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LEAN ASSESSMENT AND TRANSFORMATION STRATEGIES IN PRODUCT DEVELOPMENT: A LONGITUDINAL STUDY

Welo, Torgeir; Ringen, Geir
Norwegian University of Science and Technology, Norway

Abstract

Maintaining simultaneous focus on efficiency and effectiveness is a difficult yet necessary strategy to deliver commercially viable products in today's global world of competition. As a result, manufacturing companies aim to shift from a modus of operandi dominated by removing waste at the factory floor to leveraging value creation in all direct or indirect activities within the product value stream. One of the most popular strategies in this regard is to apply the Lean concept in product development (PD). This paper researches to which degree PD practices in a Scandinavian design and manufacturing company comply with Lean in its own context. A capability maturity tool has been developed, piloted and followed-up in the case company to identify gaps and improvement potentials. A capability maturity assessment has been conducted twice, with a time span of seven years. This longitudinal study shows that the PD team rate their performance surprisingly identical from 2009 to 2016, reflecting that an increased Lean PD awareness has brought new challenges to the surface - ones that were hidden by more obvious issues in the past.

Keywords: New product development, Design management, Risk management

Contact:
Dr. Geir Ringen
Norwegian University of Science and Technology
Mechanical and Industrial Engineering
Norway
geir.ringen@ntnu.no

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1 INTRODUCTION

1.1 Background

Recently, companies have been implementing various strategies in response to increasingly competitive markets. Lean (Womack et al., 1990). Lean is perhaps the most important concept that has been introduced to increase efficiency and productivity in manufacturing. However, Lean has undergone a shift from being a competitive frontier in its early days to become industry standard. Many companies have therefore made attempts to move the lean concept into Product Development (PD) (Womack and Jones, 1996; Baines et al., 2006). However, PD is indeed very different from manufacturing, and long-time discussions in the literature have yielded little progress in arriving at a unified understanding of Lean when applied in PD. Moreover, there exist few documented examples of successful implementation, and practises over time, of Lean PD (Welo and Ringen, 2016). Our hypothesis is that the basic nature of PD—its purpose, tasks, process, people and, last but not least, value perception—makes the understanding and application of Lean very different from its application in manufacturing. It is, therefore, a strong need in the research community to identify the basic characteristics of Lean PD, aiming to define a common ground for implementation of a Lean strategy in PD. This paper aims to contribute to a better understanding of Lean PD by analysing and providing the results from Lean PD journey (2009-2016) of a case company.

1.2 Objective and scope

This longitudinal study seeks to test and verify a tool developed to assess Lean capabilities at project team level. We use a hierarchical capability maturity model to investigate to which extent product manufacturing companies are engaged in Lean PD, assessing the degree to which various Lean capabilities are implemented, utilized and followed-up (Welo, 2011; Welo and Ringen, 2015). The framework is used as a means for gathering data about factors that influence Lean PD maturity levels. Overall, we seek to build a basis towards a more contextual implementation of Lean in PD environments. Aiming to use the Lean capability framework for data collection, an audit process has been designed using an interactive workshop with cross-functional PD teams.

A case study was conducted in a Scandinavian product manufacturing company with its R&D hub located in Norway. The assessment framework was used to identify enablers and barriers related to Lean PD. The industry goal was to identify strategies for Lean transformation, ones that support a more contextual implementation of Lean in PD. This assessment process was conducted twice, in 2009 and 2016, hence providing longitudinal data.

The assessment tool is based on an explanatory Lean PD model consisting of six components: Understanding of customer value; Knowledge transformation; Standardization; Stabilization; Continuous improvement; and Lean culture. These components, their interfaces and interrelationships make up a system, which is believed essential to value creation in most product-oriented manufacturing company. Hence, this system represents a basic premise for competitiveness in the short-term perspective. Without organizational learning, however, a competitive value chain alone is no guarantee that a company sustains competitive as markets, competitors and technology change.

The assessment model is adapted to be used within different business contexts, consisting of 22 underlying characteristics and 66 related capabilities. These capabilities are linked to a descriptive text that is anchored to a capability scale. Overall, they make up a capability maturity model for assessing leanness on project team level. Its structure is based on a traditional continuous grid method with origin from Quality Management (Crosby, 1979) where all practices are scored to a different level (Nightingale and Mize, 2002). The developed framework was used as an interactive research tool to elicit knowledge about Lean PD practices in the case company. Two overall questions prevail:

- How does the PD team rate their Lean capability on an explanatory ordinal scale relative to the levels deemed necessary to sustain competitiveness?
- How does performance of the PD team improve over a 7 year period, by having implemented and followed-up critical Lean PD principles?

To answer these questions, a semi-quantitative research study, where respondents relate their perceived situations to a scale, was done using the explanatory Lean PD model and the derivative assessment tool as a research framework.

Although the Lean principles may have some universal applicability (Sousa and Voss, 2001), a principle has limited value unless it is filled with actionable content. Therefore, the overall motivation for our research is to make a contribution towards more context-driven Lean PD implementation strategies. We presume that the capabilities for creating value are strongly dependent on both the microenvironment of the PD team and the business context of the firm.
The remainder of this article is organized as follows: Section 2 discusses the most fundamental part of any Lean strategy: understanding of value (and waste). Section 3 presents the fundament and the implementation strategy of the case study. The results from applying the assessment tool in a Scandinavian design and manufacturing company at two different instances, 2009 and 2016, is summarized in Section 4, and conclusions and further work are given in Section 5.

2 UNDERSTANDING VALUE IN THE CONTEXT OF PD

2.1 Identifying waste

The single most important factor in Lean is the understanding of value. In Lean production, value is said to be created if a specific operation or process step meets all three of the following requirements (Fiore, 2005): (a) The customer is willing to pay for (the result that leads from) the activity; (b) It transforms the physical shape of the object or product; and (c) It is done correctly first time. On the contrary, waste occurs when an operation fails to meet just one of these criteria. Waste is usually divided into two categories: Type 1 waste ('enabling activities') and Type 2 waste ('pure waste'). Type 1 activities do not create direct value but are still necessary to support value creation, typically administration, management, mandatory testing, etc. Pure waste in production is commonly divided into seven (or eight) subcategories, including defects, over-production, transportation, waiting, inventory, motion and processing (and underutilization of people).
Depending on manufacturing process, efficiency may be as high as 80 - 90 %. In product development, however, the overall value-added time is typically less than 30 % in most companies (Radeka, 2012 and Reinertsen, 1999). The high waste levels in PD (>70 %) are claimed to be mainly due to Type 1 activities. To improve leanness in PD, therefore, companies should aim to replace enabling activities with value-added time. On the other hand, seeking pure waste (Type 2) is a less viable strategy due to the nature of the activities in PD. Unlike manufacturing, waste in PD is usually not a result of doing unnecessary activities but rather a result of shortcomings in information flow and communication. Although each PD activity may be tangible in itself, in absence of a physical work-product the flow of information is mostly intangible. This makes it difficult to detect waste in due time through 'quality control' and complete 'rework' or 'sorting' before the 'part' goes to the next 'operation', and ultimately to the end customer.

2.2 Identifying value

In a traditional production value stream perspective, the understanding of value is the most essential part of a lean product development strategy. However, separating value from waste is by far more complicated in PD than in manufacturing since there is no physical object to which value can be assigned. PD may be characterized as a problem-solving endeavour, in which the 'product' is information translated into knowledge aimed at reducing the risk of taking a new product to market to an acceptable level. Its primary goal is thus "to make a recipe for producing a product that conforms to the requirements stemming from customer or market needs" (Reinertsen, 1999). The input, processing and use of information must be right to generate new, valuable information that increases the confidence in the 'recipe'. In order to maximize value, it is thus essential to get the right information in the right place at the right time. According to (Mascitelli, 2007), "all the value in product development is embodied in the essential deliverables needed to launch a new product".
There are multiple definitions of value in the literature, depending on the specific context. Table 1 lists a comparison of different definitions of value identified in the literature. To the very basic, customer value may be defined as "the difference between what a customer gets from a product, and what she has to give in order to get it". Value starts with the final customer and her perception of value based on her needs, wants, meanings and experiences associated with the product. Value is then 'pulled up' the chain of successive external (e.g. corporate buyers) and internal customers (e.g. manufacturing). Customer benefits associated with a product are related to numerous complex, multi-dimensional characteristics

(features, attributes, properties), as well as meanings and experiences of a product in everyday life (Mascitelli, 2007), representing the most difficult and precompetitive part of the customer value definition. These may be broken down into two different categories:
Product-related characteristics such as requirements, features, attributes, performance, functions, capacity, dimensions and size, quality, finish, durability, strength, stiffness, power, weight, etc.
User-related characteristics such as second-hand value, cost of ownership, scarcity (availability), and more emotional ones including (self-)esteem, design, style, fashion, as well as the meaning of the product and its use in the context of the user's life and environment.
Pulling customer value up the value chain accumulates needs from each intermediate individual customer. Transferring these effectively into value-creation activities is an extremely challenging task. Moreover, extending the value notions to business level, such as project selection and portfolio management (Cooper, 1998) makes the challenge even more complex; that is, selecting the right portfolio of projects where the company's capabilities (technology, skills and market) have the better chance to maximize customer value within the constraints of value to other stakeholders, such as owners, employees and the society. Many companies tend to select projects with the highest estimated return on investment, e.g. net present value, rather than assessing their own overall abilities to create customer value. Such a strategy is in great contradiction to Lean thinking, where the understanding of what brings value to the customer is what creates financial return (value to stakeholders) in the final end, and not the other way around.

Table 1. Different definitions of value found in the literature, several are reproduced from Chase (2001)

Source	**Value definition or Quote**
Miles, 1961:	"Value is the appropriate performance and cost."
Kaufman, 1985:	"Value is function divided by cost."
Shillito & DeMarle, 1992:	"Value is the potential energy function representing the desire between people and products."
Womack & Jones, 1996:	"Value is a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer."
Slack, 1998:	"Value is a measurement of the worth of a specific product or service by a customer and is a function of: (1) Product's usefulness in satisfying customer need (2) Relative importance of the need being satisfied (3) Availability of the product relative to when it is needed (4) Cost of ownership to the customer"
Lean Aerospace Initiative, 1998:	"Value is anything that directly contributes to the 'form, fit, or function' of the build-to package or the buy-to package: Form: Information must be in concrete format, explicitly stored Fit: Information must be (seamlessly) useful to downstream processes Function: Information must satisfy end-user and downstream process needs with an acceptable probability of working (risk)"
Browning, 1998:	"Value is balancing performance, cost, and schedule appropriately through planning and control."
Deyst, 2001:	Value is the amount by which risk is reduced per resource expended.
Stanke, 2001:	"Value is a system introduced at the right time and right price which delivers best value in mission effectiveness, performance, affordability and sustainability and retains these advantages throughout its life."
Other sites (Chase, 2001):	"Value is anything that enhances performance (form, fit, & function) as measured by cost, schedule, and risk from the perspective of the customer, be they external and internal." "Value is a balance between performance, schedule, and cost." "Value is a product design and manufacturing plan that enable the building and delivery to the customer of a product that meets the form, fit, and function requirements that the customer wants." "Value is the knowledge that adds form, fit, or function to the 'design-to' package." "Value happens when all of the stakeholders agree." "Value is in the eye of the beholder. It must be tied to who is making that judgment and what the alternative is."
Mascetelli (2007)	"Any activity or task that transforms a new product design (or the essential deliverables needed to produce it) in such a way that the customer is both aware of it and willing to pay for it".
Reinertsen (2009), and private communication:	"A development activity is value-added if the customer is willing to pay more for the product [design] after the activity is completed than before due to the risk(s) mitigated through the activity itself."
Mascitelli (2011) and private communication:	"A development activity is value-added if it transforms a new product design (or the essential deliverables needed to commercialize it) such that the product's profit margin and/or market share are positively impacted."

Continuous improvement is an important part of any Lean strategy, this being manufacturing or PD. Any change or improvement effort assumes knowing the current condition, indicators and the path forward. Thus, it is essential to be able to measure the effectiveness of a PD process by addressing value added of the activity at each step of the process. Value-based performance indicators should serve as guidance to resource allocation, process measurement and process improvement.
In the reminder of this paper, the value notion will be been taken further into the development of a practical tool for assessing leanness in areas important to PD organizations and their ability to create value in everyday operation. The goal is to test and verify a tool developed for identifying areas as a starting point for continuous improvement and Lean transformation in PD. The output from the assessment process is a list of prioritized improvement areas based on a Lean, value-based, capability maturity approach.

3 CASE STUDY

3.1 Structure of assessment tool

As a first step in developing the assessment tool, existing Lean PD models in the literature were identified, synthesized, analysed and converted into a six-component LeanPD model: (1) Customer value; (2) Standardization; (3); Stabilization; (4) Knowledge and Learning; (5) Lean Culture; and (6) Continuous Improvement. Each component was divided into sets of characteristics, describing its key attributes. Each of the characteristics was decomposed further into subsets of three practices (sub-characteristics or capabilities), which collectively represent the key attributes of each individual characteristic. Each capability was given by situational descriptions of process, practice or behaviour for different Lean maturity levels, allowing the auditee to assess the company's PD practice. To reduce complexity and detail level, descriptive statements for three different maturity levels—low (1), intermediate (3) and high (5)—were codified and linked to a Likert-scale. The respondents were asked to interpolated between low and intermediate (2) and intermediate and high (4) in case the specific practice appeared to be between one of the three levels described. The same methodology was used for both the assessment of current and desired Lean PD capability maturity levels.
It should be noted that the aim of the assessment framework is to identify Lean PD capability gaps—rather than scoring absolute maturity levels for each practice. The identified capability gaps are thus intended to define Lean transformation initiatives, although there may be reasons why a large gap is less interesting from a company business standpoint; e.g., if the gap is not a constraining factor (bottleneck) for PD outcomes, or it will take too much efforts or resources to close the gap, or potential countermeasures are not in support of the strategic direction of the company.
Each of the six components of the Lean PD model was divided into from two to five characteristics. A total of 22 characteristics and 66 capabilities were developed to cover the entire domain of the Lean PD model. In addition, a front sheet was made to capture quantitative information related to the individual respondent, the company, as well as organizational structure and performances.

3.2 Company demographics

The company selected for the case study was a Scandinavian product manufacturing company. The Norwegian branch, which was assessed, was established in 1961 and has about 250 employees, of which about 25 are in R&D. The annual sale is about 100 MUSD (2015), a slightly decrease since 2009. The firm operates mostly in the B2B segment with corporate buyers in public sector and private companies as the main customers. However, the company maintains a close link to users of the product due to its focus on design and sustainable, ergonomic and quality products. The company has a portfolio of well-positioned products with a solid strategic fundament. It supplies three brands, in which differentiation is mainly based on ergonomics and visual design.
The company operates in the high-end segment of the market for its type of products. Manufacturing is an important element of the company's strategy for producing competitive products since its production facilities and cost base are in Scandinavia. The product complexity may be classified as medium (multi-material, mechanisms, mechanical) and the development lead time is typically 3-4 years for a new product introduction. The production volume is in the medium range, typically 5-20,000 p.a. The company has Scandinavian ownership with the Norwegian unit being the global PD/R&D hub. The organization is a typical matrix structure. The PD operational modus may be classified as a balance

between being project-driven and process-driven with repetitive tasks. The lean awareness level of the organization may be characterized as medium, as the company is familiar with lean manufacturing in their production operations. Also, the project group has a well thought-through approach to many of the fundamental principles associated with Lean PD.

3.3 Implementation and execution

The first assessment done in 2009 was as a part of an ongoing manufacturing research project with the case company. The second one, in 2016, was part of a follow-up on the case company's Lean PD journey over the last seven years. In the first assessment, the research team included a chief researcher who managed and facilitated the assessment, and two researchers, who made the research protocol and data analyses. The assessment was conducted as a two half-day workshop with six people from different functional areas of the company, including design, engineering, manufacturing, functional manager(s) and head of R&D. The assessment event lasted for 7 hours in total. The 2016 event was facilitated by the same chief researcher and an assistant familiar with the methodology and concept. The same roles and functions was represented in both assessments, but among the six participants in 2016 only one was present in the assessment conducted in 2009.
The introductory part for both assessments included a discussion into the meanings of Lean in the context of the firm's PD operations. As a next step the audit team completed the questionnaire on an individual basis. In several cases, the auditees needed guidance and additional information from the research team to complete the assessment sheet. The scoring of each individual auditee was then collected and processed into a format suitable for further discussion and evaluation. It happened occasionally, however, that the ratings were significantly different between individuals. For example, manufacturing people typically scored engineering capabilities different than did engineers. In case the difference was significant, this initiated a discussion within the audit team to clarify potential misconceptions and thus arrive at a more uniform rating.

4 RESULTS AND DISCUSSION

As discussed above, understanding of value is the most fundamental principle of Lean PD. Therefore, the first part of the assessment tool requested the auditee to estimate her own time spent on value-adding activities, based on a specific definition of value in PD.
The results indicated that the average value-adding time was reported to be around 33% in 2009, going down to about 25% in 2016. Although not statistically significant, these numbers are around 10-15 % higher than claimed numbers from US companies (Kennedy et al., 2007). Resource utilization and efficiency are key factors for PD and performance, and hence business success. Here the responses in 2009 indicated that close to 100 % (varying between 80 and 120 %) of the hours were booked in advance of a work week for the team as a whole. This corresponding numbers in 2016 were reported by the majority to be less than 80%. In other words, the PD team has gone from a situation with no available time to solve unforeseen problems to allowing more time for learning, experimenting and agile learning cycles. The latter is regarded as perhaps the most fundamental facet of PD. Multitasking is a strongly constraining factor regarding efficiency, particularly in PD where focus is essential and the 'tool set-up time' is synonymous with the human brain's ability to switch focus from one problem to another. The team members claimed in 2009 to work on 4.0 projects in average, varying between 2 and 6 projects depending on function. In 2016 this number is reduced to an average of 3.2, with less variation.
The auditees were also requested to provide historical data related to PD project performance in terms of meeting initial goals related to product performance (from 81% in 2009 to 74% in 2016), lead time (from 64% to 60%), PD cost (from 76% to 67%) and product cost target (from 83% to 86%). Since the 2009 assessment, the case company has established a strategy to prioritize fewer projects and more time to solve unforeseen problems and do learning cycles. However, this particular Lean PD initiative does not seem to improve performance and degree of value adding time.

Table 2. Performance gap and delta current and desired states from 2009 to 2016

		2009		2016		Δ	
Component	Question	Current	Desired	Current	Desired	Change Current	Change Desired
Customer	11	3.0	3.0	4.0	4.5	1.0	1.5
	12	3.0	5.0	4.0	5.0	1.0	0.0
Knowledge	21	2.5	4.5	3.0	5.0	0.5	0.5
	22	2.0	4.0	2.0	4.0	0.0	0.0
	23	2.0	4.5	2.0	4.0	0.0	-0.5
	24	3.5	4.5	3.0	5.0	-0.5	0.5
Stabilize	31	3.0	5.0	3.0	4.0	0.0	-1.0
	32	4.5	5.0	4.0	4.0	-0.5	-1.0
	33	3.0	4.0	3.0	4.0	0.0	0.0
	34	3.0	4.0	3.0	4.0	0.0	0.0
	35	2.5	4.0	2.5	4.0	0.0	0.0
Standardize	41	4.0	4.0	3.5	4.0	-0.5	0.0
	42	3.0	4.0	3.0	4.0	0.0	0.0
	43	3.0	4.5	2.5	4.0	-0.5	-0.5
	44	3.0	4.0	3.0	4.0	0.0	0.0
Continuous Improvement	51	3.0	4.0	3.0	4.0	0.0	0.0
	52	4.0	4.0	3.5	4.0	-0.5	0.0
Culture	61	3.0	4.5	3.0	4.0	0.0	-0.5
	62	4.0	4.5	3.0	4.5	-1.0	0.0
	63	3.0	5.0	3.0	4.5	0.0	-0.5
	64	2.0	4.0	4.0	4.0	2.0	0.0
	65	2.5	4.0	4.0	4.0	1.5	0.0

4.1 Assessment results

Table 2 shows the assessment results for current and desired Lean PD capability maturity ratings averaged and rounded off to the closest 0.5 (due to sample size). The most significant capability maturity gaps in 2009 are associated with component 'Knowledge transformation' with gaps 2.0 or higher for three out of four characteristics. In other words, the auditee team claims that the company has a significant improvement potential in terms of; (21) 'Leveraging the role of knowledge as a means to capture new markets and grow the business', (22) 'Defining knowledge ownership and managing the knowledge transformation process', and (23) 'Improving practices for transferring knowledge between functional departments'. Considering the 2016 assessment of the component 'Knowledge', the results largely mirror the 2009 study. The ambition level related to 'Knowledge development' is in 2016 ranked slightly higher than in 2009, while current practise is status quo. This is an interesting finding, particularly since the respondents indicate that more time dedicated to learning cycles in 2016.

For the component 'Customer focus'' the capability (12) 'Interface between customer and designer' seems to have improved as the desired state remains the same in both assessments. It is interesting to note that the first statement (11) in the component 'Customer focus' (Roles and values) is now rated 1.5 points higher than in 2009. According to the assessment results, the customer plays an important role in the design and engineering process of the company. The second characteristic within 'Customer value', (12), reflected in 2009 a significant gap between current and desired capabilities. In essence, relative to Lean practices, the company had a way to go to establish practices ensuring that customer desires, needs and wants effectively reach design engineers─practises that now seem to have improved.

The assessment of statements associated with the component 'Stabilization' shows that current practise seems relatively unchanged. However, the capabilities (31) 'Resource planning' and (32) 'Portfolio

management' are now rated lower as desired states than in 2009. In 2009 one characteristic within component 'Stabilization' demonstrated a Lean PD capability gap of 2.0 point, namely (31) 'Resource planning and management'. This implied a potential in improving practices to ensure that projects and functional departments get the resources they need, when needed─a gap that now is reduced by lowering the ambition level.
Another interesting finding is that the 'Culture' component seems to have improved, especially when it comes to the capabilities (64) 'Utilization of digital tools' and (65) 'Simple and visual communication'. The capability (65) had a significant performance gap in 2009, indicating that the company had to rethink and redefine the perceived role digital tools play in achieving business and PD goals. In Lean, this means that the company must place people and process over tools and technology. Moreover, stabilization of the PD process has to take place before introducing any automation such as digital tools; the opposite may thus make the process less efficient. Note also that digital tools are for the most commercially available providing no particular competitive advantage.
The 2009 assessment also revealed a gap of 2.0 points within component 'Culture', for the capability (63) 'Creativity and entrepreneurship'. In other words, the significant capability gaps associated with the former indicate a potential for improving the way the company encourages and values creativity among individuals, and leverages this as a part of its product and technology strategy. This gap is still significant in the 2016 assessment.
The company used the results from the 2009 assessment to prioritize continuous improvement efforts based on identified capability gaps, resources, to which degree the capability constrains the output, and finally the strategic perspective. The effect of these Lean PD efforts is discussed below:

4.1.1 Customer focus

The company sets consistently high expectations about how they interact with, and understand, existing and potential customers. The gaps between these expectations and current practices are relatively low, meaning that the respondents rate themselves to be at approximately the right level with regard to customer focus. From the discussions with the assessment team, however, there might be some issues in reaching top level due to, for instance, costly and time consuming quantitative customer studies and the perceived culture of occasionally over-engineering (‘gold plating’) the product. An alternative approach may be to better understand customer value from different perspectives (for instance user vs. customer/buyer) in the value chain. There may also be a potential in designing user tests in a way that covers a broader range of products, hence utilizing such synergies to make the process for capturing understanding of customer value and desires more efficient.

4.1.2 Knowledge

It is noteworthy that all questions related to the component 'Knowledge' is assessed to have a relatively large gap between current and desired future state—i.e., the situation remains unchanged since 2009. This component covers assessment capabilities such as; 'Learning and Knowledge Value Stream', 'Knowledge Ownership and Management', 'Cross-Functional Knowledge Flow', and 'Set-Based Concurrent Engineering' (knowledge about alternatives). The discussions taking place during the assessment confirm that most knowledge is tacit and informal—except from what is documented in drawings and production documentation. Unless actions are defined to foster a culture for knowledge transformation, it is suggested that there is a risk that the combination of low people turnover and large number of ‘generalists’ create long-term challenges related to organizational learning and knowledge transformation. Discussing and evaluating knowledge per critical function─who owns this knowledge? and how to capture, store, standardize, access and reuse knowledge without making the system too bureaucratic and scaled to the practices, ambitions and strategies? Rotation of people between team and project phases may enable more learning and establishment of best practices.

4.1.3 Stabilize

Resource planning and management are rated less important in 2016 than in 2009, but the gap is still significant. Since the previous assessment the company has reorganized into product group teams. As a result they have fewer projects in the pipeline simultaneously, and they do shorter learning cycles to keep pace in the project. These improvements may lead to less need for coordination, but the capability gap remains due to long project lead times and medium departmental size (cross-functional and maybe overlapping competencies), challenging how to organize for more optimal coordination. Another

noticeable gap is related to how suppliers are involved in product development. Especially the participants from manufacturing development emphasized the importance of early supplier involvement in the PD process. The discussion about this topic also highlights the need to enable a more seamless, direct communication interface between product developers and key suppliers.

4.1.4 Standardize

The participants agreed upon a significant capability gap between current and desired 'Design strategy'—the same as seven years ago. Some participants argue that the case company should take on a more visionary design strategy, whereas others argue for increased standardization. On the one hand, most customers choose among very basic configurations. The key question is how the case company can develop a more differentiated product strategy, while enhancing modularization and key functions (also supporting knowledge carriers) more than using resources on developing a large number of individual parts and components. The visionary vs. the rational perspective is about managing risk—which can be derived further into where to take on risk and what is acceptable risk.

4.1.5 Continuous improvement

No major gaps were detected within this category—a result very consistent with what was observed in 2009. It was agreed upon within the survey team that effectiveness and efficiency are important to continuously ingrain in the way of working. One of the outcomes is the identified need of defining good, relevant leading metrics for PD productivity at team level—beyond what is existing PD practice.

4.1.6 Culture

The maturity of the culture component seems to have improved towards Lean PD since 2009, especially when it comes to the capability 'Utilization of digital tools' and 'Simple and visual communication'. So-called "iObeya" was mentioned as a new communication tool that has improved the way of working in teams. There is still a capability gap related to 'Culture for creativity and entrepreneurship'—which is consistent with the internal call for a more visionary design approach.

5 CONCLUSIONS AND FURTHER WORK

The present study concerns the use a developed Lean PD capability maturity assessment to determine the applicability of using it to identify capability gaps and initiate improvement schemes in PD. The assessment framework was first piloted Scandinavian product manufacturing company 2009. The results were used to define Lean PD transformation initiatives within the company. The most important ones were: (a) use of visualization tools (iObeya); (b) fast learning cycles and stand-up meetings for multi-site PD teams; (c) fewer projects in parallel, concentration PD resources to reduce lead time (and cost); and (d) leveraging creativity and innovation, along with more focus on capturing real customer value. Then a similar assessment workshop was conducted in 2016, including the same functions but mostly different people, except one person who attended both assessments. Based on the findings in this longitudinal Lean PD capability study, the following conclusions can be drawn:

The developed framework has proven to be well suited to identify Lean PD capability gaps and hence help companies identify, prioritize and implement Lean initiatives in their PD teams and related functional organization.

The results from two assessments conducted in 2009 and 2016, respectively, within the same company shows no major changes in terms of current capability and desired capability. This is a quite significant and surprizing result given that (i) the company has defined several significant Lean PD transformation initiatives after the first assessment; (ii) the second assessment was done with a different PD team involving the same functional responsibilities as the first one conducted 7 years earlier; iii) a number of similar assessments made in different companies across different sectors have shown that the assessment tool is capable of capturing contextual and individual differences--i.e., assessment ratings are generally very different from those of the company in this study.

The most recent assessment revealed that increased Lean PD awareness among the team and within the company has brought new challenges to the surface, ones that were hidden by more obvious issues in the past (first assessment). One example is the (Lean) concept of building a flexible organization where people can undertake multiple roles and functions. The case company has experienced a danger that taken this concept too far will (in their context) tend to create generalists, which in turn hurts maintaining

in-depth specialist focus (among existing staff), organizational learning and time for getting new recruitments up to speed.

Based on the above outcomes, further work is proposed to include studying more longitudinal Lean PD implementation initiatives. It is of particular interest to identify contextual factors being important to different Lean PD implementation strategies. More specifically, since the present study has more than indicated that the culture is a strong component - onne that may rule over business sector, technology, tools and process-systematic studies of how culture influences Lean PD transformation initiatives, and vice-versa, are strongly needed to in the future.

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