Supporting Lean Software Enterprises with Agile Development Methods

Identifying the Relationship between Lean and Agile

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Abstract

Lean principles have been seen as a potential answer to the current issues of faster development cycles and more frequent releases, as software businesses are changing towards more service-oriented offerings and cloud-based business structures. Agile software development methods have played an important role in resolving the same issues at development level. This article creates a framework for lean software enterprise theory by linking lean theory, lean software development, and agile software development methods. The findings are tested through an empirical study conducted in two significant software engineering organizations. This article presents a conceptual lean software development system that clearly combines lean and agile. The important role of people and culture is also emphasized. Agile software development methods are characterized as the tools of lean software development and while lean software development is seen as a change beyond agile, agile approach is required for competitive advantage.

Keywords

Lean; Agile; Sofware Development; Lean Software Development; Agile Software Development

Introduction

In addition to software development organizations' normal desire to be more efficient, current changes in the software business environment require companies to be able to adapt and align their products and processes to meet rapidly changing customer requirements (e.g. Sainio and Marjakoski, 2009; Suomalainen et al., 2011). Research on lean thinking and its possibilities in the software engineering sector is seen as one solution, especially in terms of agile software development practices.

The five principles typically identified for lean include value, value stream, flow, pull and perfection (Womack and Jones in 1996). The adoption of these principles is seen vital for creating lean processes, or further, a lean enterprise (e.g. Emiliani, 2003; Liker, 2004). The benefits of lean philosophy include focused enterprise-wide approach to continuous improvement, increased productivity, improved quality and managerial benefits (e.g. Hicks, 2007). Nevertheless, regardless of the potential benefits of lean, they may not be achieved by merely implementing tools, but more fundamental changes are required (Bhasin and Burcher, 2006).

The application of lean principles has proved successful in providing results in other business environments aside physical manufacturing where it was originally applied (e.g. Womack and Jones, 2003). Other concepts such as lean product development and lean enterprise are also discussed in literature (e.g. Karlsson, and Åhlström, 1996a; Bozdogan, 2010).

The software community's interests towards lean thinking are derived from the similarities of previously emerged agile software development methods and lean principles (e.g. Highsmith and Cockburn, 2001). Lean principles have been seen as a potential answer to the current issues of faster development cycles and more frequent releases, as software businesses are changing towards more service-oriented offerings and cloud-based business structures. Therefore, Lean and agile are often discussed together in the software related literature (e.g. Larman and Vodde, 2009, Poppendieck and Poppendieck, 2003).

Nevertheless, regardless of numerous articles and wide discussion in the literature, the discussion on software development and lean and agile practices has room for further studies and clarification. This article aims to provide a framework for lean software enterprise theory; clarifying general lean theory models in relation to the newly emerged field of lean software development. A contextual framework is created for academics and others interested to be used

in their future research. This study attempts to combine the most important aspects of lean for software development organizations. The validity of the findings is evaluated through an empirical study conducted in two significant software engineering organizations.

The above discussion can be condensed into the following research questions:

RQ1: What are the specific elements of lean in software development organizations?

RQ2: Are these elements recognised by existing software development organizations that use lean principles?

Lean elements relevant to SW development organizations are identified based on literature. The validity of the devised theoretical framework is tested in software development organizations that have experience in utilizing agile software development methods, and that have also implemented lean principles in their organizations.

Literature Review of Lean and Agile

Principles of Lean

The story of lean originated from Japan, however, the concept was not called lean until the world-wide benchmarking study in the automotive industry by Womack et al., (1990). Post Second World War trade restrictions played a role in the appearance of the Toyota Production System (TPS) developed during several decades of endless improvements (e.g. Ohno, 1988), which complemented with other manufacturers methods became known as lean. Lean methods have proven to be more effective than many other methodologies in different types of manufacturing companies (e.g. Womack and Jones, 2003). In the 90's, lean often meant waste reduction, while later customer value has been emphasized. Along the evolution of lean during the past few decades, the application has broadened from manufacturing to other sectors. (Hines et al., 2004)

There is a clear correlation between the development of quality management and the development of TPS (e.g. Arnheiter and Maleyeff, 2005). The quality movements that developed to become total quality control (TQC) and total quality management (TQM) have had a significant influence on the development of lean principles. (Womack and Jones, 2003). Lean has also adopted some elements of concepts such as, just-in-time and business process re-engineering (e.g. Andersson et al. 2006). Lean thinking is based on five principles, value, value stream, flow, pull, and perfection, first introduced by Womack and Jones (1996). These five principles are relevant for creating lean processes and eventually, a lean enterprise. In addition, Picchi (2001) considered the capability analysis presented by Fujimoto (1999) as one of the core elements of lean with the aim to maintain high performance and continuous improvement through three levels of capabilities, routine manufacturing capability, routine learning capability, and evolutionary learning capability (Fujimoto, 2004).

Also, the concepts of value and waste are at the heart of lean thinking (e.g. Hines et al., 2000). In lean, value is seen from the customer perspective as anything the customer appreciates, while in general business, value is often regarded as a monetary measurement. Value is seen to be meaningful only when expressed in terms of a specific product that meets customer's needs at a specific price at a specific time. (Womack and Jones, 2003). Waste, on the other hand, can be described as everything that a company does except value to the ultimate customer. Wasteful activities are abundant in any process; however, removing waste is a part of the essence of lean (Womack and Jones, 1996). The seven classes of waste originally identified in TPS include: overproduction, waiting, transportation, over-processing, inventory, movement, and defects (Ohno, 1988, Liker and Meier, 2006). Although these wastes have been derived from the production environment, they are also used as general classes of waste in lean (e.g. Liker 2004).

Value stream refers to those value-adding, and wasteful activities that are required to bring a product, or service into existence, from order to delivery (e.g. Liker and Morgan, 2006). The importance of recognizing the value stream lies in the ability to focus improvement efforts (Hines et al., 2000). Flow refers to the value-adding activities carried out smoothly i.e. flowing, adding maximal value from the product's perspective at every point of the value stream (e.g. Seth and Gupta, 2005). The pull principle simply means that no upstream process may produce any goods or services until it gets a signal to do so from downstream (Black, 2007). Similarly, as for lean in general, continuous improvement is the essence of the fifth lean principle, perfection that has a goal of striving towards perfection (e.g. Emiliani, 1998).

There are many benefits that have been identified for following the lean principles. Flow can bring speed and agility to the process when also following the pull

principle. However, if the process uses a push system to determine output levels, flow may only be partially beneficial (Hines et al. 2004). With a pull system, when an actual need is expressed from downstream, reduced lead times can be achieved (Womack and Jones, 2003). The continuous development of all practices in small increments is seen to gradually improve the competence of every process, and ensure the continuity of improvement efforts (e.g. Bhuiyan and Baghel, 2005).

Levels of Lean

Lean consists of both strategic and tactical aspects. The five principles can be viewed as strategic level principles, as they can be utilized in all parts of a supply chain, ones which are supported by operational level tools and methods. (Hines et al. 2004). The typical lean tools can be ones derived from TPS, as well as tools from other methodologies, such as Six Sigma exist. At the operational level, lean principles allow using any tools that support the organization in implementing the five principles. The most common lean tools include Kanbans, value stream mapping, just-in-time, cellular manufacturing, setup time reduction, total productive maintenance, 5S, and such (Pavnaskar et al., 2003; Bhasin and Burcher, 2006; Abdulmalek and Rajgopal, 2007; Shah and Ward, 2007; Womack and Jones, 1997; Hines and Taylor, 2000; Burton and Boeder 2003; Patten 2006). Going even beyond a strategic level, the lean principles can be expanded outside of an organization's own supply chains to form a lean enterprise, which can include both suppliers and customers. On an enterprise level, lean principles can also incorporate relative strengths from other enterprise approaches, such as TQM and Six Sigma, ones initially positioned as competing approaches that have now evolved to minimize their weaknesses and maximize opportunities (Bozdogan, 2010).

Lean Practices

Aside the potential of lean, some studies also highlighted some negative aspects of the philosophy (e.g. Lewis, 2000; Parker, 2003; Mehri, 2006; Chen et al., 2010). Only a part of companies succeed in implementing lean practices (Bhasin and Burcher, 2006). Also, substantial investment in time and money are required for a successful implementation of lean (Bhasin, 2013). The rapid evolution and a lack of definition have blurred the boundaries of lean and the concept is somewhat unclear and vague (Hines et al. 2004; Arlbjørn and Freytag, 2013). Also, Pettersen (2009) identified the absence of a clear definition of lean to be a challenge.

Nevertheless, regardless of any potential ambiguities, the lean house of Liker (2004) provides a good overview of the principles of lean. Practices such as waste reduction, standardized processes, leveled output and visual management can be potentially beneficial for any company. The potential benefits have been acknowledged, especially if a company focuses on creating its own production philosophy in the form of lean house (Miina, 2012). Lean house is a visual, presentation of a structural system that would not be stable without all the elements being of good quality (Liker 2004).

Lean in production has been studied from various perspectives in numerous articles (e.g. Shah and Ward, 2007; King and Lenox, 2001; Holweg, 2007; Karlsson and Åhlström, 1996b; Dahlgaard and Dahlgaard-Park, 2006). Nevertheless, there are much less articles on lean product development (e.g. Karlsson, and Åhlström, 1996a; Liker and Morgan, 2006; Oppenheim, 2004; Hines et al., 2006; Gautam and Singh, 2008; Browning, 2003, Blau et al., 2013). Lean has also been discussed in conjunction with other business processes (e.g. Ward and Zhou, 2006; Robinson and Schroeder, 2009; Nicoletti, 2013).

Agile Software Development

Lean principles are applicable to almost any kind of organization (Womack et al., 1990). Nevertheless, software development is a relatively new field for the application of lean principles (e.g. Petersen and Wohlin, 2011; Poppendieck and Poppendieck, 2005; Middleton, 2001). In fact, lean software development can be viewed as a part of the agile movement of the software development community (e.g. Highsmith and Cockburn, 2001; Leffingwell, 2007). The agile movement gained publicity within the software community during the 1990's, and was later concretized in the Agile manifesto, published in 2001. The authors also described twelve related principles. (Beck et al., 2001).

Agile software development can be divided into agile software development principles (e.g. Ronkainen and Abrahamsson, 2003; Martin, 2002), agile software development practices (e.g. Misra et al., 2009), and agile software development methods (e.g. Dybå and Dingsøyr, 2008).

Agile methods contain a wide set of different approaches, such as Scrum and Extreme programming

(XP) that have challenged the traditional waterfall model in software development (e.g. Salo and Abrahamsson, 2008). In many ways, the software development waterfall model could be characterized as similar to the stage-gate model in physical product development (Cooper, 1986). Agile methods and traditional SWD have some key differences including iterative development and promoting empowered teamwork (Beck et al., 2001) However, similar to lean, a common misinterpretation of agile software development is that the benefits are achieved with practices and tools, although the focus should be on being agile, instead of doing agile. (Larman and Vodde, 2009; McAvoy et al., 2012; Poppendieck and Cusumano, 2012).

Poppendieck and Poppendieck (2003) specified seven principles for lean software development, and emphasized how a common misinterpretation of improving software development processes towards lean is that software should be produced with similar methods as physical products in manufacturing environments. Nevertheless, Staats et al. (2011) suggested that manufacturing-based principles are applicable also to knowledge work; and they only viewed lack of repetition as a potential challenge. Also, Middleton et al. (2007) have found that lean principles and techniques can be successfully applied to software product development. The main themes of the Poppendieck and Poppendieck's (2003) principles have similarities to general lean principles, eliminating waste, empowerment, continuous improvement and creating flow. Eliminating waste is clear to any lean practitioner, but waste in software development can be more difficult to identify (e.g Wang et al., 2012).

There have been further attempts to scale lean and agile SWD practices into a larger context (e.g. Larman and Vodde, 2009, Leffingwell, 2007). Nevertheless, both lean and agile are in some cases conveyed as development level activities in SWD (e.g. Leffingwell, 2007, Dybå and Dingsoyr, 2008). Similar misconceptions have been made in the manufacturing world (e.g. Hines et al., 2004). The differentiation has to be made between a lean software enterprise and an organization utilizing lean SWD. The former utilizes the lean principles in the entire organization, whereas the latter uses lean SWD as an agile methodology in their development (e.g. Kettunen, 2010).

In practice, lean principles could be utilized also for a traditional waterfall-model software development since lean does not necessitate the use of specific tools. However, according to Leffingwell (2007) the use of lean thinking is a natural driver towards agile methods.. Motivations for adopting agile methods in software development have been identified including: adaptability to change, short time frames of releases, continuous feedback from customers, high-quality and bug free software (Rao et al., 2011).

In summary, it is believed that the elements of lean in software development organizations can be divided into three levels; principles, practices, and methods & tools. Principles that should guide the mindset behind all activities include value, value stream, flow, pull and perfection. Also people & culture should be seen as one of the lean principles due to their vital role in the success of lean transformation, even more than any practices. The application of principles is not limited to software, yet they are relevant for creating lean processes, or even further a lean enterprise. Practices such as standardized processes, leveled output, visual management, and waste reduction, can provide potential benefits for any company. In software development, waste can exist in the form of unnecessary features, wasteful activities and such. Continuous development of all practices, little by little, will gradually improve the capability of all processes, simultaneously ensuring the continuity of improvement efforts. Different tools and methods can be applied in software development, as far as they support lean principles. In general, agile software development methods can be characterized as the tools of lean software development as the principles behind those tools are highly similar. Also other suitable lean tools, relevant for production, product development, and other business processes may be applicable for the software sector. The elements of lean software development organizations can form a lean software development system that clearly ties together lean and agile.

Empirical Findings

Empirical evidence to support this summary was obtained by analyzing the practices of two case organizations. The organizations were chosen based on their participation in the Finnish Cloud Software Program [http://www.cloudsoftwareprogram.org/], as this study is conducted as a part of the program's on-going research activities. One of the objectives of the program is to aid organizations in adopting lean and agile ways of working in software development.

Both case companies were interviewed two weeks apart by the authors, using semi-structured open-interview sessions with pre-determined open form

questions as the basis for the interviews. The predetermined interview structure was used to get comparable data of the two case organizations. The questions were based on a literature review of lean product development and lean software development, while allowing the interviewees to explain the issues as entities. The interviewees included e.g. improvement coaches and business improvement managers. The interview sessions were recorded and the sessions were analyzed based on transcribed recordings.

The first case organization was a medium-sized development unit of a multi-national software company. The case unit has around 150 employees in their development teams, with the total number of developers in the company being several hundreds. The organization started their agile transformation in 2003, and the change was led by the idea that software could be designed in a more effective way than by using the traditional methods. The first introduction to agile was done with Scrum at a team level, gradually expanding the variety of practices within the organization.

The company started further change efforts towards lean during the latter part of 2009, with a big bang approach to several processes, as the entire business model of the company was changed. The key people viewed the change towards lean to be an expansion of the principles of agile within the organization. Nevertheless, they decided to name the process as lean only, as they felt that communicating the change within the organization would be easier in that way. Agile was viewed to have a label of being an R&D effort, and breaking this notion and making the organization to understand the effort to be beyond R&D was required.

The second analyzed case organization is a software development unit of a large product organization, with about 2,500 developers (including 700 suppliers' employees). The transformation towards lean software development was started in 2008. The transformation towards agile development had started already in 2004. The organization had noted that change towards agile was needed to gain competitive advantage, and prevent old processes becoming a disadvantage. In 2008, they had decided that the entire organization should start change beyond agile, towards lean SWD. The organization's management believed that agile should no longer be seen purely as a R&D practice, but that agile practices should be expanded to cover all aspects of the organization's work. Lean was seen as the solution for expanding agile practices. As in the first case organization, also the second one believed that agile as a term had the label of being merely a software process methodology. The company wanted to make a difference in how people viewed lean and agile, not only as a software processes but principles involving a bigger context. This was seen as a communication issue, as both lean and agile were seen to strive towards a common goal.

In both organizations, the adoption of agile methods is seen to focus development level work towards lean principles. Both organizations mainly use Scrum-based working methods, which individual teams are empowered to change to some extent. The significance of people and cultural aspects are rated very high in both organizations. An interviewee from the first case organization views the emphasis on people and teams as the major part of the lean transformation: "Team work is a very crucial part of lean in development work. We really want to give a kind of gentle push to teams even to take more responsibility, take more ownership, and take more initiative. Yes, that's an essential part of the game".

In the organizations, cultural transformation was seen as a major obstacle during agile and lean adoption. In fact, both organizations depicted the lean transformation as being particularly a cultural transformation, which involves helping people to understand the principles of lean instead of just changing their working methods: "...It is not clear to everyone, if it is thought that know-how and understanding [on the principles of lean] is statistically distributed, and… The average is not which it should be, and the dispersion is not small enough… I would say we have a good start"; Another interviewee phrased this as: "Involving people was the first attempt to reduce change resistance. Later, line managers were lured to support the change by using a semi-soft approach and asking them how we could do this... Those darn people came fast and overtook some units, taking lean and agile as far it was possible from their standpoint… and now we have our products 90 % developed following lean and agile". People and culture are seen such a large piece of the transformation that they are seen important to be emphasized clearly enough.

Both organizations experience agile and lean transformations to be the same thing, the only difference being in the nomination. This is seen to

clearly make agile development methods an integral part of the organizations' lean transformation. For the first case organization, agile methods invoked a major cultural change within the company. A lot of that change focused on the development teams and their structure.

Utilizing agile methods in development is seen to be crucial for a lean software enterprise, but there are problems in adopting the principles in other processes. An interviewee expressed this as: "...and realized that our planning process is not only poorly compatible with lean and agile, but it, our business planning process, contradicts with lean and agile. Hence, we decided to replace the process completely, starting from scratch, planning a process optimized for lean and agile". Similarly as for companies adopting lean in manufacturing, it appears that starting the lean transformation in SW development is easiest and clearest if starting in daily working practices. Adopting agile methods is seen to pose significant challenges similarly as lean production compared to mass production, as problems are seen to arise when trying to scale the principles outside software development.

The adoption of agile principles and methods indicate that the case companies value the tools that provide customer focus and efficiency. Although the application of the principles is done through agile methods, the agile principles behind these methods are quite similar to the lean counterparts. The interviews mostly support the notion of elements of lean being applied in software development organizations, yet some differences can be identified compared to principles presented in the existing literature.

The interviewees indicate that for a company to get full use of lean principles in software development, they should be supported by agile software development methods. It may be vital for the success of the lean transformation to have agile development methods in place. This is as the agile practices are seen to be based on similar principles as lean: "We do not separate lean and agile anymore, but now they have a same goal", "…so this has been like an agile transformation, so to speak. And then now, we are kind of transforming the transformation into a lean transformation." This is why the agile and lean transformations should not be seen as separate, but conjoint efforts. The core principles of lean are seen not to be related to the specific process applied. Also, to get the full benefit of lean, the principles must be adopted in all parts of the organization which is seen as a challenge.

The analyzed organizations view lean transformation as a continuum of the agile transformation. The interviewees stressed how the agile transformation is similar to adopting lean production in a manufacturing company without taking lean principles to any other processes. It may produce good results, but not enough to provide long term competitive advantage. For a long-term competitive advantage, a company may need to consider its value streams within the entire organization.

As a synthesis of the findings of this study, Fig. 1 illustrates a conceptual lean software development system. The conceptual lean software development system contains revised version of lean software enterprise principles presented by Womack and Jones (1996), in which people & culture was proposed as one of the main principles of lean. The figure also contains modified elements, practices and partially methods & tools from the lean house of Liker (2004). Agile software development is also included in methods & tools based on the findings of this article. Hence, this article complements the existing literature by presenting a conceptual lean software development system.

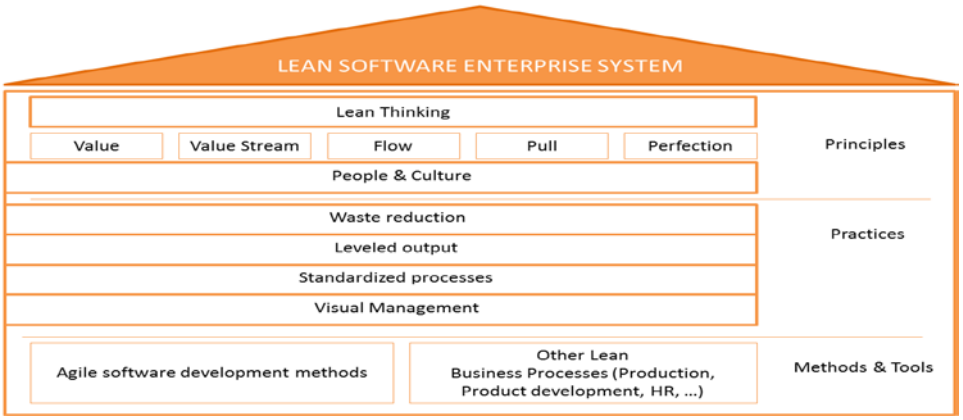

FIG. 1 CONCEPTUAL LEAN SOFTWARE DEVELOPMENT SYSTEM

Discussion

The findings of this article are in line with previous literature (Parnell-Klabo, 2006; Hallgren and Olhager, 2009) on emphasizing the similarity of lean and agile principles. This article especially emphasizes the similarities at the working level of software development. As lean does not exclude specific tools or methods as long as they support the lean principles, the tools of lean in software development can be characterized generally as agile software development methods. Hence, this article supports the previous literature on combining lean and agile approaches (e.g. Browaeys and Fisser, 2012). Agile and lean should not be seen as contradictory methodologies, but as complementing each other, if not even, in some cases, as the same principles.

This article also supports the literature on similarities between agile and lean methodologies, which is that both can be misinterpreted as practices instead of principles. As previously described by Hines et al. (2004), focus of implementing lean is on the beginning of its introduction used in production where the application of lean and its benefits are typically most easily visible. This article indicates that similar to lean implementation, agile practices are often taken into consideration in SWD without thinking about the principles that guide the mindset behind those practices.

Earlier literature (e.g. Cawley et al., 2010) has found that for a company making full use of lean principles in software development, they should be supported by agile software development methods. In light of the findings of this study, it may be beneficial for the success of lean transformation to have agile development methods in place. This is as the agile practices are based on similar principles as lean.

The findings of this study indicate that the emphasis of lean transformation is on cultural change. Both case organizations view lean transformation as a cultural transformation, with a specific emphasis on people and culture rather than on practices. The core principles of lean can be supported by a variety of practices (e.g. Bhasin and Burcher, 2006). Nevertheless, this study indicates that people and cultural aspects cannot be merely seen as voluntary practices but as an integral part of the transformation and among the core principles of lean.

Managers ought to understand that neither agile nor lean should be viewed as practices, but as guidelines on which practices, processes and organizational methods considered to be implemented. This is to support an organization in providing maximum value to its customers. There are no bespoke lean principles, or methods, as such for SWD organizations; instead all lean principles are applicable to software development environment and other business processes. Lean principles and practices can be supported by selecting those methods and tools that support the specific organization. In order to get full benefits of lean principles in software development, managers should consider supporting lean by using agile software development methods, such as Scrum or XP. Nevertheless, one must find and use organization-specific solutions that best fit their environment, and adopt the philosophy in all parts of the organization to prevent sub-optimization.

Conclusions

Research on lean software development can offer various possibilities, and enable companies to align their products and processes in a changing business environment. The similarities of lean and agile principles make lean thinking an interesting topic also for the software community. Agile software development practices play an important role in applying lean in the software sector. This article aims to provide its stake by attempting to clarify the discussion on software development, and lean and agile practices. A framework is created for lean software enterprise theory; linking general lean theory models and lean software development. The findings are evaluated through an empirical study conducted in two significant software engineering organizations.

Based on the interviews in two significant and advanced software engineering organizations, there are indications that the presented elements of lean software development organization are applicable for companies involved in software development. The change towards lean is seen as an expansion of agile principles. Lean software development is seen as a change beyond agile, while agile methods are required for competitive advantage. Nevertheless, lean and agile are both seen to strive towards the same goal, and regared as conjoint efforts. Agile seems to have a label of being an R&D effort, hence efforts beyond the use agile development tools have been called as lean in an attempt to make the organizations understand that this step is further than the old label indicates. Lean is seen as a solution for expanding agile practices to cover all aspects of the software engineering organizations' work. Agile development methods are

an integral part of lean transformation, while lean transformation in SW development is the easiest to be started in daily working practices. The adoption of agile methods is focused on development level work towards lean principles. In the case organizations, cultural transformation is seen as a major challenge during agile and lean adoption. The lean transformation is particularly depicted to involve helping people to understand the principles of lean instead of merely changing their working methods. Scaling the lean principles outside software development is seen challenging, nevertheless, companies view it as the only way to go beyond agile. It is emphasized how for a company making full use of lean principles in software development, the principles must be supported by agile software development methods.

The findings of this study are in line with previous studies regardless of any minor terminological differences (e.g. Womack and Jones in 1996; Poppendieck and Poppendieck, 2003; Liker, 2004). This study complements the previous important studies by introducing a conceptual lean software development system that combines elements from previous studies and clearly presents the role of agile software development methods in the context of lean. This study also complements the previous studies by emphasizing the role of people and culture as a lean principle. Managers should understand that neither agile nor lean should be seen merely as practices, but as guidelines on which the implementation of practices, processes and organizational methods ought to be considered.

The limitations of this study include a limited number of interviews and only analysis on the practices of two organizations. The limited number of case organizations may prevent external validation (e.g. Wohlin et al., 2000). Also, taking into account the multitude of discussion on lean, slightly different results might be obtained in the empirical evaluation of the presented framework. Also, with regards to the second analyzed organization, the scope of the research is limited to the software development organizations, a part of a larger enterprise. Naturally, also the presented conceptual lean software development system requires further confirmation. Future research could include analyzing a wider set of companies involved in software engineering.

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