focus on Lean implementations to strengthen its position in the market with high level compliance rate and on time delivery. In this initial work the main foundations are settled. The successful Lean implementation goes through 2 main challenges evoked in this paper. The Leanness measure is split into three main partial indicators: Organizational, Structural and Involvement. Beyond strategic identification of indicators, we are currently developing the formalization of these partial KLI supporting Leanness measure to provide the practitioners with concrete measures, able to be calculated and integrated, leading to corrective actions inside the company. The middle term development of this work is to build a framework to support Lean implementation in aeronautic industry with thorough and relevant steps. Application of our framework is intended to be tested on two main aeronautic companies, already chosen. Company A from aeronautic fasteners, and Company B specialized in the manufacturing of leading edge dedicated to different Aircraft models. A survey may also endorse the market needs, a collection of targeted companies is currently prepared to lead this analysis and combine the different findings in coming next scientific contribution.
6. References