Proceedings of the 11th International Conference on Manufacturing Research (ICMR2013), Cranfield University, UK, 19th – 20th September 2013, pp 89-94

LEAN PRODUCT DEVELOPMENT PERFORMANCE MEASUREMENT TOOL

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ABSTRACT

The need of applying lean thinking to product development is becoming a must for the organisations to success in the current industry. This paper presents a tool that helps to define the actual status of the organisations in relation to the lean principles. Extensive literature highlighted the need of developing a tool focused on assessing the implementation of lean principles themselves, rather than quantitate metrics. Based on the Balanced Scorecard, four perspectives, with corresponding set of questions, were defined reflecting the enablers of the product development model proposed by the LeanPPD European project. A five-level scale was customised to score the different readiness levels that define the transformation into a full lean implementation. The tool was used to assess the current and desired lean situation of an aerospace company within the research environment and resulted to be accurate to define the starting condition of the company to adopt leaner practices.

Keywords: LeanPPD, Lean Transformation, Lean Assessment.

1 INTRODUCTION

Continuous pressure on product development due to rapid changes in customers' demands forces companies to seek for more cost effective and time efficient improvements. Lean thinking improvement philosophy is a potential way to be followed in order to enhance the performance of the process of product development. There has been a previous research towards applying lean thinking in product and process development (PPD) by structuring the five core enablers of LeanPPD. Namely, list them here (Khan, et al., 2011b). In this paper these enablers set the four perspectives of a LeanPPD Performance Measurement Tool.

It is recommended that before implementing lean thinking in product development there is a need to measure the readiness of the enterprise in order to adapt lean into the current processes. The available tools that aim to measure performance are concentrated on financial aspects, and these do not consider strategy and improvements, and do not assess the product development processes. Therefore this paper addresses this need by developing a novel tool to measure current product development processes comparing them to the best case lean scenario. Thus this article presents the development of a Lean Product and Process Development Performance Measurement Tool and also discusses one case study within the research environment of an aerospace company.

2 RELATED LITERATURE

The ‘Lean Product and Process Development’ (LeanPPD) project, supported by the European Commission, analysed the different approaches followed by the research community to come up with a new product development model: The LeanPPD Model (Khan, et al., 2011b, Al-Ashaab, et al., 2013). This model based on lean thinking considers the entire product life cycle, providing a knowledge based environment to support value creation to the customers. The LeanPPD Model consists of five enablers: Value Focus, Knowledge-based environment, Continuous Improvement, Chief Engineer and Set-Based Concurrent Engineering (Khan, et al., 2011b).

Set-Based Concurrent Engineering (SBCE) is the core enabler of the model as it is the process that guides the Lean Product Development. The other four are embedded or support the process (Khan, et al., 2011b). The approach of Set-Based Concurrent Engineering defends that products are developed by breaking them down into subsystems and designing sets of solutions for them in parallel. Testing and communication with other participants narrow down the sets gradually, until the final solution is obtained. This makes sure that enough knowledge is created to support the decisions and the selections are not rushed like in many cases (Al-Ashaab et al., 2013, Sobek, et al., 1998).

The SBCE principles have been extracted from the following references: Sobek, et al., 1998; Sobek, et al., 1999; Morgan & Liker, 2006; Ward, 2007; Kennedy, et al., 2008; and summarised in Figure 1.

SBCE Principles

1. Strategic value research and alignment
   - Classify projects into a project portfolio
   - Explore customer value for project x, Align each project with the company value strategy
   - Translate customer value (product vision) to designers (via concept paper)
2. Map the design Space
   - Break the system down into subsystems and sub-subsystems
   - Identify targets/essential characteristics for the system
   - Decide on what subsystems/components you want to improve and to what level (selective innovation)
3. Create and explore multiple concepts in parallel
   - Pull innovative concepts from R&D departments
   - Explore trade-offs by designing multiple alternatives for subsystems/components
   - Ensure many possible subsystem combinations to reduce the risk of failure
   - Extensive prototyping (physical and parametrical) of alternatives to test for cost, quality, and performance
   - Communicate sets of possibilities
4. Integrate by intersection
   - Look for intersections of feasible sets, including compatibility and interdependencies between components
   - Impose minimum constraint:
   - Seek conceptual robustness against physical, market, and design variations
   - Concurrent consideration of lean product design and lean manufacturing
5. Establish feasibility before commitment
   - Narrow sets gradually while increasing detail: functions narrow their respective sets in parallel based on knowledge gained from analysis (all)
   - Stay within sets once committed and avoid changes that expand the set
   - Control by managing uncertainty at process gates

Figure 1: Set-Based Concurrent Engineering Principles

One of the tools used for performance measurement to monitor the success of an organization is Key Performance Indicators (KPIs). They are quantifiable measurements of critical factors that reflect the organization’s goals on a long-term consideration (Jovan & Zorzut, 2006). Another commonly used tool is the Balanced Scorecard (BSC), which was designed as a management decision tool providing a simple framework of balanced set of measures to link strategy and operational performance (Kaplan & Norton, 1992).

A research performed with the involvement of academics and industrial representatives (Pawar & Driva, 1999) showed the concern and importance of measuring the performance in product design and development, for instance the comparison between the real and the projected completion time, time to market, or number of trials before the production obtained a usage over 50%. These results are reinforced by other authors, which adds variables like quality of the product, novelty or management satisfaction (Barclay, 2002; Krishnan & Ulrich, 2001; Driva, et al., 2001), among others. However, all of these methods intended to measure the results obtained by a company but do not consider the product development process itself, and therefore cannot be customized to assess the applications of the lean thinking principles.

Within the Lean Thinking environment, Haque and Moore (2004) developed a set of metrics derived from lean manufacturing to adapt them into the lean thinking application in new product introduction (NPI). Their approach to promote lean thinking came up with a number of quantitative ratios that could help measuring performance and progress (e.g.: total value of engineering output versus cost of engineering department, non-compliances versus number of requirements,). These metrics are useful to identify if a company is obtaining the results of a theoretical successful implementation of lean principles in product development. Though, they do not focus on the process itself, and therefore, are unable to give evidence of the principles being actually embedded or not.

The authors found only two tools that partially measure the lean thinking application in product development. The research performed by the Lean Aerospace Initiative (LAI) came up with the LAI Enterprise Tool Triad (Perkins, et al., 2010), composed by the Lean Enterprise Model, the Transition To Lean Roadmap, and the Lean Enterprise Self-Assessment Tool (LESAT). The scope of the LESAT covers all key product lifecycle processes and is divided into sections (Lean Transformation/Leadership, Life-cycle Processes, and Enabling Infrastructure) with their corresponding subsections. It uses a generic 5 Lean competence scale that describes the maturity of the process.

Another initiative was developed by Lockheed Martin Aeronautics Company from the US. Their Lean Scorecard is a self-assessment tool to measure the maturity of the Lean implementation within their practices (Lockheed Martin Aeronautics Company, 2009). It provides a set of 8 components (Leadership, Transparency, Lean Product Development, Process Focus, Just-In-Time, Process Control, Standard Work, and Continuous Improvement) and their sub-components, together with 5 maturity levels, customized for each sub-component, to measure the Lean transformation.

The review of the literature has revealed that some of the presented tools and methods could help to measure certain aspects of Lean Thinking in product development. However, even if some have shown up as being on the good track, there is no suitable tool to accomplish the performance measurement of the Lean Transformation from all its different points of view like the process, the knowledge, the value or the continuous improvement. Therefore, there is a need of defining the requirements of the tool that would address this issue.

3 THE DESIGN OF THE LEANPPD PERFORMANCE MEASUREMENT TOOL

As the reviewed literature has identified a gap, there is a need for a new tool to measure the lean thinking application in product design and development. This measurement needs to reflect the key enablers of the LeanPPD enablers as shown in Figure 1, as well as address the key principles of Set-Based Concurrent Engineering listed in Table 1.

The authors agreed that the tool should enable the companies to identify their status in the Lean transformation by providing them with a readiness framework. The tool would also provide a template to report the results highlighting strengths and weaknesses, as well as improvement areas.

The authors adapted the structure of the Balanced Scorecard by identifying four perspectives to reflect the key areas to be measured, as listed below with the relative weight:

1. Product Development Process (30%),
2. Tools (15%) and Enablers (15%),
3. Knowledge Focus (29%),
4. and Continuous Improvement (20%).

The first perspective, Product Development Process, mainly reflects the Set-Based Concurrent Engineering. Intending to simplify the tool and due to their direct relation, two other enablers of the LeanPPD Model have been included in this perspective: Chief Engineer and Value Focus. The Chief Engineer is the technical leader that manages and leads the whole development process, and on the other hand, the aim of the process is to maximise the value of the product developed. The Tools and Enablers perspective is those key elements that need to be within the key activities of the SBCE to enable the performance of the task within that activity. This will address different elements such as requirements definition, value definition, design for manufacturing, risk assessment or functional modelling. The third perspective is Knowledge Focus because lean product development is product development in knowledge based environment (Maksimovic, et al., 2011). The fourth perspective is Continuous Improvement. The authors believe that LeanPPD is a continuous improvement via solving problem to create a knowledge environment.

However, unlike in the Balanced Scorecard, the four perspectives have different weights in the overall LeanPPD Performance Measurement Tool. The reason behind this is that the authors defend that product development cannot be performed without a well-defined process with its corresponding tools and enablers. However, product development can be done without having a formal initiative of knowledge management and continuous improvement. This has been acknowledged and approved by the industrial partners. Therefore, the loads of the different perspectives are 30% for Product Development and for Tools plus Enablers, and 20% for Knowledge Focus and for Continuous Improvement.

Each perspective of the LeanPPD Performance Measurement Tool contains a concrete number of questions. The composition of these questions enables the companies to self-assess the journey of the lean thinking application in their product design and development.

The approach taken in this research is that there are five lean readiness levels which form the SAUCE (Start-Awareness-Unstructured-Continued-Evolved) scale, and are shown below.

1. S – Start: The company does not apply the lean practices in its Product Development Process
2. A – Awareness: The company is aware of the benefits brought by the lean practices but does not have any formal method to implement them
3. U – Unstructured: The company has started implementing the lean practices in its PDP following an informal method
4. C – Continued: The company has implemented the lean practice into its PDP at some specific stages following a formal method
5. E – Evolved: The company has implemented the lean practices into in all the stages of its Product Development Process following a formal method

Once the questions are given scores and the perspectives are weighted, the current (AS-IS) level and the desired (TO-BE) level of product development processes of a company can be assessed.

In this section, an example of questions of the different perspectives is presented in order to illustrate how the principles of LeanPPD and SBCE are covered in the performance measurement tool. It is part of the innovative approach of the authors that the questions have been asked without a direct use of the key words of the LeanPPD and SBCE. This leads to less confusion when measuring current processes. For example, within the Product Development perspective, in order to reflect one of the practices of SBCE, one of the questions asks about how the conceptual design is selected, as it is shown in Table 1.

Table 1: Question related to the practice of Set-Based Concurrent Engineering

Q 1.10	**How do you select the conceptual design solution that will be developed?**
1	We only produce one solution for each component or subsystem.
2	We only produce one solution but we are aware of the benefits of multiple solutions.
3	We identify multiple solutions, and select the solution based on a subjective assessment (experience, previous projects…).
4	We identify multiple solutions, and select the solution based on a objective assessment (tests, prototyping…).
5	We initiate the design of multiple solutions in all projects, and gradually rule out the weaker solutions based on the knowledge gained from simulation and/or physical testing.

4 LEANPPD PERFORMANCE MEASUREMENT CASE STUDY

This section presents the work that had been done in one company from the UK aerospace industry and shows the examples on two perspectives, Product Development Process and Knowledge Management.

The authors performed the performance measurement of the product development process through face-to-face interviews to 15 representatives from different areas, such as: product designer, manufacturing engineering, product assembly planning, project management, purchasing, and supplier technical assistant. The results were captured individually and then it was made an average from their results.

The overall results of the performance measurement of the company show that company's product development AS-IS processes contain elements that are considered lean but are not yet part of a formal method. Moreover, the expected future level shows a totally lean product development process in all aspects, represented by score 5 and putting the company in the Evolved stage of the SAUCE scale. These overall results are the average of the separate results of the four perspectives.

The measurement regarding the AS-IS level of the product development process principle is detailed by a list of the questions and the results can be exposed in a diagram as it is shown in **Figure** . The company identified that the formal product development model is followed in specific stages (Q 1.2) but the communication of the process model needs to be improved (Q 1.1). The company believes that the manufacturing engineers are involved in the product development (Q1.5) although the formed multifunctional teams do not retain the same members from beginning until the end of the project (Q 1.6). Moreover, manufacturing suppliers are mainly involved once the final design concept is selected (Q 1.11).

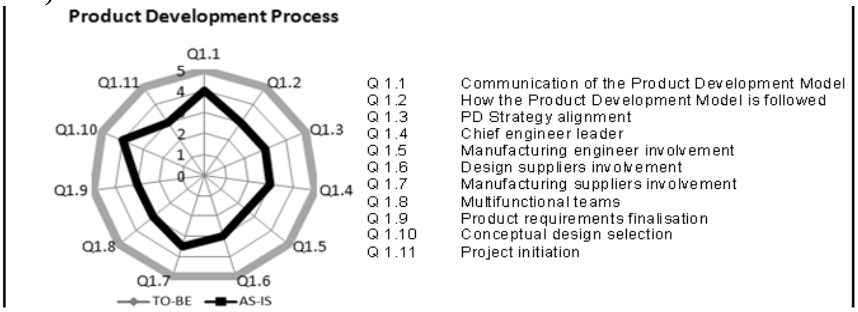

Figure 2: The product Development prospective results of the aerospace company (modified for confidentiality reasons)

The results of the assessment, presented in **Figure** , reflect that the company has already initiated a methodology for knowledge capture, re-use and creation (Q 3.1); however, they are aiming at the full implementation of a knowledge management program. Currently engineers identify the experts through their experience (Q 3.2), which does not assure that the right person is always contacted. Therefore the company has identified the importance of creating a skill directory to facilitate this task. The lessons learnt during the projects are captured at the completion of them and a strategy for further optimizing their use has been suggested (Q 3.4).

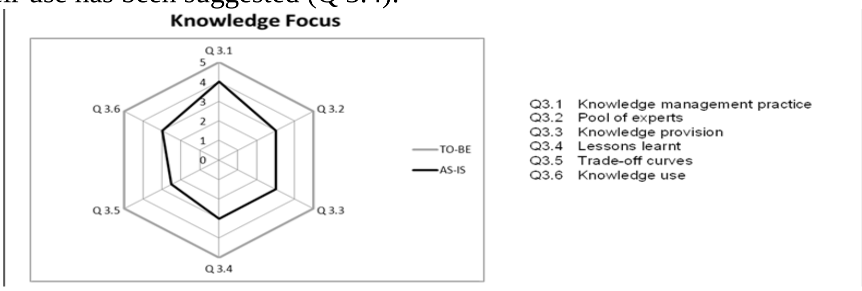

Figure 3: The Knowledge Focus perspective results of the Aerospace Company in a radiar diagram (modified for confidentiality reason)

5 CONCLUSIONS

This paper has presented the development of a tool to assess the performance of the lean thinking application in product development through measurements that reflect the key enablers of LeanPPD. The tool is composed by sets of questions, arranged according to the LeanPPD enablers (knowledge, continuous improvements, value focus and SBCE.) and SBCE principles, which provide a well-defined framework to study all product development practices in detail by focusing on aspects such as the value, the knowledge or the continuous improvement. The LeanPPD Performance Measurement tool has been used in one company from the aerospace sector within the research environment, to evaluate its current situation in the lean journey. The analysis of the results is identifying the areas of improvement in its product development models to make it more robust by implementing lean thinking practices.

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