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Lean + Agile vs Seven Wastes in Software Development

Systematic Literature Review and an Industrial Survey

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ABSTRACT

Context: Software Process Improvement uses lean principles for eliminating wastes in the software development process. Waste is defined as anything that does not add value to the customer and product. The seven traditional wastes in software engineering are partially done work, extra process, extra features, waiting, motion, task switching and defects. Using the lean principles and practices, the wastes can be reduced or eliminated. It is important to know the lean practices that are widely used in software development and to know the practices, which captures the seven wastes. From the literature, the ability of waste reduction is theoretically discussed [2], but practically only little empirical evidence is available on 'which practice is best capable in reducing specific kinds of waste.'

Objectives*:* Many software development organizations have adopted lean practices and agile practices for eliminating wastes of different kinds. Therefore, this study focuses on evaluating the effectiveness of lean practices in their ability to reduce the seven types of wastes associated with Lean Software Engineering.

Methodology*:* The methodology that is used in this study is systematic literature review and industrial survey. In order to achieve the objective on evaluating the lean practices and agile practices in their ability to reduce the seven types of wastes that have more attention in research, a systematic literature review is conducted. Thereafter, to capture the effectiveness of lean practices in waste removal, a survey is designed to capture the perception of practitioners.

Results*:* The systematic literature review has identified 53 relevant studies to the research topic. From these primary studies, the lean practices/principles, hybrid agile and lean practices, and the efficiency of agile practices in eliminating the seven wastes were identified. In addition to that, wastes that are captured by using lean practices; hybrid lean and agile practices were also identified. The reason for considering agile practices is that, agile and lean have similarities in eliminating the wastes and creating value to the customer [2][3]. Through the systematic literature review, it can be observed that researchers have not investigated all the seven wastes captured by lean practices.

Thereafter, survey is the main contribution to this research where, the responses of 55 respondents from different countries were recorded. Most of the respondents are from India with 42% of the responses. We have asked the role of every respondent in their companies, and 19 respondents are Team leaders, 16 respondents are project managers and remaining people perform various other roles in software development. 38 respondents are from large-scale industry, which constitutes the majority part of the survey. The main contribution of the survey is identifying the ability of lean practices in eliminating different wastes. The respondents were asked to provide their level of agreement related to the effectiveness of each lean practices and agile practice in waste removal. A comparison between the results of SLR and survey reveals that there is a lot of variance in the perception of researchers and practitioners regarding the lean practices in eliminating wastes. Survey captures more wastes than SLR. From the results of survey, it was also identified that using the lean practices i.e. Kanban and VSM can eliminate most of the wastes. Kanban (41) and VSM (33) are mostly used and more efficient in industries.

Conclusions: To conclude, the obtained results from this study will be quite useful for the real-time execution of lean practices. Team leaders, project managers, and organizations can adopt lean by choosing lean practices in accordance to the wastes that have to be eliminated from their software development process. This study has also identified the benefits and limitations of lean practices implemented in industry. This study helps researchers in providing necessary information that is very useful for further research in lean practices. The combinations of lean practices were also presented, which in terms one lean practice can compensate another in capturing all the seven wastes. In the survey, the additional wastes were identified when compared to SLR and this complements the literature. There is a considerable reach gap between the state of art and state of practice.

It has been identified that VSM and Kanban practices have much attention in the literature. The remaining practices like Kotter and Kaizen are less concentrated in most of the research literature. From the literature, it is evident that none of the practices is capable of eliminating all the seven wastes in software development. VSM is capable of capturing wastes like waiting, extra process and motion. In addition, Kanban captures and eliminates wastes like partially done work, defects, task switching and extra features.

With respect to the survey, Kanban and VSM practices are efficient in eliminating wastes. When the practitioners consider hybrid lean and agile practices, the combination of Kanban and Scrum, Scrum and VSM are efficient in eliminating wastes. The practitioners can consider the benefits of lean practices that are identified in this research.

Keywords: Lean software development, lean Practices, software process improvement, Waste, Empirical.

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Table of Contents

List of Tables

List of Figures

Glossary

SPI- Software Process Improvement

VSM- Value Stream Mapping

LEAST- Lean Enterprises Self Assessment tool

SLR- Systematic Literature Review

Document Development

Document: MS Word

Citation Software: Zotero, Medeley

Citations format: IEEE

Survey Questioner Development: Google Docs

1 INTRODUCTION

For the improvement of the quality of software processes, importance of lean software development has rapidly increased in past years. Lean thinking has a long history of achieving impressive improvements in many fields. In the 1980's, a mass shift in the way of production hit factories all over US and Europe. At that time, Japanese manufacturing companies established that Just-in-Time was a better approach. The widespread take up of Japanese manufacturing concepts came to be known as lean production. At the same time consideration of lean production spread to logistics, military, construction and the service industry [1]. Lean principles have proven to be universally successful at improving business results [1]

Lean thinking has got its name from the best seller called "The Machine That Changed the world: The story of lean production" in 1990s [2]. Lean thinking focuses on eliminating all the wasteful time, all the compromising steps and all the people not executing activities that contribute value to the customer [2]. Lean software development is a set of principles introduced by Toyota Product Development system in 1950s [3]. However, lean did not make any impact in conventional literature before a 5-year study of the Masachusetts Institute of Technology (MIT). MIT has identified lean as a source of huge productivity difference in the two countries US and Japan [3]. As developed by the National Institute of Standards and Technology Manufacturing Extension Partnership's lean is defined as [1]

"A systematic approach to identify and eliminating waste through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection"

Lean principles are from the manufacturing domain and they are adapted to software engineering by Poppendieck et al [1] [4]. From the above definition, continuous improvement is equally emphasized in agile software development. Parallel to the well accepted and well established agile values, principles and practices, lean software development also associates with three main elements: lean concepts, lean principles and lean practices [3]. For organizations, lean thinking enables to "specify value, line up value creating actions in an optimal sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively" [3]. In addition, lean thinking focuses on giving customers what they want, when and where they want without a waste [5]. Lean principles are guiding principles that focus on identification and elimination of waste from the process, which is beneficial to customer value [3], while practices are what you actually do to carry out the principles. Principles are universal, but it is hard to see how the principles are applied to particular environments. Practices can provide specific guidance on what to do, but they should be adopted by the industrial environment for their better implementation [5].

Lean software development builds upon the theory behind agile software development practices that gives a set of principles for the organization and tones the software development process, which works best based on their domain, capability, unique situation and customers. Further, lean has expanded the infrastructure of agile software development by applying the conventional lean principles to software development. Both lean and agile have similar values. The similarities between the agile and lean principles and is to add value to the customer, get the product in shorter time and develop cost effective product [2][3]. Agile provides practices that guide the project management for example SCRUM, and in development Extreme Programming XP [2]. On the other hand, lean has a strong focus on waste removal from the software development process and the aim is to deliver the need of customer with in short time. There are many practices and approaches for improving the software process with respect to customer value [5]. To see or have an idea on waste, Royce et.al [63] has suggested a good place to see waste, i.e. do all the steps like analysis or coding that really add value to the customers.

The first and most fundamental step of lean principles is to see the waste and to eliminate the waste [5]. Waste is defined as anything that does not add value to the customer, value to the product, more sufficient than immediately needed, moving the product around, all these factors are considered as wastes [5]. In Japanese, waste is referred as Muda, Muri and Mura [6][5][3].

- Mura is variation (in process quality, cost, delivery).
- Muri is overburden.
- Muda is a non- value added service.

In brief, a component that has no use is a waste. If a manufacturing plant produces more units than needed immediately that is waste, if the product development that is transformed from one place to another that is waste and whatever that do not satisfy the customer that is waste [5][4].

Some of the differences those are identified and noticed between manufacturing and software development are: the idea of lean software development is to maximize the flow of information and deliver value. Whereas in lean production maximization flow can be a solution to improve the flow through, but it is not the flow of information, rather the flow of material; i.e. the physical units used in production are clear and how they are flowing, i.e. what are measured and traced is also very clear. [1][7].

In lean software development, the idea is to eliminate the documents as many as possible. Though this is not always true, it might be creating many issues in large-scale development where documented information may be needed. The right level of document is always needed and it may differ very much depending on context [7]. For instance if you do not document the architecture, your most valuable and competent architecture will do nothing else than answering the same question all over again.

Whereas the mentality of massive production is to distribute the stack of frozen documents from one function to the next production [7]. In manufacturing, you are asking for produced unit. In software, it is for an implemented feature and you can measure the flow [21]. There are numerous familiar principles and procedures between manufacturing and software developments, but some aspects between these two developments differ from each other [21].

Finally, lean practices provide specific guidance in the improvement of the software development process, but they need to be adapted to specific domains and environments [5]. On the other hand, it is very important to identify and understand the lean practices that address or capture different wastes. In state of art, many studies have addressed the lean practices and some studies noticed that lean principles are not successful in some organizations because of culture and organizational habits [5].

However, the elimination of waste depends on implementing the lean practices in organizations and to understand the effectiveness of lean practices in their ability to address all seven wastes. Example: If we have our four practices, and each one of them only manages to handle waiting, a large portion of the relevant wastes is missed. Hence, to target particular wastes we need to have a starting point of knowledge of what practice is best suited for which waste. Hence, we are comparing the distinctive lean practices with each other with respect to their ability to detect wastes.

Firstly, based on the state of art, we have knowledge on the lean practices like Kanban and Value Stream Maps, and further, we know some wastes like, waiting, extra features, extra process and defects that are detected by the above lean practices. Secondly, to capture the assessment of experts on the effectiveness of lean practices to address the seven wastes, we have performed the Systematic Literature Review (SLR) on the existing research. Further, a survey was conducted using an online questionnaire based on convenience sampling.

The thesis is organized in several sections. Section 2 represents the theoretical background of lean practices/principles and wastes in software development. The research design and methodology that has been followed to perform the research is described in Section 3. Section 4 presents the SLR, which has identified distinct lean practices, and the wastes that are captured or eliminated by using lean practices. This section also represents the combination of lean and agile practices for eliminating wastes in the software development process. Further, the efficiency of agile practices in eliminating and capturing wastes is also identified in this section. Section 5 represents the survey that was performed globally. Different lean practices; wastes that are captured by these practices, efficiency of lean practices in the perspective of practitioners were identified in this section. Section 6 compares the results of SLR and survey. Conclusion and future work is presented in Section 7.

2 THEORETICAL BACKGROUND

2.1 *Importance of lean*

Lean software development provides a set of principles to analyze and improve the software process with respect to minimizing wastes and maximizing the customer value in software engineering processes. Lean software development has led many organizations to reconsider their software engineering practices, acquiring striking improvements in quality, cost and speed in developing the products [1][5]. This has led the software organizations to adopt lean thinking and implement lean principles for product quality and cost, which add value to the customers. However, the adoption of lean practices is done in very few organizations [1]. Eliminating wastes from the software development process can improve the products, quality, and speed of the development, which in terms provides what the customers want.

2.2 *Lean software development and Principles*

In order to introduce the lean practices in software development, there is a need to know the difference between the lean principles and lean practices. The principles [1][3] are guiding ideas and insight about disciplines, while practices are what you actually do to carry out the principles [1][5]. Software organizations aim to adapt the lean principles to improve the product, quality, cost, time, and speed. Based on the seven lean principles that are introduced by Toyota, several practices have been proposed in software development that focuses on a smooth and continuous process flow and minimizing the waste in the software development process [7]. Below Table 1 represents the seven lean principles.

Table 1 The seven lean principles [1]

Seven lean Principles	Description
Eliminate waste	Work done in a continuous flow. Not building the product wrong or wrong product.
Build Quality In	Examining the process of mistakes, zero tolerance of defects, and using continuous integration.
Create Knowledge	Paying attention to small intricacies of process and use the scientific method.
Defer commitment	Until the last responsible moment, make decisions that commit the organization.
Deliver fast	Speed, quality, low cost goes hand in hand. Using the queuing theory to manage the workflow.
Respect People	The purpose should be solved, challenges and responsibility.
Optimize the whole	Focus and avoid sub optimization.

The study by Jerry Kilpatrick et.al [2], has addressed different lean principles that were examined by Toyota production systems and the benefits of implementing lean [2]. The study has noticed that Toyota production systems are non-valued-added activities and are known to lean practitioners as the eight wastes that are in the manufacturing organization [2].

Mary and Tom Poppendieck et.al [5][10] have examined the underlying engineering principles that Toyota used to develop vehicles. They also have concentrated on translating the accepted lean principles to fit into the software engineering context. Case studies show that development organizations did not succeed in applying lean principles and practices [5]. At the same time, the companies that have adopted and implemented lean have achieved sufficient and sustainable performance improvements in their development process [5][11]. Kanban driven software development has been investigated with respect to its ability to remove waste, but it does not effectively prevent the waste from the process [12]. The study [12] has focused on the lean practices of Kanban and has not considered the related waste. Another case study [P6] has identified waste related problems in software engineering by using Value Stream Maps (VSM). The author has captured different kinds of wastes in the processes. However, due to lack of empirical evaluation of VSM in the software engineering, the study could not be carried out further.

Several studies have proposed different lean practices to remove wastes [6][7][9][12]. Few studies have focused on making the link between lean practices and their tangible ability to remove the seven wastes explicitly. Most of the studies have not captured the ability of waste reduction and have not followed a sound empirical research methodology. Thus, there is a need to identify and understand the lean practices that are mostly used [6][9][12][15] in the software industry and has the ability to remove wastes from the software development process.

2.3 *Software waste*

Waste is defined as everything that is not conducive to the creation of value to the customer [15]. In other words, anything that does not add value to the product is a waste. As an example, task switching (motion) is a waste and leads to waiting, and reduced efficiency [6]. The traditional seven different types of wastes that may occur in software development are shown in the Table 2. Mary and Tom Poppendieck have modified the seven manufacturing wastes to software engineering [5][6].

Table 2 The seven wastes in manufacturing and software [2[

The seven wastes of Manufacturing	**The seven wastes of Software development**	**Description of each waste**
Inventory	Partially Done Work	When the work is in process that does not have value until it is completed [2]
Extra Processing	Extra Process	Extra process steps that are not needed. Ex: creating document, which is not needed [2].
Over Production	Extra Features	Characteristics that are developed but do not add value to the customer. Extra functions [2].
Transportation	Handovers	Shifting of documents creates overhead [2].
Waiting	Delays/Waiting	Delay in development or the other team waiting for the previous process to be completed from initiating their work [2].
Motion	Task Switching/motion	Having disturbances among the team members in performing their work [2].
Defects	Defects	Problem fixing in the product [2]

2.4 Contribution

This study aims to analyze and prioritize the lean practices used in the industry that actually impact the waste removal in the process. This can be achieved based on the knowledge of the experts (practitioners) who have experience in using those lean practices in the software domain.

3 RESEARCH DESIGN AND METHODOLOGY

The main aim of this study is to identify the lean and agile practices used in the software industry and their ability to capture wastes, and to evaluate the effectiveness of lean practices in waste elimination.

This will be fulfilled by the following objectives.

- Identify the lean practices to be surveyed from the literature, and their capability in eliminating the seven types of wastes.
- Identify the hybrid agile and lean practices from the literature, and their capability in eliminating the seven wastes.
- Capture the use of the identified practices in an industry.
- Capture the practitioner's perception in using lean practices in accordance to their effectiveness in eliminating specific wastes.

3.1 Research Questions

In order to achieve the stated aim and objectives, the following research questions were formulated.

RQ1. What are the lean software practices/principles and wastes mostly discussed and focused in the literature?

RQ2. What are the lean practices that are incorporated with agile practices to eliminate waste?

RQ3. How effective are the agile practices in eliminating seven wastes of software development?

RQ4. Which lean practices are adopted in software development process in an industrial practice?

RQ5 What are the hybrid agile and lean practices are implemented in software industry?

RQ6. What are the benefits and limitations of implementing lean practices in software industry?

RQ7. How effective are the lean practices in removing the seven wastes of software development?

Before performing the research our expected outcome that we will achieve based on the research questions are:

- Identify the current lean and agile practices that are adopted by the software industry.
- Limitations and benefits of lean practices.
- Efficiency of each lean practice in eliminating seven wastes.

3.2 Research Methodology

The research methodology is selected and designed to fulfill the research aim and research questions. In order to fulfill the aim and objectives of this study, research design is based on the mixed methodology research design.

The research methodology that is followed is a collection and analysis of qualitative data followed by the collection and analysis of quantitative data [8]. Systematic Literature Review is used to collect the qualitative data and survey is used to collect the quantitative data. However, we cannot compare the studies and respondents, but lean practices and the wastes that were identified by SLR and Survey will be cross-analyzed. For analyzing the perception of practitioners upon lean practices and their efficiency, statistical analysis has been applied for analyzing the collected quantitative data.

3.2.1 Systematic Literature Review

First, a systematic literature review is conducted on lean practices/principles, the seven wastes, hybrid agile and lean practices and efficiency of agile practices. The SLR was performed by following the guidelines of Kitchenham et.al [8]. The research that will be evaluated, identified, and interpreted can be known as primary studies.

The set of reasons for performing the systematic literature review are:

- To reflect the existing evidence on the selected topic and the research questions that were framed.
- To investigate and analyze the gap in ongoing research, and to suggest further work.
- To provide a framework/background in order to appropriately position new research.

Often scientists use a systematic mapping study as a research method in order to analyze existing literature sources on a relevant topic. If the topic is quite broad, this is a good instrument. This also causes the main disadvantage of such type of reviews, i.e. its results cannot be treated as evidence-based, which plays an important role in research.

In contrast to systematic mapping using ad hoc literature selection, an SLR is a methodologically rigorous review of research results [47]. Its main goal “is not just to aggregate all existing evidence on a research question; it is also intended to support the development of evidence-based guidelines for practitioners” [47]. SLR defines the systematic steps and set of procedures to be executed in order to obtain reliable and valid results.

The required steps of the given research are outlined on Figure 1.

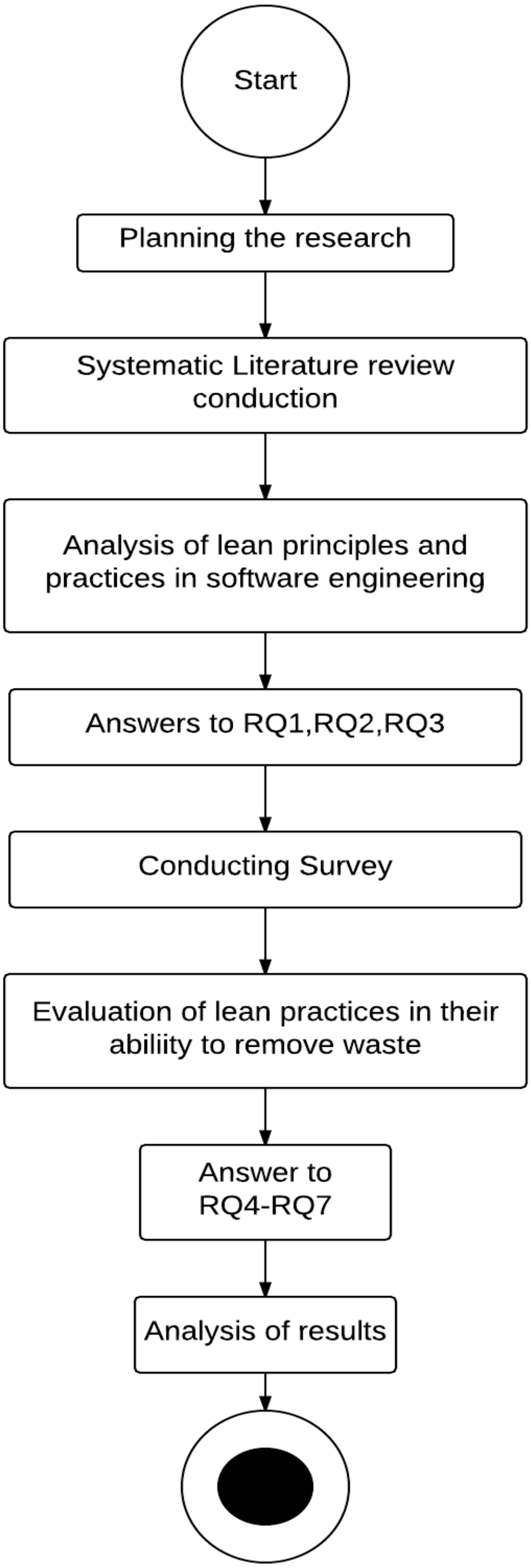

Figure 1 Overview of research design

In this study, three of the research questions require conduction of SLR. Systematic mapping cannot be used in this context, because it is more applicable for broad topics and to map the studies, while the research questions of this study were formulated precisely on lean practices and wastes. The SLR conduction allows formalizing the process of selecting the primary studies, as well the extraction of data and the assessment of the quality of primary studies. Therefore, the conclusions made based on a SLR are more reliable. The process of conducting a SLR is equipped with a SLR protocol. During SLR, the studies regarding the lean software practices/ principles and wastes, their incorporation with agile practices and their impact evaluation were searched, collected, and analyzed.

The systematic literature review covers all the following aspects:

- Focused review questions need to be formulated.
- A complete and intensive search for primary studies is conducted.
- Inclusion and exclusion criteria are applied.
- Quality assessment for inclusive studies.
- Retrieving data according to answer the questions on lean practices and seven wastes detected by them.
- Summarizing the data on study results of all the primary studies focusing on lean practices and wastes.
- Analyzing the results and report writing.

A well formulated research question generally follows the PICOC (population, intervention, comparison, outcome, context) structure to support the identification of keywords and focusing the search [8]

A research question is a clear, focused, concise, complex and arguable question that we concentrate in the research. It is very important to have the appropriate research questions for an SLR to represent appropriate and detailed findings, and to scope for the future work [8]. In order to investigate, analyze, access, and to summarize the evidence on lean practices and the seven wastes that are captured by the lean practices, the research questions were framed with the help of PICOC. Population, Intervention, Comparison, Outcome, and Context are the five, which represent the research questions. Every research question that was framed, follow this criteria. The study has not compared any methods, techniques, tools, models, principles, and practices; the remaining criteria in research question are Population, Intervention, Context, and Outcome. In this study Population are the studies that reflect their ideas and identifications towards Lean principles and lean practices. Intervention is the practices and principles or approaches that are used for software process improvement and context in software engineering and software process improvement. For a detailed protocol and PICOC, see Section 4.2.

3.2.2 Survey and Statistical analysis

The information obtained during SLR can be verified by using different methods. For example: interviews, an experiment, or a case study [48]. However, these methods are not appropriate to this study. This study targets large population and overview of lean practices and their situation in software companies, which is much controlled with experiment or a case study.

The reason for not considering case study is that a case study requires much effort, resources and organizational environment [48]. For case study implementation, we need to introduce specific lean practices in software companies, working on lean and lean practices at each stage of its development lifecycle, and they must be evaluated. The time constraint is another reason, as most of the projects usually take minimum of a year of time. In addition, we need to have permissions from the team members and the organization to implement or study the ongoing projects. Implementing our practices may disturb the organizational functionality at times.

On the other hand, to analyze the wastes that are eliminated by lean practices we need some technical information about the project, where the project's information is very confidential and the team management may refuse to provide the information. Moreover, the results of a case study could be confined to the organization where it is undertaken, and this study requires more generic information about the implementation of lean practices overall. So a case study was not preferred for this study, even though it can be used for a further research on lean practices implementation.

Experiment is not an appropriate research method in our situation as well. Experiment is a controlled study which is used to manipulate the behaviour and controls the situation systematically [48]. More over experiments need to have empirical evidence on the aspect that is implemented. Therefore, an experiment deals with simulated conditions and does not give an insight and understanding of the actual situation in industry. Moreover, experiments are time consuming and may disturb the team members in the organization. However, laboratory controlled experiments also fare poor when being evaluated from the perspective of scientific relevance [64].

As the lean practices are identified from the literature, a survey can be conducted in order to validate to what extent these practices are actually implemented in industry and also to investigate the wastes captured by them and their effectiveness. The combination of lean and agile practices is also a subject of real industrial investigations; therefore, the question about such hybrid techniques should be answered based on the opinion of the practitioners.

The survey method was used by developing a questionnaire, and providing it to the practitioners working in various organizations across the world. A survey gives "quantitative description of a population by studying a sample of the population," here in this case; the population is the software engineers from different countries. The survey is used to gather information to describe, compare or explain knowledge and behaviors [49]. Therefore, the survey denotes that the respondents must answer the questions about, experience, usage, limitations, and advantages of specific tool, method, or the team attributes [50].

The survey method has some benefits compared to other methods [50]. It takes an advantage of modern technology that is accessible to every one through out the world. The easy way of posting the survey is through online. Providing the questionnaire online consumes less time for authors to develop and for the practitioners to answer. However, there are some disadvantages of the survey method which leads to some limitations [50][51].

Respondents have different perspectives on the questions that are provided to them and they may express their views and feedback with respect to their experience. Restricting or bounding some questions to particular options may not allow us to know the inner depth. Therefore, we need to add open-ended questions to the survey, which makes the respondents to express their perspective. However, these types of questions may be difficult to analyze. Considering all benefits and disadvantages, a survey was selected as the best option to obtain the necessary information in a short time and through large population. This survey gathers information on lean practices and wastes that are captured and used in software engineering industry.

The survey was used to explore RQ4 to RQ7, i.e. the extent to which the practitioners comprehend the importance of lean practices, wastes and possible limitations in software engineering projects. By conducting the survey with respect to industry, we can investigate how existing lean and agile practices are capable of eliminating wastes from the software development process.

3.2.3 Statistical Analysis

Statistical analysis deals with the type of data that was collected and with analyzing the data depending on the variables and statistical methods [18]. It is possible to use one or both of the statistical methods such as descriptive and inferential for analyzing the data. Descriptive statistics is selected to summarize the population data by describing what was observed in the sample numerically or graphically. By performing statistical analysis, we can observe which lean practice is superior in capturing which waste with respect to each lean practice, and it answers RQ4.

The descriptive statistics was performed using Frideman test to test the overall differences between the practices and wastes. It is very important to note that the Friedman test shows the overall differences, but does not point out which practices particularly differ from each other. Friedman test consists of the number of respondents (N), Chi-square value 0.0007 and degree of freedom.

Null hypothesis: There is no significant difference in the outcome between different lean practices in eliminating wastes.

Alternative hypothesis: There is a significant difference between the outcomes of different lean practices in eliminating wastes.

4 LITERATURE REVIEW

Prior to performing a Systematic Literature Review, it is essential to have a SLR protocol and plan the review accordingly. It is essential to develop a protocol describing the steps that are going to be followed to identify, analyze, and summarize the studies.

As mentioned before the systematic literature review was performed following the guidelines of Kitchenham et.al [50]. The search string has been formulated according to the keywords reflecting our research questions. The snowball sampling technique is being used for acquiring the relevant papers. The snowball sampling is performed by reviewing the references in primary studies that are obtained by automated search, and considered into the list of primary studies.

4.1 Systematic Literature Review Protocol Development

The process of SLR conduction covers the following aspects:

- Focused review questions need to be formulated.
- A complete and intensive search for primary studies.
- Inclusion and exclusion criteria elaboration.
- Quality assessment for selected studies.
- Retrieving data according to data extraction strategy.
- Summarizing the data from primary studies.
- Analyzing the results and report writing.

The sequential steps of SLR are presented on Figure. 2.

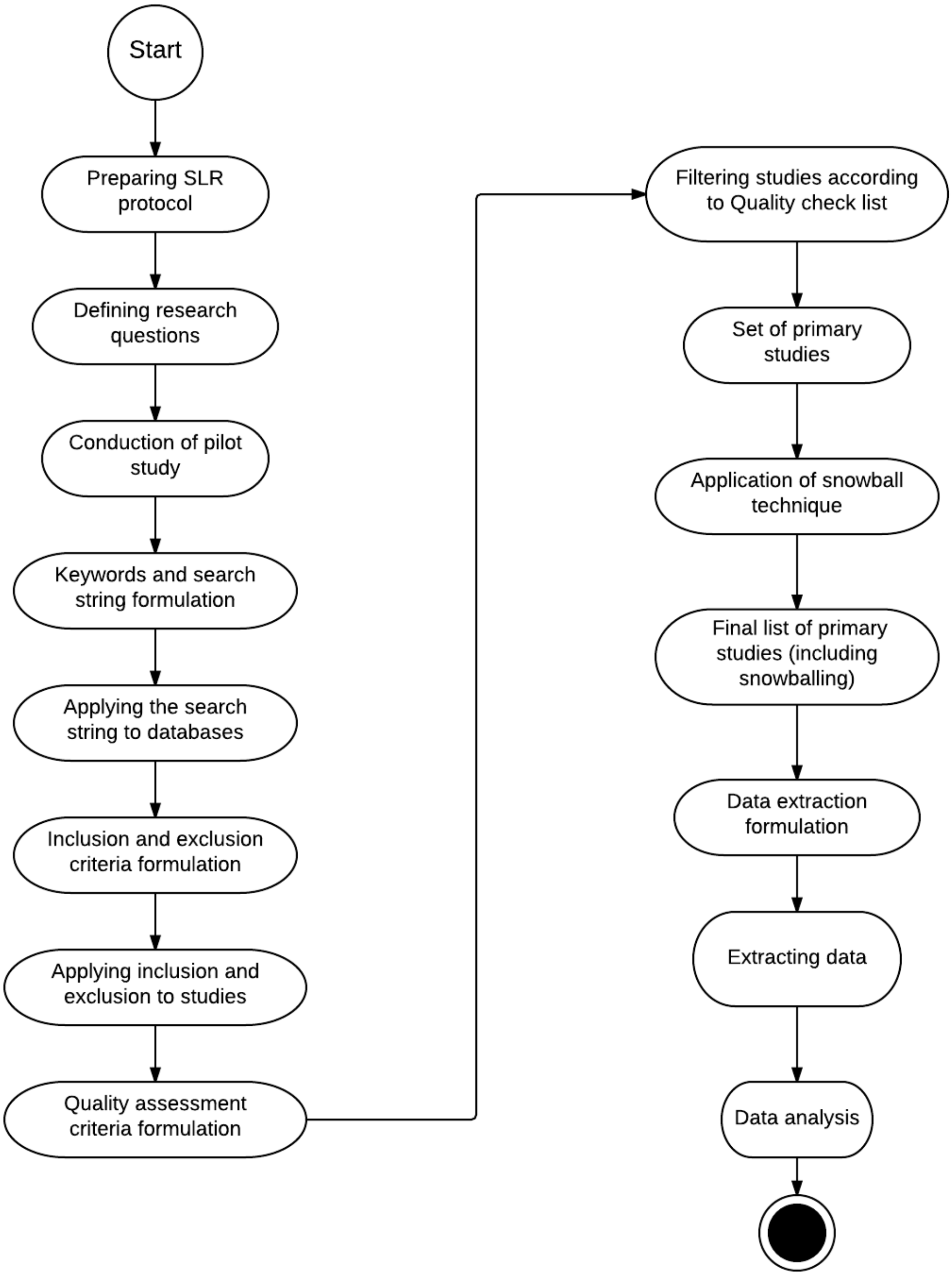

Figure 2 Steps that are followed for SLR

4.2 Definition of the search

In this study, population is the studies that reflect their ideas and identifications towards lean principles and lean practices. Intervention is the practices and principles or approaches that are used for software process improvement and context is in software engineering and software process improvement (Table 3).

Table 3 PICOC and Description

Population	Lean principles, Lean practices, Lean software development.
Intervention	Practices, Principles, and approaches used in lean software development.
Outcomes	Lean principles, Lean practices and wastes.
Context	Software engineering.

The first research question for SLR is formulated to investigate the different lean practices which are capable of eliminating wastes from the software development process. There are seven wastes, which can be eliminated from the software development process by implementing different lean practices. Specifically this research question is framed to investigate which lean practices have achieved more attention in research and which lean practice is capable in eliminating which waste.

The second research question is framed to investigate the hybrid lean and agile practices, i.e. the combination of agile and lean practices. This research question investigates different hybrid lean and agile practices and what wastes can be eliminated by using hybrid agile and lean practices in software development process. We can also observe which lean practices are combined with which agile practices and what are the wastes that are eliminated or captured in their combinations.

The third research question is on the efficiency of agile practices in eliminating wastes, which is identified from the selected primary studies. The overall percentage of each agile practice will be presented. The efficiency that is calculated or mentioned in the selected primary studies is identified and overall percentage is presented. This is to know how efficient the agile practices are in eliminating wastes.

The following steps are used to develop the search terms in SLR:

- By following the PICOC criteria, the important terms from the research questions were taken.
- By checking the relevant keywords from primary studies.
- Identifying the synonyms for the search terms.
- Using the Boolean operators “OR” and “AND”
- Using the Boolean operators "OR" for synonyms.
- Using the Boolean "AND" to link the major teams that reflect the research questions.

The keywords are also formulated based on PICOC criteria: Lean software development, software process improvement, practices, principles, wastes, and defects.

The search string having the Boolean operators is shown below. This study has four different aspects like lean, wastes, agile and efficiency. Therefore, the snowball sampling technique is also followed for finding the relevant studies on the agile practices that are efficient in wastes elimination. The databases like IEEE, Compendex, Inspec, and Science direct are used to acquire the primary studies.

4.3 Search String and Search process

(“Lean software development” OR practices OR Kanban OR Value stream mapping OR kaizen) AND (waste OR muda OR muri OR mura OR extra process OR waiting OR motion) AND (software development) AND (empirical* OR Case study OR experiment OR action research OR survey)

4.4 Search Process

Search process is a strategy for identifying the relevant studies. The search process is performed in three phases.

- Manual search process
- Automated search process
- Snowballing

4.4.1 Primary search process

The primary search is nothing but a manual search process held to search the relevant studies with the help of keywords form conferences, journal and workshops. Going through the individual journals and conference proceedings, reading each article, the manual search was performed. Initially, only two key words were included and later on, the keywords were increased until the relevant studies were acquired. The search that is performed is shown in Table 4.

Table 4 Primary search performed in search engine (Google Scholar)

S.no	Primary search
1.	“Lean software development” OR “lean practices”
2	“Lean” OR “lean development” OR “lean practices” AND “Software development”
3	“Lean” OR “lean development” OR “lean practices” AND Waste AND “Software development”
4	“Lean” OR “lean development” OR “lean practices” AND Waste OR defects AND “Software development”

For the first search, large amount of studies, citations and other sources including manufacture domain were acquired. This is because lean concepts are also implemented in the manufacturing domain. Therefore, another keyword was added which specifies that the search would be concentrated only in the software domain. However, for relevant studies with respect to years, this process acquires all the relevant studies without any limitations, but it consumes lot of time and effort to filter the most relevant papers.

4.4.2 Secondary search process

By using the databases that are provided by BTH, automated search is performed as the secondary process. The search string is applied to each database that is relevant for acquiring primary studies. The databases that are used to identify relevant studies are IEEE, Science Direct, and Engineering village (Compendex and Inspec). Here the database Engineering Village has two databases linked to it, both the databases Inspec and Compendex were selected. Moreover, IEEE also has some duplicates from Inspec database, mostly in lean manufacturing, medical, and aerodynamics, so those studies were excluded.

When compared to manual search the automated search is easy and consumes less time, but it depends on the search string that is applied to identify the studies. In addition, limitations were applied to each database and the results are limited only to papers in English, years from 1999 to 2013 and title/abstract in order to filter irrelevant papers from the search. Moreover, only studies with full text are considered for the review.

On applying the search string, 3131 articles were obtained from all the four databases. After the removal of duplicates and other irrelevant articles on medical, aerospace, architecture, chemical etc., 1834 articles relevant to this study were selected. Articles found after this process are relevant to lean, but further filtration based on the abstract, title and full text is necessary to confine the focus to lean in software engineering. From the above hits, it was noticed that many of the articles are not in full text. Therefore, the author has taken a decision to choose the articles according to title, abstract and full text. Finally, 45 studies were selected as the primary studies for this research.

Further, to acquire studies that are more relevant and to enhance the quality of the search, snowball sampling was applied to search the relevant studies from the references of the selected primary studies. The references are selected according to the title, year and by considering where the previous papers have used the references. From the snowballing process, the author has identified eight most relevant papers and included them into primary studies. The search engines have acquired same studies that are selected in manual search, so the primary studies that are selected in manual search are not described separately.

After the inclusion of studies found using snowballing process, 53 primary studies were selected, as shown in the Figure 3. Some of the search databases are very particular on the punctuations and the Boolean operators used in the search strings. Punctuations like inverted commas, brackets, and stars used in the search string helps in acquiring the most relevant papers and helps in limiting the papers according to the quality needed by the review. All the search databases that are selected for identifying and acquiring the studies are shown below.

The search string that was formulated for automated search is shown below. Firstly, the search string was applied on all the selected databases. The second search string consists of some keywords that are added after some relevant studies were identified from the first search. The keywords that are considered for second search string are the keywords that are mentioned in the relevant studies acquired from first search.

The third search string will eliminate some of the irrelevant papers. For example, lean thinking is also used in manufacturing domain, medical domain, and other domains that are not relevant to this study. Therefore, in the third search string, some of the lean practices and some wastes are added only to restrict the studies from other domains. The lean practices are identified from the relevant studies, which were obtained until this step. The fourth search string is a combination of the search strings that were formulated previously and in addition; some of the keywords based on the research methods were also added. This is because, if there are any studies that have concentrated on all the lean practices in different research methods, they can be acquired and can be utilized in this study.

1. (“Lean software development”) AND (waste OR defects) AND (software development)

2. (“Lean software development”) AND (waste OR defects) AND (software development OR software process improvement OR SPI OR software development process)

3. (“Lean software development” OR practices OR Kanban OR Value stream mapping OR kaizen) AND (waste OR muda OR muri OR mura OR extra process OR waiting OR motion) AND (software development)

4. (“Lean software development” OR practices OR Kanban OR Value stream mapping OR kaizen) AND (waste OR muda OR muri OR mura OR extra process OR waiting OR motion) AND (software development) AND (empirical* OR Case study OR experiment OR action research OR survey)

The search string applied in the databases is shown in the Table 5 below.

Table 5 Databases and search string

Databases	**Search string**	**Number of first hits**
IEEE	Lean software development” OR practices OR Kanban OR Value stream mapping OR kaizen AND waste OR muda OR muri OR mura OR extra process OR waiting OR motion AND software development AND empirical* OR Case study OR experiment OR action research OR survey	22834
Inspec and Compendex	Lean software development” OR practices OR Kanban OR Value stream mapping OR kaizen AND waste OR muda OR muri OR mura OR extra process OR waiting OR motion AND software development AND empirical* OR Case study OR experiment OR action research OR survey	285
Science Direct	(“Lean software development” OR practices OR Kanban OR Value stream mapping OR kaizen) AND (waste OR muda OR muri OR mura OR extra process OR waiting OR motion) AND (software development) AND (empirical* OR Case study OR experiment OR action research OR survey)	12

Databases that are used for acquiring primary studies

- IEEE
- Engineering Village (Inspec or Compendex)
- Science Direct

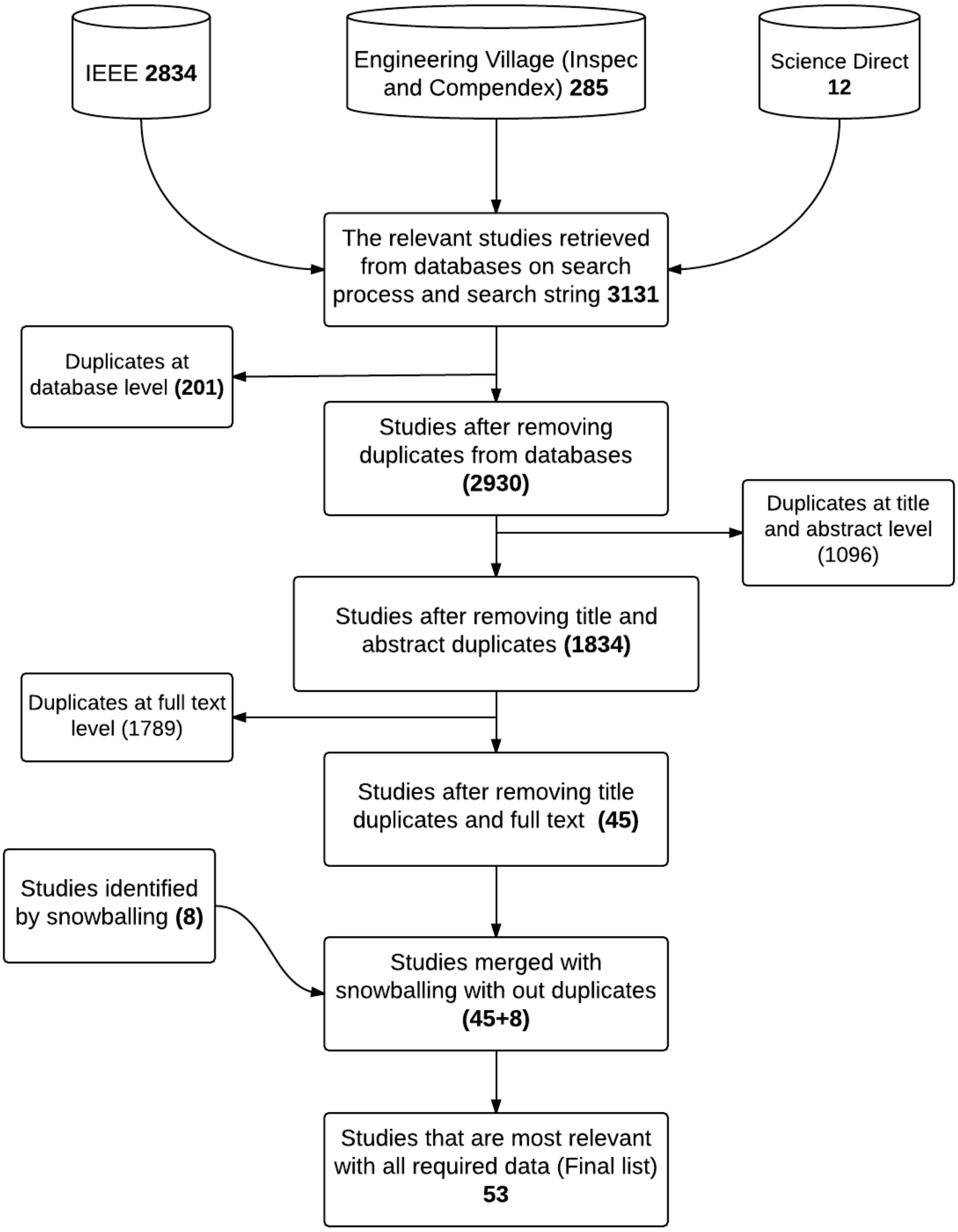

Figure 3 Search Process that is followed for acquiring relevant papers

4.5 Inclusion and Exclusion process

For finalizing the primary studies, the inclusion and exclusion criteria was followed on the studies that are retrieved using automated search in databases. The aim of exclusion criteria is to exclude the irrelevant and duplicate studies retrieved from the databases. Some studies that are retrieved based on title, but not relevant in abstract and content, are excluded. The studies that are retrieved using manual, automated and snowballing are merged and the detailed criteria that are followed are:

- Duplicates are removed at database level.
- Duplicates are removed based on authors, venues, and titles.
- Irrelevant studies are excluded, even though they are in full text.
- Irrelevant studies are excluded based on titles and abstract.
- Studies that are not available in full text are excluded.

All the included 53 primary studies (Table 6) are based on the complete review of whole abstracts to conclusions. If the study focuses on the relevant attributes that supports the review, and if the study has most peer reviewed references, such studies are included. If the demission is to exclude the study, a brief search was performed on the references that address the relevant data, and if the study still had any conflicts, the help of expert researchers has been taken. The criterion on which the studies are included, and on which basis the studies are excluded, are provided in the following section.

4.5.1 Inclusion criteria

The following are the detailed inclusion criteria:

- Studies must be documented in English.
- The study that is in full text is included.
- Studies that concentrate on lean practices and principles are included.
- Studies that identify wastes in software development are included.
- Studies that focus on software process improvement by either agile or lean are included.
- Studies that concentrate on the lean principles and captures waste are included.
- The study having evaluation, it could be experience report. Therefore, the experience reports are included.
- The study should focus on evaluating the lean and agile practices.
- The study that is published after 1999
- Studies that are published before 1999 are also considered if they are obtained by snowballing.
- Journals, Conferences and Workshops are included.
- The studies from academia and industry are included, because industry involves experienced practitioners, which helps in having good quality of evaluation and experience.

4.5.2 Exclusion criteria

The following is the exclusion criteria:

- Studies other than English are excluded.
- All the studies that involve lean in manufacturing and production are excluded.
- Studies that only have agile software development without relevant or focus on wastes are excluded.
- Studies with focus other than lean software development are excluded.
- Studies having previous lean history are excluded; as lean has come from manufacturing domain, these studies may concentrate on manufacturing.

Table 6 Selected primary studies for Review

S ID	Primary studies	Study ID	Reference
1	M. Poppendieck and P. Llc, 2002.	[P1]	[1]
2	K. Petersen, 2010	[P2]	[2]
3	X. Wang, K. Conboy, and O. Cawley, 2012.	[P3]	[3]
4	S. Mujtaba, R. Feldt, and K. Petersen, 2010.	[P4]	[4]
5	M. Poppendieck and T. Poppendieck, 2003	[P5]	[5]
6	K. Petersen and C. Wohlin, 2010.	[P6]	[6]
7	M. Poppendieck, 2011.	[P7]	[7]
8	J. P. Womack, D. T. Jones, and D. Roos1990.	[P8]	[9]
9	A. Droste, 2007.	[P9]	[10]
10	M. Poppendieck and T. Poppendieck, 2006.	[P10]	[11]
11	Jonsson, S. Larsson, and S. Punnekkat, 2013.	[P11]	[12]
12	Kniberg, "Kanban and Scrum 2009	[P12]	[13]
13	M. O. Ahmad, J. Markkula, and M. Ovio, 2013.	[P13]	[14]
14	P. Middleton and D. Joyce, 2012	[P14]	[15]
15	M. Ikonen, P. Kettunen, N. Oza, and P. Abrahamsson, 2010.	[P15]	[16]
16	T. Karvonen, P. Rodriguez, P. Kuvaja, K. Mikkonen, and M. Oivo, 2012.	[P16]	[17]
17	M. Mehta, D. Anderson, and D. Raffo, 2008.	[P17]	[18]
18	V. R. Basili, 1995.	[P18]	[19]
19	D. Raffo, M. Mehta, D. J. Anderson, and R. Harmon, *,2010*	[P19]	[20]
20	J. Pernst, R. Feldt, and T. Gorschek, 2013.	[P20]	[21]
21	A. Sillitti and G. Succi, 2005.	[P21]	[22]
22	J. Cho, and C. State, 2011.	[P22]	[23]
23	M. C. Paulk, N. Davis, and L. Maccherone, 2009.	[P23]	[24]
24	J. M. Fernandes and M. Almeida, 2010.	[P24]	[25]
25	X. Wang, 2011.	[P25]	[26]
26	K. Long and D. Starr, 2008.	[P26]	[27]
27	K. Nottonson and K. DeLong, 2008.	[P27]	[28]
28	F. Kinoshita, 2008.	[P28]	[29]
29	E. R. Willeke, 2009.	[P29]	[30]
30	J. O. Birkeland, 2010, pp.	[P30]	[31]
31	C. R. Jakobsen and T. Poppendieck, *2011*	[P31]	[32]
32	G. I. U. S. Perera and M. S. D. Fernando, *2007*	[P32]	[33]
33	S. Jalali and C. Wohlin, 2010.	[P33]	[34]
34	B. Barton, *2009*	[P34]	[62]
35	K. Rutherford, P. . Shannon, C.Judson, and N. Kidd, 2010.	[P35]	[35]
36	K. Nottonson, 2011.	[P36]	[36]
37	A. Hui, 2013.	[P37]	[37]
38	P. Hodgetts, 2004.	[P38]	[38]

39	P. Rodríguez, J. Markkula, M. Oivo, and K. Turula, 2012, p. 139.	[P39]	[39]
40	B. Swaminathan and K. Jain, *2012*.	[P40]	[40]
41	M. Cristal, D. Wildt, and R. Prikladnicki, 2008.	[P41]	[41]
42	C. R. Jakobsen and J. Sutherland, *2009 Agil*	[P42]	[42]
43	J. Sutherland, C. R. Jakobsen, and K. Johnson, 2008.	[P43]	[43]
44	G. K. Hanssen and T. E. Fgri, 2008.	[P44]	[44]
45	K. Korhonen, 2012.	[P45]	[45]
46	David. J, Anderson, 2010.	[P46]	[59]
47	M. Lindvall, V. Basili, B. Boehm, P. Costa, K. Dangle, F. Shull, R.Tesoriero, L. Williams, M. Zelkowitz, 2002.	[P47]	[60]
48	C. Ebert, P. Abrahamsson and N. Oza, 2012	[P48]	[61]
49	P. Middleton, 2001.	[P49]	[49]
50	M. Inoki, Fukazawa, 2007	[P50]	[47]
51	R. Mahanti and J. Antony, 2006	[P51]	[48]
52	E. Danovaro, A. Janes, G. Succi, 2008	[P52]	[49]
53	P. Middleton and D. Joyce, 2012	[P53]	[50]

4.6 Quality assessment criteria

4.6.1 Study Quality Assessment checklist

In the quality assessment criteria, some questions were formulated that allow assessment of the quality of selected primary studies, in addition to general inclusion and exclusion criteria. Based on the questions below, the primary studies having all the qualities mentioned in our checklist were chosen. The paper quality is assessed based on the research contribution. The questions were formulated with the help of Kitchenham guidelines [8]. All papers should satisfy the inclusion criteria and quality checklist to be better primary studies. Scores were assigned to each study based on the quality criteria checklist.

4.6.2 Quality of evidence provided by primary studies

To extract data from the relevant studies, the quality assessment criteria should be applied to each study. The quality criteria of primary studies must be performed to minimize the extent bias and maximization of the internal and external validity [8][47]. The list of quality criteria is presented in Table 7. The scale for their measurement varies from 1 to 5 points. To estimate the content of primary studies, the following detailed quality criteria were used.

We have a scale of 1-5 points to each question and quality assessment score for each primary study is given in the Table 7 and in Appendix A.

Table 7 Quality Assessments for Primary Studies with respect to Methodology and validations

Study Quality	Score
If the study describes a clear and related research to the reader.	5
If a study was performed by using a clear methodology. The techniques used, the models that involve more attention in the lean	5
If the study discusses the validity. The validity of the study should be described in detail.	5
If the study has performed a clear description and proper performance but the reader cannot understand	4
If the study design is briefly described and followed the systematic methodology, but not specific to the practices or methods.	3
If the validations are mentioned but not provided any motivation or description.	2
No proper description in evaluating the study	1
No proper methodology or study design is used but focus is on relevant topic	2
No proper validations are shown; no proper threats are described but still relevant to the study.	1

A detailed quality criterion was applied while evaluating the primary studies. They allow analysis of the content of studies. The results are given in Table 7.

The papers of high quality provide the complete description of lean principles and practices and their combination with agile methods. They identify principles, practices, and captured wastes. The papers of the lower quality miss to provide validations and evidence on the evaluation of their effectiveness and incorporation of particular practices with agile methods. The articles that specified the essence and impact of lean practices and also have provided their analysis with proper description of the research methods are considered as good papers, which are obtained to a large extent. Moreover, most of the selected articles have described their results. The important aspect that needs to be mentioned is that nearly half of the primary studies have not considered any kind of validations of research results.

4.7 Data Extraction Strategy

Initially the inclusion and exclusion criteria and quality assessment criteria are formulated for selecting primary studies in general. The data extraction process will describe what type of data is extracted in addition to the study quality checklist. A data extraction checklist is designed in order to extract the relevant data according to the three research questions. The data extraction checklist is mentioned in the Table 8, with three types of agreements with respect to primary studies. The agreements are represented as YES, NO, and partially. The overall score for each primary study is shown in Appendix A.

DE1: Does the study reflect Lean principles in software engineering?
1.1 Does the study have appropriate validations in their result?
1.2 Does the study results have empirical validations for the proposed lean practices.
DE2: Does the study reflect the software wastes?
2.1 Does the paper investigate wastes that are captured by lean practices/lean principles?
2.2 Does the paper address usage of lean principles?
2.3 Are the results of the study validated by using any kind of validations?
DE3: Does the study focus on incorporating lean principles into agile?
3.1 Are the resulted effective lean principles compared to agile principles?
3.2 Does the study focus on capturing wastes by agile or lean principles.

The following data is extracted from the primary studies in four steps.

- Initially the general data is extracted with respect to the quality checklist, research questions, and inclusion criteria. Some data has been extracted from the abstract of every primary study which represents their intention to perform the research, based on the methodology that is followed by the author for his study, lean principles, lean practices, lean thinking, software wastes.

- The first step includes extracting the data for RQ1. The studies are selected according to title and abstract. Then data regarding lean practices and lean principles is extracted. Further, a search was conducted for the studies, which have carried out their research in wastes. In these studies, the data was extracted regarding the seven wastes and the lean practices capable of eliminating the wastes. In addition, a check was performed for valid results in each primary study. Some studies may not specify the lean practices but they focus on lean principles capturing wastes and the usage of lean principles and practices, so those data are also extracted.

- In the second step we search for the studies focusing on hybrid lean and agile practices /principles that answer RQ2. The hybrid agile and lean practices were extracted and the data was summarized. In addition, the focus was also on extracting the wastes that are eliminated using hybrid agile and lean practices. The attention was on the lean practices and agile practices that are compared. If the comparisons are performed, what suggestions are provided by the author. Some studies have focused on lean practices and agile principles whereas some studies focus on agile practices and lean principles. Those studies were considered and lean and agile practices were extracted.

- The third step consists of efficiency of agile practices in capturing wastes, which answers RQ3. The data was extracted on the efficiency of agile practices. The efficiency that is extracted was based on the percentage of efficiency of agile practices in eliminating wastes and defects mentioned in the primary study. Some studies have performed surveys on usage of agile practices but they have not concentrated on eliminating the wastes, so only usage of agile practices was extracted.

Table 8 Data Analysis criteria

ID	**Criterion**	**Scores**		
		Yes (4)	**Partially (2)**	**No (0)**
DE1	QC1: Does the study reflect Lean principles in software engineering?			
1.1	Does the study have appropriate validations in their result?			
1.2	Are the research results properly specified and described?			
DE2	Does the study reflect the software wastes?			
2.1	Does the paper investigate wastes that are captured by lean practices/lean principles?			
2.2	Does the paper address usage of lean principles/practices?			
2.3	Does using any kind of validations validate the results of the study?			
DE3	Does the study focus on incorporating lean principles into agile?			
3.1	Does the study focus on capturing wastes by agile or lean principles?			

4.8 Results of SLR

4.8.1 Overview of Primary studies

The inclusion and exclusion process have filtered the primary studies that are most relevant to our research. We have considered the primary studies, which are dated from 1990. The reason for considering the primary studies from the year 1990 is that lean thinking has come into existence from the same year [9]. Figure 4 and Table Appendix A, shows the distribution of primary studies according to the year of publication. The primary studies are considered until the year 2013. From the distribution of studies, it was observed that most of the studies were published in the year 2010 and only six studies were published from 1990 to 2006.

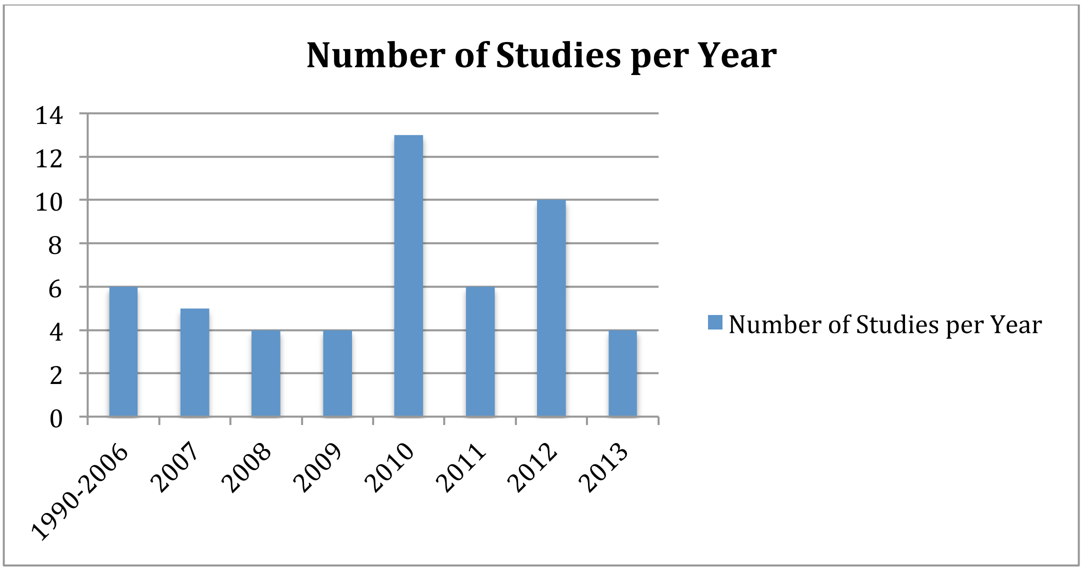

Figure 4 Distribution of Primary studies over the Years

This section concentrates on three aspects with respect to the research questions. 53 primary studies were reviewed out of which, 21 studies report on lean practices that are mostly used in the software domain, 24 studies report on agile and lean hybrid practices and eight studies report on agile practices and their efficiency in eliminating wastes. The list of primary studies with their encoding is given in Appendix A (Table A.1). When reviewing the primary studies on lean practices, it was observed that some of the studies have only focused on lean principles. Some of the studies have not specified the agile and lean practices, but have considered agile and lean principles as generic lean and agile in those studies. The overall classification of primary studies according to their reports is shown in the Figure 5 below. The primary studies according to their classifications are summarized in the Appendix A (Table A.2).

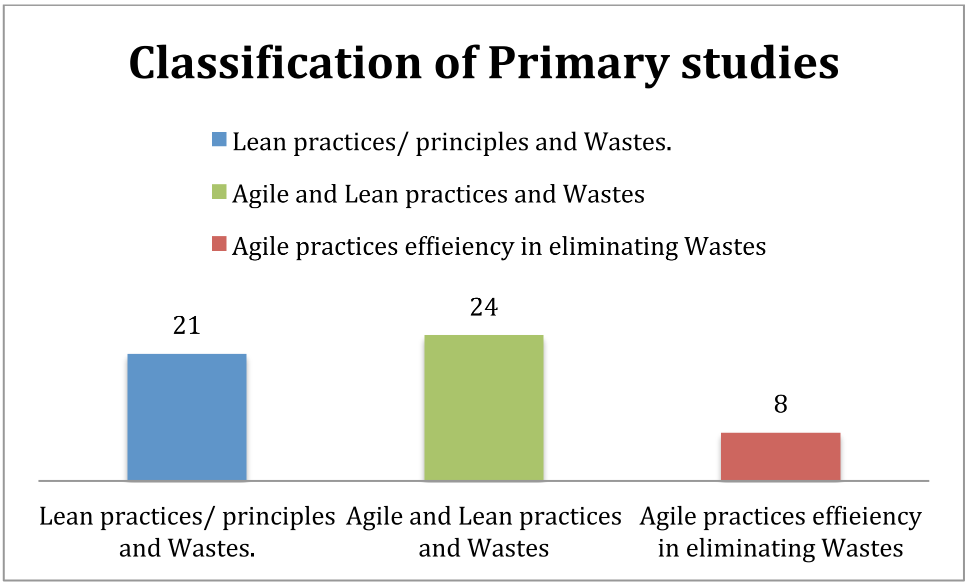

Figure 5 Number of studies acquired

The distribution of primary studies per year is given in Figure 4. It can be observed that starting from 2006, researchers have shown a stable interest to the problems of lean practices and principles and their combination with agile in software engineering companies.

4.8.2 Analysis of Lean practices/principles that have most attention in the research

In most of the primary studies, authors refer to Womack and Jones the books [P8][P9] while explaining lean in general. When it comes to the classification of lean in the software development Poppendiecks et.al [P10] were the most sited books in software domain [P7][P5][P10]. The formulation of lean software development principles by Poppendieckset.al [P10] was adopted, and implemented in the industries. Brief analyses of Poppendiecks et.al [P10] lean principles in software development are shown below in the Table 9. The study [P10] concentrates on the lean principles/practices combined with agile and lean practices, and wastes in the software domain. In this specific section, the focus was on the lean practices/ principles and wastes that have much attention in research. Only the lean principles in software were summarized even though Poppendiecks et.al have mentioned lean principles in production. Technical and organizational issues are less covered in the principles proposed by Poppendiecks [P10].

Many studies have discussed that lean principles are transferred from manufacturing domain to software engineering and mentioned seven lean principles [P11][P7][P5].When coming to the lean practices, there are many other practices that are mostly discussed in research. Some of them are Kanban, Kaizen and Value stream mapping (VSM) (Figure 6).

Table 9 Lean principles identified from studies.

Study Author	Principles
Poppendiecks et.al [P10]	Eliminate Waste Build Quality In Create Knowledge Defer Commitment Deliver fast Respect People Optimize the Whole
Womack and Jones [9]	Identify what really matter to the customer Eliminate discontinuous in the value stream Ensure that every activity add value to the customer Production is initiated by demand
Anderssson [18]	Visualize the work flow Limit work in progress Manage Flow Make process policies explicit Improve collaboratively

The three practices have gained more attention as lean practices in the software domain that can identify and eliminate waste. From seven lean principles, it can be noticed that the first principle, eliminating waste has been concentrated more in all the lean research studies. The three practices Kanban, Kaizen, and Value stream mapping can be said as practices/ tools that can eliminate waste in the software domain.

The article [P17] has specified a number of key lean principles in the context of software development. The practical strategies for making trade-offs between the core lean principles, providing the highest possible customer value; maximizing the workflow and eliminating wastes are focused in this study. The author of the study [P17] has chosen a medium scale industry with 32 persons in a team, lasting for 12 months. Further, they have implemented the lean principles into the project and addressed key problems in development using lean. From the overall study [P17], we can understand that the author has concentrated towards the lean principles implementation, taking different aspects like work flow, customer value and eliminating waste. The wastes found or eliminated while implementing the lean principles into the software domain are not specified [P17]. Few wastes like extra process and defects are taken out and the solutions to reduce the wastes are mentioned.

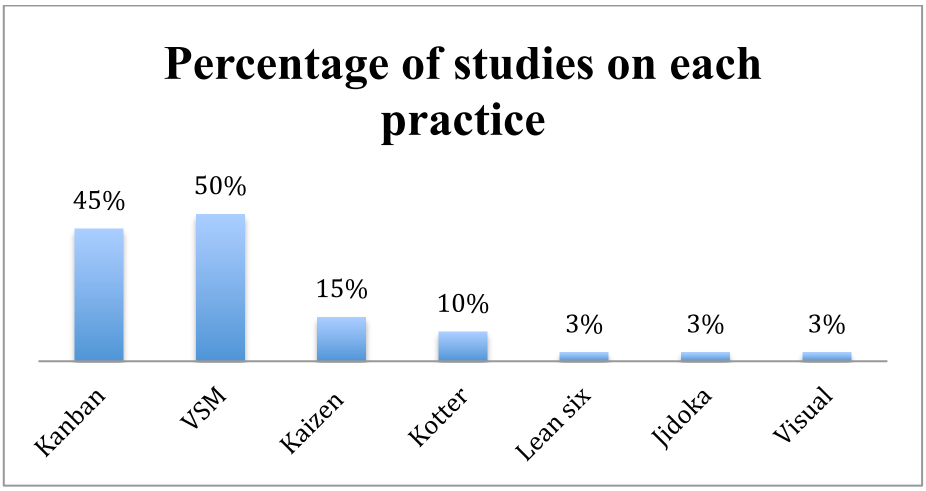

Figure 6 Frequency of lean practices covered in research

In recent years, software Kanban practice [P46] has become more popular in software development. The same study [P46] on software Kanban practice stated five principles, which are feasible for practice and mostly concentrated on management, when compared with Poppendiecks principles. The study, which has focused on all types of wastes, is [P46]. The authors of [P46] have introduced and applied TPS to large-scale development of business application software and emphasized the importance of identifying and eliminating the seven types of wastes.

Kanban in software development allows project teams to visualize the workflow, limit work in progress at each workflow stage and measures cycle time [P12]. The results of Kanban usage in software development have shown positive results, corresponding to manufacturing domain. The Kanban approach is the most recent and popular addition to agile and lean software development research [P13]. A systematic literature review on Kanban has been performed by the study [P13] in order to analyze the usage, benefits and challenges of Kanban approach in software development. The same study [P13] has referred the Kanban principles reported in the study [P46], which appears to be largely overlapping the lean and Kanban principles (see in Table 8). The percentage of research done for the past years has been reviewed and analyzed in the study [P13].

Implementation of lean concepts described by Womack and Jones were discussed in the study [P11] when applied to the software development. The benefits of Kanban have been reviewed by [P11], reflecting that Kanban gives better understanding of whole process, improved quality and customer satisfaction. When it comes to the organizational and technical aspects the set of principles proposed by these studies have low coverage. The summary of lean principles in software development process are shown in the Table 10 below [P7][P1][P5].

Most of the studies on Kanban software development were published in the year 2011. From this it can be analyzed that the usage of Kanban by practitioners and researchers is growing constantly. One of the best examples for using Kanban is BBC Worldwide [P14], where the lead time to deliver software was improved by 37%, the consistency of delivery increased by 47%, and the number of defects reported by customer was reduced by 24%. The three studies [P46] [P48] [P49] showed that, the overall performance of development team has improved, team communication and coordination with stakeholders was improved. Further, the primary studies suggest that Kanban needs to be implemented gradually in software development. The study [P48] has clamed that Kanban is a basic controlling tool, which needs the support from other practices [P48]. Instead of replacing new methods, the Kanban method can be added as a plugin for Scrum existing methods.

Table 10 Summary of Lean principles

S.no	Lean Principles
1	Eliminate Waste
2	Build Quality In
3	Create Knowledge
4	Defer Commitment
5	Deliver fast
6	Respect People
7	Optimize the Whole

The operational efficiency of the software projects can be warranted by using Kanban based software projects based on the empirical evidence methodology [P15]. The study [P15] has determined different kinds of wastes using the empirical analysis. The methodology that was used for determining the wastes and its source are identified by interviews. The interviews in the study [P15] are performed based on the research model considering seven elements [P6] as an interest of research. The interviews have revealed wastes and increased understanding of the functioning of Kanban method. The findings of the study [P6] have determined the potential sources of wastes, which can be also called as the root causes at varying levels.

The second is finding different kinds of wastes, but this has not significantly contributed to exploring the success of the considered project. The wastes and the sources of waste found when the Kanban is implemented in industry are shown in the Table 11. The sources and the wastes summarized in the table are referred form the study [P15]. Hence the study [P15] determines that even the Kanban method helps to minimize the non-value-adding work, and most of the wastes are well noticed, by the case study they performed. The software development team must particularly concentrate on the wastes like delay in the critical path, extra process, extra features, and motion. There is a dependency between the two wastes task switching and waiting.

Table 11 Wastes and their sources [P16]

Wastes found by Kanban practice	Sources discovered in case project using Kanban
Partially done work	• Delay in critical path • To implement a task required another, yet unimplemented task
Extra process	• Kanban-based routines unnecessary for tiny task • Inefficient retrospective meetings
Extra features	• Unawareness of the key requirements

Task switching	• Two tasks need each other in implementation phase • Disruptions: helping other people or contributing other tasks • Avoidance of waiting
Waiting	• Waiting for customer representatives • Waiting for IT support • Waiting for hardware shipments for all projects • Unavailability of person when someone needs assistance
Motion	• Lack of communication
Defects	• Defects that are found at last minute

VSM is a popular practice in lean for eliminating waste, only few studies reports on using VSM practices in software domain. From the above, the study [P4] has applied VSM to software product customization process. They have identified wastes related to waiting, process and motion. Using Value Stream Maps the study [P4] has identified the waste related problems in software product customization. VSM is based on the lean principles and it is used for identifying the opportunities for significant process improvement. VSM helps to uncover bottlenecks in a process, which can prevent it from flowing at its optimum [P4]. The organizations can understand any workflow, taking an end-to-end view of their process capability by using VSM. The authors of the study [P4] have followed the workflow of VSM from the notations used by Poppendieck [P5] who demonstrated an example of how value stream mapping is applied to software domain. The same study [P4] has identified different kinds of wastes in software product customization with the goal of reducing lead-time. By performing the VSM in software product customization process, the author have identified different kinds of wastes and suggested the solutions for eliminating three different wastes [P4].

The study [P4] mainly focuses on the most critical wastes in software product customization and root causes for the identified wastes. The solutions for eliminating or reducing the identified wastes and impact that it makes on shortening the total lead-time were suggested. The solutions to reduce wastes were found while implementing VSM in software product customizations. They are described by the author [P4], which can help the practitioners to improve the software product customization while implementing VSM in the industry. The overall results of the study [P4] are beneficial for the researches as well as practitioners by proposing the solutions for reducing the wastes in software product customization. Some of the solutions, proposed by the study [P4], are not known to the practitioners, this indicates that practitioners are not aware of the solutions to reduce waste in the software development process. The future state map of the study [P4] is also described in the study by considering all the solutions with an approximate time to reduce waste. The wastes that are found while using VSM for the software product customization are tabulated in the Table 12.

Another study [P16] has proposed the adoption of the Lean Enterprises Self Assessment tool (LESAT) to guide the transformation of software development companies towards lean. The purpose of LESAT is to set targets for desired future state as well as to assess an enterprise current statue in terms of lean capability. The results of this study indicate that involving VS (value stream), seeks an optimized end-to-end collection of actions for bringing the product to the customer. LESAT may complement lean assessment in software domain at enterprise level [P16].

Table 12 Wastes found while implementing VSM [P4]

Waste	Description of each waste
Waiting	• Waiting Time in Design • Waiting Time for Customer sign-offs • Waiting time for system integration testing
Extra Process	• For Solution Proposal Building • For design
Motion	• Motion of Requirements

Lean software development distributes two important principles that help software process improvement. Identifying waste in the process and considering interactions between each part of software process is considered in [P6]. Petersen and Wohlin [P6] have proposed a novel approach to bring the quality improvement and lean software development practices together and named the approach as software process improvement through lean measurement. This method SPI-LEAM was designed for improving the flow in software development and applied in large-scale industry. The method is implemented in industry and an initial evaluation of the method has been performed [P6]. SPI-LEAM consists of a framework based on the QIP [P18] consisting of 6 major steps. The study [P6], concentrates on Kaizen with the continuous improvement focused on lean aspects.

Performing the approach SPI-LEAM, the study combines the quality improvement paradigm with lean measurements, and aims to enable continuous software process improvement leading to lean software process, and to avoid problems related to resistance of change by improving in a continuous manner. This study [P6] claims that inventories also increase waiting times, extra features without customer value and uncomplimentary tasks. So, this method can also be considered as the lean practice with combination of measurement [P6].

Kaizen continuous improvement in software development is considered in [P50]. The term comes from two Japanese words, which mean measurement and improvement. This practice makes a stress on the strategy of continuous improvement of all software development processes. Kaizen principles are consistent with agile methodologies. They include [P50]:

- Focus on clients;
- Continuous changes in small steps;
- Processes discussion;
- Open admission of a problem;
- Creation of communities;
- Project management with the help of cross functional teams (similar to SCRUM, where the professionals in different domains work together to solve the problem);
- Forming the supporting relationships;
- Self-discipline development (similar to SCRUM self-managed teams).

Primary study [P50] states that according to Kaizen, each team member must be informed about any business information changes, so that all information should be transparent. The other study discusses the issue of delegation of authority to team members. The authors of the study [P50] check the hypothesis about the fact that creative and efficient solutions can be found by team employees who have many responsibilities.

So far, many studies have suggested lean practices, which can be implemented in software development, either individually or by the combination of different methods to improve the software process improvement. Recently, the study [P20] published in the year 2013 has identified and classified the state of art in the large-scale software development domain with a particular focus on lean. The same study [P20] has identified the gaps and proposed extensions to lean product development in relation to the well-known principles and practices. The identified and classified state of art and the knowledge gained are used to support industrial partners on software process improvement project. The review performed by the study [P20] has considered 16 primary studies on large scale setting in different industrial sectors. Most of the practices and methodologies identified by [P20] are generic lean. Kanban practice was noticed to 5 percent and remaining all the practices that are noticed by this study was very less. The different types of practices that are used for software domain are included in the Table 7. In addition, the study [P20] has identified some practices that are relevant to generic lean, generic lean and agile, and Kanban. In some studies, lean practices are applied in combination with agile methods and in some studies, it was not clear, which methods they have used in specific. Some of the practices noticed by this study include agile methods like Scrum and XP, where the lean software development was combined with agile software development.

Lean manufacturing principles are closely related and integrated with the six-sigma paradigm in software engineering domain. Six-sigma quality analysis is combined with lean development speed (for example, reducing process lead time) within the framework of the deploying company's resources and tools used for software development [P51]. Applying lean principles in modern business systems requires a special focus on analyzing time-based performance measures such as cycle time, lead time, tact time, and delivery speed [P51]. The authors of [P51] emphasize that measuring time-based performance is the essence of lean practices. The same measures are also considered by six-sigma projects aiming at achieving organizational excellence. Another study [P19], mentioned that lean six sigma principles and methods have been successfully applied in a variety of industries. This paper aims to articulate how applicable Lean six sigma principles can be coupled with the Value based software engineering (VBSE) to improve the software development life cycle by improving the identifications and delivery of customer value as well as the reduction of waste.

Lean six-sigma approach to process improvement must consider the following aspects [48]:

- Developing a current-state VSM with information and measures that are necessary for applying six-sigma methods.
- Using VSM as a platform for the application of six-sigma and lean tools.
- Integrating lean techniques into six-sigma methodology, to prescribe the set of process structural changes that will benefit performance.
- Applying lean techniques as a continuous improvement effort to reduce process waste and increase its effectiveness.
- Reflecting parametric and structural changes made to the process by developing a future-state VSM.
- Working intensively on creating a cultural change, in an organization towards six-sigma accuracy and lean effectiveness, in all business functions.

Jidoka lean practice is about the introduction of quality inside the production process and product. This lean practice provides machines to operators with the ability to detect when an abnormal condition has occurred and immediately stop work [P53]. In software industry, Jidoka has not yet been fully exploited. The authors of primary study [P53] suggested a holistic approach to insert Jidoka in software production. The study [P53] describes a software tool that introduces Jidoka practice to software development process. According to Jidoka if the errors are identified, the system must decide whether to stop software production or not based on a set of rules. These rules require the specific data to be collected about software resources consumption and process output [P53].

Lean visual management is one of the practices used in lean manufacturing. It is often used in combination with lean visual planning. Its application in software industry can benefit the development process by [P53]:

- improving communication of key information;
- same picture of the development process is provided to every one in the team
- providing a forum where all staff are able to raise any issues;
- helping the team identify and solve problems;
- measuring progress, identifying trends and analyzing performance;
- focusing on and establishing goals for continuous improvement.

Conclusion

Overall, 21 primary studies on lean principles and lean practices that can eliminate waste in the software development process were reviewed. It was found that many studies focus on the lean principles that are implemented in the software industry for eliminating the waste. In these studies, only 10 studies have mentioned the wastes that are eliminated or captured by lean practices. Some of the primary studies [P46], [P14], [P4], [P16], [P6] have focused on the lean practices that capture waste when they are implemented in large-scale software industry. We found that eight studies have focused only on the lean practices without describing or identifying the wastes while using the specific lean practices. Most of the primary studies that were found are experience reports, implementing the lean practices, frameworks for implementing lean principles in the industry.

On the other hand, the literature search could identify some studies, that have clear and brief explanation on implementing the lean principles and practices in the software industry, and the different wastes that can be captured by specific lean practices. The summary of lean practices, wastes, and their description that were identified from the primary studies are shown in the Table 13.

Table 13 Lean practices that capture wastes.

Lean practice	**Wastes captured**	**Description of each waste**
Kanban [16]	Extra Process	• Kanban-based routines unnecessary for tiny task • Inefficient retrospective meetings
	Extra features	• Unawareness of the key requirements

	Parallel done work	• Delay in critical path To implement a task required another, yet unimplemented task
	Task Switching	• Two tasks need each other in implementation phase • Disruptions: helping other people or contributing other tasks • Avoidance of waiting
	Waiting	• Waiting for customer representatives • Waiting for IT support • Waiting for hardware shipments for all projects • Unavailability of person when someone needs assistance
	Motion	• Lack of communication
	Defects	• Defects that are found at last minute
VSM [2]	Waiting	• Waiting Time in Design • Waiting Time for Customer sign-offs • Waiting time for system integration testing
	Extra Process	• For Solution Proposal Building • For design
	Motion	• Motion of Requirements
Kaizen Continuous improvement [6]	Overproduction	• Production of extra lines of code • Realization of extra functions • Realization of duplicated functions
	Defects	• Eliminating defects in programming code • Support of software requirements verification
	Waiting	• Waiting time in requirements analysis • Waiting time during software deployment
	Processing	• Making changes on the software maintenance stage
Lean Six Sigma [48]	Motion	• Transmission of software artifacts between employees on all development stages
	Defects	• Errors during software construction
	Waiting	• Waiting time in requirements collection and analysis • Waiting time during software construction
Jidoka [49]	Overproduction [49]	• Extra processes implementation
	Defects	• Design and programming code errors • Prevention or errors
Visual Management	Waiting	• Waiting time during software requirements analysis, software design, construction and testing

4.8.3 *Analysis of Lean practices that are incorporated in Agile for elimination of waste*

Agile software development methodologies have become most popular for software quality assurance and software process. Since the last decade, the popularity and usage of agile methods have increased in software industries for a better quality product. Agile methods are capable of managing the requirements, customer satisfaction, quick delivery, support interaction, and produce high quality products. Some of the agile methods that are more popular in software industry are listed in the studies [P21][P22][P23][P24]. Mainly motivated by the agile community, the software industry has started to look at lean [P21].

Some studies have focused on agile practices and noticed the removal of wastes in software development. Twenty-four studies were considered which have focused on lean practices/principles combined with agile methods/practices. As mentioned before, in [P20] it was noticed that some of the papers are generic lean and some are generic lean and agile. The frequency of studies covered on each aspect is shown in the Figure 7.

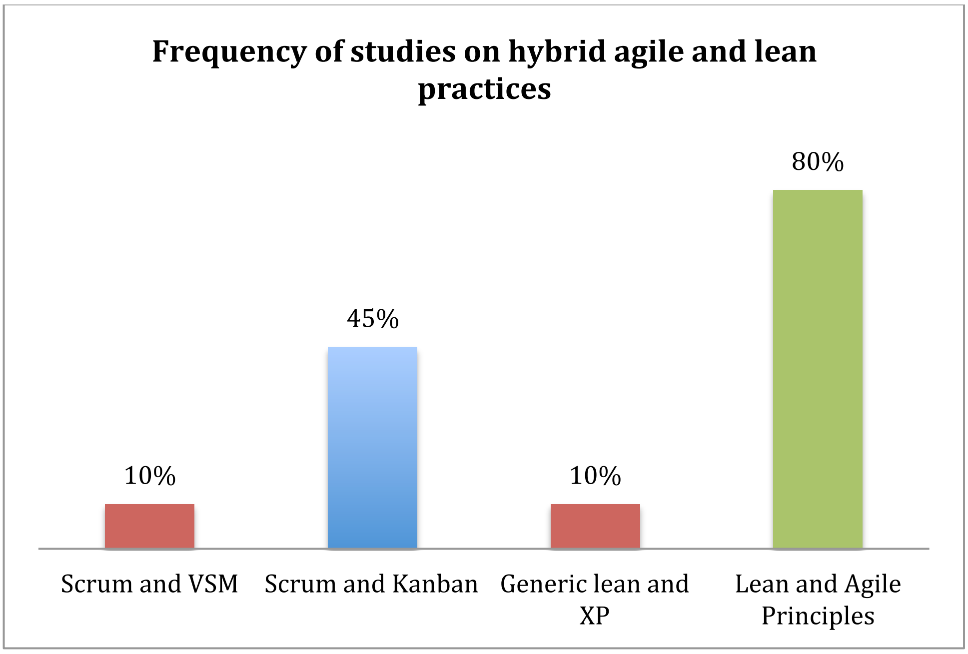

Figure 7 Frequency of Studies covered on each aspect

The conference study Xiaofeng Wand et.al [P3] has analyzed a combination of agile and lean practices in software development as an experience reports on multiple cases. From the results of the study [P3], it was concluded that lean is generally applied for agile development practices and they both can be combined in different manners for different purposes in software development. According to the findings of the studies [P3] the two paradigms, agile and lean can be combined at practice level in several organizations.

Agile software development and the lean software development both seem to be similar in focusing on the customer and responding to their needs rapidly [P25]. The goals of lean and agile are similar; we need to know, whether agile methods are capable of eliminating wastes from the software development process. However, lean software development mainly focuses on providing approaches to systematically detect and remove waste in the software development process, i.e. anything that does not add value to the customer.

The study [P25] has reported the experience reports on the combination of agile and lean practices in software development. Many studies that are referred in the study [P25] concentrates on agile and lean combination, but they have not distinguished between them. On the other hand, the study [P25] have claimed that lean practices like VSM, root cause analysis, 5 whys, were applied to analyze the process of a product, before Scrum was chosen as an agile method. The studies [P25] have also claims that the two paradigms, agile and lean can be combined at practice level in several organizations. Based on the evidence of these studies [P3][P25], it can be clearly understood that lean principles and agile methods can be combined and they are implemented individually for capturing and removing wastes. However the study [P25] has not elaborated about the lean and Scrum individually.

Three experience reports [P26][P27][P28] have mentioned that agile and lean are used in parallel and there is no specific distinction between them. Similarly the study [P27] claims that the adoption of agile and lean practices, and Scrum, BabyCenter's journey from chaos to a relatedly mature agile organization was able to build production environment with 99.99%, but agile and lean practices are listed in parallel without further elaboration. On the other hand, studies like [P29][P30] have focused on the transaction form Scrum to flow based lean process in international business and effort-taking. According to the studies [P29][P30], starting with the application of lean practices to improve agile process, organizations have ended in a situation where lean process became dominant and agile practices are in a supporting role.

To have a clear idea and to use the agile methods on behalf of lean practices, the study [P2] has compared both development paradigms agile and lean. By comparing the goals and principles of the development paradigms, the study [P2] has mapped the similar principles and goals between lean and agile. Many similarities map these two developments, mainly the removal of waste in the software development process. Mostly every aspect of agile principles focuses on eliminating waste and customer satisfaction [P2]. The study [P2] has compared many aspects like practices that are implemented in agile and lean with the principles, quality assurance practices, software release practices, project planning, and team management.
When the practices that are used in agile and lean software engineering are compared with flow practices, almost all the practices are similar in agile and lean. For instance, VSM has mapped to agile principles as well as lean principles. The study [P2] has claimed that lean is agile, where the principles of lean reflect the principles of agile, while lean is unique in stressing the end-to-end perspective and flow. Kanban pull system has mapped to elimination of waste and customer prior [P2]. Based on these results of the study [P2] we can understand that agile and lean principles are very much similar and capable of eliminating waste and providing value to the customer. Both paradigms SCRUM and XP consist of set of principles, but they describe a workflow and artifacts that are produced in the process [P2].

The study [P47] states that the practices that are known in agile have been adopted by lean. In the practices like Value stream mapping, inventory management, Kanban pull systems, agile uses the practices that are not used in lean. On the other hand, Scrum and XP are the leading practices in agile, which can eliminate waste form the software development process [P47]. The flow of these practices itself focuses on eliminating the waste and adding value to the customer [P47]. The study [P31] has performed an experiment on using lean software development for optimizing software process. The study reveals the experience from the last five years since they have performed the experiment. They have captured some of the wastes that should be reduced in their experiment, such as waiting, defects, and extra features. They have used lean software development as troubleshoot for Scrum in agile for optimizing software process. As it was noticed that both the principles of lean and agile are similar, the study [P31] shows that both paradigms can be implemented for analyzing and improving the software process.

At the same line, [P32] aims to identify possible improvable parts in agile and explores how the lean principles could be used to improve the agile software development which lead to a hybrid practice. The study [P32] has claimed that agile software process development can be improved by using lean practices. On the other hand, the same study [P32] claims that lean practices cannot be taken as a complete process model for the software development, because it only provides the behavioral approach for project success. The study [P32] have conducted an experiment with 10 student projects and found that the hybrid process of lean and agile will produce more lines of code than the agile process, but the study has not stated or involved the practices.

Another study [P33] has performed a systematic literature review on agile practices that are used in global software engineering. In the same study [P33], the search string that was used is agile and lean to denote agile practices, which indicates that there is not much difference between these two paradigms. On the other hand, studies [P34] [P48] have noticed that based on Scrum, many organizations consider their work as lean implementation. On the other hand, the study [P48] claims that in IT or embedded software systems, between 30 and 50 percent of all unnecessary features add overheads. B.Barton et.al [P34] appeals that Scrum implements a process for eliminating waste to smooth the flow through the system and prevent overloading with the help of a lean "pull" technique.

The empirical evidences of lean and agile applications and their implementations are addressed by the study [P3]. The study [P3] focuses on how the lean approaches are applied to agile practices. The authors of the study [P3] have examined thirty experience reports on lean approaches in agile software development. The same study [P3] has noticed six categories of lean applications in agile software development. The five strategies that are identified are: agile within, lean out reach, lean facilitating agile adoption, lean within agile, from agile to lean and synchronizing agile and lean. Another study [P3] reports that usage of various lean applications to improve agile process is a pattern that appears repeatedly in 13 experience reports. On the other hand the studies [P29][P34][P30][P35] noticed the cases in the form of agile to lean category, with the lean elements applied in different domains in different organizations. The list of organizations and categories are listed below in the Table 14.

Table 14 Cases that are considered from "the studies [P29][P34][P30][P35]"

Organization name	Business domain	Lean elements applied
Yahoo!	Internet services	***Concept:*** *Flow* ***Principle:*** *Eliminate waste, reduce batch size.* ***Practice:*** *MMF*
Inkubook	Online photobook	***Concept:*** *Pull* ***Practice:*** *Kanban, Limited WIP, MMF*
Code weavers	Financial and insurance web services	***Concept:*** *Flow* ***Practice:*** *Value stream mapping, Kanban, Limited WIP, CONWIP, MMF*
Other	Other	***Concept:*** *Vale* ***Principle:*** *Manage flow, Limit WIP, Visualize the workflow* ***Practice:*** *Kaizen, Visualize all work items, Same-size work items.*

Lean practices like Kanban and Kotter are used for waterfall to agile as stated in experience report [P36]. The study [P36] has provided an experience report on a new approach referred to lean change. The technologies designed to tackle the uncertainty from other domains have been adopted by this lean change, to provide a framework for existing agile transformations more efficiently [P36].

In another study [P35], the authors have worked for two years in two organizations to approach agile transformations using lean startup principles. They have noticed three types of key risks that can be overcome for a successful startup. Three risks noticed by the study [P35] are Product Risk, Customer Risk, and Market Risk. From the study [P37] the overall experience report in which it was found that, evolving and applying lean change method to four separate agile transformations, helps to bring structure with discipline and feedback. The same study [P37] has involved three methods though disciplines MVC (Model View Controller), A3 and Kanban that determine the change Canvas advocated for lean change, as likely to be one of the many options, which can be substituted depending on the context. The study [P37] claims that many organizations have modified their development system based on Scrum and considered their work as lean implementation.

K.Nottonson et.al [P36] has noticed key differences between agile and lean practices and examined the possible improvements to agile practices from the lean principles. The problem that is specified by the study [P32] is based on the obstacles of agile practices. Overall, the intention of the study [P32] is not to develop an experiment or any new software development paradigm, but to improve the agile methods using lean principles and practices [P32]. Another study [P47] has noticed two major issues on agile practices, which are most relevant on project team members with expert knowledge and project management. Where the lean practices are concerned, it cannot be considered as the complete process model for the software development [P47], as the lean practices only provide the behavioral approach for project success [P47].

When coming to the practical implementation of agile and lean practices in the software industry, one of the study [P38] has performed a survey in 200 software organizations with 408 responses. This study has carried out many aspects like the percentage of usage, reasons for adopting agile, reasons for adopting lean and reasons for adopting combined lean and agile in their organizations, as well as the future plans for adopting these practices. From this study, we can observe the usage agile and/or lean practices are 58%, mainly with the combination of lean and agile at 21%. According to the study [P38], the authors concentrate on combination of agile and lean practices in software domain. Therefore, the mentioned percentage from the study [P38] was considered. From one of the observations of [P38], it was noticed that the main goal for adopting agile and lean practices in the industry is to increase the speed, defects, and quality of the products as well as to reduce time to market.

Many reasons have been taken out by the study [P38] for adopting agile and lean practices in the industry. Another study by B.Swaminathan et al [41] has performed a case study on application of lean principles to the software development. The findings of the study [P40] show that applying the concepts of continuous improvement and flow to agile, seem to have significant benefits. The study [P40] has explored the implementation of ideas, of continuous improvement, and flow, which are so central to lean and agile software development. However, the study [P39] has not described or noticed any specific lean principle/practice that can be implemented on an agile software development in the software development.

Conclusion
On the whole many studies have focused on combination of agile principles, usage of agile and lean principles, similar principles of agile and lean that corporate on elimination of waste. However, few studies have mentioned and used particular hybrid agile and lean practices for eliminating waste. The authors of the studies [P33, P36, P3] have not mentioned which

practices they have used and the waste they captured. For instance, the study uses Scrum but the study has not mentioned the lean practices, but claims that they have used lean principles. Some have focused on the improvement of software process by eliminating or overcoming the wastes, but the studies have not specified the practices they have used. The overall review of the agile and practices that are combined with lean for removing the waste, principles that are similar in agile and lean and their description are summarized in the Table 15. The number of studies that have focused on lean and agile principles and studies that mentioned wastes and studies that have used and specified the practices were also summarized in Figure 5.

Table 15 Hybrid practices and wastes that are found in Research

Agile practices	**Combinations of Lean**	**Common principles**	**Wastes found**
Scrum [P34]	Kanban Pull system	Eliminate waste, reduce batch size	Waiting, Defects, Extra features.
	Value Stream Mapping	Manage flow, Limit WIP, Visualize the workflow [P37]	Waiting, Extra process
XP [P47]	Generic Lean		Waiting
Agile Principles [P35]	Kaizen	Visualize all work items, Same-size work items.	Not mentioned
Agile Principles [P36]	Kotter		Not mentioned

4.8.4 Analysis of the efficiency of agile practices in eliminating wastes

In this section, the efficiency of agile practices in eliminating the wastes based on the results of the selected primary studies was identified.

The study [P5] has argued that agile software development also seeks to eliminate wastes. When it comes to the specific agile practices that are capable of eliminating waste from the software development, five papers that specify the amount of wastes they have captured and the efficiency of the practice they have used in their projects were identified [P5]. Agile has the reputation of providing value to the customer, flow, iteration, custom satisfaction, and fast processing [P5].

The study [P41] has proposed a lightweight process to incorporate improvements using the philosophy of scrum. The authors of the study [P41] have implemented the proposed approach in two small companies, and they have found that the approach sets out to guide the process improvement in small companies.

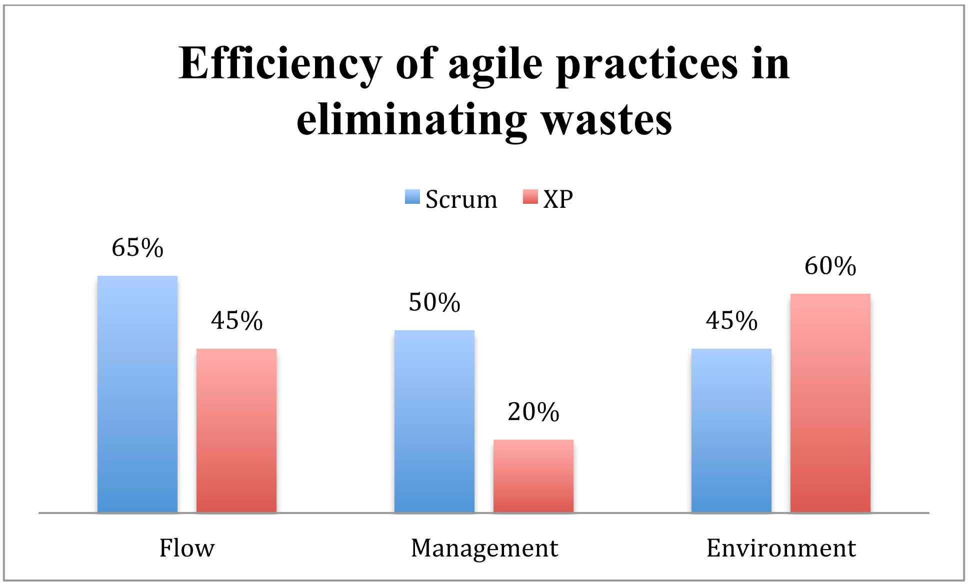

Figure 8 Efficiency of Agile practices in eliminating wastes

Another study [P38] has reported that mostly two practices, Extreme Programming (44.4%) and Scrum (48.15%) are used in the industries. The remaining practices like Crystal Clear and Feature driven development are mostly not mentioned and less used by the industries [P38] [P39].

By the introduction of Scrum on a permanent basis, a CMMI company has doubled the productivity and reduced the wastes by 40% by concentrating on time to fix and early testing [P42]. The study [P42] reports that, combining the Scrum and CMMI brings a powerful combination of adaptability and predictability and suggest how other companies combine them to achieve the Toyota level performance. The same study [P42] have reported that by using this combination of Scrum, it was possible to improve the flow up to 59% and this was implemented in the year 2008. The study [P42] has also observed that the wastes elimination and process overhead, which has eliminated extra process by 75% with a small team. In the same line, another experience report [P42] has also combined the CMMI and Scrum. The study [P42] says that they have implemented the combination previously and reduced the defects by 40% during the test level and they are able to reduce the total work required and rework by 50% using Scrum.

Another study [P43] has showed that they are able to reduce the waste called extra features by 64% and stated that end users will rarely use more features in fixed contract. The study [P43] has performed a quantitative analysis which indicates that the adoption of agile process has improved the quality of software by reducing the serious errors and defects. The study [P43] reports that they have reduced 50% of showstopper errors, fewer than 10% of critical errors, and 25% of cosmetic errors. Where the Scrum practice is concerned, they have reduced the critical defects by 13% and the cosmic error remains same as 25%. The study [P32] has emphasized the key differences between the lean and agile practices and examined the possible improvements to the agile software development. They have reduced the time and waiting wastes up to 95% by implementing lean practices. The survey results of the study [P32] reports that after using the agile practices, defects are found earlier than before. They have summarized that the defect detection is improved by using agile practices on 57.2% in 6 months and on 65% in 12 months. However this study has not specified which agile practices are implemented.

The study [P44] has performed a case study on defect management and supporting agile transformations. The same study [P44] that has focused on the combination of agile and lean by using lean as scrum troubleshooter, has focused on the Scrum practices and captured that flow was increased to 60% and waiting time was reduced to 10% when using the Scrum with lean. The study [P44] has observed that the early detection of wastes can be found using the agile practices and they have summarized that the flexibility and motion are reduced by 67% and other defects are reduced to 54% by using agile transformations. At the same time, the study [P44] has not mentioned the practices they have used to reduce the wastes.

Conclusion

It was found that some studies have focused on the defects and wastes that can be eliminated by using agile practices, but the practices are not mentioned or described. Some survey reports summarizes the rate of defect and wastes detection in the form of surveys, but they have not mentioned the wastes and agile practices. The overall report of the efficiency of agile practices, which are capable of capturing and eliminating wastes are shown in the Figure 8 below. The Figure 8 shows that using Scrum captures 67 % of wastes in the software industry and 45% of defects are captured using the XP practices. It was found that very less papers are available on agile practices capable of eliminating wastes. To overcome this, lots of research is required to observe the implementation in the industry, to know the efficiency of agile practices in eliminating wastes. This study has reported the efficiency of agile practices in eliminating wastes according to the identified studies.

However, it was found that very less amount of studies have focused on the efficiency of Agile practices in eliminating wastes. Most of the papers that were found are based on the management sector of Agile and some focus on the flow of the software development. Very few papers were found that focus on the wastes that can be eliminated using agile practices. Most of the papers have claimed that Scrum practice is capable of eliminating wastes. For instance, some papers claim that Scrum can eliminate wastes like waiting, motion and defects, but some papers focus on the team size and team management. As mentioned before, some studies have used agile practices and lean practices individually depending on the specific organizational settings. When considering the papers that are focused on the hybrid agile and lean practices, very few studies have focused on the agile practices and the wastes that are captured using them. Some studies claim that, using the combination of agile and lean can eliminate and capture more wastes instead of using agile practices.

4.9 Discussion and Conclusion of SLR

From the systematic literature review, focusing the three research questions RQ1, RQ2 and RQ3 as mentioned in the Section 2.1, 21 papers were selected on lean practices and wastes that have more attention in state of art. Twenty-four papers on the combination of agile and lean practices and the waste captured were identified. Eight papers were identified on the efficiency of agile practices in elimination of wastes.

4.9.1 Overview of SLR results

Firstly, in the state of art, most of the primary studies have focused on the lean principles and the wastes captured in the software development process. It can be observed that most of the studies have a base of Poppendieck and Xingo [1][2]. In this study, it could be observed that VSM (Value stream mapping) has been discussed in most of the primary studies with empirical evidence. As reported by [P4], it was observed that most of the wastes are captured and reduced using the lean practice VSM. VSM was implemented in the large-scale sectors with current state map of their projects, and was able to capture different wastes. Due to lack of concrete research or literature available in VSM practice, some of the studies have not performed further extension.

Another lean practice Kanban was also a mostly discussed and popular practice that has gained more attention in the state of art. Kanban "Pull" also captures the wastes from the software development process and this practice has received more attention in research. Remaining lean practices as Kotter and Kaizen have very less attention on capturing wastes and are not much popular in research. Lean Six Sigma is another practice that avoids waste, reduces environmental impacts and can increase product lifespan. However, the practices like lean six sigma, Jidoka, visual mapping are less concentrated, and they are used in the manufacturing domain.

The seven kinds of wastes were only focused in one primary study and remaining studies have only focused on the practices and wastes captured by using the lean practices. Table 13 shows different kinds of wastes that are captured with different lean practices. Wastes that are captured by theses practices are at managerial level, environmental level, and testing phases. Based on the project environment and organizational setting, i.e. according to the project, VSM has been used with the current state map and captures different wastes. The wastes reduction is also performed by some of the experience reports.

Secondly, the study has focused on the hybrid lean and agile practices that are capable of capturing wastes. Lean software development system is aligned with many agile principles. Lean principles are almost similar to the agile principle that focuses on eliminating wastes, customer satisfaction and deliver fast. However, when it comes to the practice level, different practices capture different wastes. Some of the studies have not focused on the practices that they were using, but have focused on the lean and agile principles. Agile and lean combination is been used according to the unique stetting of the specific organization. Practices like Scrum and VSM are used in some of the organizations and in state of the art. On the other hand, practices like Scrum and Kanban are also used in some experience reports. When these practices are used in the organizations, it can be observed that most of the organizations have captured different wastes.

Lean can be used as troubleshoot for Scrum by making the efficient flow and in capturing wastes. In some of the organizations, lean principles and agile principles are used individually according to the specific need of the organization. Most of the literature says that agile and lean are same, but they are implemented according to the specific setting of an organization. Some studies have claimed that agile practices are also capable of capturing wastes from the software development process [P44][P42][P39].

Agile practices are used for specific organizational setting to speed up the process flow. From the experience reports and surveys, it can be said that Scrum and XP are mostly focused and used by the organizations. These practices can capture wastes from the software development process, but are not much related to the wastes that are in lean. When it comes to the wastes captured using agile practices, some studies have mentioned them as defects. When the agile and lean practices are combined, wastes like motion, waiting, and extra process can be captured. Defects are mostly found and reduced by the agile practices like Scrum and XP. It can be observed that the usage of Scrum and XP is more than the usage of other agile practices like Crystal Clear. By this, we can understand that, agile practices can also capture wastes but they are represented as defects and very few defects like waiting time, extra process can be captured.

4.9.2 What is missing in the literature

Overall, researchers need to specify the practices that they are using for capturing the wastes and some of the authors have mentioned that agile and lean principles are similar in eliminating wastes without describing the practices that they have used.

- Some of the research needs further information on practices. Where the experience reports are concerned, they are implemented in the industry with respective project aspects and organizational structure. Many experience reports have observed that in implementing lean in organizations, it takes some time for it to be adopted by the team and organization as well. Researchers need to concentrate on the adoption and how to adopt the lean practices in software industry. Guidelines and recommendations for adopting the lean practices need to be identified focusing on each lean practice, and how effectively can they be adopted and implemented in software industry.

- It can also be observed that researchers still need to validate and identify specific lean practices and for their efficiency. On the other hand, regarding the implementation of the combinations of lean and agile practices, none of the studies have discussed regarding the effort and cost that is needed to implement the combination practices in industry.

This study has identified different lean practices and the wastes that are captured by these lean practices (Table 12), which have more attention in state of art. By performing a literature review, the results have to be validated and generalized. For validating and identifying the lean practices and wastes, this study intends to perform a survey in the software industries. By performing the survey, this research can identify which lean practices are capable of capturing which wastes, the usage of lean practices, limitations while implementing lean practices and benefits of lean practices in software industry.

4.10 SLR validity threats

While performing the systematic literature review, it is very important to overcome the risks and specify the mitigations for extracting and summarizing the data. Firstly, it is important to have a dynamic search string for acquiring primary studies. Irrelevant studies may be acquired along with the studies that are not having quality. To mitigate the risks, an inclusion and exclusion criteria was formulated in the Section 4.4. Lean concepts are involved in manufacturing, health care, and life sciences, so there is a chance of acquiring some studies in these domains. This risk is mitigated by framing appropriate search string, including the software development keyword and excluding the studies on manufacturing.

Another risk that may occur is regarding the quality of primary studies. The results might have acquired some studies that do not have proper validations and have not following a systematic methodology. To mitigate this type of risk, quality assessment criteria was defined, which will evaluate the quality of selected studies, which is detailed in the Section 4.5. Here it was observed that, some of the primary studies are not having validations, but the studies are very relevant, so the data that is very relevant to this study irrespective of validations was also extracted.

In the process of search string formulation and search process, the results might miss some of the relevant studies on lean and lean practices. To overcome this, snowballing was performed, which will target the references of selected studies and extract the data from those reference studies. The reason behind this is, the studies that are already mentioned and referred, might have the chance of quality and it is the easy process for acquiring primary studies.

In this study, the focus was on three aspects, to where SLR is concerned. In the first aspect, relevant and direct studies focusing on lean and wastes were obtained. The studies on agile and wastes are also direct and they are selected by following the quality criteria and inclusion and exclusion process. However, for the third aspect, hybrid lean and agile, the studies were focusing on both agile and lean practices in capturing wastes. Therefore, these studies were considered for both agile practices capturing wastes and lean practices capturing wastes. The reason for considering these studies for all the three aspects is that there will be a chance of obtaining more data on three aspects and this study might not miss some practices in data extraction.

In the data extraction process, as the research is performed by one author, the primary studies are selected with the help of expert researcher. The data was extracted according to the data extraction strategy that was described in the Section 4.6. The author has selected the studies according to the title, abstract, and conclusion. Some of the studies have different titles, which are not related, or focusing only one aspect in their study, those studies are also reviewed completely. Most of the studies are selected according to title, abstract, and conclusion. Experience reports are given high priority as the primary research method is performing the industrial survey, which is close to experience reports. If the title is relevant and the abstract was not relevant, then the complete review is performed. If the author was not able to decide whether to consider the study or not, then the study was completely reviewed and the points were discussed with the expert researcher. If the expert was satisfied by the information, then the study was considered.

Finally concluding and summarizing the results of this SLR, there is a chance of missing some information and the results might not address some of the primary studies in this document. Therefore, the author has taken a decision to create an Excel sheet and address each primary study at each phase by different numbers. At each reference, the number that was given in the Excel sheet was mentioned. After all the data was extracted and summarized, then the author has addressed them with proper references. For constructing the references, the author has used Mendeley and Zotero with IEEE format.

5 INDUSTRIAL SURVEY

The survey was performed by considering the four lean practices, agile practices and seven wastes that are identified from SLR. There are more than four lean practices identified in SLR, but the practices that are very popular and core to the software development were considered for this survey. However, this study focuses on the major software lean practices that are more popular. Moreover, the study [3] has mentioned some more practices, which are at abstraction level, and some are part of high-level lean practices. This study has considered high level and popular lean practices. Even though, considering the abstraction levels may not allow completion of the survey, as the responses for so many questions may not be an efficient survey.

5.1 Objective

The objective of the survey is to (1) evaluate the spread of usage of the lean practices, (2) evaluate the ability of lean and agile practices to eliminate wastes based on the perception of practitioners from their work experience; (3) capture the quality benefits and disadvantages of lean and agile practices. This information provides the answers to RQ4-RQ7.

5.2 Data collection

There are different approaches to collect the data from respondents. They include personal surveys, phone surveys, mail, and electronic surveys [54]. The author has chosen the electronic surveys by developing a questionnaire and posting the questionnaire in social networks in related groups on lean and agile development. The networks comprise of a wide range of practitioners working with agile practices. The reason for selecting an electronic survey is to collect the data from a wide range of respondents, e.g. with respect to company characteristics and countries. The strategy of posting on social networks is reflecting a convenience sampling strategy. Provided, Google docs is used for data collection. Google docs are very comfortable and they provide free account for developing and posting the survey.

Interviews are also an appropriate method for collecting the data. However, interviews are not most suitable for this research. The main reason is (a) to have a wider reach, and (b) that the results have a set of studies with qualitative information from case studies, though little information of a larger sample and range of companies is missing. The reason behind this is that the author has distributed the survey globally, and asked the respondents from different countries through out globe. This is not possible while performing interviews. Interviews are restricted to less quantity. However, online survey was selected because they are suitable for large number of respondents, consumes less time and preparation time, very confidential, optional to provide the personal information, easy to analyze, and manages data. Therefore, online survey was selected for collecting the data. Survey provider will automatically classify the feedback from respondents and provide clear results that are answered by different respondents.

5.3 Planning and executing the Survey

In order to perform the survey, the following steps were followed that are shown in Figure 9. This includes planning, designing and executing the survey.

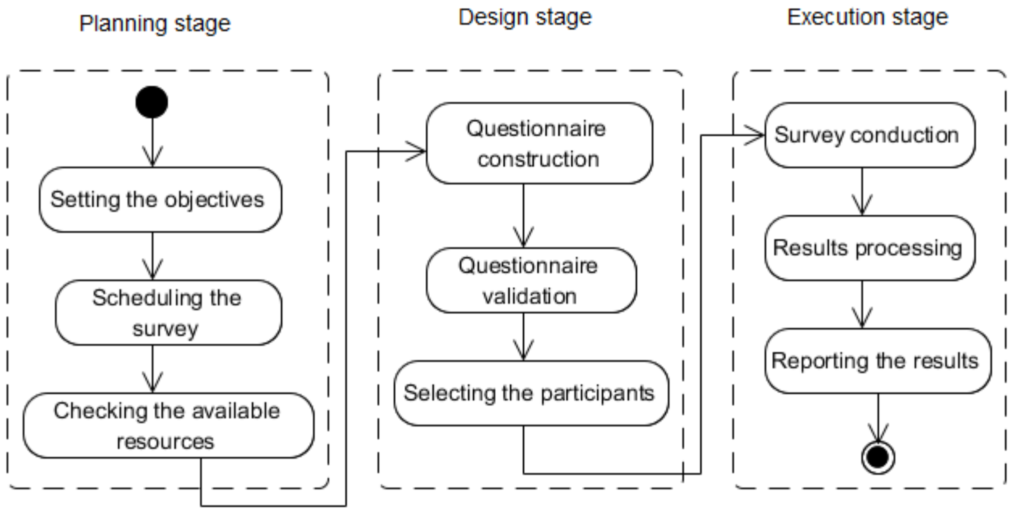

Figure 9 Survey Design and Conduction process

5.3.1 Scheduling the survey

According to the data that is identified through SLR, the author has estimated a minimum of two weeks to provide the survey link online. After two weeks, the survey link was not available anymore to collect further answers due to time constraints in the project. However, some respondents indicated an interest in answering the survey, so the link for the survey was provided for another couple of days.

5.3.2 Checking the available resources

For posting the survey and making it available to be answered by all the respondents who are most familiar with Lean practices, agile practices and wastes, the following social networking sites were selected.

- LinkedIn
- Google groups
- Yahoo Forums
- Twitter

In these social networks, many resources were searched where appropriate and genuine answers could be obtained. The author has decided to search for the following

- Lean Groups
- Agile Groups
- Leagile groups
- Kanban Groups
- Kotter Groups
- VSM Groups
- Scrum Groups and XP.

The groups were selected because many practitioners with relevant experience for this study are members in these groups, and large quantity of data can be obtained.

5.3.3 Questionnaire development

The questionnaire consists of two parts. The first part contains general information about the respondents' country, roles in the industry, experience, and sector in which the respondent is currently working. Furthermore, team size and the size of the organization have been captured. The second part of the questionnaire contains the questions about lean practices, agile practices, and wastes that are captured by the lean and practices. The author has also asked for the level of agreement and the level of usage of each lean practices in capturing wastes. The detailed survey questionnaire can be found in Appendix B.

In the second stage, more information was added to the questions and open-ended questions were asked. There are two types of questions, open ended and close ended [55]. In the open-ended questions, the respondents can provide their own answers in the form of text or in the form of numbers, i.e. a text box is provided to type their own opinion or remarks. In the close ended questions the respondents need to choose among the available variants of answers, i.e. some set of answers are provided as options and the respondent can select one or two options from the list provided. The questionnaire includes both types of questions. The close-ended questions are used for the lean and agile practices by providing the wastes to select the level of agreement in mitigating wastes. The level of agreement was given by following a X-point likart scale. In the open-ended questions, a text box is provided to answer the benefits and limitations of the lean practices. At the end of the survey form, the author has asked the respondents to provide their Email address or a contact to deliver the results after the survey has been completed.

5.3.4 Questionnaire validation

It is an important task to validate the questionnaire before posting the survey. If the respondents are not able to answer or understand the survey, genuine anwers cannot be acquired. Three iterations were chosen in order to validate the survey. The questionnaire reliability can be estimated in different ways; a test-retest method was chosen; wherein testing the questionnaire in the form of iterations would be performed [56][57]. The iterations that were followed for testing the questionnaire are shown in the Table 16.

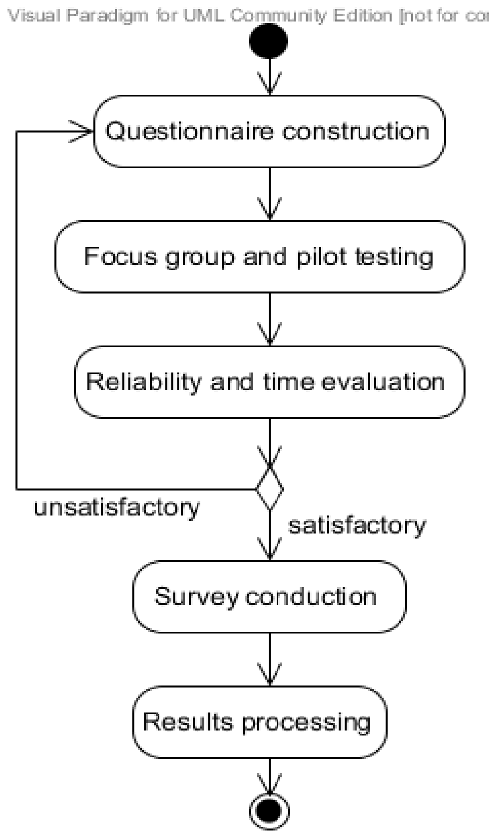

Figure 10 Questionnaire validation process

The iteration process includes understandability of the questions, number of questions; time to complete the questionnaire and finally reliability. When the first questionnaire was developed, known participants and an expert researcher were asked to evaluate the questionnaire according to the process mentioned.

Table 16 Survey questionnaire validation

Criteria	**Step 1**	**Step 2**	**Step 3**
Number of questions	36	23	19
Questions Understandability	There are 8 questions that are not understandable because there are number of questions that are separated for every aspect. The way of asking questions	4 questions are not understandable, because the level of agreement asked specific to each lean practice and waste, which is a bit confusing.	All the questions are understandable because the terminology was changed and questions were reduced and some questions made into one or two.
Time to complete	18 min	14 minuets	10 minuets

Initially, 36 questions were framed. Separate questions are framed for each lean practices and each waste. This is time consuming and the practitioner may run out of interest to answer the questions. In the second iteration, the author has framed the questions to level of agreement for each practice with respect to waste. For the third iteration, the questions were reduced to 19. In this step, all the aspects were considered, which can make the respondents to feel comfortable, and have them interested in answering the questionnaire. From the 19 questions, five questions should be answered completely and the remaining is optional. The questions, which are optional, are the experience on agile methods, usage on agile methods, the frequency of usage and waste capturing on the lean practices. The reason for making the usage of lean practices optional is that the practitioners may not use all the practices, so that the practitioners can select the practices, from the questioners and mark their usage.

5.3.5 Selecting the participants

Prior to posting the survey and making it available to the respondents, it is very important to make sure that the respondents are most relevant to this research. According to Kitchenham and Pfleeger [58], a valid sample is a representative subset of the targeted population. In the perspective of this research, the targeted populations are the software employees, lean coaches, who are working and training on the lean concepts and practicing lean in real time. The sampling methods that are mentioned in [58] are the probabilistic and non-probabilistic methods. A probabilistic sample is the one in which every member in the targeted population are known and non-zero probability of being included in the sample [58]. The second type of sampling is non-probabilistic sampling, in which the respondents are chosen because they are easily accessible or the researches have some justification for believing that they are representative of the population [58].

In this case, the author has chosen the non-probabilistic sampling as specific population was targeted. The author has considered convenient sampling, which obtains responses from the people, who are willing to take part in this survey. In the section checking the available resources, some specific groups were chosen, which are most relevant to lean practices and agile practices for posting the survey. The reason for posting the survey in those groups is that, the selected groups have high number of potentially relevant respondents having the expertise to answer the survey.

5.4 Survey Results

5.4.1 Overview of Participants

The author has reviewed the answers of 60 respondents. Only 55 persons completed the survey. Therefore, the completion rate of the survey is 92%, which is high enough to consider the results of the survey. This is the evidence of the high quality of this questionnaire, as a high number of respondents have completed it. The participants of the survey are the employees of the software development companies. All of those participants, who completed the survey, gave consistent answers to all questions.

The participants mentioned the country where they are from (Figure 11). The respondents from 12 countries took part in the survey. Most of the respondents are from India (42%); other countries have fewer representatives – Brazil and Sweden (11%), Canada (9%).

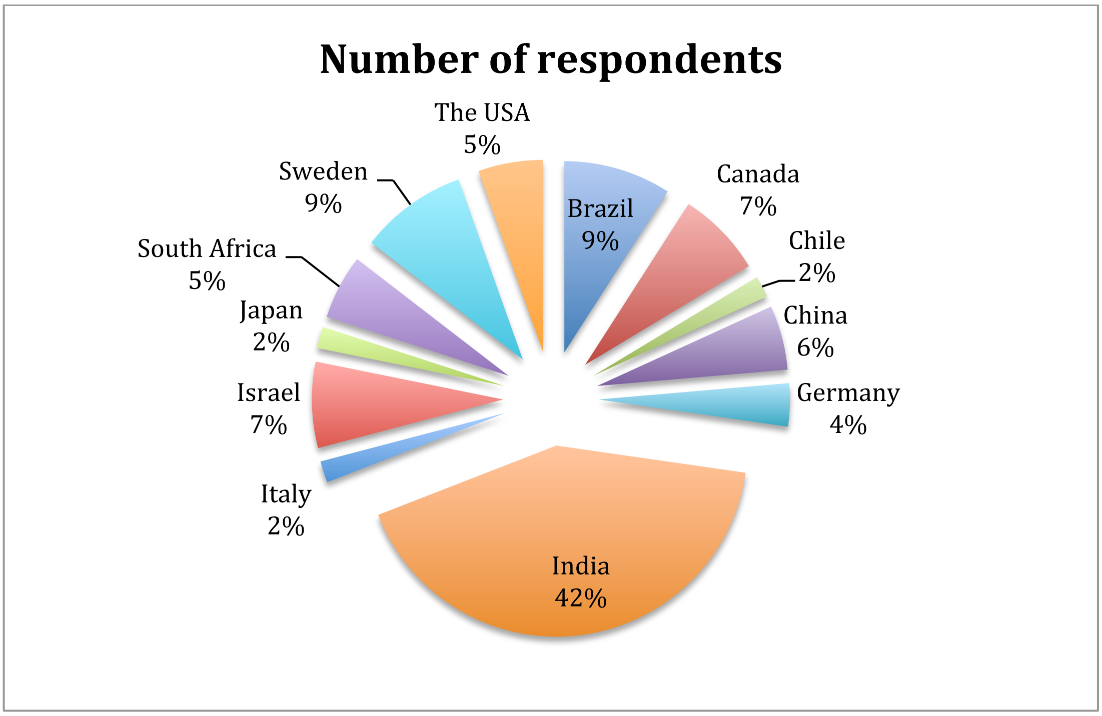

Figure 11 Occurrence of respondents globally

The author has targeted employees who occupy different roles in their companies. The distribution of the roles is shown on Figure. 12. Under the "Other" option, the respondents mentioned business development manager and design engineer. The majority of the respondents were project managers (29%) and team leaders (34%). Exactly these people are responsible for introduction of new practices and methods to the development project. Therefore, it can be said that the participants of the survey are familiar with the topic of the survey.

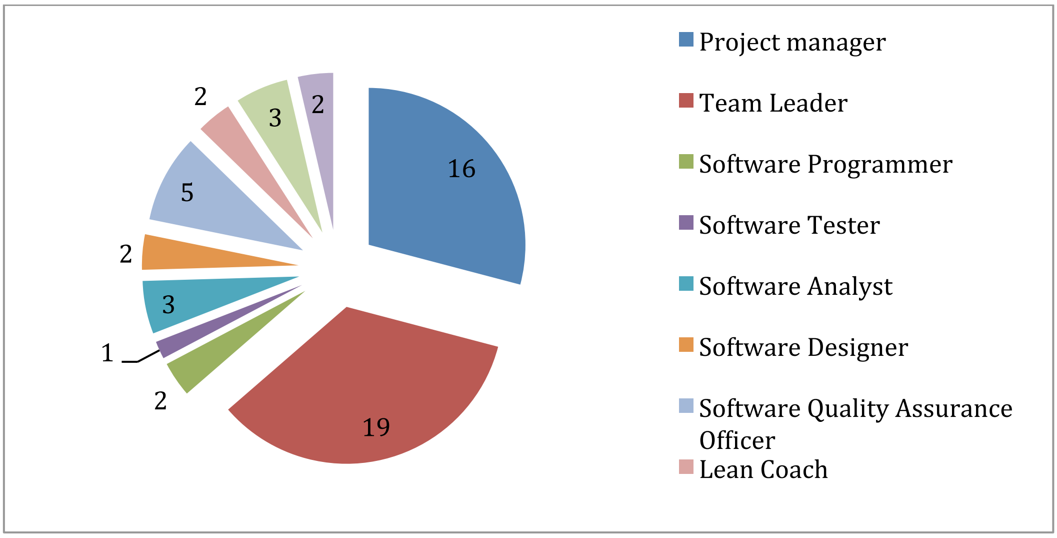

Figure 12 Respondents roles

The author has asked respondents about the size of their teams (Figure 13). It was found that lean practices are used in medium (10-20 people) and large- scale (more than 20 people) teams. Fifty-one respondents (93%) defined their current teams as small, medium and large.

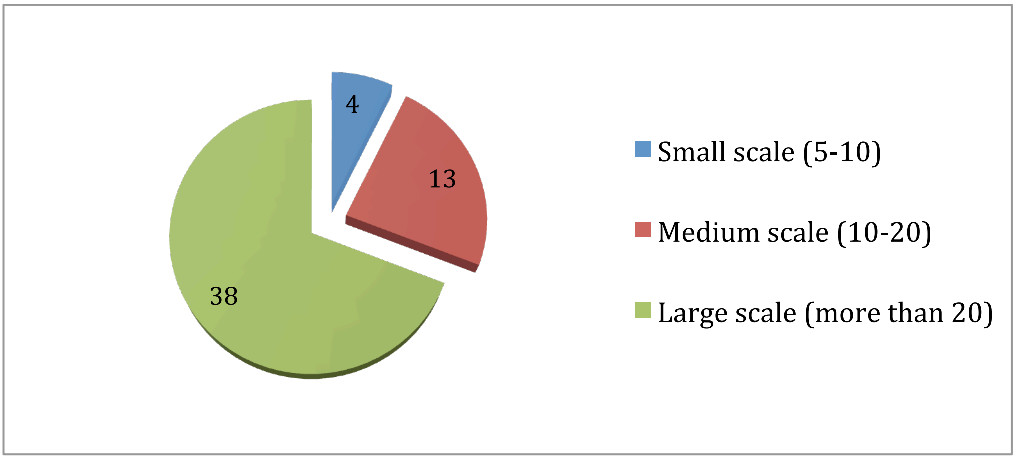

Figure 13 Team Size

Another important factor in this research is the experience in software industry. The number of years in industrial or the software development projects is shown on Figure 14. It can be observed that 39 persons (71%) have been working in software engineering domain for more than 5 years. This ensures the quality of the results of the survey.

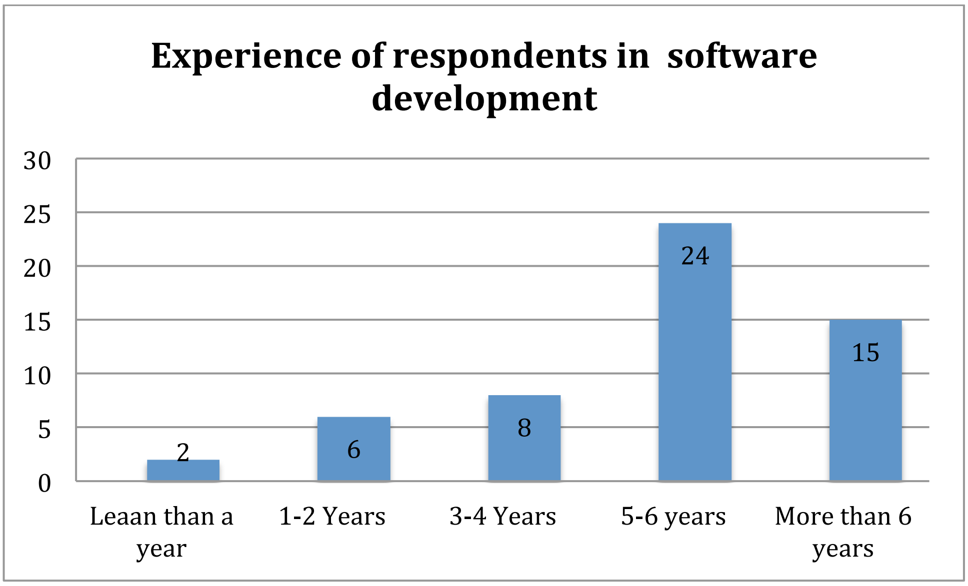

Figure 14 Occurrence of working experience in industry

The work experience of our respondents in software industry is calculated statistically in minimum years of experience, maximum years of experience, mean, and standard deviation (Table 17).

Table 17 Statistical representation of working experience in industry

Minimum	Maximum	Mean	Standard Deviation
2	24	11	8.66

The experience in lean practices usage is even more important for this research, since reliable information is required about their effectiveness in wastes capturing, benefits and limitations. The number of years in lean software development projects is shown on Figure 15. Forty-one practitioners mentioned their experience in lean software projects to be from 3 to 6 years. Generally, it can be concluded that 43 respondents (78%) have more than 2 years of work experience with lean practices, which allows capturing insights on benefits and limitations.

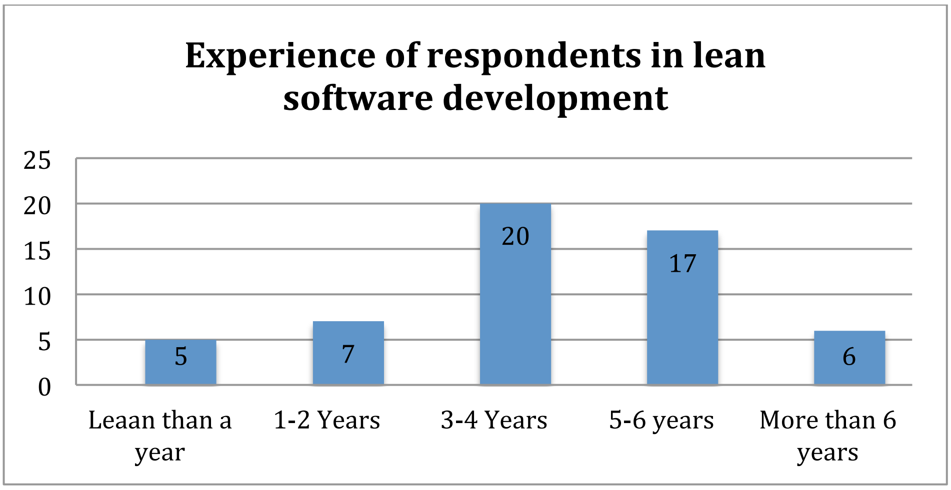

Figure 15 Occurrence of working experience in Lean software development

For the statistical calculation of the respondents, who have minimum number of experience and maximum years of experience in lean software development with mean and standard deviation is shown in the Table 18 below.

Table 18 Statistical representation of working experience in lean software development

Minimum	Maximum	Mean	Standard Deviation
5	20	11	6.96

The research is intended not only towards lean practices, but also in agile methods, especially their combination with lean. The number of years of work with agile methods is shown on Figure 16. Most of the respondents have been working with Agile methodologies for 3-4 years (25 people – 45%). 43 persons (78%) have more than 2 years of experience in agile software development. So the respondents are experienced enough in both lean and agile, which influences positively the results of the survey.

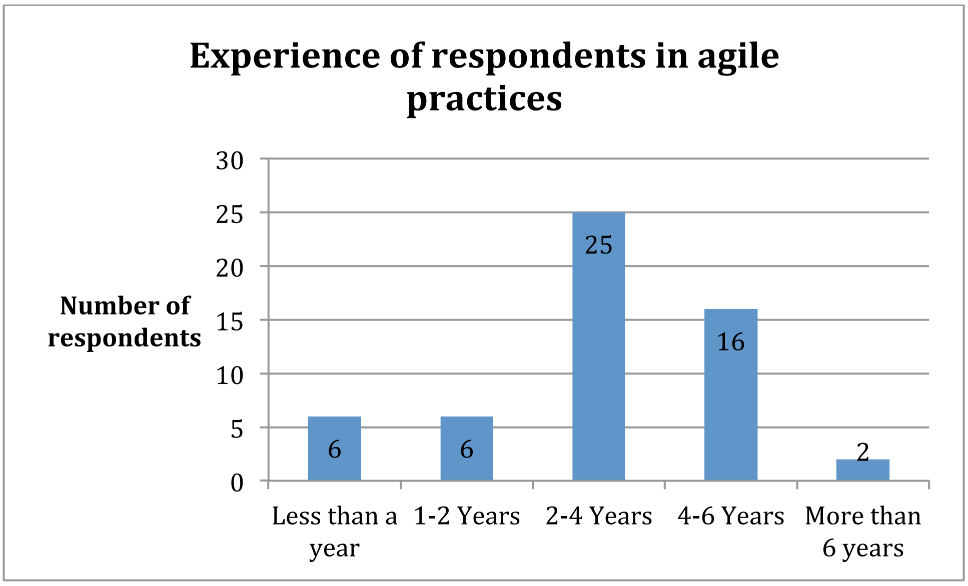

Figure 16 Occurrence of working experience with agile practices

The experience of respondents who are working for agile software development was also considered. The minimum and maximum years of experience of respondents are calculated with mean and standard deviation. In all the experience aspects, the given value is the number of respondents. In the Table 19 below, two respondents are have answered they have minimum experience and 25 respondents have answered they have maximum experience.

Table 19 Statistical representation of experience of the respondents

Minimum	Maximum	Mean	Standard Deviation
2	25	11	9.38

Finally, the questionnaire has asked for the domain of application of lean and agile methods. The respondents were asked to mention software product type (Figure 17). The biggest part of answers refer to business oriented (28%), customer-oriented software (15%), and mobile applications (20%). Generally, the respondents work on various projects: starting from embedded systems and finishing with aerospace applications. Therefore, it can be said that lean and agile practices are widespread in the software development companies and their application can be found in very different domains.

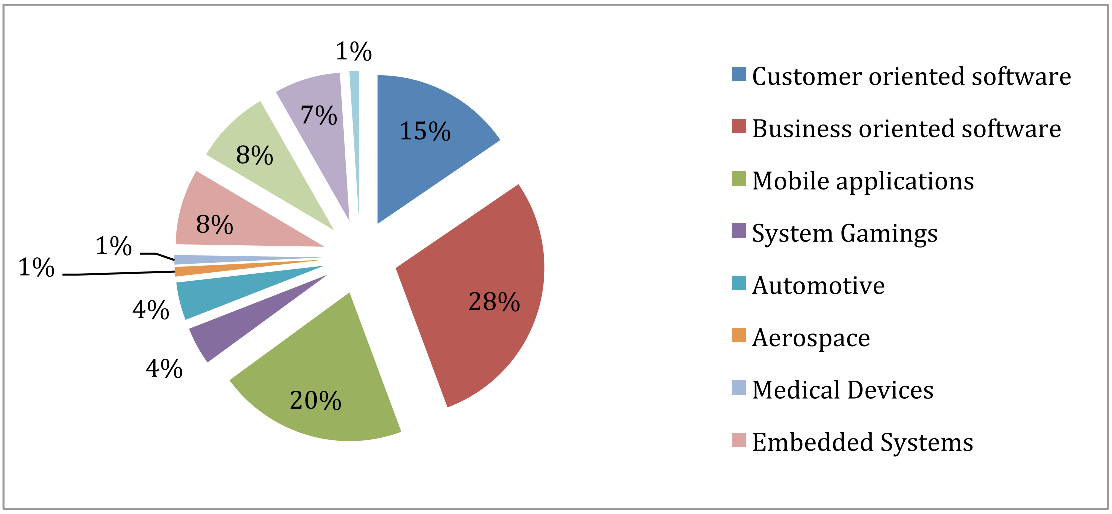

Figure 17 Distribution of industrial sectors among respondents

5.4.2 Frequency of usage of different lean and agile practices in industry

The rest of the questions from the questionnaire are devoted directly to lean and agile practices, their effectiveness in wastes capturing and their benefits and limitations of implementation.

Having various options to choose from, the participants specified the most commonly used lean practices in software projects. The results are presented in Figure 18. The most widely used practices are Kanban and VSM. Under "Other" option, respondents mentioned Jidoku, Lean Six Sigma and Visual management.

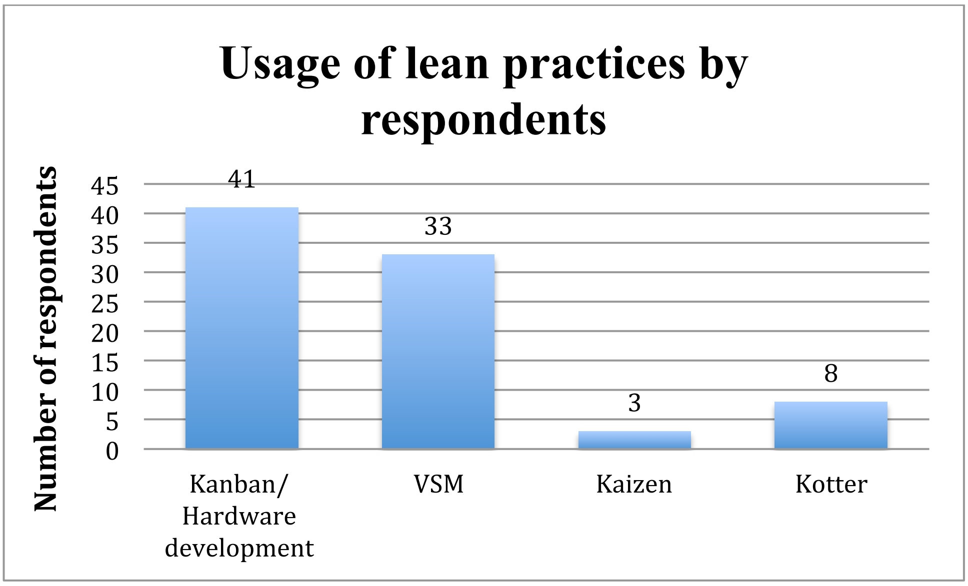

Figure 18 Usage of lean practices by respondents

Table 20 Statistical representation of usage of lean practices by respondents

Minimum	Maximum	Mean	Standard deviation
3	41	13.75	18.31

The respondents were asked to address the similar question concerning agile practices (Figure 19). Most of the participants (69%) use SCRUM methodology in their everyday work. The second place is occupied by XP (18%).

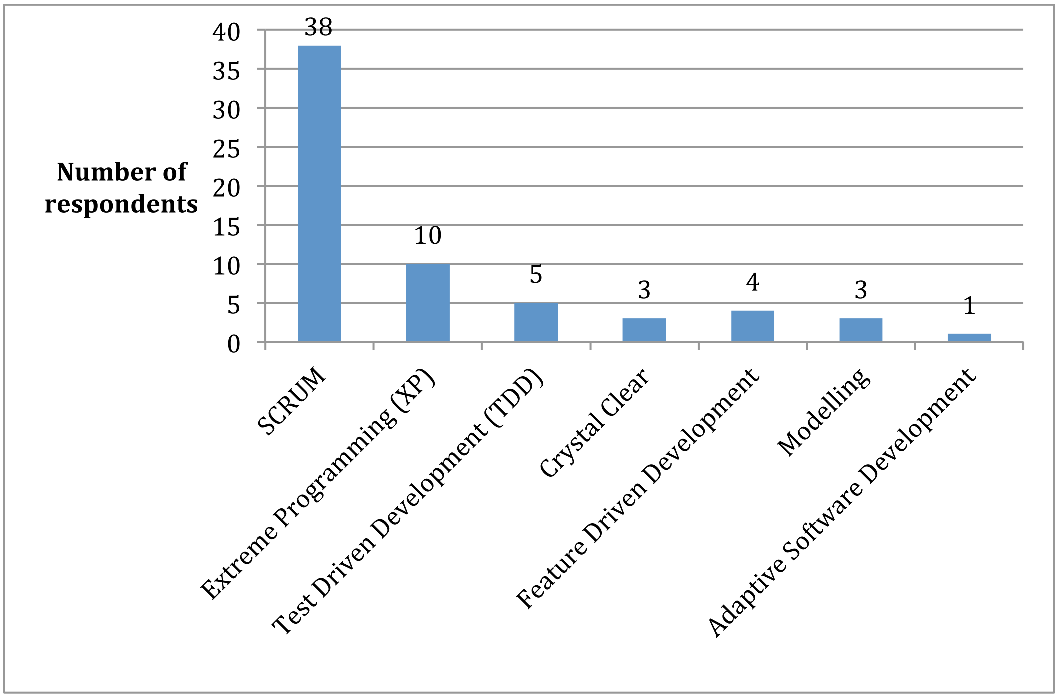

Figure 19 Usage of Agile practices by respondents

The frequency of usage of lean practices allows making conclusions about their importance and significance for practitioners (Table 21). It could be seen that Kanban and VSM are the most widespread in practical applications. The table shows the dark shade for the high values of respondents. The Kanban has highest value at always using the practice. VSM is highest at very frequently using the practices, Kaizen is at very rare, and Kotter is highest at never.

Table 21 Frequency of lean practices usage

Practices	Always	Very frequently	Occasionally	Rarely	Very rarely	Never
Kanban	33	11	6	2	3	0
VSM	12	27	8	3	0	5
Kaizen	6	1	8	8	19	13
Kotter	3	3	9	2	8	28

5.4.3 Effectiveness of lean practices in capturing wastes

To find out which wastes are mostly captured by particular practice the respondents were asked to give their perspective on each practice in capturing wastes. The respondent's perspective can be seen in the level of agreement for each practice. Here, the strongest suits of each practice with respect to seven wastes can be seen in the form of heat maps. i.e. the strongest agreement is seen in the dark color and the lowest agreement is seen in the light color in Table 22.

Table 22 Agreement of effectiveness of wastes according to Kanban practice

Approach	Waste	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
Kanban	Partially done work	36	8	6	3	2
	Extra processes	34	16	3	2	0
	Extra features	22	16	11	3	3
	Task switching	8	25	12	5	5
	Waiting	14	21	14	3	3
	Motion	19	11	22	3	0
	Defects	5	22	16	12	0

Kanban practice is most effective in eliminating partially done work, extra process, task switching, motion, and defects. The results for VSM are given in Table 23. As it is expressed by the participants, VSM practice has a positive impact on elimination of partially done work, extra process, extra features, task switching and waiting.

Table 23 Agreement of effectiveness of wastes according to VSM practice

Approach	Waste	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
VSM	Partially done work	30	14	5	3	3
	Extra processes	27	20	8	0	0
	Extra features	25	19	11	0	0
	Task switching	22	16	12	3	2
	Waiting	22	16	11	3	3
	Motion	20	13	17	5	0
	Defects	8	17	16	14	0

The ability to capture wastes by Kotter practice is shown in Table 24. Kotter lean practice approves itself in eliminating extra process and extra features strongly. In addition, it is good in task switching and defects capturing. Very less number of respondents has agreed strongly for the wastes extra process, task switching, waiting, and defects. Here, high numbers of respondents are undecided where the wastes cannot be decided, whether they can be eliminated using Kotter. From the perception of eleven practitioners, they strongly disagree that Kotter will eliminate partially done work.

Table 24 Level of agreement with wastes captured by Kotter

Approach	Waste	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
Kotter	Partially done work	12	5	14	13	11
	Extra processes	16	6	19	9	5
	Extra features	0	17	20	10	8
	Task switching	0	21	11	14	9
	Waiting	3	8	25	11	8
	Motion	3	5	22	16	9
	Defects	0	19	11	19	6

Kaizen practice eliminates wastes in different manner (Table 25). It can be seen that mostly, respondents specified partially done work and extra process as the wastes that can be effectively captured by Kaizen practice. From the perception of practitioners' elimination of wastes with Kaizen practice is undecided.

Table 25 Level of agreement of wastes captured by Kaizen practice

Approach	Waste	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
Kaizen	Partially done work	22	12	14	5	2
	Extra processes	20	16	14	5	0
	Extra features	9	9	31	6	0
	Task switching	5	9	27	14	0
	Waiting	11	5	35	3	1
	Motion	9	5	19	20	2
	Defects	14	5	25	6	5

The most widespread agile methods according to SLR are SCRUM and XP. Therefore, the respondents were asked to determine their effectiveness in wastes capturing. The results for SCRUM are given in Table 21. SCRUM is effective in capturing such wastes as partial done work, extra process, extra features, and motion elimination.

Table 26 Level of agreement of wastes captured by Scrum practice

Approach	Waste	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
Scrum	Partially done work	36	11	3	3	2
	Extra processes	28	14	7	3	3
	Extra features	24	16	6	6	3
	Task switching	19	21	6	6	3
	Waiting	16	20	9	5	5
	Motion	22	11	13	6	3
	Defects	14	24	8	6	3

Extreme programming is less popular according to the survey results. However, the respondents are familiar with this methodology and expressed their understanding of wastes capturing by XP (Table 27). From the perspective of the respondents, XP technique is effective in elimination of extra process and extra features, and in task switching capturing.

Table 27 Level of agreement of wastes captured by XP

Approach	Waste	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
XP	Partially done work	11	13	16	6	9
	Extra processes	5	24	14	5	7
	Extra features	5	24	22	0	4
	Task switching	5	20	16	5	9
	Waiting	13	13	19	0	10
	Motion	6	19	19	6	5
	Defects	17	19	16	0	3

5.4.4 Analysis of each lean practices in relation to waste

Here, the analysis in relation to each waste i.e. which technique is best for removing which waste can be seen. The high number of agreement level is shown in dark color and the low number agreement is shown in light color. This analysis helps the practitioners to choose the practice for eliminating the wastes. The overall analysis is presented in the Table 28.

Table 28 wastes with respect to practices

Waste	Approach	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
Partially done work	Kanban	36	8	6	3	2
	VSM	30	14	5	3	3
	Kotter	12	5	14	13	11
	Kaizen	22	12	14	5	2
	Scrum	36	11	3	3	2

	XP	11	13	16	6	9
Extra processes	Kanban	34	16	3	2	0
	VSM	27	20	8	0	0
	Kotter	16	6	19	9	5
	Kaizen	20	16	14	5	0
	Scrum	28	14	7	3	3
	XP	5	24	14	5	7
Extra features	Kanban	22	16	11	3	3
	VSM	25	19	11	0	0
	Kotter	0	17	20	10	8
	Kaizen	9	9	31	6	0
	Scrum	24	16	6	6	3
	XP	5	24	22	0	4
Task switching	Kanban	8	25	12	5	5
	VSM	22	16	12	3	2
	Kotter	0	21	11	14	9
	Kaizen	5	9	27	14	0
	Scrum	19	21	6	6	3
	XP	5	20	16	5	9
Waiting	Kanban	14	21	14	3	3
	VSM	22	16	11	3	3
	Kotter	3	8	25	11	8
	Kaizen	11	5	35	3	1
	Scrum	16	20	9	5	5
	XP	13	13	19	0	10
Motion	Kanban	19	11	22	3	0
	VSM	20	13	17	5	0
	Kotter	3	5	22	16	9
	Kaizen	9	5	19	20	2
	Scrum	22	11	13	6	3
	XP	6	19	19	6	5
Defects	Kanban	5	22	16	12	0
	VSM	8	17	16	14	0
	Kotter	0	19	11	19	6
	Kaizen	14	5	25	6	5
	Scrum	14	24	8	6	3
	XP	17	19	16	0	3

5.4.5 Analysis of hybrid lean and agile practices

With respect to the perspective of the respondents, agile and Kanban are mostly used as the hybrid practices for capturing wastes in their organizations. Most of the respondents have answered that they use Kanban practices mostly in their organizations. Where the agile practices are concerned, Scrum practice is the answered as the mostly used practice in the organizations. From our analysis, most of the organizations use Kanban and Scrum practices as a hybrid practice to eliminate wastes. The below figure 27 shows the average usage of hybrid agile and lean practices in organizations.

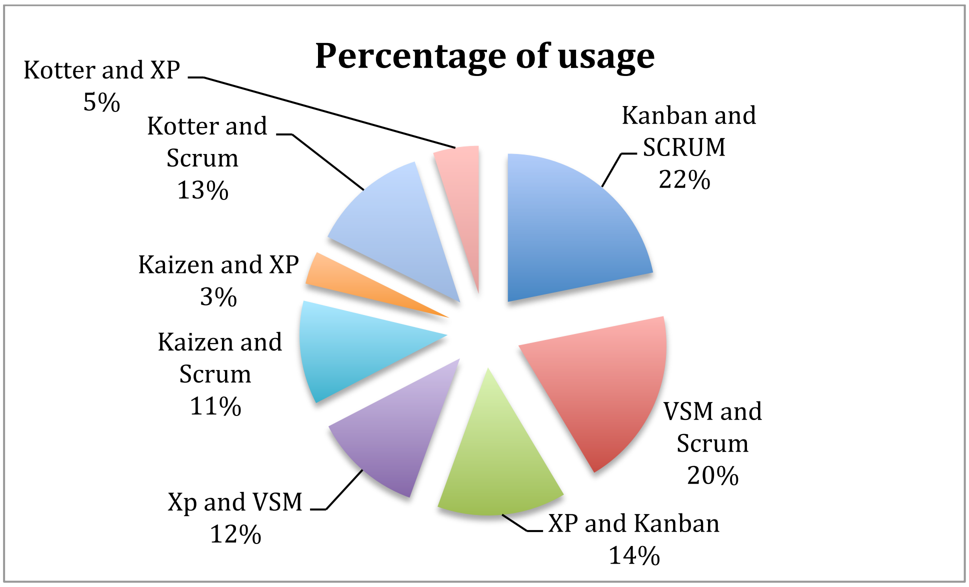

Figure 20 Usage of hybrid agile and lean practices

5.4.6 Analysis in efficiency of Lean practices according to wastes

The total effectiveness of each practice is considered based on the strong agreement of practitioner. There are seven wastes and four practices in our study. To calculate the effectiveness of each practice, the average of very strong, undecided and strongly disagree, agreement of each lean practices upon wastes was considered. The ranking of the efficiency and fault content of each lean practices in shown below.

The mean rank is shown for the three agreements below. The output of Friedman test is shown below as Test Statistics. In the test statistics, the Chi-square, degree of freedom and significance level that show the Null Hypothesis were calculated.

The hypothesis is tested below as T-test.

Null Hypothesis H0: $\mu 1 = \mu 2$

Alternative Hypothesis H1: $\mu 1 \neq \mu 2$

The effectiveness of each lean practices is shown in the form of Mean value. Frideman test consists of the number of respondents (N), Chi-square value 0.0007 and degree of freedom is number of variable subtracted by 1.
The chi-square formula is given below. The mean ranks for each practices indicates how the practices are differed. However, the median value for each waste with respect to each practice was mostly considered. In the statistical tests provided below, the overall statistical

significant difference between the mean ranks of each waste with respect to practices can be seen. It is very important to note that the Friedman test shows the overall differences, but does not point out which practices particularly differ from each other. The over all test statistics with mean values, median, standard deviation are shown in the tables for each waste in Appendix B.

$$X^2 = \Sigma \frac{(Observed\ values - expected\ values)^2}{Expected\ values}$$

All the respondents are asked to rate the lean practices in capturing the seven wastes. The agreement levels are, strongly agree (5), agree (4), undecided (3), disagree (2), and strongly disagree (1). Based on the five agreement levels, the statistical test was performed for the seven wastes in order to rank the practices in eliminating wastes. The output of Friedman test is shown below. The mean ranks and test statistics for all the practices with respect to all the wastes are shown below.

5.4.6.1 Test Statistics for the efficiency of waste partially done work

The statistical test for the waste partially done work is show in the Table 29. The Chi-square test, mean, standard deviation with assumption significant is show by calculation the Frideman test. The mean rank for each practices has been calculated, Kanban has the mean rank of 2.90, VSM at 3.60, Kotter at 3.90, Kaizen at 3.50, Scrum at 2.70 and XP at 4.40. The test was performed to know the variance between each practice with respect to the waste partially done work.

Table 29 Statistical analysis of the waste partially done work

Practices	Chi-Square	Df	Mean	Standard deviation	Assumption significant
Kanban	3.000	5	11.0000	14.17745	.700
VSM	3.000	5	11.0000	11.55422	.700
Kotter	3.000	5	11.0000	3.53553	.700
Kaizen	3.000	5	11.0000	7.87401	.700
Scrum	3.000	5	11.0000	14.43953	.700
XP	3.000	5	11.0000	3.80789	.700

5.4.6.2 Test Statistics for the waste Extra Features

The statistical test for the waste extra features is show in the Table 30. The Chi-square test, mean, standard deviation with assumption significant is show by calculation the Frideman test. The mean rank for each practices has been calculated, Kanban has the mean rank of 3.10, VSM at 3.30, Kotter at 4.20, Kaizen at 3.20, Scrum at 3.30 and XP at 3.90. The test was performed to know the variance between each practice with respect to the waste extra features.

Table 30 Statistical analysis of the waste Extra features

Practices	Chi-Square	Df	Mean	Standard deviation	Assumption significant
Kanban	1.450	5	11.0000	8.27647	.919
VSM	1.450	5	11.0000	11.20268	.919
Kotter	1.450	5	11.0000	7.87401	.919
Kaizen	1.450	5	11.0000	11.76860	.919
Scrum	1.450	5	11.0000	8.77496	.919
XP	1.450	5	11.0000	11.13553	.919

5.4.6.3 Test statistics for the waste Extra Process

The statistical test for the waste extra process is show in the Table 31. The Chi-square test, mean, standard deviation with assumption significant is show by calculation the Frideman test. The mean rank for each practices has been calculated, Kanban has the mean rank of 2.90, VSM at 3.00, Kotter at 4.00, Kaizen at 3.50, Scrum at 3.20 and XP at 4.40. The test was performed to know the variance between each practice with respect to the waste extra process.

Table 31 Statistical analysis of the waste extra process

Practices	Chi-Square	Df	Mean	Standard deviation	Assumption significant
Kanban	2.619	5	11.0000	14.31782	.758
VSM	2.619	5	11.0000	12.12436	.758
Kotter	2.619	5	11.0000	6.20484	.758
Kaizen	2.619	5	11.0000	8.24621	.758
Scrum	2.619	5	11.0000	10.51190	.758
XP	2.619	5	11.0000	8.15475	.758

5.4.6.4 Test Statistics for the waste Task Switching

The statistical test for the waste task switching is show in the Table 32. The Chi-square test, mean, standard deviation with assumption significant is show by calculation the Frideman test. The mean rank for each practices has been calculated, Kanban has the mean rank of 4.00, VSM at 2.90, Kotter at 3.70, Kaizen at 3.20, Scrum at 3.50 and XP at 3.70. The test was performed to know the variance between each practice with respect to the waste task switching.

Table 32 Statistical analysis of the waste task switching

Practices	Chi-Square	Df	Mean	Standard deviation	Assumption significant
Kanban	1.154	5	11.0000	8.33667	.949
VSM	1.154	5	11.0000	8.54400	.949
Kotter	1.154	5	11.0000	7.64853	.949
Kaizen	1.154	5	11.0000	10.31988	.949
Scrum	1.154	5	11.0000	8.33667	.949
XP	1.154	5	11.0000	6.74537	.949

5.4.6.5 Test Statistics for the waste Motion

The statistical test for the waste motion is show in the Table 33. The Chi-square test, mean, standard deviation with assumption significant is show by calculation the Frideman test. The mean rank for each practices has been calculated, Kanban has the mean rank of 3.10, VSM at 3.10, Kotter at 3.80, Kaizen at 3.40, Scrum at 3.60 and XP at 4.00. The test was performed to know the variance between each practice with respect to the waste motion. The detailed Frideman test is shown in Appendix B.

Table 33 Statistical analysis of the waste motion

Practices	Chi-Square	Df	Mean	Standard deviation	Assumption significant
Kanban	1.006	5	11.0000	9.61769	.962
VSM	1.006	5	11.0000	8.33667	.962
Kotter	1.006	5	11.0000	7.90569	.962
Kaizen	1.006	5	11.0000	8.15475	.962
Scrum	1.006	5	11.0000	7.31437	.962
XP	1.006	5	11.0000	7.31437	.962

5.4.6.6 Test Statistics for the waste Waiting

The statistical test for the waste waiting is show in the Table 34. The Chi-square test, mean, standard deviation with assumption significant is show by calculation the Frideman test. The mean rank for each practices has been calculated, Kanban has the mean rank of 3.70, VSM at 3.50, Kotter at 3.80, Kaizen at 2.60, Scrum at 4.00 and XP at 3.40. The test was performed to know the variance between each practice with respect to the waste waiting. The detailed Frideman test is shown in Appendix B.

Table 34 Statistical analysis for the waste waiting

Practices	Chi-Square	Df	Mean	Standard deviation	Assumption significant
Kanban	1.765	5	11.0000	7.84219	.881
VSM	1.765	5	11.0000	8.27647	.881
Kotter	1.765	5	11.0000	8.33667	.881
Kaizen	1.765	5	11.0000	13.92839	.881
Scrum	1.765	5	11.0000	6.74537	.881
XP	1.765	5	11.0000	6.96419	.881

5.4.6.7 Test Statistics for the waste Defects

The statistical test for the waste defects is show in the Table 35. The Chi-square test, mean, standard deviation with assumption significant is show by calculation the Frideman test. The mean rank for each practices has been calculated, Kanban has the mean rank of 3.30, VSM at 3.10, Kotter at 3.70, Kaizen at 3.80, Scrum at 3.50 and XP at 3.60. The test was performed to know the variance between each practice with respect to the waste defects. The detailed Frideman test is shown in Appendix B.

Table 35 Statistical analysis of the waste defects

Practices	Chi-Square	Df	Mean	Standard deviation	Assumption significant
Kanban	.512	5	11.0000	8.71780	.992
VSM	.512	5	11.0000	7.07107	.992
Kotter	.512	5	11.0000	8.27647	.992
Kaizen	.512	5	11.0000	8.68907	.992
Scrum	.512	5	11.0000	8.30662	.992
XP	.512	5	11.0000	8.80341	.992

5.4.7 Experience influencing the variance between the lean practices respect to each wastes

To know whether the variance between the answers is due to the experience factor or by the lean practices, a statistical analysis is performed. The statistical test that was performed is the non-parametric statistics with Wilcoxon signed rank test. The statistical test are that are performed were shown in Appendix B.5.
Firstly, the test was performed to know whether the set is different with respect to the predicted ability of eliminating wastes through Frideman test. The hypothesis is as follows:

Null Hypothesis: There is no difference in the perceived ability to eliminate waste, further between the four practices.

Alternative Hypothesis: There is a difference between the perceived ability to eliminate waste.

Thereafter, the experience was categorized into two from 1-3 and 4-5 with respect to each practice. Then the comparison, whether the answers differ between the two groups was performed. That is do people with less experience (1-3) answer differently for each practice than people with experience (4-5).

From the statistical test that was performed to know the influence of experience on lean practices with respect to the waste partially done work, the values obtained are N=55, Chi-Square=105.811, Df=3 and Assumption significance=0.000, by Friedman Test.

When it come to the waste extra process the value of N=55, Chi-Square=99.313, Df=3 and Assumption significance=0.000, by performing the Friedman Test. For the waste extra features N=55, Chi-Square=126.000, Df=3 and Assumption significance=0.000. The waste task switching has the value as N=55, Chi-Square=100.113, Df=3, and Assumption significance=0.000.

When the test was performed with respect to the waste waiting, N=55, Chi-Square=103.484, Df=3 and Assumption significance=0.000. When it come to the waste motion the values are N=55, Chi-Square=134.217, Df=3 and Assumption significance=0.000. Finally for the waste defects, N=55, Chi-Square=89.050, Df=3 and Assumption significance=0.000.

For most of the wastes with respect to each practices, the answers given by most of the experience people is in lower number than inexperienced people. Hence, experience is confounding factor that influencing in the results. From the statistical tests that were performed the significance=0.000, for all the wastes. Hence distribution is different, thus the experience level leads to very different responses. Hence, there is a confounding factor in the test, which is a validity concern and it was stated in the validity threats.

5.4.8 Benefits and limitations of lean practices

To find out about the limitations and benefits of lean practices, open-ended questions were asked in order not to restrict the ideas of respondents by the predefined options.

The benefits and limitations of lean practices are identified from survey. An open-ended question has been given to the respondents to provide their experience on benefits and limitations of implementing lean practices in software industry. By analyzing the data provided by the respondents, answers can be distributed in three different ways. The limitations are categorized into, organizational, physiological, and technical. The benefits of lean practices are grouped into three categories, for employees, for organization, for customer.

Firstly, the limitations of lean practices implementation will be considered. The answers of the respondents were generalized. Their analysis allows the grouping of different limitations into three categories: organizational, psychological, and technical factors (Figure 21).

Organizational

- Very close to waterfall model
- Requires professional requirements analyst
- Time for adaptation is high
- Adoption requires high effort of Planning in advance
- Reorganization of IT departments
- Lack of necessary design and documentation

Psychological

- Requires professional coaching
- Requires lean knowledge for all team members
- Production squeesesDiscourage of employees
- Decrease of leadership
- Requires team cohesiveness which is not possible in distributed teams

Technical

- Intensive testing of the software
- Time used by the developers of the software is reduced
- Not enough time to analyze and introduce user's experience
- Not enough time for innovation
- Requires clear idea and well formalized requirements to software product

Figure 21 Limitations of lean practices

Organizational factors deal with the issues of management of lean practices implementation. Some respondents mentioned that the introduction of lean to the software development requires the software lifecycle to be close to the waterfall model with clearly specified stages. Another factor of risk is the time necessary for adaptation of newly introduced principles and methods in practice. This may take additional time. The role of business analyst is vital to projects in understanding and gathering the requirements, which influence the amount of wastes captured by lean practices. Some respondents suppose that incorporation of lean principles to software engineering process requires high effort of advanced planning. The possible reorganization of the company’s structure is considered to be disadvantage of lean practices implementation. Finally, lack of useful design documentation and guidelines about lean practices implementation is also a possible limitations. The frequency of these factors mentioning is presented in Figure 22. The most critical organizational issue is time necessary for lean principles incorporation.

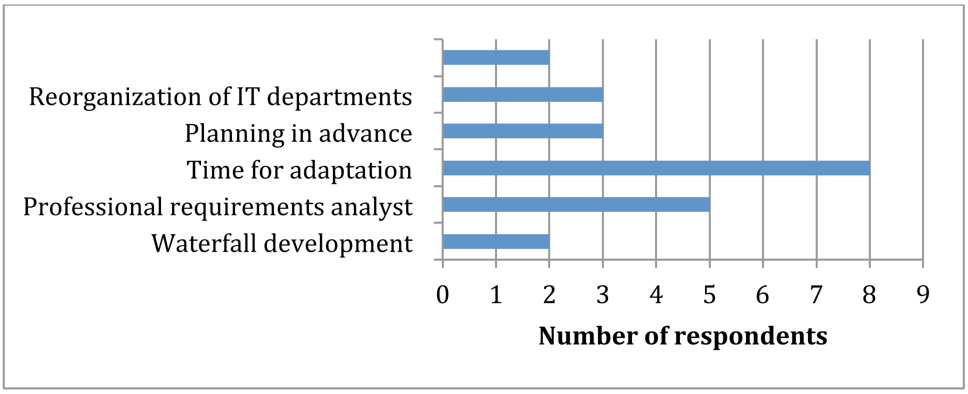

Figure 22 Frequency of organizational limitations of lean practices

Psychological factors are related to people management caused by the lean practices implementation. Most of the respondents recognized that the successful implementation of lean practices requires professional coaching and training of employees. Also the involvement of team members is an essential factor, i.e. all team members should be aware of lean. In addition, survey participants expressed the following idea "*When a certain level of refinement is met, using lean methods to squeeze more economy from production can discourage workers, reversing their positive motivation*." The implementation of lean practices may decrease the role of leadership as well, which is important for team leaders and project managers. Finally, in order to be good at lean practices, the team must be cohesive enough, which is not always possible in the case of distributed teams. The frequency of these factors is represented in Figure 23.

Technical factors can be considered as most essential in the implementation of lean practices. Introduction of lean methods requires additional intensive testing, as the respondents mentioned. This is connected with the fact that the time the software is used by its developers is reduced. Since often the development time is considered as a waste, which should be captured and decreased, the work with the target software users is also decreased. This may impact negatively the final software quality. The same can be said about innovation projects. There is not enough time for additional research, so lean practices are not much suitable for innovative the software development. Moreover, the most frequently mentioned limitation is that "*a team must have a clear idea about the software product*." This means that software requirements must be developed and formalized carefully and should cover all aspects of system functioning. This requires an intensive work of system analysts and business processes analysts. The frequency of the described limitations is shown on Figure 24.

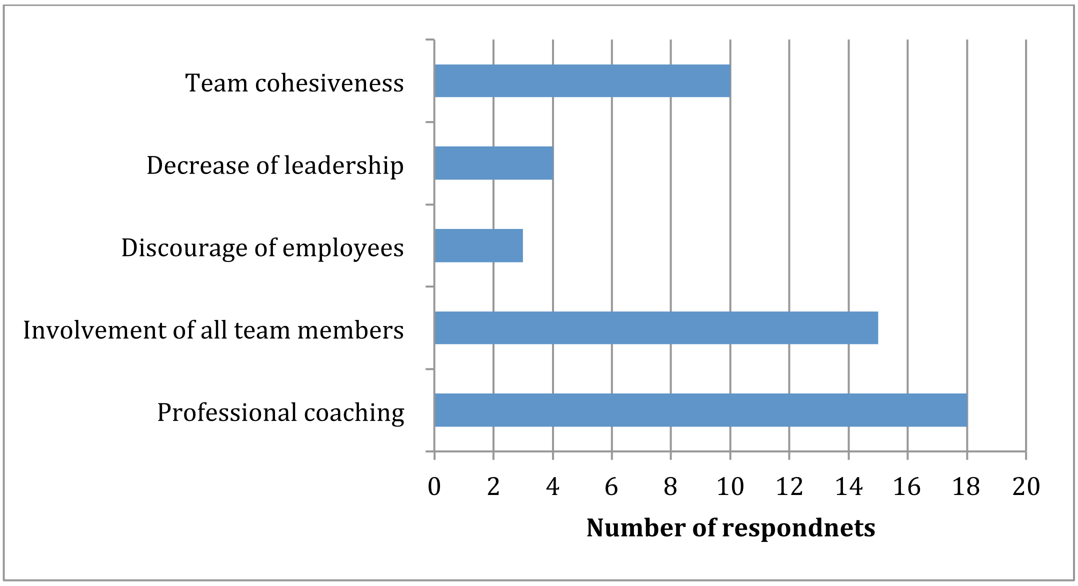

Figure 23 Frequency of psychological limitations of lean practices

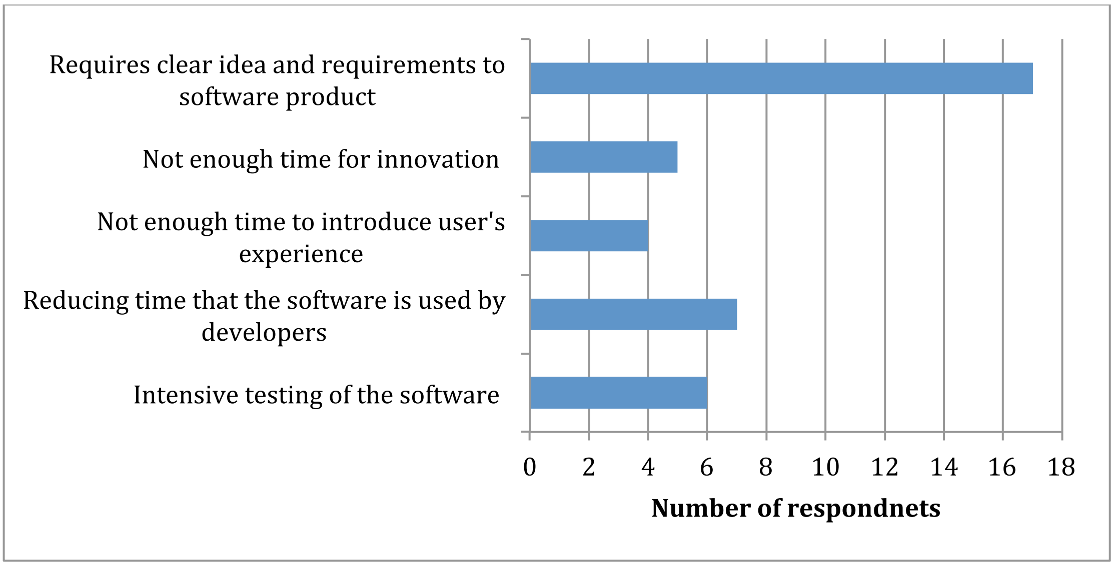

Figure 24 Frequency of technical limitations of lean practices

The benefits of lean practices implementation are the factors that make them so useful and popular among practitioners. The answers were analyzed and it was discovered that all benefits could be considered from the point of view of the customer, the software development company, and its employees (Figure 25).

The following benefits of lean practices implementation from customer's point of view can be named. Customer can get more functionality in a shorter period. The quality of final software product is increased in terms of its reliability, efficiency, usability, etc. Moreover, lean practices make the conversations of unprepared customers with system analysts easier and more understandable. The frequency of these benefits mentioning is shown on Figure 26. The delivery time seems to be the most important benefit from customer's point of view.

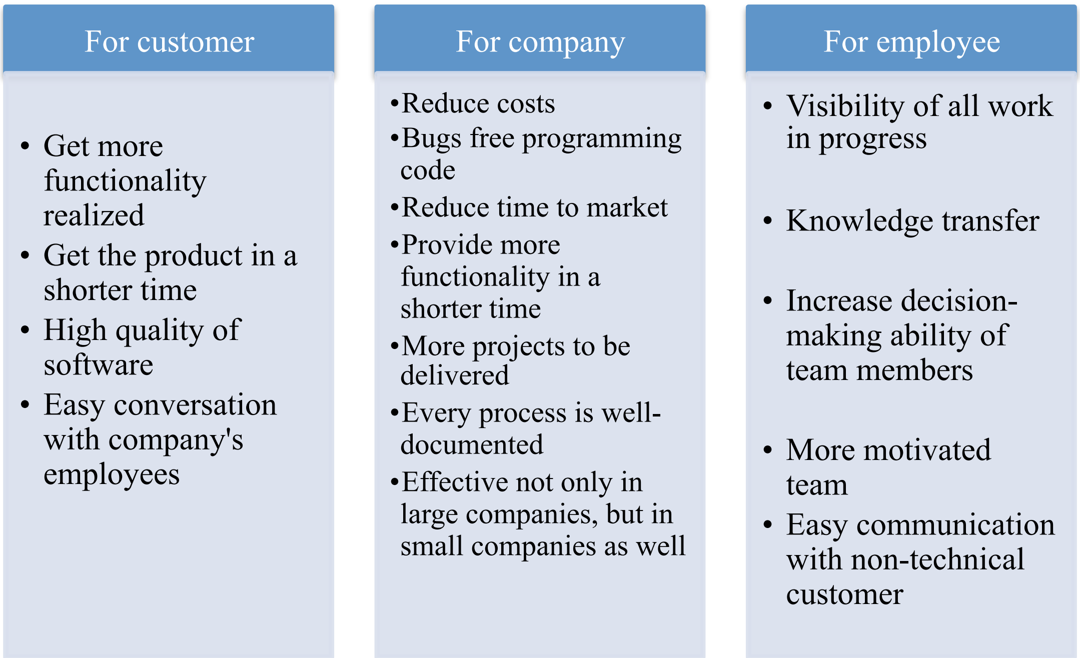

Figure 25 Benefits of lean practices implementation

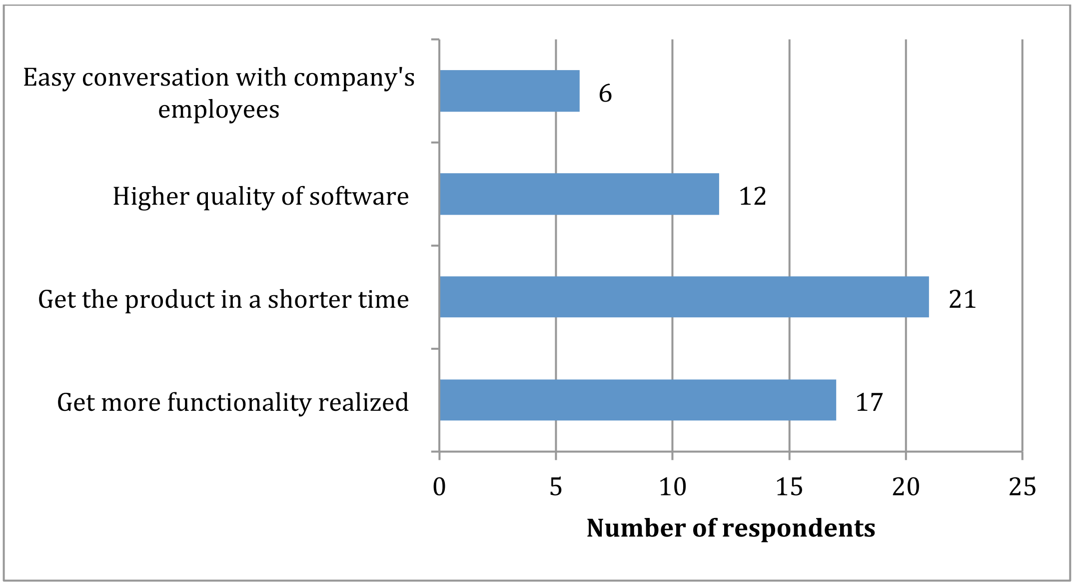

Figure 26 frequency of benefits of lean practices implementation (for customers)

The interests of the software development companies are the business interests. They deal mostly with money and time. So, lean practices help to reduce costs and time to market. This leads to the increment of the number of delivered projects. At the same time, the amount of provided functionality is increased. The fact that all software engineering processes are well documented is useful for software developers. In addition to this, what makes lean so popular is that it is suitable for not only large companies and teams, but also for small companies. These benefits are presented on Figure 27. Reduced time and costs are the most essential for companies.

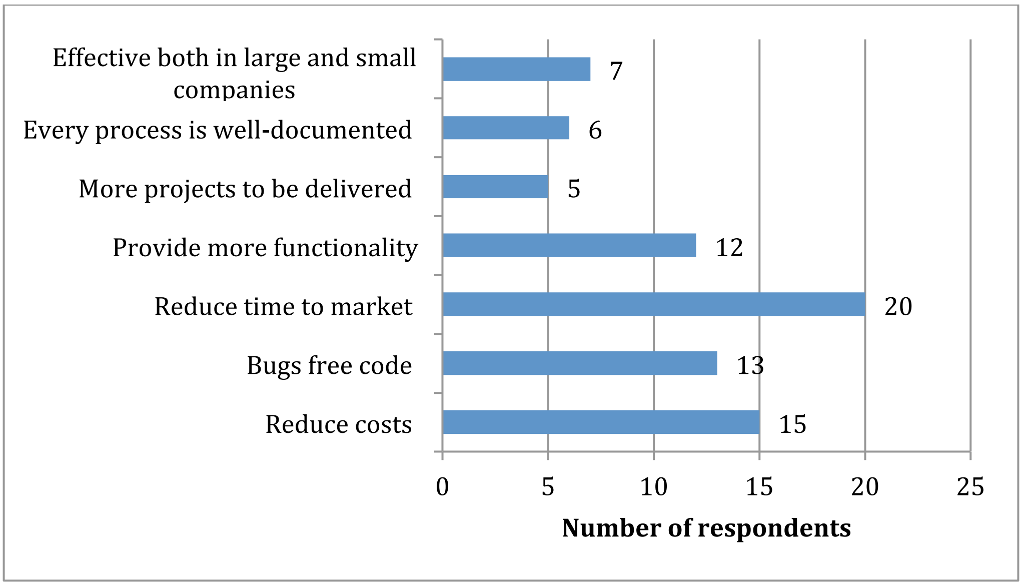

Figure 27 Frequency of benefits of lean practices implementation (for company)

Analyzing benefits for companies' employees, it can be said that implementation of lean practices makes the progress of work more visible. This helps employees to realize the situation and to pay attention to processes that meet some problems. Knowledge transfer among team members is also encouraged by lean principles. This helps employees to obtain necessary experience in a shorter time. "*Empowerment of the development team helps in developing the decision-making ability of the team members, which, in turn, creates a more motivated team*." In addition, lean practices provide tools for easy communication with non-technical customers, which is especially important during requirements gathering. The frequency of these factors is presented on Figure 28. Most comfortable way of representation of work in progress is identified to be the most important benefit from employee's point of view.

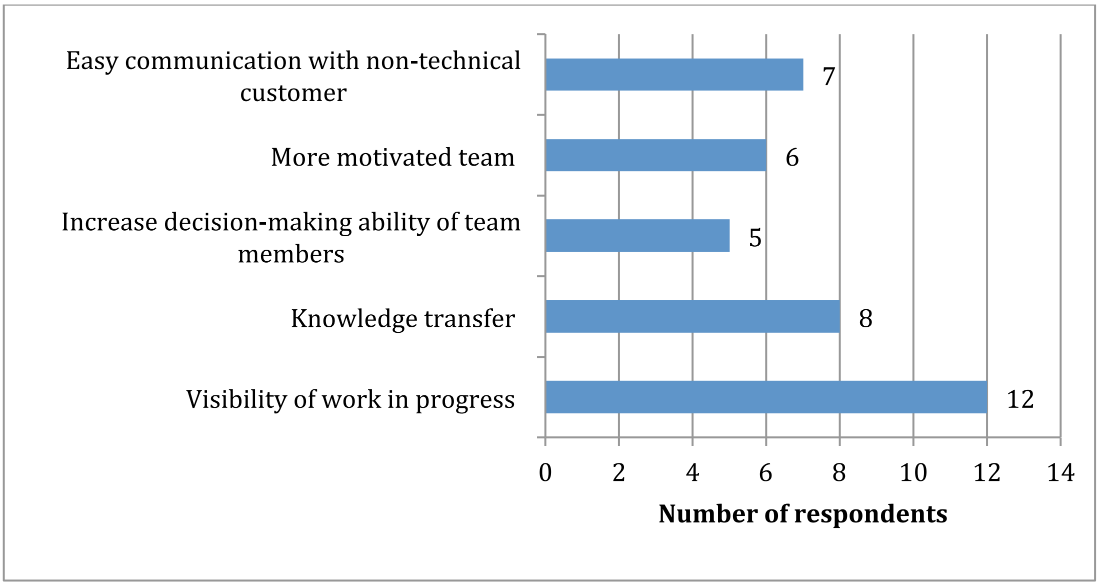

Figure 28 Frequency of benefits of lean practices implementation (for employees)

5.5 *Summary of Survey*

After analyzing the general information about respondents and their companies, it can be said that 85% of participants have been working in software engineering industry for more than 2 years. 78% of participants have more than 2 years experience in both lean and agile software development. So the respondents are experienced enough to provide relevant data concerning corresponding practices. These positively influence the results of the survey and make them more reliable.

Most of the respondents work in the role of project manager and team leader (63%). Since these employees are responsible for implementation of lean and agile practices, it can be said that, the participants can give the reliable information. 93% of respondents work in medium and large-scale software development companies, which provide the necessary environment for lean principles and practices implementation. 63% of respondents work in the projects devoted to the development of customer-oriented, business-oriented and mobile software applications. These areas represent a huge market share of software products.

The most widespread lean practice is Kanban (Figure 29). It is frequently (always and very frequently) used by 80% of respondents. VSM is frequently used by 71% of respondents. Practitioners rarely use the lean practices like Kaizen and Kotter, although they know about these practices.

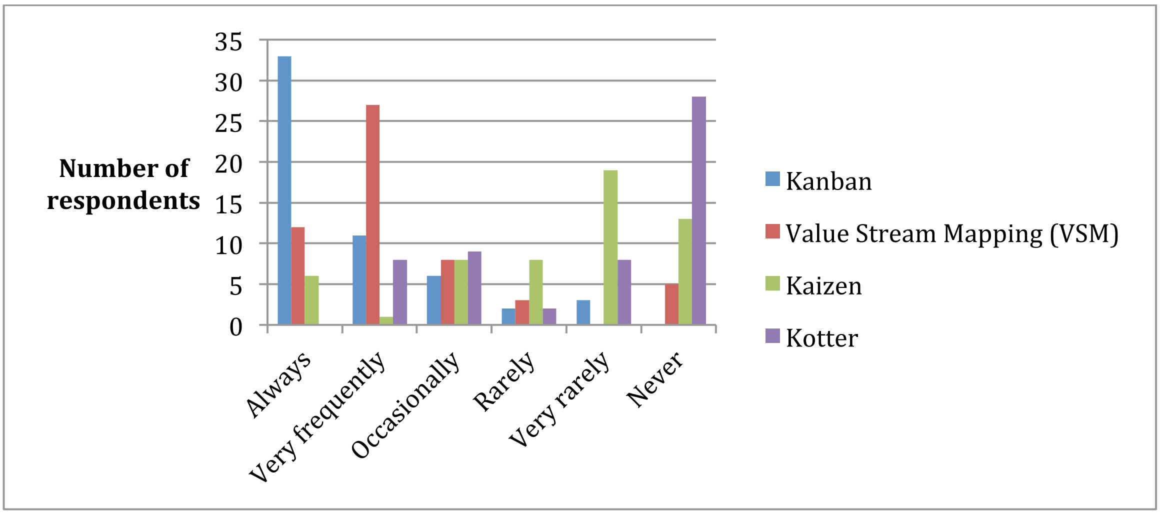

Figure 29 Frequency of lean practices implementation

The opinion of practitioners on wastes captured by these lean practices is important for this research. Data was collected about each practice (Figure 30). It can be concluded that partially done work is strongly captured by Kanban and VSM, extra process by Kanban. Other wastes are captured by VSM more successfully.

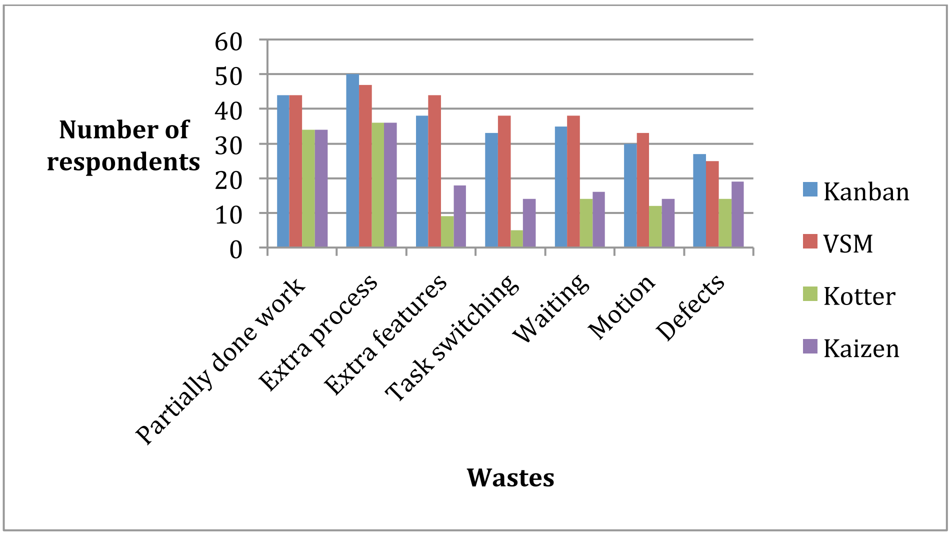

Figure 30 Capturing of Wastes by Lean practices

The results help in identifying three groups of limitation factors of lean practices implementation. They include organizational, psychological, and technical reasons. Organizational factors are related to the costs of lean practices introduction to the software development lifecycle. This means that additional processes have to be included to the lifecycle. In addition, employees are required; in particular, a company needs a professional business analyst, who can help to organize the work in a proper way. Extra planning and reorganizational activities may be required in order to get the full benefits from lean practices.

Psychological factors of risk deal with human resources management. First, it was discovered that the success of lean practices implementation strongly depends on team cohesiveness. This means that all team members must be involved in this process. To support this, proper training and coaching must be organized, because lean practices require special knowledge to be implemented successfully.

Technical factors are related to the software development process. Most of practices require a team to have a clearly done software requirements document. An explicit idea of a product and well-formulated, unambiguous requirements are the necessary conditions of lean practices usage. It can be concluded that a team must pay more attention to testing. Another possible limitation is that lean practices presuppose that a team does not spend much time to communication with customer and to additional deep research, which implies that the innovative products cannot get the benefits from their implementation.

However, the benefits of lean practices often are bigger than possible limitations. The benefits can be distinguished from different points of view. As expressed by the respondents, customer can obtain a greater value from usage of lean practices. More functionality within a shorter time can be provided to the clients. Moreover, a customer gets software of higher quality.

A software development company can get more money, since the time for software production decreases and the number of potential projects increases. Therefore, the costs are reduced. The same can be told about the number of revealed errors and defects. The processes of code generation and testing are improved which leads to more reliable software development. Moreover, what makes lean so attractive to companies is that it is suitable for both large and small companies.

Company's employees get some benefits as well. Lean practices implementation support the atmosphere of free knowledge and experience transfer among team members. Project managers and team leaders as well as other employees can easily see the progress of work and build efficient plans for the future work. Employees are encouraged to take decisions and feel more responsibility for their decisions. Therefore, lean practices help teams to become more motivated.

Therefore, a survey was conducted with practitioners in order to collect their opinions about lean and agile practices implementation, captured wastes and effectiveness of different practices. The benefits and limitations of lean practices implementation, which could not be found from SLR results could also be identified through the survey. The obtained results are checked subject to their reliability via statistical methods. Therefore, it can be ensured that the findings are reliable enough and can be supposed that they can be useful for software engineering practitioners.

5.6 Survey Validity Threats

The validity of survey consists of four validations. External validity, internal validity construction validity, and conclusion validity

In the external validity, the members of the population could be a risk. One cannot guarantee that the respondent is from specific domain or specific company or having experience. There is a chance of presenting wrong answers, which may lead to biased and inaccurate results. Therefore, the lean and agile groups were only searched in social network. More over, the population cannot be described in convenient sampling with diversity. The groups that are in the social networks have proper representation and many professionals are connected to those groups, which allows trusting them and posting the survey. Some of the social networking sites allow direct posting of the survey in their account.

The internal validity deals with the internal part of the questionnaire like type of questions and available answers provided. In this validity, respondents may refuse or may not use the practice in their industry. To mitigate this risk, the questions were framed in an understandable way to be answered by the respondents. Close-ended questions like the agreement level and efficiency level may confuse the respondents and some of the respondents may not use the practices in their industry. So the options like, disagree and never used, were used and these options could enable the respondents in being comfortable to answer the questions appropriately.

On the other hand considering diversity in the sampling and effectiveness of lean practices is a risk as all the respondents may not be clear about the lean practices and some respondents may not have experience. For this type of risk, the questionnaire has provided the option for the experience question with less than a year, one to two years of experience. Moreover, all the respondents should completely answer the questioner or else the survey cannot be submitted. However, to know whether the difference between the answers was due to the experience of respondents or due to the lean practices, a statistical analysis is performed to check for the control of experience as a confounding factor. The detailed statistical test was detailed in Appendix B.5 and in Section 5.4.7.

In the construct validity, it will be checked whether the questionnaire has revealed the essential factors. To avoid the risk of irrelevant information of irrelevant questions in the survey form, the questions were formulated in relevance to the results of SLR. However, the number of primary studies cannot be compared to the number of respondents, and the comparison was only made on the lean practices from SLR and Survey. The lean and agile practices, which are identified by SLR, are considered for the questions in addition to the traditional seven wastes that were added in the survey questions. Some of the practices that are identified in the SLR are not used in survey results as the focus was only on identifying the lean practices that are most relevant and mostly used in software industry. Some lean practices like those that Lean Six Sigma is used in manufacturing domain, and therefore was avoided.

The conclusion validity threat represents the truthfulness and the genuinely of the obtained results. The risk was mitigated by analyzing the results very carefully and by using the principles of statistical analysis. The results that are obtained by the survey needs to be analyzed in different ways. The questions that are asked for the respondents are made easy to obtain accurate answers and at the same time, they have to be analyzed according to our aims and objectives. The percentage and the variance of the lean practices are the most important factors in the survey. The limitations and benefits of implementing the lean practices are in the form of text, as the question is an open-ended one. The limitations and benefits need to be categorized according to the feedback given by respondents

6 COMPARISONS OF SLR AND SURVEY

Comparison of SLR and industrial survey, different factors in lean practices and wastes captured by them were estimated. The research could identify different lean practices that have more attention in research and the lean practices that are mostly used and efficient in capturing wastes in software development process. We cannot compare survey participants with primary studies. However, the study focus on lean and agile practices, the practices and wastes that were identified by SLR are compared with the practices and wastes captured in Survey. It was found that the results of survey provide more insights compared to the results of SLR.

The lean practices that have more attention in research are shown in the Figure 5. In addition, the lean practices that are mostly used in the industry are shown in Figure 18. On the other hand, the study has also identified the agile practices and the practices that capture wastes. This phenomenon is also carried out in SLR and Survey. A conclusion can be made that the lean practices and agile practices are similar in SLR and Survey results. Some of the lean practices are not considered by this study because they are involved in manufacturing domain.

When coming to the wastes that are captured by lean and agile practices individually, the rate of Survey is higher than the rate of SLR. The usage of lean practices is not identified through literature but is identified through Survey. To have a scope of real world environment it is better to identify the usage of any practice implemented in the industry. It can be estimated that the usage of lean practices in industry and the attention of lean practices in research are not similar. Usually, we should accept the fact that an article cannot cover all the aspects of lean practices, but they can identify one or two aspects. Moreover, the lean practices that are identified by literature are considered for survey, and it could be reported that there is no difference between the lean practices. The difference in the lean practices capturing the wastes could be observed.

In the survey, the respondents are asked to mark the frequency of usage of lean practices and the level of agreement of capturing wastes, which cannot be done in literature. The usage and efficiency of lean practices are identified additionally in the survey. The benefits and limitations of lean practices are also identified from Survey. The reason behind this is that one can acquire efficient results in the real world.

This comparison allows to a conclusion that literature has given less attention in capturing the wastes from different lean practices. This can be said based on the results of survey. Some wastes that are not captured by lean practices in literature are captured by the lean practices in survey. This shows the major difference in results of SLR and survey. The lean practices implementation in different sizes of software industry are similar in both SLR and Survey. Most of the literatures are experience reports from large-scale industrial size, where as the survey results also say that lean practices are mostly implemented in large-scale sector. The experience cannot be notified from the literature, it can be asked to particular person.

However, the results of survey allow making a conclusion that the lean practices need to be paid more attention in literature and should analyze the capturing of wastes by different lean practices. From the results of our survey, Kanban has more efficiency, more usage and captures more wastes compared to the results reported in literature. VSM practices also have major difference in the results of SLR and Survey. The Wastes captured by VSM is twice in the survey results compared with SLR. Lean practices as Kotter and Kaizen have different results; SLR results suggest very less usage and very less wastes captured. However, the results of survey say that both the practices Kaizen and Kotter can capture wastes and used in industry. The rate of usage and capturing of wastes by the Kotter and Kaizen are bit more than the literature.

The difference between the results of SLR and Survey are shown in the Figure 31 below.

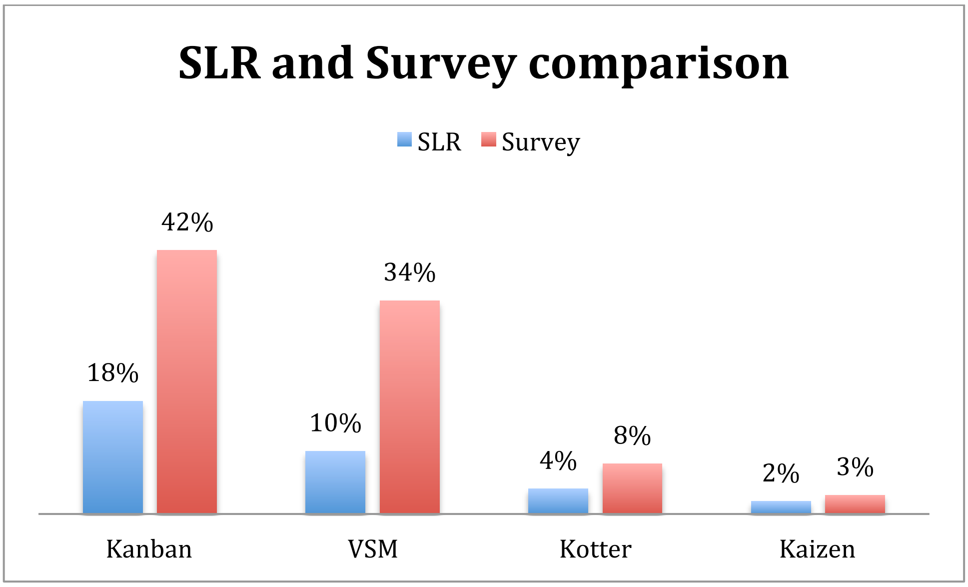

Figure 31 Comparison of lean practices in SLR and Survey results

The above Figure 31 shows that the attention of Lean practices in literature and the usage of lean practices from survey. To compare the results of SLR and Survey in capturing of wastes by lean practices, the results based on the frequency and level of agreement in survey were presented. Where the literature results are concerned, the level of agreement in capturing wastes by each lean practice cannot be identified, but the study can identify which lean practices captures, which wastes. Therefore, the results of SLR and survey on which lean practices is capable of capturing which waste were compared in Figure 31.

7 CONCLUSIONS AND FUTURE WORK

Lean practices in the software development process are very important and they have more identity in the software industry. The study was performed in two ways, qualitative and quantitative.

The qualitative study has identified different core lean practices having more attention in literature and which lean practice captures which waste. It has been identified, which agile practices are efficient in eliminating the wastes. This answers the three research questions RQ1, RQ2, and RQ3. By considering the identified lean practices from the SLR, a survey was conducted in different aspects. The aspects that are surveyed in this study are, which lean practices is capable of eliminating which wastes, level of agreement of lean practices eliminating wastes, usage of lean practices in software industry, size of the organizations that implement lean practices, agile practices capturing wastes, benefits and limitations of lean practices in software industry. These aspects have answered RQ4 to RQ7.

From the results of systematic literature review, it can be concluded that the identified lean practices and captured wastes from the survey have a major difference. However, there is a difference between the answers given by the respondents. To know whether the experience of respondents influence their answers with lean practices eliminating wastes, statistical tests were performed to check the confounding factor.

The researchers need to specify and focus on the lean practices and wastes that are captured. The majority of usage and wastes captured by the lean practices are identified more from survey rather than SLR. This means that, researchers have concentrated less on the lean practices due to lack of further information, organizational factors, restricted projects and lack of empirical information. It is very clear that most of the literature has focused on the projects rather than the practices. The empirical validations need to be more specific by performing case studies or experiments on each lean practice. Implementing different research methods for identifying the wastes captured by lean practices should be equivalent to the real world performance, which can make sense for the researchers as well as practitioners.

The results of survey helped in identifying which lean practices capture which wastes, the practitioners' level of agreement on lean practices capturing wastes, frequency of lean practices implementation in software industry, wastes captured by agile practices, and benefits and limitations of lean practices. Many practitioners have answered that Kanban captures more wastes, followed by VSM, and then the remaining practices. The waste "partially done work" has more percentage compared to other six wastes and the waste "Defects" is less captured by the lean practices. Many organizations are implementing lean practices and using Kanban most frequently. Both the results of SLR and survey reflect that, Kanban practices have much attention in literature and are mostly used, and efficient in software industry. Kaizen practices have less attention in research and rarely used in software industry.

When coming to the usage of agile practices, Scrum is mostly used than XP. The remaining agile practices have very less rate in capturing the wastes. Even from the results of systematic literature review, Scrum and XP have more attention than remaining agile practices. From the systematic literature review, it is evident that the hybrid agile and lean practices Kanban and Scrum are mostly used for capturing wastes. When it comes to the survey results, the rate of Scrum and Kanban practices are more in capturing wastes.

When the lean practices are considered, not all the lean practices are capable of eliminating all the seven wastes. There is a possibility that using more than one lean practice can eliminate most of the wastes instead of using one. From the statistical test, combinations of lean practices like Kanban and Kotter, VSM upon Kaizen can be used to eliminate maximum wastes in the software development. However, effort and cost are the two factors that should be considered, while using the combinations. There is a scarcity of information on the cost and effort in using lean practices in an organization, which is not mentioned in almost all the literature.

The prioritization of lean practices from overall study is shown in the Table 31 below. The priority of the lean practices given in the Table 36 is according to the usage, efficiency and more concentration in research.

Table 36 Prioritization of practices

Position	Lean Practices
Rank 1	Kanban
Rank 2	VSM
Rank 3	Kaizen
Rank 4	Kotter
Rank 5	Other

This study has identified and prioritized different lean practices and showed which lean practices is capable of eliminating which waste. The data that is identified by this study can be taken as an evidence for performing experiments on Kotter and Kaizen.

The practitioners and the organizations that are implementing lean practices can be benefited more by using the findings of this study on benefits of lean practices and industries can implement lean in their organizations with a better understanding of the practices. The adoptions of lean practices in software organizations will be improved by following the benefits identified by this study. But to follow the benefits of lean practices, there is need to identify the mitigations for the limitations of implementing lean practices and identifying causes of benefits by the researchers. Finally, this study has contributed in identifying lean practices, which are efficient in capturing wastes, benefits, and limitations of lean practices, which helps practitioners in choosing the lean practices in their industry and in the elimination of specific wastes in their projects. This study also helps the researches, to know the level of attention on lean practices in literature and what need to be investigated further.

7.1 Future Work

There is a need to investigate on the adoption of lean practices in an industry and the mitigations of the limitations. By performing this, there will be a chance of adopting the lean practices in software industry.

Secondly, a case study can be performed in real time environment related to the combinations of lean practices, which can provide much deeper insights. In addition, investigating the root causes of each waste that occur in implementing the lean practice will be more helpful.

It would also be interesting to perform empirical research before implementing lean practice in real time environment and to investigate the effort and cost of the lean practices when implemented in an industry.

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APPENDIX A

Table A.1- Primary studies with encodings

S ID	Primary studies	Study ID
1	M. Poppendieck and P. Llc, 2002.	[P1]
2	K. Petersen, 2010	[P2]
3	X. Wang, K. Conboy, and O. Cawley, 2012.	[P3]
4	S. Mujtaba, R. Feldt, and K. Petersen, 2010.	[P4]
5	M. Poppendieck and T. Poppendieck, 2003	[P5]
6	K. Petersen and C. Wohlin, 2010.	[P6]
7	M. Poppendieck, 2011.	[P7]
8	J. P. Womack, D. T. Jones, and D. Roos1990.	[P8]
9	A. Droste, 2007.	[P9]
10	M. Poppendieck and T. Poppendieck, 2006.	[P10]
11	benefits. Jonsson, S. Larsson, and S. Punnekkat, 2013.	[P11]
12	benefits. Kniberg, "Kanban and Scrum 2009	[P12]
13	M. O. Ahmad, J. Markkula, and M. Ovio, 2013.	[P13]
14	P. Middleton and D. Joyce, 2012	[P14]
15	M. Ikonen, P. Kettunen, N. Oza, and P. Abrahamsson, 2010.	[P15]
16	T. Karvonen, P. Rodriguez, P. Kuvaja, K. Mikkonen, and M. Oivo, 2012.	[P16]
17	M. Mehta, D. Anderson, and D. Raffo, 2008.	[P17]
18	V. R. Basili, 1995.	[P18]
19	D. Raffo, M. Mehta, D. J. Anderson, and R. Harmon, *,2010*	[P19]
20	J. Pernsl, R. Feldt, and T. Gorschek, 2013.	[P20]
21	A. Sillitti and G. Succi, 2005.	[P21]
22	J. Cho, and C. State, 2011.	[P22]
23	M. C. Paulk, N. Davis, and L. Maccherone, 2009.	[P23]
24	J. M. Fernandes and M. Almeida, 2010.	[P24]
25	X. Wang, 2011.	[P25]
26	K. Long and D. Starr, 2008.	[P26]
27	K. Nottonson and K. DeLong, 2008.	[P27]
28	F. Kinoshita, 2008.	[P28]
29	E. R. Willeke, 2009.	[P29]
30	J. O. Birkeland, 2010, pp.	[P30]
31	C. R. Jakobsen and T. Poppendieck, *2011*	[P31]
32	G. I. U. S. Perera and M. S. D. Fernando, *2007*	[P32]
33	S. Jalali and C. Wohlin, 2010.	[P33]
34	B. Barton, *2009*	[P34]
35	K. Rutherford, P.Shannon, C.Judson, and N. Kidd, 2010.	[P35]
36	K. Nottonson, 2011.	[P36]
37	A. Hui, 2013.	[P37]
38	P. Hodgetts, 2004.	[P38]
39	P. Rodríguez, J. Markkula, M. Oivo, and K. Turula, 2012, p. 139.	[P39]
40	B. Swaminathan and K. Jain, *2012*.	[P40]
41	M. Cristal, D. Wildt, and R. Prikladnicki, 2008.	[P41]
42	C. R. Jakobsen and J. Sutherland, *2009 Agil*	[P42]
43	J. Sutherland, C. R. Jakobsen, and K. Johnson, 2008.	[P43]
44	G. K. Hanssen and T. E. Fgri, 2008.	[P44]
45	K. Korhonen, 2012.	[P45]

46	David. J, Anderson, 2010.	[P46]
47	M. Lindvall, V. Basili, B. Boehm, P. Costa, K. Dangle, F. Shull, R.Tesoriero, L. Williams, M. Zelkowitz, 2002.	[P47]
48	C. Ebert, P. Abrahamsson and N. Oza, 2012	[P48]
49	P. Middleton, 2001.	[P49]
50	M. Inoki, Fukazawa, 2007	[P50]
51	R. Mahanti and J. Antony, 2006	[P51]
52	E. Danovaro, A. Janes, G. Succi, 2008	[P52]
53	P. Middleton and D. Joyce, 2012	[P53]

Table A.2- Distribution of Studies in the three aspects

Lean Practices/Principles and wastes	**Hybrid Agile lean practices and wastes**	**Agile practices and their efficiency in capturing wastes**
[P1], [P5], [P4], [P7], [P8], [P9],[P10], [P11], [P12], [P13], [P14], [P15], [P16], [P17], [P19],[P20], [P50], [P51], [P52], [P53]	[P5], [P21], [P22], [P23], [P24], [P20], [P3], [P25], [P26], [P27], [P28], [P29], [P30], [P31],[P32], [P33], [P34], [P35], [P36],[P37],39], [P39], [P47]	[P41], [P42], [P51]

Table A.3- Number of Studies per Year

Year	**Number of Studies**
1990-2006	6 (1 study from 1990)
2007	5
2008	4
2009	4
2010	13
2011	6
2012	10
2013	4

APPENDIX B

Table B.1- Quality Checklist and Score for Primary Studies

S ID	Primary studies	Methodology	Content	Description	Relevance
1	M. Poppendieck and P. Llc, 2002.	1	4	4	4
2	K. Petersen, 2010	5	5	5	5
3	X. Wang, K. Conboy, and O. Cawley, 2012.	2	3	3	3
4	S. Mujtaba, R. Feldt, and K. Petersen, 2010.	4	4	4	5
5	M. Poppendieck and T. Poppendieck, 2003	3	3	3	4
6	K. Petersen and C. Wohlin, 2010.	3	3	3	4
7	M. Poppendieck, 2011.	3	2	3	3
8	J. P. Womack, D. T. Jones, and D. Roos1990.	3	2	2	2
9	A. Droste, 2007.	3	3	2	3
10	M. Poppendieck and T. Poppendieck, 2006.	2	3	2	3
11	Jonsson, S. Larsson, and S. Punnekkat, 2013.	4	4	3	4
12	Kniberg, "Kanban and Scrum 2009	4	4	3	3
13	M. O. Ahmad, J. Markkula, and M. Ovio, 2013.	3	3	2	3
14	P. Middleton and D. Joyce, 2012	3	3	2	3
15	M. Ikonen, P. Kettunen, N. Oza, and P. Abrahamsson, 2010.	4	4	2	3
16	T. Karvonen, P. Rodriguez, P. Kuvaja, K. Mikkonen, and M. Oivo, 2012.	2	2	2	1
17	M. Mehta, D. Anderson, and D. Raffo, 2008.	2	2	1	1
18	V. R. Basili, 1995.	2	1	1	1
19	D. Raffo, M. Mehta, D. J. Anderson, and R. Harmon, *,2010*	2	1	1	1
20	J. Pernstl, R. Feldt, and T. Gorschek, 2013.	4	3	3	3
21	A. Sillitti and G. Succi, 2005.	3	2	2	3
22	J. Cho, and C. State, 2011.	2	1	1	1
23	M. C. Paulk, N. Davis, and L. Maccherone, 2009.	3	2	2	1
24	J. M. Fernandes and M. Almeida, 2010.	1	1	2	1
25	X. Wang, 2011.	3	2	2	2
26	K. Long and D. Starr, 2008.	1	1	1	1
27	K. Nottonson and K. DeLong, 2008.	2	2	2	2
28	F. Kinoshita, 2008.	3	3	2	1
29	E. R. Willeke, 2009.	2	3	2	2
30	J. O. Birkeland, 2010, pp.	2	2	2	1
31	C. R. Jakobsen and T. Poppendieck, *2011*	3	4	2	3
32	G. I. U. S. Perera and M. S. D. Fernando, *2007*	3	3	3	3

33	S. Jalali and C. Wohlin, 2010.	3	3	3	2
34	B. Barton, *2009*	*2*	3	4	3
35	K. Rutherford, P. . Shannon, C.Judson, and N. Kidd, 2010.	2	3	1	3
36	K. Nottonson, 2011.	3	3	3	3
37	A. Hui, 2013.	1	2	1	2
38	P. Hodgetts, 2004.	1	1	1	1
39	P. Rodríguez, J. Markkula, M. Oivo, and K. Turula, 2012, p. 139.	4	2	3	3
40	B. Swaminathan and K. Jain, *2012*.	3	3	3	2
41	M. Cristal, D. Wildt, and R. Prikladnicki, 2008.	3	3	2	3
42	C. R. Jakobsen and J. Sutherland, *2009 Agil*	3	3	2	4
43	J. Sutherland, C. R. Jakobsen, and K. Johnson, 2008.	4	3	3	4
44	G. K. Hanssen and T. E. Fgri, , 2008.	3	2	2	3
45	K. Korhonen, 2012.	3	2	3	3
46	David. J, Anderson, 2010.	3	2	1	1
47	M. Lindvall, V. Basili, B. Boehm, P. Costa, K. Dangle, F. Shull, R.Tesoriero, L. Williams, M. Zelkowitz, 2002.	1	1	1	1
48	C. Ebert, P. Abrahamsson and N. Oza, 2012	2	1	1	1
49	P. Middleton, 2001.	1	1	1	1
50	M. Inoki, Fukazawa, 2007	4	2	2	3
51	R. Mahanti and J. Antony, 2006	3	4	3	3
52	E. Danovaro, A. Janes, G. Succi, 2008	3	4	3	3
53	P. Middleton and D. Joyce, 2012	3	2	2	3

B.2 Data extraction checklist

Table B.2 Data extraction form

S ID	CQ1.1	CQ 1.2	CQ2.1	CQ2.2	CQ2.3	CQ3.1
[P1]	Partly	Yes	Yes	Yes	No	Partly
[P2]	Yes	Yes	Yes	Partly	Yes	Yes
[P3]	Yes	Yes	Partly	Yes	Yes	Partly
[P4]	Yes	Yes	Yes	Yes	No	No
[P5]	Partly	Partly	Yes	Yes	Partly	Partly
[P6]	Yes	Yes	Partly	Partly	Partly	No
[P7]	Partly	Partly	No	Yes	Yes	No
[P8]	Yes	Partly	No	Partly	Partly	No
[P9]	Partly	Partly	Partly	Yes	Partly	Partly
[P10]	Partly	Partly	Partly	Yes	Partly	No
[P11]	No	Partly	Partly	Partly	No	No
[P12]	Yes	Yes	Partly	Partly	Yes	Yes
[P13]	Partly	Yes	Partly	No	Partly	No
[P14]	Yes	Yes	Partly	Partly	Partly	Partly
[P15]	Partly	Yes	Yes	Yes	No	No

[P16]	Partly	Partly	No	Partly	Partly	No
[P17]	No	Partly	No	No	No	No
[P18]	Partly	Partly	Partly	No	No	No
[P19]	No	Partly	Partly	Partly	Partly	No
[P20]	Yes	Partly	Partly	Partly	Partly	No
[P21]	No	Yes	No	No	Yes	No
[P22]	No	Partly	No	Partly	Yes	Partly
[P23]	Partly	Partly	Partly	Partly	Yes	No
[P24]	No	Partly	No	No	Yes	Partly
[P25]	Yes	Yes	Partly	Partly	Yes	Yes
[P26]	No	No	No	No	Yes	No
[P27]	Partly	No	No	No	Partly	No
[P28]	Partly	No	No	No	Yes	No
[P29]	Yes	Partly	Partly	No	Partly	Partly
[P30]	Partly	No	Partly	No	Yes	No
[P31]	Yes	Yes	Yes	Partly	Yes	Yes
[P32]	Partly	Partly	Partly	Partly	Yes	Yes
[P33]	Partly	Yes	No	No	Yes	Partly
[P34]	Partly	Partly	Partly	Yes	Yes	Yes
[P35]	Partly	Yes	Partly	Yes	Yes	Partly
[P36]	Yes	Partly	Yes	Yes	Yes	Yes
[P37]	Partly	Yes	Partly	No	Partly	No
[P38]	Yes	Partly	No	Partly	Yes	Yes
[P39]	Yes	Partly	Partly	Partly	Yes	Partly
[P40]	Partly	Partly	Partly	No	Yes	No
[P41]	Yes	Partly	No	No	Yes	Partly
[P42]	Yes	Yes	Partly	No	Yes	Partly
[P43]	Yes	Partly	Partly	No	No	Partly
[P44]	Yes	Yes	No	No	Partly	Partly
[P45]	Partly	No	No	No	No	No
[P46]	Yes	Partly	No	Yes	No	No
[P47]	Yes	Yes	No	Partly	No	No
[P48]	Yes	Partly	Yes	Partly	No	No
[P49]	No	Partly	Partly	Partly	Partly	Partly
[P50]	No	Yes	Partly	Partly	Partly	No
[P51]	Yes	Partly	No	Partly	Partly	No
[P52]	No	Partly	Yes	Yes	No	No
[P53]	Yes	No	Yes	Yes	No	No

B.3 Survey Questionnaire

Survey on usage and efficiency of Lean and Agile practices in eliminating wastes from the software development.

1. Name of the country where your organization was located *

2. Number of years in industrial Software Development projects *
Mark only one oval.

Less than a year
1-2 Years
2-4 Years
4-6 Years
more than 6 years

3. Number of years with lean Software Development projects *
Mark only one oval.

Less than a year
1-2 years
2-4 years
4-6 years
more than 6 years

4. Number of years of experience with agile methods

5. Please mention your Software Product Type *
Check all that apply.

Customer oriented software
Business oriented software
Mobile applications
System Gaming
Automotive
Aerospace
Medical Devices
Embedded Systems
Operating Systems
Real time control software
Other:-------------

6. Your Current Designation *
Mark only one.

Project manager
Team Leader

Team Member
Software Programmer
Software Tester
Software Analyst
Software Designer
Software Quality Assurance Officer
Lean Coach
Scrum Master

7. Size of your organization *
Mark only one oval.

Small scale (5-10)
Medium scale (10-20)
Large scale (more than 20)

8. What are the lean practices that are used in your organization to eliminate waste from the software development process? *
Check all that apply.

Kanban / Hardware development
Value Stream Mapping (VSM)
Kaizen
Kotter
Other:

9. What are the agile methods that are mostly followed in your organization?
Check all that apply.

SCRUM
Extreme Programming (XP)
Test Driven Development (TDD)
Crystal Clear
Feature Driven Development
Modeling
Adaptive Software Development

10. Indicate the frequency of use in your work for the following practices.
Mark only one oval per row.

	Always	Very Frequently	Occasionally	Rarely	Very Rarely	Never
Kanban						
Value Stream Mapping (VSM)						
Kaizen						
Kotter						

11. Kanban lean practice has been useful in my practical work to eliminate wastes.
Mark only one oval per row.

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Partially Done Work					
Extra Process					
Extra features					
Task Switching					
Waiting					
Motion					
Defects					

12. Value Stream Mapping has been useful in my practical work to eliminate wastes.
    Mark only one oval per row.

	Strongly agree	Agree	Undecided	Disagree	Strongly Disagree
Partially Done Work					
Extra Process					
Extra Features					
Task Switching					
Waiting					
Motion					
Defects					

13. Kotter lean practice has been useful in my practical work to eliminate wastes.
    Mark only one oval per row.

	Strongly agree	Agree	Undecided	Disagree	Strongly Disagree
Partially Done Work					
Extra Process					
Extra Features					
Task Switching					
Waiting					
Motion					
Defects					

14. Kaizen lean practice has been useful in my practical work to eliminate wastes.
    Mark only one oval per row.

	Strongly agree	Agree	Undecided	Disagree	Strongly Disagree
Partially Done Work					
Extra Process					
Extra Features					
Task Switching					
Waiting					
Motion					
Defects					

15. Scrum has been useful in my practical work to eliminate wastes.
    Mark only one oval per row.

	Strongly agree	Agree	Undecided	Disagree	Strongly Disagree
Partially Done Work					
Extra Process					
Extra Features					
Task Switching					
Waiting					
Motion					
Defects					

16. Extreme Programming (XP) has been useful in my practical work to eliminate wastes.

Mark only one oval per row.

	Strongly agree	Agree	Undecided	Disagree	Strongly Disagree
Partially Done Work					
Extra Process					
Extra Features					
Task Switching					
Waiting					
Motion					
Defects					

17. What are the major limitations of lean practices that you have experienced while implementing . *

18. What are the major benefits of lean practices that you have experienced while implementing . *

19. Please provide your E-mail Id or Contact
Optional

B.4 Descriptive statistics

Test statistics for waste Partially Done Work

Descriptive Statistics

Practices	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles 25th	Percentiles 50th (Median)	Percentiles 75th
Kanban	5	11.0000	14.17745	2.00	36.00	2.5000	6.0000	22.0000
VSM	5	11.0000	11.55422	3.00	30.00	3.0000	5.0000	22.0000
Kotter	5	11.0000	3.53553	5.00	14.00	8.0000	12.0000	13.5000
Kaizen	5	11.0000	7.87401	2.00	22.00	3.5000	12.0000	18.0000
Scrum	5	11.0000	14.43953	2.00	36.00	2.5000	3.0000	23.5000
XP	5	11.0000	3.80789	6.00	16.00	7.5000	11.0000	14.5000

Test statistics for the waste Extra Features

Descriptive Statistics

Practices	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Kanban	5	11.0000	8.27647	3.00	22.00	3.0000	11.0000	19.0000
VSM	5	11.0000	11.20268	.00	25.00	.0000	11.0000	22.0000
Kotter	5	11.0000	7.87401	.00	20.00	4.0000	10.0000	18.5000
Kaizen	5	11.0000	11.76860	.00	31.00	3.0000	9.0000	20.0000
Scrum	5	11.0000	8.77496	3.00	24.00	4.5000	6.0000	20.0000
XP	5	11.0000	11.13553	.00	24.00	2.0000	5.0000	23.0000

Test statistics for the waste Extra Process

Descriptive Statistics

Practices	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Kanban	5	11.0000	8.33667	5.00	25.00	5.0000	8.0000	18.5000
VSM	5	11.0000	8.54400	2.00	22.00	2.5000	12.0000	19.0000
Kotter	5	11.0000	7.64853	.00	21.00	4.5000	11.0000	17.5000
Kaizen	5	11.0000	10.31988	.00	27.00	2.5000	9.0000	20.5000
Scrum	5	11.0000	8.33667	3.00	21.00	4.5000	6.0000	20.0000
XP	5	11.0000	6.74537	5.00	20.00	5.0000	9.0000	18.0000

Test statistics for the waste Task Switching

Descriptive Statistics

Practices	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Kanban	5	11.0000	9.61769	.00	22.00	1.5000	11.0000	20.5000
VSM	5	11.0000	8.33667	.00	20.00	2.5000	13.0000	18.5000
Kotter	5	11.0000	7.90569	3.00	22.00	4.0000	9.0000	19.0000
Kaizen	5	11.0000	8.15475	2.00	20.00	3.5000	9.0000	19.5000
Scrum	5	11.0000	7.31437	3.00	22.00	4.5000	11.0000	17.5000
XP	5	11.0000	7.31437	5.00	19.00	5.5000	6.0000	19.0000

Test statistics for the waste Motion

Descriptive Statistics

Practices	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Kanban	5	11.0000	9.61769	.00	22.00	1.5000	11.0000	20.5000
VSM	5	11.0000	8.33667	.00	20.00	2.5000	13.0000	18.5000
Kotter	5	11.0000	7.90569	3.00	22.00	4.0000	9.0000	19.0000
Kaizen	5	11.0000	8.15475	2.00	20.00	3.5000	9.0000	19.5000
Scrum	5	11.0000	7.31437	3.00	22.00	4.5000	11.0000	17.5000
XP	5	11.0000	7.31437	5.00	19.00	5.5000	6.0000	19.0000

Test statistics for the waste Waiting

Descriptive Statistics

Practices	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Kanban	5	11.0000	7.84219	3.00	21.00	3.0000	14.0000	17.5000
VSM	5	11.0000	8.27647	3.00	22.00	3.0000	11.0000	19.0000
Kotter	5	11.0000	8.33667	3.00	25.00	5.5000	8.0000	18.0000
Kaizen	5	11.0000	13.92839	1.00	35.00	2.0000	5.0000	23.0000
Scrum	5	11.0000	6.74537	5.00	20.00	5.0000	9.0000	18.0000
XP	5	11.0000	6.96419	.00	19.00	5.0000	13.0000	16.0000

Test statistics for the waste Defects

Descriptive Statistics

Practices	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
Kanban	5	11.0000	8.71780	.00	22.00	2.5000	12.0000	19.0000
VSM	5	11.0000	7.07107	.00	17.00	4.0000	14.0000	16.5000
Kotter	5	11.0000	8.27647	.00	19.00	3.0000	11.0000	19.0000
Kaizen	5	11.0000	8.68907	5.00	25.00	5.0000	6.0000	19.5000
Scrum	5	11.0000	8.30662	3.00	24.00	4.5000	8.0000	19.0000
XP	5	11.0000	8.80341	.00	19.00	1.5000	16.0000	18.0000

B.5 Statistical test for the influence of experience, on each practice with respect to each waste.

Test Statistics for Partially done work

Ranks

	Mean Rank
Knban	3.16
VSM	2.95
Kotter	1.39
Kaizen	2.49

Test Statistics[a]

N	55
Chi-Square	105.811
df	3
Asymp. Sig.	.000

a. Friedman Test

To know whether the answers differ with respect to experience a non-parametric statistics with Wilocxon signed rank rest is performed for each waste.

Ranks

		N	Mean Rank	Sum of Ranks
Kanban4to5 - Kanban1to3	Negative Ranks	0[a]	.00	.00
	Positive Ranks	19[b]	10.00	190.00
	Ties	4[c]		
	Total	23		
VSM4to5 - VSM1to3	Negative Ranks	0[d]	.00	.00
	Positive Ranks	23[e]	12.00	276.00
	Ties	0[f]		
	Total	23		
Kotter4to5 - Kotter1to3	Negative Ranks	0[g]	.00	.00
	Positive Ranks	23[h]	12.00	276.00
	Ties	0[i]		
	Total	23		
Kaizen4to5 - Kaizen1to3	Negative Ranks	0[j]	.00	.00
	Positive Ranks	22[k]	11.50	253.00
	Ties	0[l]		
	Total	22		

a. Kanban4to5 < Kanban1to3	g. Kotter4to5 < Kotter1to3
b. Kanban4to5 > Kanban1to3	h. Kotter4to5 > Kotter1to3
c. Kanban4to5 = Kanban1to3	i. Kotter4to5 = Kotter1to3
d. VSM4to5 < VSM1to3	j. Kaizen4to5 < Kaizen1to3
e. VSM4to5 > VSM1to3	k. Kaizen4to5 > Kaizen1to3
f. VSM4to5 = VSM1to3	l. Kaizen4to5 = Kaizen1to3

Test Statistics[a]

	Kanban4to5 - Kanban1to3	VSM4to5 - VSM1to3	Kotter4to5 - Kotter1to3	Kaizen4to5 - Kaizen1to3
Z	-3.872[b]	-4.413[b]	-4.420[b]	-4.235[b]
Asymp. Sig. (2-tailed)	.000	.000	.000	.000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Test Statistics for Extra Process

Ranks

	Mean Rank
Kanban	3.21
VSM	2.99
Kotter	1.50
Kaizen	2.30

Test Statistics[a]

N	55
Chi-Square	99.313
df	3
Asymp. Sig.	.000

a. Friedman Test

Ranks

		N	Mean Rank	Sum of Ranks
Kanban4to5 - Kanban1to3	Negative Ranks	26[a]	13.50	351.00
	Positive Ranks	0[b]	.00	.00
	Ties	2[c]		
	Total	28		
VSM4to5 - VSM1to3	Negative Ranks	23[d]	12.00	276.00
	Positive Ranks	0[e]	.00	.00
	Ties	0[f]		
	Total	23		
Kotter4to5 - Kotter1to3	Negative Ranks	0[g]	.00	.00
	Positive Ranks	23[h]	12.00	276.00

	Ties	0[i]		
	Total	23		
Kaizen4to5 - Kaizen1to3	Negative Ranks	23[j]	12.00	276.00
	Positive Ranks	0[k]	.00	.00
	Ties	0[l]		
	Total	23		

a. Kanban4to5 < Kanban1to3	g. Kotter4to5 < Kotter1to3
b. Kanban4to5 > Kanban1to3	h. Kotter4to5 > Kotter1to3
c. Kanban4to5 = Kanban1to3	i. Kotter4to5 = Kotter1to3
d. VSM4to5 < VSM1to3	j. Kaizen4to5 < Kaizen1to3
e. VSM4to5 > VSM1to3	k. Kaizen4to5 > Kaizen1to3
f. VSM4to5 = VSM1to3	l. Kaizen4to5 = Kaizen1to3

Test Statistics[a]

	Kanban4to5 - Kanban1to3	VSM4to5 - VSM1to3	Kotter4to5 - Kotter1to3	Kaizen4to5 - Kaizen1to3
Z	-4.594[b]	-4.363[b]	-4.326[c]	-4.414[b]
Asymp. Sig. (2-tailed)	.000	.000	.000	.000

a. Wilcoxon Signed Ranks Test b. Based on positive ranks   c. Based on negative ranks.

.

Test Statistics for Extra Features

Ranks

	Mean Rank
Kanban	3.07
VSM	3.51
Kotter	1.27
Kaizen	2.15

Test Statistics[a]

N	55
Chi-Square	126.000
df	3
Asymp. Sig.	.000

a. Friedman Test

Ranks

		N	Mean Rank	Sum of Ranks
Kanban4to5 - Kanban1to3	Negative Ranks	23[a]	12.00	276.00
	Positive Ranks	0[b]	.00	.00

	Ties	0[c]		
	Total	23		
VSM4to5 - VSM1to3	Negative Ranks	23[d]	12.00	276.00
	Positive Ranks	0[e]	.00	.00
	Ties	0[f]		
	Total	23		
Kotter4to5 - Kotter1to3	Negative Ranks	23[g]	12.00	276.00
	Positive Ranks	0[h]	.00	.00
	Ties	0[i]		
	Total	23		
Kaizen4to5 - Kaizen1to3	Negative Ranks	23[j]	12.00	276.00
	Positive Ranks	0[k]	.00	.00
	Ties	0[l]		
	Total	23		

a. Kanban4to5 < Kanban1to3	g. Kotter4to5 < Kotter1to3
b. Kanban4to5 > Kanban1to3	h. Kotter4to5 > Kotter1to3
c. Kanban4to5 = Kanban1to3	i. Kotter4to5 = Kotter1to3
d. VSM4to5 < VSM1to3	j. Kaizen4to5 < Kaizen1to3
e. VSM4to5 > VSM1to3	k. Kaizen4to5 > Kaizen1to3
f. VSM4to5 = VSM1to3	l. Kaizen4to5 = Kaizen1to3

Test Statistics[a]

	Kanban4to5 - Kanban1to3	VSM4to5 - VSM1to3	Kotter4to5 - Kotter1to3	Kaizen4to5 - Kaizen1to3
Z	-4.263[b]	-4.326[b]	-4.378[b]	-4.332[b]
Asymp. Sig. (2-tailed)	.000	.000	.000	.000

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

Test Statistics for Task Switching

Ranks

	Mean Rank
Kanban	2.77
VSM	3.59
Kotter	1.55
Kaizen	2.08

Test Statistics[a]

N	55
Chi-Square	100.113
df	3
Asymp. Sig.	.000

a. Friedman Test

Ranks

		N	Mean Rank	Sum of Ranks
Kanban4to5 - Kanban1to3	Negative Ranks	0[a]	.00	.00
	Positive Ranks	13[b]	7.00	91.00
	Ties	8[c]		
	Total	21		
VSM4to5 - VSM1to3	Negative Ranks	0[d]	.00	.00
	Positive Ranks	23[e]	12.00	276.00
	Ties	0[f]		
	Total	23		
Kotter4to5 - Kotter1to3	Negative Ranks	0[g]	.00	.00
	Positive Ranks	23[h]	12.00	276.00
	Ties	0[i]		
	Total	23		
Kaizen4to5 - Kaizen1to3	Negative Ranks	0[j]	.00	.00
	Positive Ranks	23[k]	12.00	276.00
	Ties	0[l]		
	Total	23		

a. Kanban4to5 < Kanban1to3	g. Kotter4to5 < Kotter1to3
b. Kanban4to5 > Kanban1to3	h. Kotter4to5 > Kotter1to3
c. Kanban4to5 = Kanban1to3	i. Kotter4to5 = Kotter1to3
d. VSM4to5 < VSM1to3	j. Kaizen4to5 < Kaizen1to3
e. VSM4to5 > VSM1to3	k. Kaizen4to5 > Kaizen1to3
f. VSM4to5 = VSM1to3	l. Kaizen4to5 = Kaizen1to3

Test Statistics[a]

	Kanban4to5 - Kanban1to3	VSM4to5 - VSM1to3	Kotter4to5 - Kotter1to3	Kaizen4to5 - Kaizen1to3
Z	-3.272[b]	-4.280[b]	-4.355[b]	-4.332[b]
Asymp. Sig. (2-tailed)	.001	.000	.000	.000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Test Statistics for Waiting

Ranks

	Mean Rank
Kanban	2.99
VSM	3.25
Kotter	1.35
Kaizen	2.40

Test Statistics[a]

N	55
Chi-Square	103.484
df	3
Asymp. Sig.	.000

a. Friedman Test

Ranks

		N	Mean Rank	Sum of Ranks
Kanban4to5 - Kanabn1to3	Negative Ranks	17[a]	13.00	221.00
	Positive Ranks	4[b]	2.50	10.00
	Ties	6[c]		
	Total	27		
VSM4to5 - VSM1to3	Negative Ranks	0[d]	.00	.00
	Positive Ranks	17[e]	9.00	153.00
	Ties	0[f]		
	Total	17		
Kotter4to5 - Kotter1tp3	Negative Ranks	0[g]	.00	.00
	Positive Ranks	23[h]	12.00	276.00
	Ties	0[i]		
	Total	23		
Kaizen4to5 - Kaizen1to3	Negative Ranks	20[j]	10.50	210.00
	Positive Ranks	0[k]	.00	.00
	Ties	3[l]		
	Total	23		

a. Kanban4to5 < Kanabn1to3	g. Kotter4to5 < Kotter1tp3
b. Kanban4to5 > Kanabn1to3	h. Kotter4to5 > Kotter1tp3

c. Kanban4to5 = Kanabn1to3	i. Kotter4to5 = Kotter1tp3
d. VSM4to5 < VSM1to3	j. Kaizen4to5 < Kaizen1to3
e. VSM4to5 > VSM1to3	k. Kaizen4to5 > Kaizen1to3
f. VSM4to5 = VSM1to3	l. Kaizen4to5 = Kaizen1to3

Test Statistics[a]

	Kanban4to5 - Kanabn1to3	VSM4to5 - VSM1to3	Kotter4to5 - Kotter1tp3	Kaizen4to5 - Kaizen1to3
Z	-3.874[b]	-3.743[c]	-4.420[c]	-4.053[b]
Asymp. Sig. (2-tailed)	.000	.000	.000	.000

a. Wilcoxon Signed Ranks Test b. Based on positive ranks c. Based on negative ranks.

Test Statistics for Motion

Ranks

	Mean Rank
Kanban	3.33
VSM	3.38
Kotter	1.38
Kaizen	1.91

Test Statistics[a]

N	55
Chi-Square	134.217
df	3
Asymp. Sig.	.000

Ranks

		N	Mean Rank	Sum of Ranks
Kanban4to5 - Kanban1to3	Negative Ranks	0[a]	.00	.00
	Positive Ranks	19[b]	10.00	190.00
	Ties	1[c]		
	Total	20		
VSM4to5 - VSM1to3	Negative Ranks	11[d]	7.00	77.00
	Positive Ranks	2[e]	7.00	14.00
	Ties	11[f]		
	Total	24		
Kotter4to5 - Kotter1to3	Negative Ranks	23[g]	12.00	276.00
	Positive Ranks	0[h]	.00	.00
	Ties	0[i]		
	Total	23		
Kaizen4to5 - Kaizen1to3	Negative Ranks	23[j]	12.00	276.00
	Positive Ranks	0[k]	.00	.00
	Ties	9[l]		
	Total	32		

Test Statistics[a]

	Kanban4to5 - Kanban1to3	VSM4to5 - VSM1to3	Kotter4to5 - Kotter1to3	Kaizen4to5 - Kaizen1to3
Z	-3.921[b]	-2.496[c]	-4.323[c]	-4.253[c]
Asymp. Sig. (2-tailed)	.000	.013	.000	.000

a. Wilcoxon Signed Ranks Test b. Based on negative ranks. c. Based on positive ranks.

a. Kanban4to5 < Kanban1to3	g. Kotter4to5 < Kotter1to3
b. Kanban4to5 > Kanban1to3	h. Kotter4to5 > Kotter1to3
c. Kanban4to5 = Kanban1to3	i. Kotter4to5 = Kotter1to3
d. VSM4to5 < VSM1to3	j. Kaizen4to5 < Kaizen1to3
e. VSM4to5 > VSM1to3	k. Kaizen4to5 > Kaizen1to3
f. VSM4to5 = VSM1to3	l. Kaizen4to5 = Kaizen1to3

Test Statistics for Defects

Ranks

	Mean Rank
Kanban	2.60
VSM	2.64
Kotter	1.51
Kaizen	3.25

Test Statistics[a]

N	55
Chi-Square	89.050
df	3
Asymp. Sig.	.000

a. Friedman Test

a. Kanban4to5 < Kanban1to3	g. Kotter4to5 < Kotter1to3
b. Kanban4to5 > Kanban1to3	h. Kotter4to5 > Kotter1to3
c. Kanban4to5 = Kanban1to3	i. Kotter4to5 = Kotter1to3
d. VSM4to5 < VSM1to3	j. Kaizen4to5 < Kaizen1to3
e. VSM4to5 > VSM1to3	k. Kaizen4to5 > Kaizen1to3
f. VSM4to5 = VSM1to3	l. Kaizen4to5 = Kaizen1to3

Ranks

		N	Mean Rank	Sum of Ranks
Kanban4to5 - Kanban1to3	Negative Ranks	27[a]	14.00	378.00
	Positive Ranks	0[b]	.00	.00
	Ties	0[c]		
	Total	27		
VSM4to5 - VSM1to3	Negative Ranks	16[d]	8.50	136.00
	Positive Ranks	0[e]	.00	.00
	Ties	0[f]		
	Total	16		
Kotter4to5 - Kotter1to3	Negative Ranks	23[g]	12.00	276.00
	Positive Ranks	0[h]	.00	.00
	Ties	0[i]		
	Total	23		
Kaizen4to5 - Kaizen1to3	Negative Ranks	23[j]	12.00	276.00
	Positive Ranks	0[k]	.00	.00
	Ties	0[l]		
	Total	23		

Test Statistics[a]

	Kanban4to5 - Kanban1to3	VSM4to5 - VSM1to3	Kotter4to5 - Kotter1to3	Kaizen4to5 - Kaizen1to3
Z	-4.696[b]	-3.619[b]	-4.630[b]	-4.323[b]
Asymp. Sig. (2-tailed)	.000	.000	.000	.000

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.