Chapter 36
Literature Review of Lean Methodology and Research Issues for Identifying and Eliminating Waste in Software Development

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Abstract Lean principles is a methodology that focuses on identifying and eliminating activities or tasks that are not considered as important by the customer and do not add value, whether it is a manufacturing or software process. Be it manufacturing or a service industry, there are some components which can be identified as waste. Lean is a customer-centric concept; hence, activities which do not add value to the customer are considered as waste. An activity in a process which does not add value to customer consumes resources and adds cost or time can be can be called as waste or useless and hence can be eliminated. Lean is a widespread concept of manufacturing but seldom used in software industry. Literature contribution on Lean methodology in software and manufacturing industry are fragmented and show some significant limitations. Aim of this paper is to promote Lean concept in software industry.

36.1 Introduction

Lean is a unique idea for providing better service for the user by means of removing items which are considered as waste. A task in a process that tends to consume time or resources without increasing the price is considered as a target for removal. Lean concept is widely practiced in manufacturing industries but is not popular in the software sector. In a production context, the products and production methods are closely observed; hence, waste is simple to perceive, whereas waste in software sectors are not as same as in the manufacturing/production. Many industries do not realize the importance of Lean methodology hence retaliate to change the organizational culture that suits implementation of Lean methodology rather they flow the conventional way. But the constantly changing market situation put more demand to pay greater attention on client which without a doubt adds value. The motivating factor behind this study is to analyze the Lean concepts for IT industry taking Indian IT sector as domain due to the reason that Indian IT sectors are not achieving that

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A. N. R. Reddy et al. (eds.), *Intelligent Manufacturing and Energy Sustainability*,
Smart Innovation, Systems and Technologies 213,
https://doi.org/10.1007/978-981-33-4443-3_36

much profit ratio as compared to the foreign IT sector. Main reasons are wastes produced during the business process and less quality product. This research aims to introduce the Lean mindset and its requirements in the software industry.

36.2 Review of Literature

Word "Lean" was first used by Krafcik in 1988 to elucidate the Toyota manufacturing system. However, this became a widely used concept after the release of a book entitled "The Machine that changed the world" (Womack et al. 1991). Another e-book entitled, "Lean Software Development: An Agile Toolkit," authored by using Poppendieck and Poppendieck particularly been a bedrock of many Lean initiatives in software development domain. Poppendieck and Poppendieck [13] laid the foundation of Lean tasks. The authors provide justification as to why the Lean principle works in improvising the software devices. They also provide seven concept of Lean software development. According to Economic Times, when one of India's eminent software exporter Wipro, was searching solutions increased inflation and outsourcing complexities, Wipro, alongside many other Indian software industries possessed all the quality certifications viz ISO 9001 to SEI CMM. But like most initiatives and certificates, even that they had become mere tags and did not help to form a difference as a result of which Wipro thought of adapting the Lean methodology. Unlike conventional methods of improving performance and quality of software projects, Lean focused on identifying and cutting waste to enhance ROI. In a software sector, waste could include duplication of efforts, and time utilized in preparing for a new project. Wipro has almost 1600 projects which are Lean and save an average of almost 20% yearly. In 2004, the organization launched a pilot "Lean" initiative: an attempt that attempted to translate the Lean manufacturing concepts from production to S/W development, and operational performances were highly impacted by the Lean initiative at Wipro. Its observed that Lean initiatives have higher performance rate, reduced efforts, and overall performance than non-Lean projects. The idea of "going for short wins" is intuitively famous, although he understood the concept of Lean as an ongoing development tool. Every industries or manufacturer should learn to implement the concept of Lean. Lean is not just a thing they ought to usher in practice, but they ought to also attempt to bring various other Lean concepts into account. Lean should not be implemented by itself to achieve maximum output, and it should be implemented strategically. Industries like Timberline Inc. adapted the Lean subculture. Here, Lean principles are employed by the software development agency so as to extend productivity and to attenuate waste. Timberline extensively uses the concept of takt and an everyday stand up assembly acquainted from their plans and also to motivate individual. After adapting Lean, the time required to review defect from the entire improvement cycle dropped by 65–80%, among other improvement. Alvarez et al. observed that the implementation of Lean methodology results in operational excellence, continuous development and elimination of non-value-added activities.

Taylor et al. provided a Lean framework to analyze the impact of Lean. With comparison within Lean culture, Lean layout, Lean supply chain management with the traits, and factors of various ways of innovation various strategies for various industries to attend stability while implementing Lean and innovation at the same time are also discussed. Behrauzi et al. (2010) analyzed the idea of Lean production system which was initiated from Toyota, a Japanese automating company, which has been continuously growing within the international market from years. Ohno in 1988 discussed and reviewed the Toyota production system which improved business to deal with the production difficulties the company had to face as consequences of the World War II. TPS was compelled to pick the waste discount to attend strategic aim. Bhim et al. (2010) talked about the benefits of value stream mapping (VSM), a concept of Lean manufacturing, to improve the assembly line for production companies. Gadre et al. [9] studied that the Lean is considered to be a system for financial savings, reduction of inefficiency, and to increase customer satisfaction. In a Lean approach, the mixture of change control and an integrated method approach, throughout all elements that impacts worker **behavior** in an economic services agency, is the most effective manner to work successfully to achieve sustainable results. As Lean is being widely used in manufacturing industries, it has also stared to mark its presence in software industries too, Wipro is one of the best example for the same. Unlike manufacturing industries, software industries have their own challenges to implement Lean, since the processes type of outcomes in software are completely different; hence, the Lean principles also vary. Table 36.1 represents the Lean principles in software industry.

Waste elimination is a key principle of Lean methodology. Waste is considered as anything, a process or a task which does not add value to the customer. In context of manufacturing industry, inventory is considered as waste. One reason of it may be the undiscovered defects in inventory. These defects later tend to be more expensive to fix in the process. In software industry, an unfinished product can be considered as waste or the waiting time required for products for testing or any other type of approval can be considered as waste (Table 36.2).

Table 36.1 Key principles of Lean software development

Principle	Description
Waste elimination	Lean strives to eliminate waste all through. Activities that do not add value to the customer are eliminated
Amplify learning	Eliminating waste requires constant learning and knowledge creation
Deliver fast	Reduce development time without compromising the quality
Build quality in	Identifying the root cause of bugs and eliminating them will result in building a bug-free system
Optimize	Optimize the whole system rather than individual components
Respect people	Empowering the team allows those that are experienced make the decisions to avoid delays due to overheads. It helps to motivate the team
Defer commitment	Do not commit until sufficient information is acquired. This lessens the probability developing useless work

Table 36.2 Lean software wastes from literature

Waste	Description
Partially done work	Unfinished code or features
Extra processes	Unneeded processes that do not add value to customer
Over production	Extra features not needed by the user
Motion	Cost of task switching
Delays	Delays occurred while waiting for others
Defect	Unidentified bugs
Transportation	Hands-off caused while waiting for others

The worldwide organization, BBC, introduced Lean practices during a nine person team working for BBC with different roles and responsibilities within the organization. Middleton et al. (2012) main target was to review the lead time. By minimizing variance and decreasing dimension of units of work, they were ready to limit the work to capacity. However, switching from agility to Lean was described as "an advanced improvement that agility is not abandoned when Lean is accepted." This is often natural, because agile practices focus more on project development, whereas Lean focuses on the entire value chain. Wang et al. (2012) the "Agile Manifesto" emerged in early 2001 to provide a solution to the problems of current software program improvement strategies and hastily changing surroundings. Lately, agile framework has begun to seem closer to Lean software improvement tactics. Software products are not as tangible as manufacturing products; hence, the Lean principles of manufacturing process differ to that of the software processes. Table 36.3 represents variety of the Lean methods and their results from literature. If one controls the enterprise and merchandise, it could be much easy to attain Lean.

Table 36.3 Lean methods and their outcomes

Author and year	Lean method	Result type achieved
Adam et al. (1991)	Continuous improvement (Kaizen)	Redesigned assembly line resulted in reduced WIP, reduced delays, and reduced waiting time
	Kanban	Reduction of work in progress, optimized floor layout; visual information
Malek and Rajgopal (2007)	Value stream mapping(VSM); total productive maintenance (TPM); setup time	VSM optimizes the flow process resulting in reduced flow time, inventory and lead time

36.3 Research Gap

A thorough study of lean methodology is performed to perceive the scope of adapting lean in software development. Lean ideas from various researches are studied and presented a couple of authors have provided more educational frameworks [13], while others have focused on case studies. Middleton et al. (2012) mainly focus on lean application on Indian IT zone because agile has already been implemented and also studied in software process improvement initiatives (Dyba et al. 2008). Cawley et al. [5] did a survey on the adaption of Lean and agile methodology, wherein they mentioned that Lean methods have the potential to enhance and improve safety critical systems. Shah et al. evolved an operational degree of lean production and presented a framework that identifies its most salient dimensions. Although very useful, the tool is not always commonly applicable, and it is especially designed for manufacturing sector and hence cannot be applied in software development process. There is intrinsically no definitive listing of Lean software development ideas. Identified wastes in a software product customization process using the value stream map with the intention to reduce lead time: waiting time, extra features, and motion which were the identified wastes. The value stream map helped in identifying the non-value-added activities in the process. Table 36.4 gives an in-depth survey and review of research papers from various domains to spot research gaps scope of improvement while implementing lean.

36.4 Conclusion

Lean principles from literature have been studied and presented here, some authors designed frameworks [13] (Poppendieck et al. 2009, 2010), whereas some of them have focused on case studies (Middleton et al. 2012). This research mainly emphasizes on the application of Lean in the software development since agile methods have already been studied and adapted in many software projects (Dyba et al. 2008). Lean approaches seem to be better than agile (Wang et al. 2012), because of which Lean and Lean principles are the basis of this research. Dyba et al. (2008) organized a systematic literature review on agile software development till 2005, and from the identified 36 studies, they identified that only one applied Lean practice to software development. Shah et al. developed an operational measure of Lean production and provided a framework that identifies its most salient dimensions. Although very useful, the instrument is not generally applicable because it was developed for a production environment and not for other environment. Software industries especially in India need to adopt the Lean culture to improve investments and customer satisfaction. Lean focuses on reducing waste, whereas agile focuses on flexibility and adapting to customers' requirements. There is no specific well-defined list of Lean principles. To achieve "Lean," a software sector needs to identify certain Lean factors like types of waste and Lean principles relevant for the adaption of Lean

Table 36.4 Literature review and identified research gap

Sr. No.	Name of paper	Major idea	Findings	Research gap
1	"Lean Performance Evaluation"	Paper introduces an AI based quantitative model to measure Lean performances for a manufacturing company	A Lean performance measure would help the managers and decisions makers to get a better understanding of Lean performance	This model is restricted to manufacturing domain as it cannot be directly applied to software domain
2	Application Authors of mahalanobis distance as a Lean assessment metric: Jayanth Srinivasaraghavan and Allada (2006)	Authors propose a quantitative Leanness assessment tool	The calculation of MD by the Gram–Schmidt orthogonalization process is more informative and useful when compared to the inverse correlation matrix method	According to Kaizen Institute, value stream mapping cannot and should not be applied as it is something like a software product
3	"Redesigning an assembly line through Lean manufacturing tools," Alvarez et al. (2009)	Authors have redesigned an assembly line in a manufacturing unit using a Lean tool (VSM) with an objective to identify and eliminate non-value-added activities	Inventories have been reduced. This provokes the reduction of idle times, from initial 32–10. Nine improvement objectives were twofold: reducing stocks while avoiding idle times or movements of worker due to accumulated material. Both have been reached	Response to the questionnaire was limited by respondent's knowledge about Lean practices. Hence, employees need to be educated with the Lean principles before implementing Lean or else the outcome will be unreliable input data/poor response rate
4	"A survey on Lean practices in Indian machine tool industries," Eswaramoorthi et al. (2011)	The primary aim of this study is to find out the needs and examine the degree to which the concepts of Lean manufacturing are put into practice within Indian machine tool industries	The survey result revealed that 31.6% of the companies have implemented different Lean tools and techniques in selected areas. The remaining 68.4% of the companies have not yet taken up the Lean initiatives	Proposed taxonomy appears widely applicable, organizations with different software development cultures may experience different waste types

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Sr. No.	Name of paper	Major idea	Findings	Research gap
5	”Software Development Waste,” Sedano T, Ralph P, Peraire C	The purpose of this paper is to identify and describe different types of waste in software development	This paper introduced the first empirical waste taxonomy. It identifies nine wastes and explores their causes, underlying tensions, and overall relationship to the waste taxonomy found in Lean software development	Not used the insights from shop floor employees to validate the instrument and was developed for service environment
7	Defining and developing measures of Lean production, Shah and Ward (2007)	Adapted the Lean measurement method developed by Shah and Ward (2007) for a logistic service environment		Although very useful, the instrument is not generally applicable because it was developed for a production environment and not for another environment
8	Model Development of a Virtual Learning Environment to enhance Lean Education, Gadre A	Developed an instrument to measure Lean production and presented a framework that could highlight the most important features		Needs to be implemented in real environment. Limited to production/manufacturing domain. Does not talk about the other domains
9	Zhuravskaya O., Michajlec M., Mach P. “Success Case–Study Lean Production Electronics Manufacturing Workshop,” IEEE	Designed a virtual laboratory which provided a simulation platform to perform production line experiments	The platform provided students a real-world experience and an opportunity to visualize and improve their work	Focused on electronic industry and uses the VSM method of Lean

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Table 36.4 (continued)

Sr. No.	Name of paper	Major idea	Findings	Research gap
10	Materials flow improvement in a Lean assembly line: a case study, Alvarez and Melodià (2014)	The paper describes the core idea of Lean production as a methodology with series of tools for continuous improvement in the electronics manufacturing.	By implementing Lean, production line was able to: increase output for a key product group, from 1162 units per day on one operator to 1912 units per day on one operator—more than 60% increase of operator productivity; use more than 60% less floor space than in their previous assembly area; improve product quality and reduce rework; increase employee awareness about	The findings are limited due to the focused nature of the case study. Although the solution is designed for a particular plant, the methodology is fully exportable. The paper shows a real case study illustrative for systems management
11	An exploratory study of waste in software development organizations using agile or Lean approaches: A multiple case study at 14 organizations, Hiva, A.	The paper analyzes the flow of material in an assembly line of Bosh industries with the objective to identify the bottlenecks and optimize the assembly line	The empirical results drawn from the case study serve to demonstrate that an operating decision has helped to improve the Lean metrics, particularly the transportation time, increased learning. Reduction in waste in terms of excessive inventory. All of this without making major changes in the process	To identify and eliminate waste, a Lean mindset is needed which is agreed upon by the entire organization

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Table 36.4 (continued)

Sr. No.	Name of paper	Major idea	Findings	Research gap
12	"Leagile" software development: An experience report Analysis of the application of Lean	Authors investigate the concept of waste in agile/Lean software development organizations and how it is defined, used, prioritized, reduced, or eliminated in practice	Various wastes, categorized in 10 different categories were identified by the respondents. It was concluded that task switching was considered as the most important waste and extra features as the least important one	The Lean aglile concept is yet not widely adapted in software industry
13	Lean Software Management: BBC Worldwide Case Study, Middleton and David (2012)	This paper explores the application of Lean in agile software development	Lean approaches seem to scale better than agile	The framework used would not necessarily be adapted by other organizations as this was a specific organization
14	Empirical studies of agile software development: A systematic review Dingsøyr			Agile methods are mainly applied to and studied in smaller scale software development projects
15	Lean/Agile Software Development Methodologies in Regulated Environments—State of the Art Cawley, O., Wang, X.	The review investigates what is currently known about the benefits and limitations of, and the strength of evidence for, agile methods	Conducted a systematic literature review (SLR) of empirical studies of agile software development and LSD and identified 36 relevant empirical studies	The study was focused on safety critical systems. Although they mentioned that Lean methods have the potential for improving the development of safety critical systems. Authors point out the need of further investigations in
16	Using metrics in Agile and Lean Software Development—A systematic literature review of industrial studies, Kupiainen, E., Mika, V.	Authors conducted a SLR on the adaption of Lean and agile methodology by safety critical system developments	Authors identified that most of them have adopted agile practices along with traditional plan driven development methods	This study could have been improved by studying the reference list of the primary studies

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Table 36.4 (continued)

Sr. No.	Name of paper	Major idea	Findings	Research gap
17	Adapting the Lean Enterprise Self-Assessment Tool for the Software Development Rodríguez and Kuvaja (2012)	This paper presents a systematic literature review (SLR) on using metrics in industrial agile software development. Authors identified 774 papers, which we reduced to 30 primary studies through our paper selection process	Results show that although agile teams use many metrics suggested in the agile literature, they also use many custom metrics. Finally, the most influential metrics in the primary studies are velocity and effort estimate	This paper presents an initial proposal for adapting LESAT for software. However, existing evaluation is still limited and more empirical studies, in which LESAT for software is applied in individual company cases, are needed to validate the tool and make a more comprehensive
18	Agile to Lean Software Development Transformation: a Systematic Literature Review	This paper presents a proposal for adapting the Lean enterprise self-assessment tool (LESAT) to guide the transformation of software development companies toward Lean	In this study, concepts and expressions of LESAT were analyzed and mapped to software development following the ISO/IEC 12207 standard. Seven assessment items concerning life-cycle processes were modified from the original LESAT	Challenges faced: Inculcating the Lean mind set and Lean thinking, identifying non-value-added activities
19	An exploratory study of waste in software development organizations using agile or Lean approaches: A multiple case study at 14 organizations (Hiva et al. 2019)	Authors have tried to identify drivers, barriers, and metrics required for Agile to Lean transformation	Outcomes: reduced cycle time, improved learning, optimized flow	No distinction is made between waste and overhead, especially when it comes to identification and measurements of wastes. In addition, another issue h is the identification of domain-specific vs. common wastes

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Table 36.4 (continued)

Sr. No.	Name of paper	Major idea	Findings	Research gap
20	Lean Software Development Domain (Udo et al. 2008)	This paper investigates the concept of waste in Lean software development organizations. They studied how waste is identified, prioritized, and eliminated in practice. The data were collected using semi-structured open-interviews. Two practitioners from 14 embedded software development organizations	Various wastes categorized in ten different categories that were identified by the respondents. From the identified wastes, not all were necessarily waste but could be symptoms caused by wastes. Task-switching and extra features the former was identified as one of the most crucial waste	
21	LEAN Software Development is Feasible? Sowmyan Raman, The Boeing CO, Seattle, WA 981240-7803-5086-3/98/$10.00 01998 iEEE	This paper presented the Lean S/W Dev domain, which is an important approach in the software development	Authors advocated that the Kanban Lean tool will help in achieving desired results in planning and scheduling project development	
22	The Combination of Agile and Lean in Software Development: An Experience Report Analysis, Wang (2011)	This paper discusses the feasibility of Lean adaption in software development	Question project by the authors resulted to be positive. Hence, it is feasible to use lean in S/W development	

approach. This investigation aims to identify the Lean requirements which can be adaptable in the software development domain. The research study gives an idea on how to apply Lean concepts for the software industry sectors and make it as a Lean organization.

With Lean concepts, IT sectors will have the following advantages:

– More disciplined process	– Decreased cycle time less inventory	– Improved productivity
– Increase capital utilization	– Improved quality of the product and process	– Improved efficiency
– Reduction in 5 m's (men, machine, material, money, and management)	– Improved quality of the product and process – Customer satisfaction	– Reduced staff turnover

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