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Lean automation development: applying lean principles to the automation development process

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Abstract

By a broad empirical study it is indicated that automation development show potential of improvement. In the paper, 13 lean product development principles are contrasted to the automation development process and it is suggested why and how these principles can facilitate, support and improve the automation development process. The paper summarises a description of what characterises a lean automation development process and what consequences it entails. Main differences compared to current practice are also identified. The incentives for, and expected effects of, applying the identified lean principles to the automation development process are discussed.

Keywords: Automation development, lean, process development

Introduction

Automation is a well-known means of improving productivity, efficiency, quality and safety as well as lowering cost in operation. However, in spite of the numerous benefits and advantages that automation offers, it is not always the best solution and in some cases it is not even a feasible one (Groover, 2008; Cruz Di Palma and Basaldúa, 2009; Spath et al., 2009). Actually, the wrong technology, or even the right technology poorly implemented, can be disastrous (Baines, 2004). Further, previous research shows that the main problems with automation are not associated with the actual automation level or the lack of technology, but rather with its implementation and difficulties in choosing and incorporating it (Sambasivarao and Deshmukh, 1995; Durrani et al., 1998). The key to a successful use of automation therefore lies in finding, selecting, acquiring and properly implementing the right type and level of automation in relation to the company's needs,

goals and prerequisites (Baines, 2004; Säfsten et al., 2007; Daim and Kocaoglu, 2008; Ceroni, 2009; Spath et al., 2009). The process of developing automation, which includes all these steps, is thus a crucial part in determining the success of automation investments and thus reaping the benefits of automation (Baines, 2004; Spath et al., 2009). However, while the importance of the automation development process is clear it is in practice often time consuming, costly and experienced as difficult to manage (Granlund and Jackson, 2013; Granlund, 2014).

The development of complex socio-technical systems, which the development of automation solutions could be described as, have been the object of study within multiple fields of research. One field contributing to this subject is the lean product development. Lean production has in manufacturing industry been recognized as a means for achieving competitive advantage by focusing on two primary objectives: eliminating waste and creating value for the customer. Authors such as Morgan and Liker (2006) see that “lean thinking” can also, with great positive effects, be applied to areas outside the actual manufacturing operations such as to development processes where lean product development (LPD) is one example which has received much attention with proved benefits.

With the overall aim to support the successful use of automation in industry, the research presented in this paper investigates how the automation development process can be facilitated and improved by adopting a lean mind-set. The objective is therefore to investigate how LPD principles can be applied to facilitate and improve the automation development process and thus support successful use of automation in industry.

Background to Lean Product development

Lean thinking is an improvement philosophy focusing on the creation of value and the elimination of waste. Lean production is a well-researched area but there has been comparatively less research done to apply lean thinking to product and process development (Khan et al., 2013) and there is a clear lack of a consistent theory base for LPD (Hoppmann et al., 2011).

The roots of LPD, just like lean production, goes back to Toyota. Khan et al. (2013) identifies five different approaches that researchers and practitioners have taken to LPD. These are in overview:

1. Rebranding concurrent engineering as LPD.
2. Adopting ideas from Lean production to product development in combination with other theories.
3. Integrating elements of the Toyota Product Development System (TPDS) with Lean production principles and methods and applying them to product development.
4. Describing Toyota concepts based on a case study of TPDS.
5. Practitioners attempting to apply Toyota concepts in product development.

Authors from the fourth category have received the most attention through their careful studying of the product development practice at Toyota and by capturing the essences of TPDS which entails more than just lean production principles applied to the product development process. One description of the TPDS is by Morgan and Liker (2006) who have distinguished and presents 13 LPD principles divided in three sub-systems based on the three elements of the socio-technical model: people, process, and technology. These 13 principles are in overview listed in Figure 1. Morgan and Liker (2006) however emphasizes that these principles do not exist in isolation, insulated from each other and the outside world. Instead they interact, overlap and are interdependent and work together to create a coherent whole.

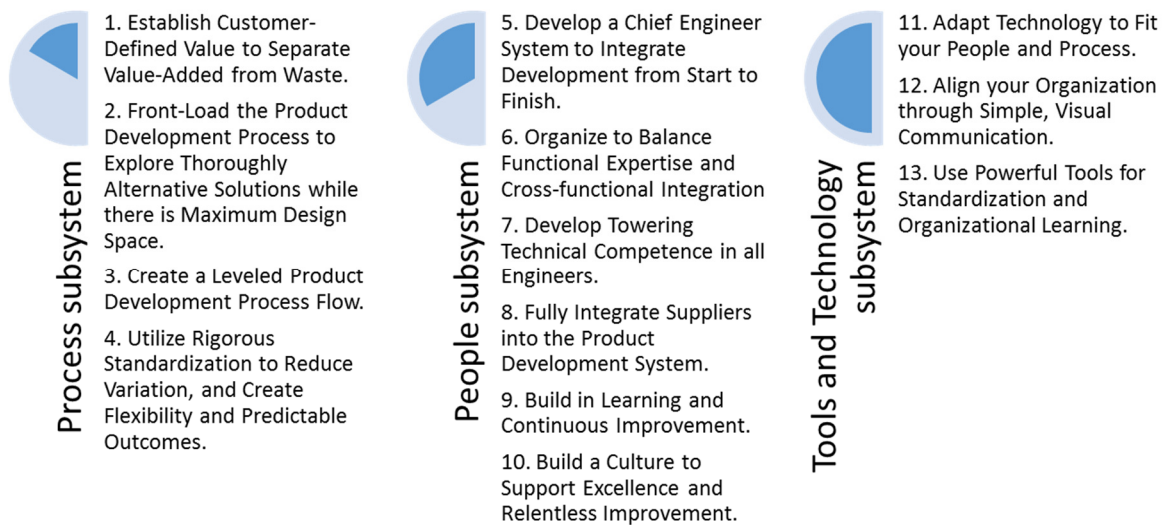


Figure 1 – The 13 Lean product development principles structured in three subsystems.
After Morgan and Liker (2006)

In line with the first principle Ward (2009) point out that the foundation in a Lean Development System is understanding what is value in development before you can design the system that should produce it. When designing the system, focus should with a lean mindset be to eliminate waste in the process. In product development, there are two broad categories of waste (Morgan and Liker, 2006):

1. Waste created by poor engineering that results in low levels of product or process performance.
2. Waste in the product development process itself.

Besides the central value focus, Ward (2009) present four “cornerstones” of LPD: Entrepreneurial System Designer, Teams of Responsible Experts, Set-Based Concurrent Engineering (SBCE) and Cadence, Pull and Flow. SBCE (also lifted by Morgan and Liker (2006) in their second principle) is an important aspect of LPD since paradoxically, as in the case of Toyota, delaying decisions and following a large number of alternatives for the same product module contributed to better and faster product development (Ward et al., 1995).

Another main key to Toyotas success is the high degree of integration (Sobek et al., 1998) both between product design and manufacturing-process design and between other business functions. The incorporation of new knowledge into checklist or similar to be applied to all the company’s products is also identified by Sobek et al. (1998) as a key to success and thus an important part of LPD.

Method

In order to investigate how the automation development process can be improved, current practice in industry has been mapped through interviews and participant observations. The process of developing automation has, during the years 2008-2013 from different aspects, been investigated at 32 companies through a total of 76 interviews. The companies were mainly producing companies in various lines of businesses, but to cover a wider sample were also warehousing and distribution centres as well as hospitals included, but underrepresented. The sizes of the participating companies ranged from small to large, but medium and large sized companies dominated the selection. The interviews performed were of semi-structured character and ranged from 15 to 95 minutes. The primary interviewees were production managers, production engineers and

project managers responsible for or involved in automation development at their respective company. These interviews covered the way of working with automation development and with special focus on mapping and understanding the process and its underlying structure. Ten factory and/or purchasing managers responsible for automation investments were also interviewed to cover how the aspects of value and benefit were considered in the automation development process.

At three of the companies (one small, one medium and one large sized manufacturing company) the automation development process was followed and studied in real time through participant observations. The development processes studied ranged from seven to 14 months, not including the implementation phase which was only covered by follow up interviews. During the development processes, at least ten workshops and/or project meetings were attended during each process and complementary interviews were conducted to get a complete picture of the process. Focus was on mapping and understanding what was done, how and why, and to identify prerequisites to and experiences from performing automation development.

All gathered data have been used to create a view of common practice on automation development in industry. The data was also analysed to identify problems and weaknesses in the current way of working. The described state-of-practice from the industrial studies has then been contrasted to the LPD literature to identify differences and improvement potentials.

Empirical findings

The empirical studies of current automation development practice revealed numerous successful cases of automation and organisation for automation, contributing to highly competitive solutions and companies. However, the studies also indicated seven characteristics in need of further development, elaborated in the following.

- Lack of processes, routines and support documents for automation development
- Reliance on key individuals and automation experts
- Automation development seen as a procurement effort
- Lack of automation strategy
- Non-defined value of automation
- Unclear responsibility of automation
- Dependency of system suppliers or integrators

The empirical studies of current automation development practice made evident that in the vast majority of the companies studied, the automation development process is conducted in an ad-hoc manner. Only at a handful of the respondents' companies did a process model particularly adjusted for automation development exist. In most companies were processes including established routines and support documents suitable for automation development lacking. Several respondents conveyed that they and their colleagues respectively, based on their own experiences and know-how, had developed their own way of working during the automation development process. This also led to unclear decision points during the automation development process.

The studies also indicated that there, even in the larger companies, often is only a few individuals that have knowledge and experience in automation. There is both a strong dependency on these individuals during the development processes and the success of past automation measures were also often credited to the contribution of these individuals.

Another common practice that emerged was that the resulting automation solution was decided early in the development process, in some cases to the extreme that a decision for a particular investment was the trigger for the automation development process. In the

cases a formal process existed, it was typically used for investment projects and the project gates were closely related to the gates in the formal purchasing order document used by the company. In the development process there is thus a strong focus on technological solution development or procurement and comparatively little time is spent on the early phases such as mapping and clarifying of needs, goals and prerequisites, apart from the material that is needed for a formal request for quotation. As a result there is often a poor base for evaluation and decision making and decisions during the process are thus often made ad-hoc. Also, as a result of the lack of process models there were often no or few clear decision points during the automation development process. The importance of a thorough specification of requirements for a successful outcome the automation development was understood, but there was poor support for formulating it, both from the point of view of the content and process.

There was most often a lack of, particularly strategic, motivation and overall view of the desired way of working with and using automation. This often resulted in miss-fitting, or one of a kind solutions with limited strategic alignment between them and in relation the overall operations in which the automation should be part. The findings also indicated a narrow understanding and definition of the customer value that is expected and desired from automation measures. Actual customer value was also poorly evaluated.

Another key character is an often common awareness within companies, of the limited time spent on both defining desired value and on evaluating actual value. Instead, consistently high value from automation projects is assumed to come as a result of standardised investment procedures. That is, standardised acquisition, installation and documentation procedures are assumed to lower investment and operating costs, thereby increasing the value from automation. However, many of the companies seemed to make the same mistakes over and over again and this was analysed as a result of poor or lacking evaluation and follow up both of the investments itself but particularly on the development process. At a few of the companies studied it was routine to write a white paper after each automation project. However, the interviews revealed that these papers were rarely used or considered in future projects. Also, in many of the companies studied the development process and the decisions made during it were scarcely documented, making evaluation and thus the generation of lessons learnt difficult. There was also seldom routines for how to work with reviewing, improving and standardising of the automation development process.

Further, the responsibilities of different functions during the automation development process is often unclear and some tasks and activities in the process are often divided or assigned to be performed by certain departments or functions rather than by the cross functional project group. In the cases where use of cross-functional project groups were well developed and applied throughout the process, it was experienced that projects were more successful in terms of better adjusted solutions. In some of those cases the respondents also saw a faster and more efficient development process. Also, staff commitment was raised and the often experienced resistance towards automation was considered to decrease as a result of the use of cross functional teams.

All case companies studied engaged system suppliers or integrators, at least at some stages in the automation development process. The stage in the automation development process when companies were most likely to engage a third party, was when alternative automation solutions were to be developed. The stage when companies were least likely to involve a third party, was when problems or possible areas of improvements were to be identified. This was, however, one of the stages considered most difficult in the improvement process. Most companies were, to varying degrees, thus dependent on third parties during the automation development process. It was, however, especially by the

companies with limited automation knowledge and experience considered difficult to find an appropriate level of collaboration with system suppliers. Respondents explained that the third party could take too much control over the project, which in some cases had resulted in a solution that did not fit into the rest of the production system or in a solution that the company could not operate after the implementation. A few respondents had also experienced problems during collaboration regarding who owned or were responsible for the implemented solution.

Analysis and discussion

One of the most influencing differences between the identified common practice in automation development and LPD practice is related to the value focus advocated by Ward (2009) and included in the first principle by Morgan and Liker (2006). The narrow or insufficient identification and definition of desired value from automation measures creates poor prerequisites for the establishment of requirements and thus the base for evaluation and decisions.

A thorough establishment and definition of value would come as a natural part in a front-loaded automation development process (principle 2), which in common practice is not the case since focus instead is on solution development. A stronger focus on the early phases that besides establishment of value also should include identification of the customers' needs and requirements and mapping of the organisation's goals and prerequisites would create a better base for evaluation and decisions. It was in the current practice identified that decisions were often taken early in the process and in an ad hoc manner, something supported in literature (Säfsten et al., 2007; Winroth et al., 2007). The often poor base for evaluation and decision was in turn identified as one of the main reasons to miss-fitting solutions or in other ways unsuccessful uses of automation.

A SBCE-practice, advocated as one of the cornerstones of LPD and in focus in the second LPD principle, would translated to the automation development process entail a process where several solutions (both several automation based solutions but also alternative solutions) are explored during the development process and the decisions of which solution to implement is made later in the process compared with the common practice. A strategic view of the desired use and way of working with automation and its development would be a large support and give input to and help develop solutions and decision making along the process. This strategic view, preferably in the form of an automation strategy, would be constructed to ensure the adoption of the right technology for the given prerequisites, corresponding to principle 11.

Another identified main difference between LPD and common automation development practice with large impact on the process and its outcome is the aspect of standardisation and particularly the fourth LPD principle. Common practice indicated that few companies have or use a standardised process suitable for automation development but there was in the same time a high confidence that consistently high value from automation projects would come as a result of standardised investment procedures. In order to achieve this, the automation development process must be standardised and process support in terms of routines and other support documents suitable for automation development must be established to facilitate the process and make a standardised structure possible.

When developing a standardised process for automation development it is important to identify and involve key individuals in the company with knowledge and experience in automation development and make use of their expertise. These individuals are highlighted by Meredith (1987), who addresses "automation champions" and their role in successful automation projects. The role of these key individuals/automation champions

can thus be compared to the chief engineers pinpointed in principle 5 and which should have a prominent role during automation development.

Even though the chief engineer should have a leading role during automation development it is also of great importance to spread knowledge internally in the company to avoid the strong dependency of individuals identified in common practice. This is addressed in principles 6 and 7. Having clear, structured and well supported routines for the automation development process (a need concluded above) would support especially inexperienced staff during this process and thus help share responsibilities (principle 6) and even the workload (principle 3) but also support additional individuals building experience and knowledge in automation and its development.

Bringing back knowledge into the automation development process is also a key task in the continuous improvement mind-set representing lean. The empirical studies however revealed an often insufficient evaluation and follow up and that the companies seldom made use of lessons learnt, something being an important part of SBCE (Sobek et al., 1999; Ward, 2009). This was analysed as partly caused by an ad hoc decision process and poor documentation of the process. As advocated in principle 9 it is important to build in learning and continuous improvements during the automation development process and this can be supported and facilitated by a structured and standardised development process dealt with above. The process should for example include steps and routines for decision making and evaluation and follow up (of both the process and its outcomes) as well as the aspects of when and how documentation is to be made during the process (principle 13). Also Baines (2004) addresses the importance of explicitly documenting knowledge in his suggested technology acquisition process by creating databases and portfolios. To enable this built-in learning and continuous learning improvement, it is important that the tenth principle is in place and that the crucial commitment is secured which as shown in common practice can partly be achieved through the use of cross-functional teams throughout the entire process. Commitment can however seldom be secured without guidance and understanding for the process. It is thus important to in an accessible way communicate the company's automation strategy including the desired way of working with and during the automation development process which is incorporated in principle 12.

During the empirical studies there were accounts of how the strong reliance on third parties had caused unsuccessful automation investments that poorly met the companies' needs and prerequisites. It is however argued that the cause of these unsuccessful investments is not necessarily in the actual involvement of third parties during the automation development process but rather in the way that they are involved and how the responsibility is divided. Involving third parties during automation development is an excellent way to access state-of-art competence and compensate for and help overcome lacking knowledge about automation and its possible applications, especially when it comes to new technology (Daim and Kocaoglu, 2008). However, the identification of problems and possible areas of improvements was the step in improvement work that the companies most often chose to do themselves and not involve third parties, i.e. not taking advantage of them in one of the steps perceived as most difficult and being important from the front-loading perspective of LPD.

Also, previous unsuccessful investments identified in the studies can also be traced to the customer's (the company buying the service from the third party) lack of insight into and understanding of the automation development process, the limited insight in desired value and poor base for decisions that leads to inappropriate selection. This is especially a risk when relying too heavily on the third party and letting them take the decisions without proper insight into either prerequisites, requirements or goals, something that

should be provided by the customer for a successful supplier-driven approach (Säfsten, 2002). Principle 8 in combination with principles 1, 2 and 11 is thus of the most decisive importance in overcoming this particular problem and improving the automation development process.

Table 1 summarises how the identified 13 LPD principles can be translated to the automation development context. In the table, the corresponding 13 Lean Automation Development (LEAD) principles are listed and briefly explained.

Table 1 – The 13 Lean Automation Development (LEAD) principles

	LEAD principle	Main features/motivation
Process subsystem	1. Establish customer-defined value to separate value-added from waste.	Understand the customers' needs and define desired value from automation measures. Develop an automation strategy supporting a value adding process and outcome.
	2. Front-load the automation development process to thoroughly explore alternative solutions.	Focus on early phases to map customer needs, goals and prerequisites and create a detailed and firmly based specification of requirements. Explore, develop and evaluate alternative solutions and push the decisions for actual solution late in the process.
	3. Create a levelled automation development process flow.	Level the workload throughout the process and divide and schedule responsibilities across functions/ departments/ individuals. Avoid overloading key individuals creating fragile systems.
	4. Utilise rigorous standardisation to reduce variation and create flexibility and predictable outcomes.	Develop a standardised automation development process. Develop and establish suitable process models, routines and support documents
People subsystem	5. Develop a chief engineer system to integrate development from start to finish.	Appoint a chief engineer representing the voice of the customer managing integration and decisions making along the process.
	6. Organise to balance functional expertise and cross-functional integration.	Identify and acquire key knowledge/expertise necessary for automation development and distribute over functions.
	7. Develop towering technical competence in all engineers.	Make sure knowledge/expertise is transferred internally to create a robust system less dependent on individuals.
	8. Fully integrate suppliers into the automation development process.	Involve third parties early in the process and make sure they have a complete picture of the needs, goals and prerequisites in order to make appropriate decisions.
	9. Build in learning and continuous improvement.	Make sure there are routines and support for knowledge transfer, evaluation and follow up as well as continuous improvement of the process.
	10. Build a culture to support excellence and relentless improvement.	Be open and communicate the automation strategy and explain how it is structured to create value. Value process and structure observance and lead by example.
Tools and Technology subsystem	11. Adapt technology to fit your people and process.	The automation strategy should act to support value adding automation measures and make sure the right type and level of automation for the given prerequisites is developed and that suitable tools and technology is used during the development process.
	12. Align your organisation through simple, visual communication.	Communicate the automation strategy and visualise the development process, both planned and actual outcome. Make sure it is clear who is responsible for what and avoid information/communication overload.
	13. Use powerful tools for standardisation and organisational learning.	Make sure there are standardised routines for all steps in the development process, that they are followed and continuously revised.

Conclusions and areas of future research

The research concludes that lean mind-set and principles can be transferred to the development of automation. This since the essence of this process is to, in an effective manner (by eliminating waste) find the automation solution giving the best benefits to the company (i.e. best correspond to the customer's needs). The lean development practice have previously been well elaborated in product and software development contexts, but more rarely in production system settings, and particularly not concerning automation development.

The empirical studies indicate that in current automation development practice main focus is on technological solution development and comparatively little time is spent on clarifying needs, goals and prerequisites. This is possibly a cause of ad-hoc or unstructured development processes. Further, while companies are heavily dependent on third parties such as system suppliers, they are at the same time experiencing difficulties cooperating with them. The involvement of third parties can support the use of automation but the successful involvement is dependent on the manufacturing company's understanding of the development process and its ability to provide the base for appropriate evaluation and decisions. Current practices also involve miss-fitting solutions with limited strategic alignment as well as a narrow understanding and definition of the value that is expected and desired from automation measures. Actual value is also poorly evaluated.

By developing a process to better establish, define and evaluate value and by front-loading the automation development process, it is believed that the requirement setting can be improved and thereby reducing the risk of miss-fitting solutions. Organising to balance expertise, integrate suppliers into the development process and to make better use of cross-functional teams during the process is also relevant for identifying, selecting and developing an appropriate automation solution. Furthermore, technological development rapidly changes automation possibilities, challenging the efforts on standardization, initiated to secure long term value from automation projects. Finally, other areas of lean automation development, such as a levelled and standardised development process and built-in learning and continuous improvement processes will improve the process and increase the successful use of automation.

By adapting a lean mind-set to the process of developing automation, the waste in both the development process and the resulting solution can be reduced. A lean automation development process can contribute to sustainable automation solutions which better correspond to the customer's needs, requirements and knowledge. Companies would thus better benefit from the use of automation technology, and together with a resource and time effective development process based on lean principles, reach less costly automation equipment and higher return on the investments.

The research presented in this paper contributes to the operations management theory by elaborating on the concept of lean automation development. By addressing how a lean mind-set and LPD principles can facilitate and improve the process of developing automation, the possibility of successful automation measures and industrial competitiveness increases.

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