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Investigating the Suitability of Extreme Programming for Global Software Development

A Systematic Review and Industrial Survey

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ABSTRACT

Context: Over the past few years, Global Software Development (GSD) has emerged as an evolving trend in the software industry. The reasons behind this evolution are globalization, economic benefits, time to market, organizational and strategic location, access to skilled labor and reduction of costs. But despite its benefits, GSD also has challenges associated with communication, coordination and control. The challenges are mainly due to temporal, geographical and socio-cultural distances. Due to flexibility, and emphasis on frequent communication in agile methods, researchers have shown interest in incorporating agile methods in GSD. Extreme Programming (XP) is one of the most widely known agile methodologies that values simplicity, communication, courage and feedback. In this research study, we have investigated the suitability of XP in GSD by exploring its benefits and challenges in the state of art and state of practice.

Objectives: This study aims at investigating the benefits and challenges associated with the combination of XP and GSD both in the research literature and in practice. The study also explores practices or solutions adopted in order to address the challenges of XP-GSD combination. Moreover, this study compares challenges of XP-GSD combination with the traditional GSD challenges.

Methods: This research study has been accomplished with the help of a systematic literature review (SLR) and an industrial survey. For the systematic review, the snowballing approach was applied, and an initial set of papers was selected from IEEE Xplore and Google Scholar. After selecting the initial set of papers, backward snowballing was conducted by searching the reference list of the selected articles. Then, forward snowballing was conducted by looking for the citations of the selected articles. After completing the systematic review, the industrial survey was conducted to complement the findings of the literature review. The data collected from both SLR and survey was analyzed both separately and collectively.

Results: Through SLR, we have identified 21 benefits, 17 challenges, and 18 solutions to the identified challenges. The benefits and challenges have been classified according to communication, coordination and control in correspondence with temporal, socio-cultural and geographical distance. From the survey, we have identified 19 benefits, 20 challenges, and 17 solutions to the identified challenges. However, 13 benefits, 9 challenges, and 8 solutions were in common. The majority of challenges found in both literature review and survey were however traditional GSD challenges.

Conclusions: The scarcity of research literature in the area suggests that more work needs to be done to successfully implement XP in GSD projects. The benefits and challenges extracted from literature and industry suggest that the application of XP can be beneficial for GSD since the majority of the reported challenges are traditional GSD challenges. Nevertheless, application of XP practices can alleviate these challenges. Based on the results, we conclude that XP can be successfully adopted in GSD projects.

Keywords: Global Software Development, Extreme Programming, Global Software Engineering, Distributed Software Development, Agile

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ABBREVIATIONS

No	Short Form	Word
1	**GSD**	Global Software Development
2	**GSE**	Global Software Engineering
3	**DSD**	Distributed Software Development
4	**XP**	Extreme Programming
5	**SLR**	Systematic Literature Review
6	**QDA**	Qualitative Data Analysis
7	**QCA**	Qualitative Comparative Analysis
8	**Com**	Communication
9	**Coord**	Coordination
10	**Ctrl**	Control
11	**Ben**	Benefit
12	**Chlg**	Challenge
13	**Sol**	Solution
14	**SUR**	Survey
15	**Gen**	General
16	**Pr**	Productivity
17	**Qlty**	Quality

1 INTRODUCTION

Over the past few years, many new trends have emerged in the field of software engineering. These emerging trends have affected the methods and practices of software engineering to a large extent. Software is no longer developed by engineers working on their computers in collocated places. Software organizations are shifting towards Global Software Development (GSD). In GSD, also known as Global Software Engineering (GSE) or Distributed Software Development (DSD), people from different countries, time zones and cultures work together to develop a software [1]. Due to globalization trends in software development, a large number of enterprise level software products are mostly developed in more than one location across continents. Economic benefits, short time-to-market, strategic and organizational location, and access to skilled work force are some of the reasons behind this trend [2]. But so far, most of the companies have not been able to achieve these benefits [3] because GSD brings with itself a number of issues related to communication and coordination, cultural differences, lack of trust between organization and time-zone differences [4], [5].

Agile software development methods mitigate on the limitations of traditional software development, and are flexible to requirement' changes in all phases of software development [6]. Agile methods encourage small self-organized teams and focus on collaboration between customers and developers [7]. Frequent informal face-to-face communication makes agile an adaptive, repetitive and minimally defined process [8]. Due to its emphasis on frequent face-to-face communication researchers are interested in combining agile methods with GSD to cope with some issues of GSD. Extreme Programming (XP) [9] is one of the most widely used agile methods. XP focuses on doing the simplest things to get the job done, and is mainly used for software development activities that have changing requirements. XP follows a set of values in developing software products. While communication is one of the four values of XP, it's one of the major challenges in GSD. Despite the fact that XP has some significant differences with GSD, it is interesting to explore whether XP is suitable for GSD.

The main purpose of this research study is to investigate the suitability of XP for GSD by finding out the benefits and challenges of XP-GSD combination. The data gathered from the literature (through forward and backward snowballing) is compared against the data collected from the industry practitioners (through survey). The study also aims at exploring the similarities and differences between the findings of literature and industry. In addition, it investigates whether the application of XP improves or worsens the already existing challenges of GSD.

The rest of this document is organized as follows. Chapter 1 provides an introduction to the topic, background of the study, aims and objectives, research questions, expected outcomes and related work. Chapter 2 discusses research methodology, and chapter 3 describes planning and conducting of the systematic literature review. Chapter 4 presents the results of SLR along with discussions around them, and discusses the data analysis. Chapter 5 provides details of survey design, results, analysis, discussion and conclusion of the survey. Chapter 6 discusses validity threats as well as the lessons learnt, and finally chapter 7 presents the conclusion and future work.

1.1 Background

Global software development is an emerging trend in modern software industry and a large number of software products are developed in global environment nowadays [4]. The major reasons behind this shift are round the clock development, access to skilled workers, and reduction of cost [3]. Most of the companies started shifting to GSD for cheaper, faster and better software development but the empirical research in the area suggest that it is not

easy to realize these benefits of GSD [10]. There are many challenges associated with GSD e.g. lack of communication and trust, time-zone differences, language and cultural differences [11].

Agile methods could be incorporated into GSD to solve some of its challenges but the combination seems to be incompatible at the first place because communication and close collaboration among the team members are the critical features of agile software development whereas these are the major problems in GSD. Although agile methods have previously been successfully incorporated into GSD [P9], there are still challenges associated with this combination. Some of these challenges are lack of communication, lack of trust, time zone and cultural differences. In order to solve these issues more work is required [12].

XP is one of the most widely used agile methods due to its potential to address the existing problems of traditional plan driven methods. XP is based on four values namely communication, courage, simplicity, and feedback. Based on these four values, XP consists of twelve independent practices. These practices are planning game, small releases, metaphor, simple design, testing, refactoring, pair programming, collective ownership, continuous integration, 40 hour week, on-site customer, and coding standard [9]. Traditional software development methods focus on processes such as heavy documentation, strict project management, and minimum requirements' changes during the course of the project development. Instead, XP focuses on informal processes and is flexible to requirements' changes.

According to [13], many factors that help to coordinate the work in co-located environment are not applicable in GSD. Some of these factors are a common recognized environment, sharing the same project view, and frequent formal and informal communication. GSD requires quick response to changes but is very hard to achieve due to the challenges related to communication, coordination and control brought by temporal, geographical and socio-cultural distances [14]. On the other hand, XP values simplicity, communication, courage, and feedback, which all together make XP one of the most suitable methods for GSD.

According to [12], XP is one of the most widely known agile methods in the context of GSD. However, it is not clear whether XP is a suitable choice for GSD because XP focuses frequent communication with the customer, which is very difficult to attain in GSD. Besides, XP does not provide specific guidelines for project management [15]. These issues make the combination of XP with GSD challenging.

1.1.1 Related Work

There are some research studies conducted on the use of extreme programming in global software development. However, most of the studies have not directly discussed the benefits and/or challenges associated with the combination of XP and GSD. Most of the studies discussed the incorporation of XP into their projects and then discussed how this incorporation helped them or created problems for them in their software development processes. A brief summary of relevant studies is given below.

Fowler [16] has explained how they implemented agile process in an offshore project between the US and India in which both offshore and onshore teams successfully implemented agile practices. The applied practices were continuous integration, small iterations, several different communication modes, and proxy customer. However, the practices such as continuous integration and test process pointed out many integration problems earlier, so that they could be fixed as quickly as possible. It is concluded that applying these practices helped to avoid problems related to communication as well as

culture and time zone differences, to deliver business value, and to response to the changes quickly.

Simpson and Duan [58] have explained how they adopted agile in a distributed project. They have stated that pair programming and continuous integration helped with early fault identification. In addition, efficient communication with the customer helped in getting prompt feedback and building trust between the customer and the developing organization. However, it is mentioned that time-zone differences made it difficult for them to kick off iteration.

In [P9], the potential benefits of adopting agile methods in GSD are discussed as well as the unsolved problems that agile teams faced in GSD setting. It is based on the current research literature.

Nisar and Hameed [P3] discussed the introduction of agile practices in an offshore setting to improve customer satisfaction. It is stated that agile practices (i.e. XP in this case) can be successfully implemented in offshore software development. It is concluded that agile practices (i.e. standard documentation practices, continuous integration, short iterations, small releases, proxy customer, and frequent communication) helped to cope with different issues related to lack of communication, lack of project visibility, lack of interaction with the customer, project management and synchronization, and cultural differences.

In [P23], the author has reported the challenges faced in adopting XP in a distributed setting. The identified challenges were due to cultural differences, difficulty in continuous integration and differences in priorities across different regions. The author has also discussed lessons learnt from these challenges in the current processes.

A study by Xiaohu et al. [P11] presents the experience of adopting XP in GSD in which an offshore team collaborated with an onshore customer. The team was located in China and the customer in the USA. The main intention with adopting XP has been to improve the major obstacles due to lack of communication and poor quality of communication. It helped the organization to save costs up to 60% compared to doing the project onshore.

In [17] and [18], the authors have discussed the use of continuous integration, small releases, unit tests, automatic tests, and continuous builds. Both papers have discussed the usefulness of agile practices but they found it hard to implement these practices in GSD settings due to the challenges introduced by distance.

1.1.2 Research Motivation

Previous research studies show that different XP practices (e.g. pair programming, continuous integration, small releases, proxy client, unit testing, simple design, etc.) have been successfully adopted in different distributed contexts. These practices have more or less mitigated some existing challenges of GSD. However, available research evidence is not sufficient (both qualitatively and quantitatively) to conclude that XP is completely suitable in different GSD settings. Therefore, this study aims at comprehensively collect evidence from both research literature and software companies on benefits and challenges of combing XP in GSD. Analyzing the identified pros and cons associated with the combination of XP-GSD leads to answering several interesting questions such as whether XP alleviates or intensifies traditional GSD problems related to communication, control, coordination.

Although it would have been interesting to conduct a research on all agile methods in GSD context, due to time limitation and the scope of this research project it was not feasible to explore all agile methods. Furthermore, XP is one of the most frequently used agile methodologies and this motivated us to investigate whether it actually benefits GSD by solving some of GSD challenges.

In this study, we have investigated the benefits and challenges of adopting XP practices in GSD both in the available research literature and in practice since no prior study has collected and summarized them from both perspectives (i.e. researchers and practitioners). Besides, the study has also investigated the way different organizations and researchers have dealt with the issues of XP in GSD contexts. The study has also investigated whether the introduction of XP has affected the existing GSD challenges related to communication, coordination and control.

1.2 Aims and Objectives

The main purpose of our study is to explore the suitability of extreme programming for global software development. Hence, the major objective of this research is to study benefits and challenges of combining XP and GSD, and possible ways to alleviate the challenges. The objectives can be summarized as follows.

- To identify benefits and challenges of XP-GSD combination in the research literature and in practice
- To compare the benefits of this combination against the challenges
- To classify the challenges of XP in GSD according to their severity
- To identify solutions proposed to cope with the challenges in the literature and by practitioners
- To identify similarities and differences between the evidence found in literature and industry
- To compare the challenges of XP in GSD with traditional GSD challenges

1.3 Research Questions

We have derived the following research questions related to the topic.

RQ1. What is reported in the available research literature about XP practices in GSD?
- **RQ1.1.** What are the benefits and challenges?
- **RQ1.2.** Which challenges are severe and require more attention than others?
- **RQ1.3.** What strategies are adopted to deal with the challenges?

RQ2. What is being done in software organizations that have utilized XP practices in their GSD projects?
- **RQ2.1.** What are the benefits and challenges?
- **RQ2.2.** Which challenges are severe and require more attention than others?
- **RQ2.3.** What strategies are adopted to deal with the challenges?

RQ3. Does GSD benefit from XP practices?
- **RQ3.1.** Which of the identified challenges are traditional GSD problems?
- **RQ3.2.** Which XP practices can alleviate GSD challenges?
- **RQ3.3.** Which XP practices are applied in which GSD settings?

1.4 Expected Outcomes

The expected outcomes of our research will be as follows:

- A list of benefits of adopting XP practices in GSD projects categorized according to the specific GSD setting
- A list of challenges (categorized according to their severity) of adopting XP practices in GSD projects in the specific GSD setting

- A list of strategies adopted to deal with the challenges of using XP practices in GSD projects in a specific GSD setting
- Differences and similarities between the findings from literature and industry
- A list of challenges specific to the combination of XP and GSD
- A list of practices specific to XP that alleviate traditional GSD challenges
- A list of applied XP practices for each GSD setting (e.g. offshore insourcing, onshore outsourcing, etc.)

1.5 Structure of Thesis

We have organized the thesis into three main categories. The Figure 1 illustrates the thesis structure.

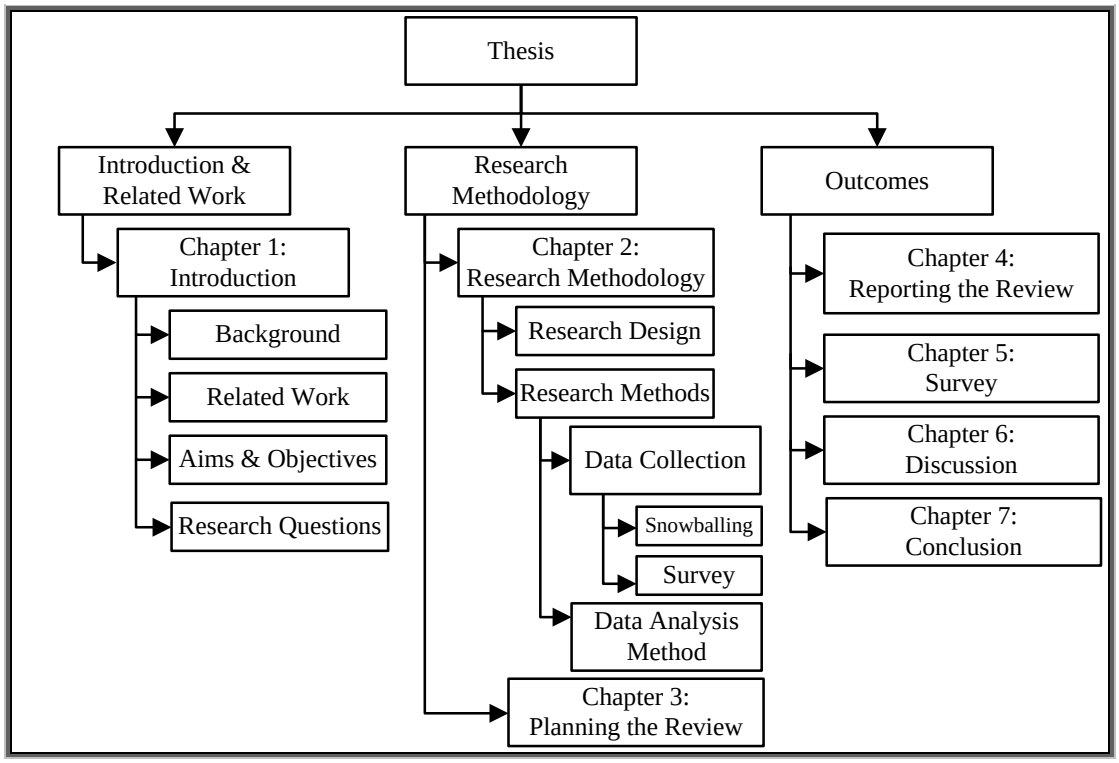

Figure 1 Thesis Structure

1.6 Terminology

- ***Benefit:*** Getting profit form something is known as benefit [45]
- ***Challenge:*** Challenge is stimulating task or problem [45]
- ***Severity:*** A problem requiring great effort to solve is said to be having more severity [45]
- ***Practice:*** Activities based on knowledge, skill or competence and which are used as a normal way for doing something [47]
- ***Solution:*** An action or process used for solving a problem [45]
- ***Outsourcing:*** Outsourcing is of two kinds. An external company develops a software product for a client or provides software development activities to client. This kind of organizational setting is known as offshore outsourcing. Whereas in onshore outsourcing both the client company and sub-contracting companies are located in the same country [46].
- ***Offshoring:*** In offshoring or offshore insourcing, software development centers are established by a company in another country to handle the demands of that particular market [46].

- ***Distributed Teams:*** In distributed teams, the team members located in different places work on different task with or without informal face-to-face meetings [46].
- ***Virtual Teams:*** In virtual teams, team members located in places work jointly on the same tasks [46].

2 RESEARCH METHODOLOGY

In this chapter we have presented the research design, the research methods to answer the posed research questions and the motivation for using the selected methodology.

2.1 Research Design

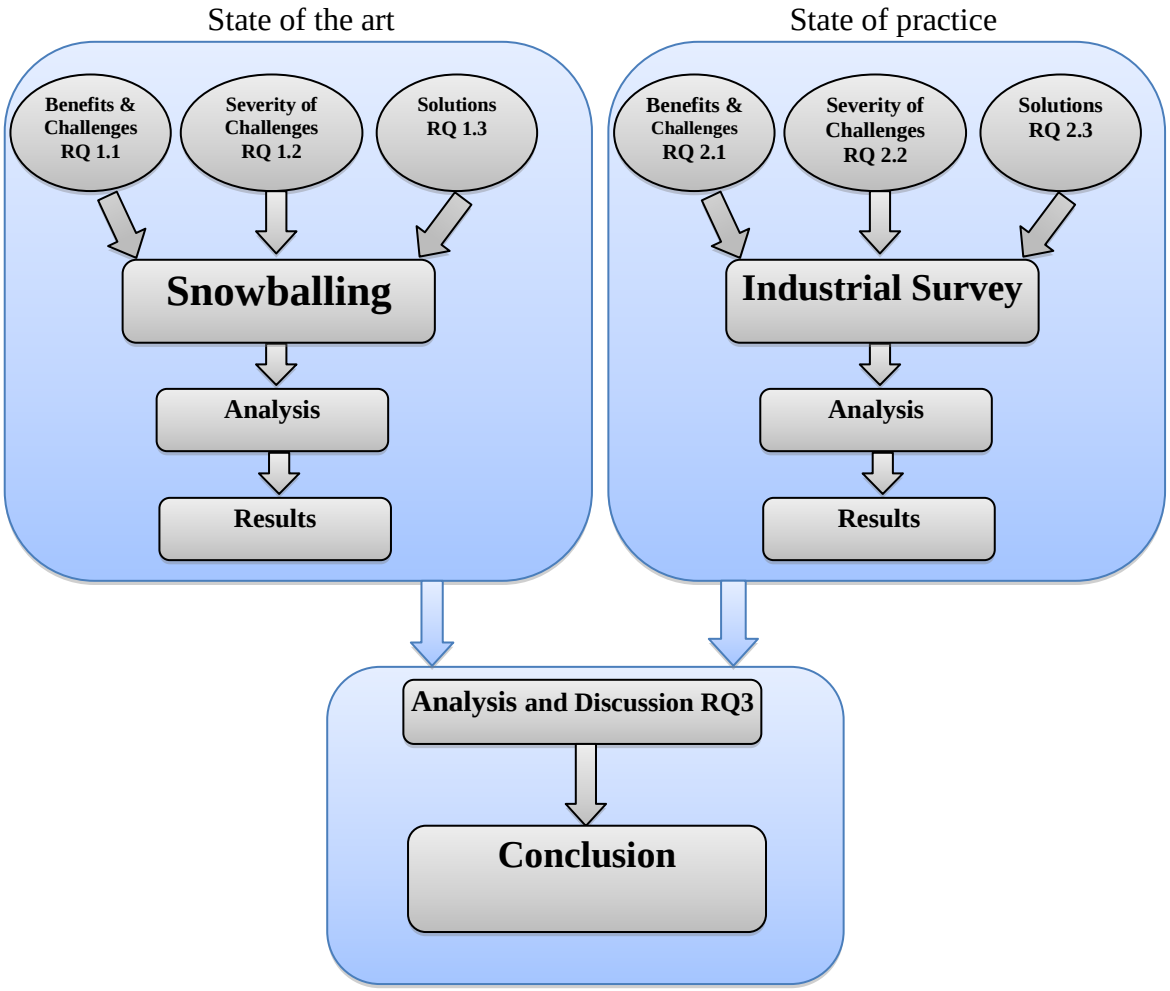

Figure 2 Research Design

We have conducted this study in three different phases. In each of the first two phases, different research methods are employed to get the answers for the posed research questions. In the third phase descriptive and comparative analysis has been performed on the data collected from phase I and phase II.

In the first phase of the research, we applied forward and backward snowballing as discussed in [19]. The purpose of this phase was to collect data from literature and to qualitatively explore the benefits and challenges associated with the application of XP in GSD. The study has also explored the solutions proposed for different challenges associated with the combination of XP and GSD. The data was analyzed both qualitatively and quantitatively and the results related to RQ1 and its sub-questions have been presented.

In the second phase of the research we have conducted an industrial survey in order to explore the benefits, challenges and their solutions in relation to applying XP practices in GSD in software companies. We used both open-ended and close-ended questions in the survey. The data gathered from the survey was analyzed to get the answer for RQ2.

Finally in the third phase, comparative analysis [20] has been conducted on the results of both phase I and phase II in order to understand the similarities and differences between their results. The outcome of this phase provides answer to RQ3.

2.2 Research Methods

According to [21], research is "original investigation undertaken in order to gain understanding and knowledge". A researchers' work is basically built on the application of some methods and techniques [22]. A research work can be conducted by applying qualitative, quantitative or mixed method approaches. In our research work we have adopted a mixed method (combination of qualitative and quantitative) approach. The reason for choosing mixed methodology is that it helps in making the results consistent [22].

2.2.1 Systematic Literature Review (Snowballing)

According to [23], Systematic Literature Review(SLR) can be defined as "a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest". Literature survey (a combination of literature search and literature review) helps in providing a starting point to the researchers and sets the context of the project [24]. SLR is known as a secondary review while the individual research studies included in the SLR providing the original information are known as primary studies [23].

According to [23] and [25], SLR helps in conducting a very accurate methodological review of research evidence and synthesizes the scientific work in a fair way. Besides SLR, two other kinds of literature reviews exist which can be used as alternatives to SLR. The first one is systematic mapping, which is conducted in a situation where the area of research is very broad and very little evidence is available in literature. The second one is known as tertiary review, which is conducted when a number of systematic literature reviews are already conducted. During our preliminary literature survey we have found that systematic mapping and tertiary reviews are not suitable for us because our area of research is neither too broad nor too narrow. We have found that there are studies available on the combination of XP and GSD but no SLR has been conducted in this area. Therefore, we have chosen SLR as one of the methods for our research. We will conduct the SLR in the following steps.

- Planning a literature review by developing a review protocol and justifying the need for SLR
- Conducting the review according to the protocol (selection of primary studies, data extraction and data synthesis)
- Reporting the review by documenting the analyzed data and presenting the results

2.2.2 Survey

After completing the SLR we conducted empirical research in order to complement the findings of SLR. Empirical research can be conducted by applying different methods [26]. Some of these methods are surveys, case studies and experiments. Due to the controlled nature of experiments and the fact that they are used to control the situation and manipulate the behavior directly and precisely [26], experiments are not suitable for this research. On the other hand case studies are conducted in order to observe why and how things happen and to investigate the facts related to the context[27]. Collecting the benefits and challenges of adopting XP in GSD through case study would have been difficult.

Besides, generalizing the results of case study in the context of our research was also difficult. That's why case study was not suitable for this research. So, the empirical research was conducted with the help of an industrial survey. We conducted an industrial survey to investigate the XP practices adopted in the industry in GSD settings, the benefits of these practices, challenges associated with adopting these practices and the practices/solutions adopted to cope with these challenges.

The reason for conducting the survey was to gather more information from the practitioners working at different positions in different organizations. Survey helps in understanding the opinion of a larger population and in generalizing the results [26].

Based on the evidence found in literature we designed our questionnaire. We contacted different persons working at different positions in the industry and asked them to participate in our survey. We also joined different GSD and agile communities and forums online and distributed our survey on those communities' web pages. After the completion of the survey we found the similarities and differences between the evidence found in literature and industry.

2.2.3 Data Analysis

Non-numeric information having different kinds of values is known as qualitative data [28]. Qualitative data can also be termed as information in descriptive form which can neither be counted nor measured [29]. Qualitative data analysis (QDA) is used to convert these kinds of immeasurable data into rational findings. Due to the fact that QDA is unique and is heavily dependent upon the thinking and decision making of analyst, there is no precise formula for QDA [30]. Due to these mentioned facts QDA becomes more difficult. However, there are different kinds of guidelines available for QDA. The data collected from SLR and Survey was first analyzed separately and then jointly.

2.2.3.1 Narrative Analysis

In order to qualitatively analyze the data extracted from snowballing we conducted narrative analysis. According to [51], narrative analysis can be used to analyze reviews from both qualitative and quantitative research. It is the most commonly used analysis method for analyzing the data collected from systematic reviews. A defining characteristic of narrative analysis is the adoption of narrative summary of the findings of studies to the synthesis process [54]. It can happen alongside or instead of statistical analysis. Besides describing the findings of a review, it involves in the selection, ordering and reporting of data extracted from literature [55]. The use of narrative analysis helped in extracting interpretations on a high level of abstraction. The data extracted from both systematic review and open-ended questions in the survey was analyzed using narrative analysis. The results from both systematic review and survey were classified in tabular form.

2.2.3.2 Descriptive Analysis

The close-ended questions in the survey were analyzed by using descriptive analysis. Descriptive analysis summarizes what the data shows. It provides summaries of the sample and the measures [52]. Descriptive analysis is also used to describe the basic features of data in a study. Descriptive analysis also helps in summarizing and classifying the collected data in clear and understandable way [40]. We used descriptive analysis to evaluate the sample size from the survey.

2.2.3.3 Comparative Analysis

Comparison is a very important part of any kind of research. In order to understand the similarities and differences between entities and to build a conceptual model between them, researchers use different kinds of logical and systematic techniques [20]. Qualitative Comparative Analysis (QCA) is a technique which can be applied on the problems making causal interferences on a small number of variables [31].

In QCA an entity is compared with other entities in order to find which features are distinct and which are common among them [32]. Since finding the similarities and differences between state of the art and state of practice regarding the application of XP in the context of GSD is one of the objectives of this research, we decided to use QCA.

2.2.3.4 Alternative Analysis Methods

There are multiple alternatives for analyzing both the qualitative and quantitative data. One possible alternative for analyzing the data extracted from literature review and survey (open-ended questions) was Ground Theory [56] [57]. According to [53], the researchers should not have any pre-conceived idea about the data for conducting grounded theory. However, in our case, we were pretty much sure about the extracted data, its analysis and what we were looking for.

We could also use thematic analysis [55] as an alternate analysis method. As compared to narrative analysis thematic analysis implies restriction on the data being analyzed because it looks for recurrence of themes in the available data [55]. Narrative analysis also helps in finding recurring themes in the available data but the difference between narrative analysis and thematic analysis is that narrative analysis does not just focus on one particular recurring theme.

3 SYSTEMATIC LITERATURE REVIEW (SNOWBALLING)

In the first part of our research we conducted a systematic review to gather data about the application of XP practices in GSD. Literature review can provide results with a high scientific value if it is performed systematically and thoroughly [33]. The primary purpose of conducting the SLR in this thesis was to go through the reported literature in XP and GSD and find the benefits and challenges of XP in the context of GSD i.e. answer to RQ1. The SLR was conducted according to [19] and we had a pre-defined review protocol based on our research questions.

There are three main steps in systematic review. These steps are planning the review, conducting the review and reporting the review.

3.1 Planning the Review

The planning step of systematic review consists of all the planning for conducting the systematic review. In the planning step we defined a review protocol which consisted of search strategy definition, formation of the search string, selection of data sources, inclusion and exclusion of studies, data extraction and quality assessment criteria.

3.1.1 Search Strategy

In order to make the search results clear we recorded all the search results. We maintained a log of the review process where we stored the information about both the included and excluded studies. Before starting our search we formulated a search string based the search keywords from research questions and inspected the search results according to pre-defined selection criteria. Our search strategy consisted of the following steps as suggested by [19].

1. In order to get a starting set of papers start searching in the leading journals and/or conference proceedings
2. Review the reference list of the relevant articles in step 1 and 2
3. Find the citations for the articles found in step 1 and 2

3.1.2 Search String Generation

We have formulated our search string on the basis of the major keywords from the research questions. We have also added different alternative terms to the keywords. Also in order to intersect or incorporate search results of different keywords Boolean operators AND and OR have been used.

{A1 OR A2 OR A3 OR A4 OR A5} AND {B1 OR B2 OR B3 OR B4 OR B5 OR B6 OR B7 OR B8 OR B9 OR B10 OR B11 OR B12 OR B13 OR B14 OR B16 OR B17}

No	Search Keyword
A1	Agile
A2	extreme programming
A3	Xp
A4	xp2
A5	Flexible
B1	distributed software development
B2	global software development
B3	collaborative software development
B4	global software engineering
B4	globally distributed work
B6	collaborative software engineering
B7	distributed development
B8	distributed teams
B9	global software teams
B10	globally distributed development
B11	geographically distributed software development
B12	dispersed teams
B13	multi-site software development
B14	software offshor*
B15	software outsourc*
B16	software onshor*
B17	software insourc*

Table 1 Search Keywords

3.1.3 Study Selection Criteria

We reviewed studies written in English only. We decided inclusion of the studies on the basis of title and abstract. If we were unable to decide the inclusion or exclusion of a study on the basis of title and abstract we reviewed the full text of the article. This was to make sure that we do not miss any studies relevant to our systematic review. We discarded those articles, which were not available in full text. We removed duplicate studies in the beginning of our review and it helped us save substantial amount of time for the review process. The detail of our inclusion and exclusion criteria is given below.

3.1.3.1 Inclusion Criteria

- Availability of the articles in full text
- Articles are published in journals, conference proceedings
- Articles are empirical studies on XP and GSD or they provide an overview of XP in GSD or they discuss the benefits and/or challenges of adopting XP practices in GSD or they propose solutions/practices/frameworks/strategies to cope with the challenges of XP in GSD.

3.1.3.2 Piloting Inclusion/Exclusion Criteria

A pilot study is small scale preliminary study conducted before performing a complete systematic review in order to have a mutual understanding between the authors [34]. It helps in avoiding bias and brings consensus between the authors. We applied our inclusion/exclusion separately on the downloaded papers. In the beginning we applied our inclusion/exclusion criteria on three randomly selected papers. Based on our inclusion/exclusion criteria each one of us individually decided whether to include a particular paper or not. In order to be sure of the selection of studies by both of us, we also performed Kappa statistics. Kappa statistics is used to measure the level of agreement between two raters/researchers [35]. Kappa is useful in cases where all the disagreements are equally serious [35]. In Kappa each sample of subjects is rated on a nominal scale from

0.0 to 1.0. A higher value suggests more reliability where as a lower value suggests a lower level of agreement [36]. In order to be consistent while describing the relevant strength of agreement according to Kappa statistics the labels in **Table 2** are assigned to the corresponding ranges [36]. For calculating kappa we used online kappa calculator [50]. Our kappa reliability measure was 0.632, which was acceptable according to **Table 2.**

In case of a very high level of disagreement, we sat to discuss the conflicts and tried to develop a mutual understanding and consensus. After having a mutual understanding we started the actual study selection process.

Kappa Statistics	Strength of Agreement
<0.00	Poor
0.00-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost Perfect

Table 2 Kappa Statistics

Regarding agreement about the extraction of data, we extracted data from five papers initially and sent it to our supervisor. After verification and acknowledgment of the supervisor regarding the extracted data we started extraction of the selected primary studies.

3.1.3.3 Quality Assessment of Studies

After going through the inclusion criteria the studies were assessed for quality according to predefined checklist. Quality assessment of studies is performed to provide a more detailed inclusion/exclusion criteria and to minimize the possibility of bias among the researchers [34]. The following table presents the quality assessment criteria for our selected studies.

S. No	Quality Assessment Checklist	Yes/No
1	Is the context of the study clearly described?	
2	Are the results of the study clearly described?	

Table 3 Quality Assessment Checklist

3.1.3.4 Data Extraction Strategy

We used a pre-defined data extraction form to collect data from the selected studies. We divided the extracted data into three main categories. The first one is general information, the second one is background information and third one is specific information. All the three categories and their specific attributes are described below. See **Appendix 8.2** for a complete data extraction form.

3.1.3.4.1 General Information

- Title of article
- Name of author(s)
- Year of publication
- Type of Article
- Database source

3.1.3.4.2 Background Information

- Empirical method
- Research background
- Collaboration mode
- No. of sites

3.1.3.4.3 Specific Information

- XP practices adopted
- Benefits highlighted
- Challenges highlighted
- Solutions or practices adopted

3.2 Conducting the Review

We conducted the review according to our defined review protocol. In order to start searching we followed the steps mentioned in Section 3.1.1. The following sections discuss the step-by-step process of conducting the review.

3.2.1 Data Retrieval

For getting an initial set of papers we started searching in IEEE and Google Scholar. Initially we chose to apply our search string in IEEE from 2000 onwards. The reason for choosing 2000 as the starting year was the fact that due to globalization GSD is recognized as a trend of the 21st century [37][10]. The reason for starting our search in IEEE was to get an idea about which year had the most published papers, so that we could set that year as an initial year for starting snowballing. Among the 203 results we got from IEEE 14 papers were relevant. Among the selected 14 papers each 2004 and 2007 had three published papers. We selected 2004 for starting our search in Google Scholar for backward snowballing. We found 10 relevant research papers in Google Scholar after applying our search string in Google Scholar. We reviewed the reference list of the selected papers. The process continued iteratively until no relevant references were found. After completing backward snowballing we started looking for the citations of the papers selected during backward snowballing. We used Google Scholar for the citations as well. The processes continued iteratively until no further citations of the selected papers were found. The search strings applied are mentioned in **Appendix 8.1**. The review process is described in Figure 3.

3.2.2 Data Synthesis

Synthesis is the process of combining small bits of data to form an integrated unit [38]. We summarized and sorted the extracted data with respect to descriptive and quantitative synthesis [34]. In descriptive synthesis extracted information about the studies (intervention, population, context and sample size etc.) should be tabulated in such a way that it is consistent with the review questions whereas in quantitative synthesis the data should be included in tabular form consisting of sample size for each intervention, difference between the mean value for each intervention and units used for measuring the effect etc. [34].

First we tried to find evidence of benefits and challenges of adopting XP in GSD. We also looked for any solutions/practices proposed to cope with the issues of adopting XP in GSD. We stored the extracted data in a Microsoft Excel tables and finally analyzed the data collected in these tables and presented it in the results.

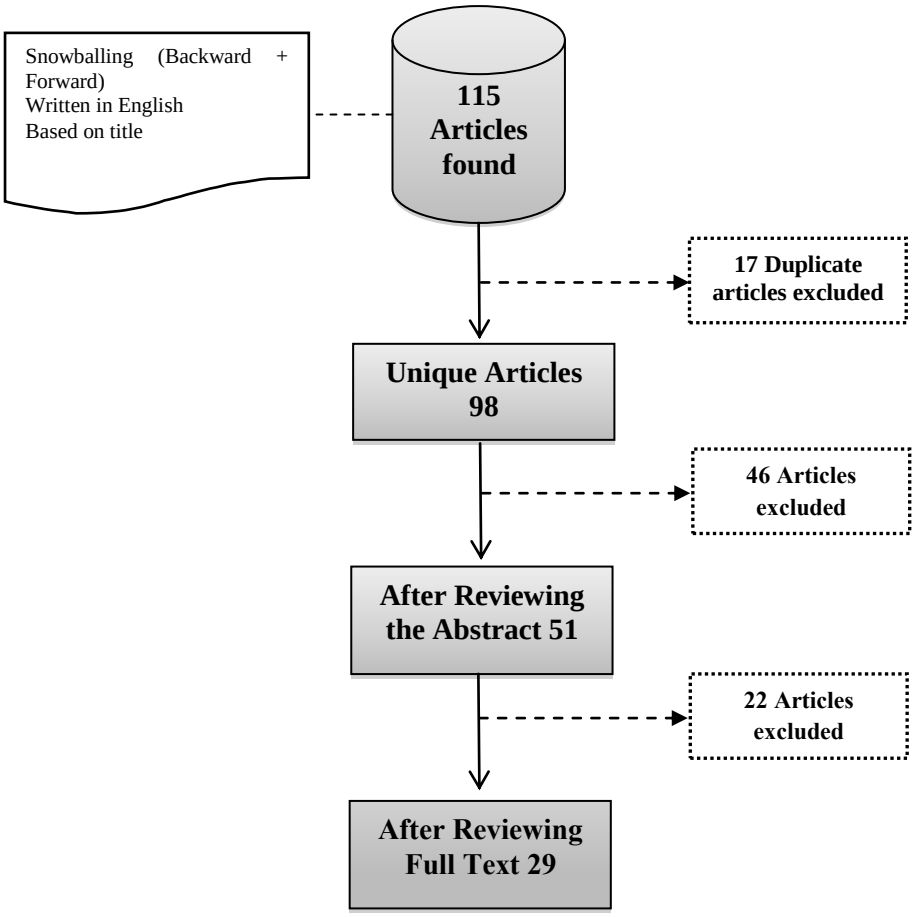

Figure 3 Review Process

4 REPORTING THE REVIEW (RESULTS)

The final phase of SLR is reporting the review, which initiate from the planning phases. In this chapter we have statistically presented the results of the review according to different characteristics. The results of the review have been presented according to the year of publication, research types, application domain, different XP practices applied and GSD context. We have also given a discussion and conclusion of the most widely used XP methods.

4.1 Publication Years

Based on pre-defined inclusion/exclusion criteria we selected 29 peer reviewed published primary studies for our review. For 2000 and 2002, we did not find any relevant research paper. While for 2001 and 2003 we have only 1 research paper each. The reason for this lower number of publication in the beginning of the decade is because the organizations had just started moving their development to global sites and XP was not mature as a software development process. In 2004-05 organizations started combining XP and GSD and the proceeding years saw a growth in the combination of XP and GSD. Much of the work on the combination of XP and GSD is done between 2006 and 2009. This growth in the number of papers between these years is because organizations started taking interest in combining XP and GSD to reap the benefits of both and to overcome the problems associated with GSD.

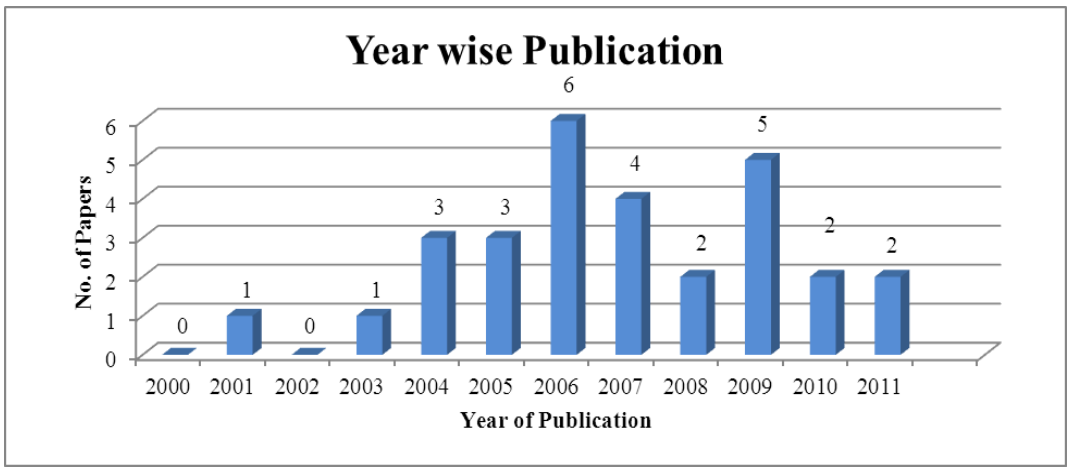

Figure 4 Year Wise Publication

4.2 Research Method

In most of the cases in the primary studies it was difficult to identify different settings used by these studies for conducting research, collecting and analyzing data and validating the results. Different research methods had been adopted by the selected primary studies. Some of the papers had adopted multiple research methods to conduct their research. Among the 29 research papers, 14 studies had employed case study as their primary research method, 6 studies were experience report, 3 studies had adopted experiment as a research method. 5 studies consisted of literature reviews. One of the research papers had adopted canonical action research. Much against our expectations we did not find any survey related to our research. And most of the experiments were conducted on an academic level.

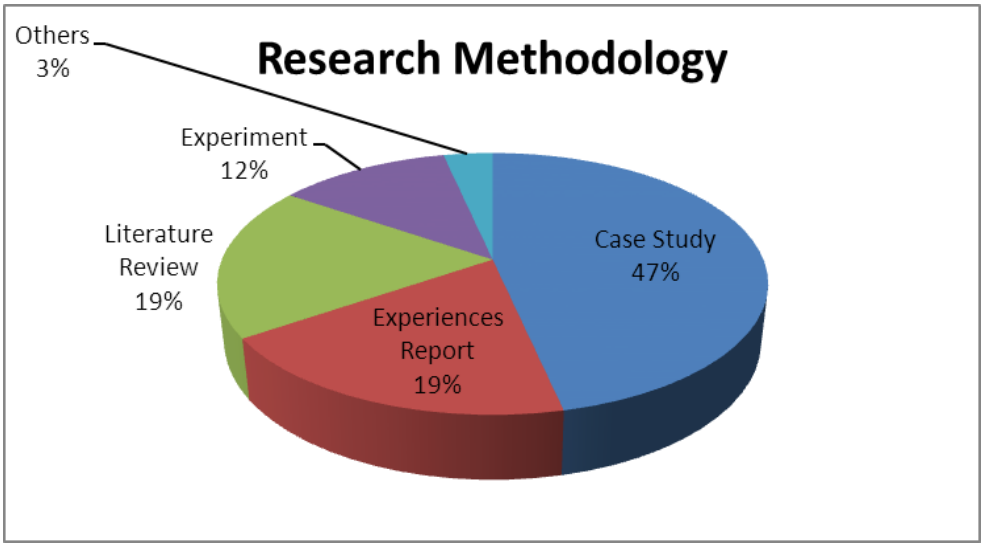

Figure 5 Research Methods

4.3 Research Context

Table 4 consists of contextual information of the selected research papers. The contextual information consists of research background, GSD collaboration mode and subjects of investigation. Among the 29 research papers found in this study, 7 studies were conducted in academia, 17 in Industry and 5 in both academia and Industry. As for GSD collaboration, 13 studies were conducted in inter-organizational context and 8 in intra-organizational context. 9 research papers had unclear GSD background. Among the 29 studies, students had participated in 4 studies, practitioners in 18 and both students and practitioners in 2, whereas 5 studies had not provided any information about subjects of investigation. We also included those papers in our research which discussed distributed settings within the same country because the advantages and challenges were more or less the same.

Project Context		No. of Publications
Research Background	Academia	7
	Industry	17
	Mixed	5
Collaboration Mode	Inter-Organizational	13
	Intra-Organizational	8
	Unclear	8
Participants	Students	4
	Practitioners	18
	Mixed	2

Table 4 Research Context

4.4 Countries Involved

Among the 29 research papers we have found 18 different geographical locations involved in the development. The most frequently mentioned locations are, USA (14), India (4) and China (4). Among the rest of the locations Brazil, UK, Italy, Singapore, Hong Kong and Mexico have been mentioned twice, whereas the remaining locations have been mentioned only once. **Figure 6**, shows the names and percentage of the countries involved in the development.

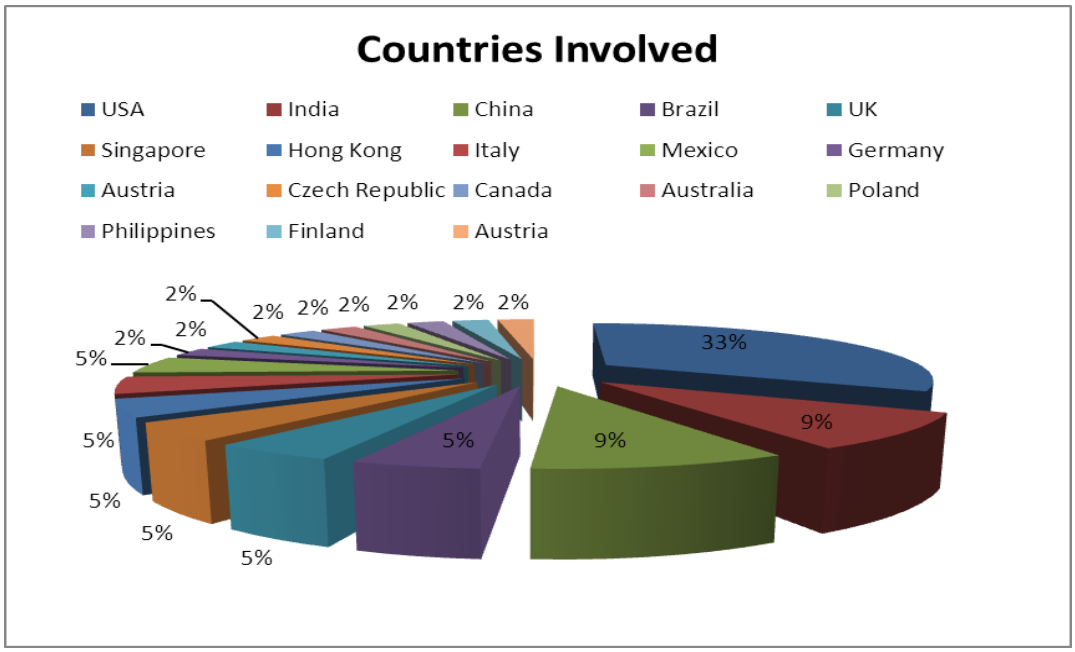

Figure 6 Countries Involved

4.5 Reported XP Practices

Among the 29 selected papers different XP practices have been reportedly used. Pair programming was used in as many as 16 papers. 7 papers had reported continuous integration and small releases. 6 papers reported on-site customer. Planning game, collective ownership, refactoring, testing, simple design and metaphor was reported in 4 papers, 40 hours-week was reported in 3 papers and coding standard was reported in 2 papers. Figure 6 shows different XP practices reported in literature. In some 8 papers it was not clearly mentioned which XP practices had been used.

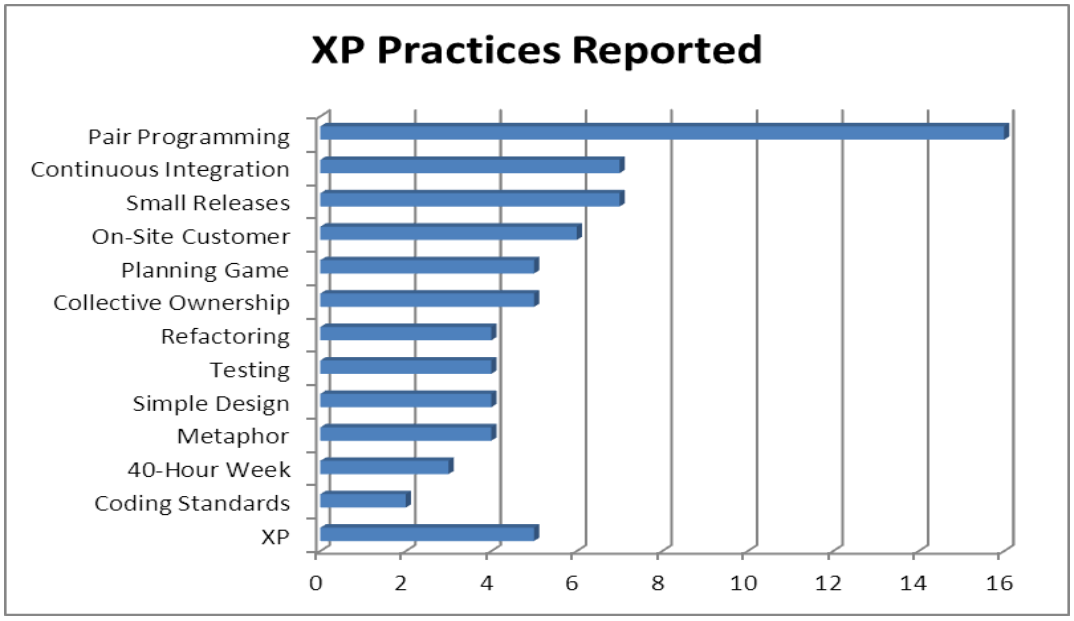

Figure 7 Reported XP Practices

4.5.1 Reported Benefits and Challenges of Applying XP Practices in GSD

Many benefits of XP in the context of GSD have been reported in literature. The following section describes the reported benefits associated with the combination of XP and GSD. Among the selected primary studies 17 papers have discussed benefits of adopting XP in their projects. Due to the fact that distance is the main factor separating distributed development from co-located development, we have classified the identified benefits and challenges on three dimensions of distance (i.e. temporal, geographical and socio-cultural) [39]. The benefits having similar features or solving similar problems have been grouped together. Each of these three dimensions of distance affects communication, coordination and control [39]. **Table 5** presents an overview of benefits extracted from literature.

Benefits – Extracted from Literature			
No	**ID**	**Description**	**References**
1	SLR_Com_Ben1	1. Reduction in communication delay 2. Increased customer feedback	[P1] [P6] [P3] [P3] [P4] [P5] [P6] [P7]
2	SLR_Com_Ben2	Improvement in communication quality	[P5] [P6] [P9] [P10] [P11] [P12] [P13]
3	SLR_Com_Ben3	"Improved encouragement" and "increased trust"	[P14] [P2] [P4]
4	SLR_Com_Ben4	1. Increased team cohesion 2. Helps in finding a common vision	[P4] [P5]
5	SLR_Com_Ben5	More informal communication	[P2]
6	SLR_Com_Ben6	1. Reduced socio-cultural distances 2. Improved understanding between the involved persons	[P22] [P13] [P4]
7	SLR_Coord_Ben1	1. Increased time overlap 2. Decreased development time	[P22] [P4] [P12] [P1] [P6] [P3]
8	SLR_Coord_Ben2	Reduced temporal distance	[P13]
9	SLR_Coord_Ben3	1. Transparency of process and easier decision making 2. Improved program visibility	[P4] [P28] [P6]
10	SLR_Coord_Ben4	Easier configuration management	[P4] [P6]
11	SLR_Coord_Ben5	Improves and eases knowledge transfer	[P10] [P2] [P3] [P27]
12	SLR_Pr_Ben1	Improved productivity	[P10] [P1] [P12] [P4] [P27]
13	SLR_Pr_Ben2	Increased concentration and focus on tasks	[P28]
14	SLR_Pr_Ben3	Helps in understanding and improving the design Ease in understanding the requirements	[P13] [P6] [P11] [P24]
15	SLR_Pr_Ben4	Improved quality	[P1] [P5] [P12] [P13] [P28] [P7]
16	SLR_Qlty_Ben1	Removal/avoidance of errors	[P10] [P13] [P6] [P7]
17	SLR_Qlty_Ben2	Client satisfaction	[P9] [P3] [P6][P27]
18	SLR_Qlty_Ben3	Increased code readability and maintainability	[P5]
19	SLR_Qlty_Ben4	Reduced complexity	[P11]
20	SLR_Cost_Ben1	Reduction of cost	[P1]
21	SLR_Cost_Ben2	Easier project estimation	[P4]

Table 5 Benefits – Extracted from Literature

Besides the benefits mentioned in **Table 5**, the introduction of XP to GSD projects also introduces some challenges. Like the extracted benefits, the extracted challenges are also relevant to communication, coordination and control. **Table 6** presents an overview of challenges extracted from literature. By comparing the extracted benefits and challenges we have seen that some benefits do actually contradict with the challenges. For example SLR_Com_Ben5 (*More informal communication)* has been reported as a benefit in one research paper while the opposite has been reported in another paper e.g. SLR_Com_Chlg3 *(Lack of frequent informal communication).* We have reported both in order to highlight the similarities and differences.

Challenges – Extracted from Literature			
No	**ID**	**Description**	**References**
1	SLR_Com_Chlg1	1. Lack of communication due to asynchronous coordination 2. Difficulty in having synchronous collaboration	[P8] [P8]
2	SLR_Com_Chlg2	Reduced productivity due to communication overhead	[P4]
3	SLR_Com_Chlg3	Lack of frequent/informal communication	[P4] [P15] [P16] [P17] [P18] [P19] [P20] [P21]
4	SLR_Com_Chlg4	1. Lack of trust 2. Lack of team cohesion	[P9] [P18] [P21] [P18]
5	SLR_Com_Chlg5	Lack of interaction with the customer	[P4]
6	SLR_Com_Chlg6	1. Cultural differences 2. Language barriers [P17]	[P9] [P23] [P17]
7	SLR_Coord_Chlg 1	Time zone difference	[P23]
8	SLR_Coord_Chlg 2	Conflicting work/unnecessary delays due to lack of coordination	[P8]
9	SLR_Coord_Chlg 3	Difficulty in having an on-site customer	[P24] [P20] [P17]
10	SLR_Coord_Chlg 4	Lack of experience of XP	[P10] [P25] [P8]
11	SLR_Coord_Chlg 5	1. Difficulty in configuration management and version control system 2. Difficulty in editing shared data simultaneously 3. Difficulties due to weak technical infrastructure	[P9] [P23] [P8] [P10] [P17] [P21]
12	SLR_Coord_Chlg 6	Lack of productivity due to geographical distance	[P26]
13	SLR_Coord_Chlg 7	Difficulty in coordination	[P16] [P21]
14	SLR_Coord_Chlg 8	1. Lack of accessibility of information 2. Difficulty in maintaining tacit knowledge	[P4] [P18] [P19]
15	SLR_Ctrl_Chlg1	Difficulty in accepting shared ownership	[P23] [P4]
16	SLR_Ctrl_Chlg2	Difficulty in making independent decisions due to dependency on the superiors	[P4]
17	SLR_Ctrl_Chlg3	Customer not aligned with agile	[P22]

Table 6 Challenges – Extracted from Literature

4.5.1.1 Temporal Distance

4.5.1.1.1 Communication

The most effective and ideal means of communication are face-to-face meetings, but in GSD, teams are located in a geographically distributed location and most often in a different time zone as well. Temporal distance is a hindrance in effective communication in a GSD environment normally. But the introduction of XP has reportedly reduced communication delay [P1]–[P3]. The introduction of XP has also increased customer feedback in distributed projects [P4]–[P7].

According to [P1], the customer was located in USA whereas the development team was located in China with no time overlap. And the teams mostly depended upon asynchronous communication but the introduction of XP improved communication between the teams and the product was successfully implemented. In [P2], the teams were located in Italy, USA and Brazil. Despite temporal distance between the development sites, the project was successfully implemented by using XP and pair programming. The use of XP helped the organizations in reducing delay in communication. In [P3], the company developed products for clients in USA, UK, UAE and Germany by using XP practices. According to the authors the use of XP practices helped them in improving communication quality and reducing communication delay. Application of XP practices in their organization also helped them in increasing customer feedback. In [P3], the offshore maintenance team in India successfully applied XP practices on the maintenance of project for a client in USA. The use of XP practices helped them in getting a thorough feedback from the customer. In [P7], the use of XP practices helped the development teams working in India and Germany get an increased and quick feedback from the customers.

On the other hand we have also found out in our systematic review that the use of XP practices had a negative impact on communication. According to [P2], while using pair programming in distributed context it was difficult to have synchronous collaboration. In distributed environment communication is done asynchronously most of the time and the use of asynchronous means often slow down communication.

4.5.1.1.2 Coordination

In GSD team coordination is negatively affected because the development teams are not in the same time zone or in other words there is little or no time overlap. The introduction of XP has brought both positive and negative effects on coordination of teams. But the main factor is time overlap. According to [P4] [P13] [P22], coordination between the development teams improved provided they reduced temporal distance or increased overlap in time. On the other hand if the time zone difference between the two teams is increased the coordination will be decreased [P23].

4.5.1.2 Geographical Distance

4.5.1.2.1 Communication

In GSD software development is done in multiple sites. These software development sites are often separated by geographic boundaries. The geographical distance brings with itself a number of challenges due to lack of face-to-face meetings. But the introduction of XP to GSD has brought both benefits and challenges to communication related to geographical distance.

According to [P5] [P6] [P9] [P10] [P11] [P12] [P13] the use of different XP practices helped them in improving communication quality. In [P5] the development team was located in China and the customer was in USA. The development team worked on reverse engineering project in their offshore location in China by using XP. The use of XP helped

the development team complete the software successfully and improved the quality of communication during the development. Whereas in [P6], the use of XP in offshore maintenance project helped them improve communication between the onshore and offshore teams. In [P10] the teams were working on a corporate project and were located in Austria and India. The teams used distributed pair programming for improving communication and coordination. The teams found that the introduction of pair programming helped them improve communication between the two distributed sites. According to [P13], a large telecommunication company transformed from traditional waterfall model to XP for their telecommunication software. They used an Onsite-Offshore Model for development. The development teams consequently saw an improvement in communication with the introduction of XP in their development.

According to [P14], they adopted on-site customer for improving trust among the team members and the customers. The use of on-site customer encouraged the development team and increased trust between them. According to [P4] the application of XP increases team cohesion among remote software development teams.

Despite these benefits, geographical distance has some negative effects on communication when applying XP in a distributed environment. The challenges found in this regard are more or less like the challenges faced in global software development as reported in [14]. In distributed XP teams productivity can decrease due to communication overhead [P4]. Lack of frequent/informal communication has been reported in literature multiple times [P4] [P15]–[P21]. According to [P15], although the development teams were located in the same country but different locations, it was difficult for the teams to continue frequently. The introduction of XP and its reliance on informal communication added to the problems of distributed teams working on a telecommunication project in USA and Czech Republic [P20]. Lack of trust has also been reported by teams using XP in their distributed projects [P9], [P18], [P21]. Frequent interaction with the customer is one of the key success factors of XP, but it is impossible to achieve in distributed environment which adds to the already existing challenges of GSD [P4]. In a co-located environment XP teams would be communicating with each other, which increases team cohesion and creates a sense of teamness among the team members. Whereas lack of teamness and team cohesion is seen in the teams using XP in their distributed projects [P18].

4.5.1.2.2 Coordination

Due to the fact the GSD teams have limited opportunities of having face-to-face meetings caused by geographical distance, XP-GSD teams faced a lot of challenges in this regard. Although there are a few benefits reported in GSD projects, but the challenges are more serious and more in numbers. According to [P4], XP makes software development process in distributed teams transparent and the decision making becomes easier due to the flexibility offered of XP. The use of suitable tools in XP-GSD projects make configuration management easier despite geographical distance between GSD teams [P4], [P6].

But despite these few benefits, XP-GSD teams face some very important challenges regarding coordination related issues affected by geographical distance. According to [P8] XP projects faced conflicts in the ongoing work due to lack of coordination. Unnecessary delays were also caused by lack of coordination in XP projects. On-site customer is one of the most important XP practices. Most of XP projects require a customer to be available on-site. For XP projects to be successful it is very important to have customer available all the time through most of the project phases. He not only helps the development team but is also part of the team. While applying XP practices in a GSD project, it is very difficult to have a customer available all the time [P17] [P20] [P24]. The purpose of on-site customer is that the developers seek for help from the customer in case of ambiguity in requirements. Also the developers clarify and approve the developed module or part of the software from the customer. According to [P10] [P25] [P8], lack of experience with XP

projects negatively affected coordination among the GSD teams. In XP since the projects are developed in small iterations and are released continuously, it is very difficult to configure all the project work simultaneously [P9] [P23]. Managing different versions of the project is also an issue in XP-GSD projects. According to [P26] [P16] [P21], lack of coordination among the team members caused lack of team work and reduced productivity of the team. It was also difficulty for the development teams to edit or change shared data at the same time due to lack of coordination [P8]. According to [P10] [P17] [P21], there is no technical infrastructure available for distributed XP teams, which makes it difficult for the development teams to coordinate with each other and make considerable contribution to the ongoing project.

4.5.1.2.3 Control

The introduction of XP to GSD project gave some benefits and challenges to control related issues due to geographical distance. According to [P5], XP helped the organizations find a common vision, which improved communication and coordination between the team members and consequently improved control of the whole project and involved teams. The application of XP encouraged the team members to work for a common goal. Beside this one benefits, the introduction of XP also brought some challenges to GSD teams. Collective code ownership is an important XP practice, in which any person can change any part of the code and improve the product. The whole team is responsible for the system design in collective ownership. Accepting collective ownership can be very difficult. According to [P23] [P4], the team members found it difficult to accept collective ownership. According to [P4], the team members become dependent on the decisions made by senior staff members or project team leaders which make it difficult for them to make independent decisions. It becomes difficult for organizations to start adopting XP practices in their GSD project if the customer does not have any experiences of XP [P22].

4.5.1.3 Socio-cultural Distance

4.5.1.3.1 Communication

In GSD projects the teams are from different nationalities most often. The socio-cultural diversity in GSD teams brings with itself a number of benefits and challenges. The introduction of XP has reportedly both benefited and challenged the socio-cultural diversity of the GSD teams. The introduction of XP helped teams communicate informally despite the socio-cultural differences between the development teams [P2]. According to [P22] [P13] the introduction of XP helped in reducing socio-cultural distances between the development teams. In [P13], the developing organization started using XP for the first time which helped the onshore and offshore teams in reducing socio-cultural distances. Also according to [P4] the introduction of XP improved understanding between the persons involved in the development project.

The introduction of XP has also affected the development environment negatively. According to [P9] [P23], cultural differences was one of the challenges faced by XP-GSD teams. Language barrier has also been reported in the literature as one of the challenges faced by XP-GSD teams. However these challenges are more due to the difference in nationalities of the involved persons than the impact of XP.

4.5.1.3.2 Coordination

In terms of socio-cultural coordination, very few benefits and challenges have been seen in the literature. According to [P10] [P2] [P3] [P27], the introduction of XP improves socio-cultural coordination and consequently improves and eases knowledge transfer between organizations and individuals. But others have argued against this notion of improved knowledge transfer. According to [P18] [P19], they found it difficult to maintain tacit knowledge between the organizations and individuals due to lack of socio-cultural

coordination in their XP-GSD projects. Also according to [P4], it was difficulty for the development organization to access necessary information required for the development of the project.

By investigating and exploring the reported benefits and comparing with the classification done by [14] [39], the benefits and challenges identified can be classified according to (temporal, geographical and socio-cultural) communication, coordination and control. The reason is because most of the reported challenges are identical and similar to the challenges reported in [14].

Based on the classification of challenges we have followed a similar pattern for classifying the benefits because most of the reported benefits help in solving problems related to communication, coordination and control.

Table 7 and 8 represent the classification of benefits and challenges according to the pattern followed by [14] [39]. Cells with question mark did not have any relevant benefits or challenges reported.

Classification of Benefits – Extracted from Literature			
	Temporal	**Geographical**	**Socio-Cultural**
Communication	SLR_Com_Ben1	SLR_Com_Ben1	SLR_Com_Ben2
	SLR_Com_Ben2	SLR_Com_Ben2	SLR_Com_Ben3
	SLR_Com_Ben5	SLR_Com_Ben5	SLR_Com_Ben5
Coordination	SLR_Coord_Ben1	SLR_Coord_Ben4	SLR_Com_Ben4
	SLR_Coord_Ben2	SLR_Coord_Ben5	SLR_Com_Ben6
	SLR_Coord_Ben3		SLR_Coord_Ben5
Control	**?**	**?**	**?**

Table 7 Classification of Benefits - Extracted from Literature

The reason for classifying some of the reported benefits in more than one category is that these reported benefits could be helpful or beneficial in either category. See **Table 5** and **Table 6** for description of these classified benefits and challenges.

Classification of Challenges – Extracted from Literature			
	Temporal	**Geographical**	**Socio-Cultural**
Communication	SLR_Com_Chlg1	SLR_Com_Chlg2	SLR_Com_Chlg3
	SLR_Com_Chlg2	SLR_Com_Chlg3	SLR_Com_Chlg4
	SLR_Com_Chlg3		SLR_Com_Chlg5
			SLR_Com_Chlg6
Coordination	SLR_Com_Chlg6	SLR_Coord_Chlg1	SLR_Coord_Chlg2
	SLR_Coord_Chlg2	SLR_Coord_Chlg2	SLR_Coord_Chlg4
	SLR_Coord_Chlg3	SLR_Coord_Chlg3	SLR_Coord_Chlg8
	SLR_Coord_Chlg4	SLR_Coord_Chlg4	**?**
	SLR_Coord_Chlg7	SLR_Coord_Chlg6	
		SLR_Coord_Chlg7	
		SLR_Coord_Chlg8	
Control	**?**	**?**	SLR_Coord_Chlg5
			SLR_Ctrl_Chlg1
			SLR_Ctrl_Chlg2
			SLR_Ctrl_Chlg3

Table 8 Classification of Challenges - Extracted from Literature

4.5.1.4 General

Besides the benefits and challenges related to communication, coordination and control due to temporal, geographical and socio-cultural distances, we have found three more categories in literature, which are benefited by the introduction of XP in GSD projects. These three categories are productivity, quality and cost. Description of the benefits related to productivity, quality and cost could be found in **Table 5.**

4.5.1.4.1 Productivity

We have found in our systematic review that productivity gets benefits from XP in GSD projects. According to [P10] [P1] [P12] [P4] [P27], the introduction of XP improved productivity of the teams in their GSD teams. Besides, the introduction of XP decreased the development time and as a result improved productivity [P12] [P1] [P6] [P3]. The use of XP also increase the concentration and focus of the persons involved in the development [P28]. According to [P13] [P6], XP helped them in understanding and improving the design of their product. Requirement analysis and specification becomes easier when XP is used as a development methodology [P11] [P24].

4.5.1.4.2 Quality

Besides productivity, software quality is another factor which is improved when XP is applied in GSD projects. According to [P1] [P5] [P12] [P13] [P28] [P7], the introduction of XP in to GSD projects improved product quality. When XP is adopted in a GSD project it helps in removal/avoidance of errors at an early stage [P10] [P13] [P6] [P7]. According

to [P9] [P3] [P6][P27], the introduction of XP also helps organizations in satisfying their clients. Program readability, maintainability and visibility improves when XP is used a software development methodology [P5] [P6] [P28]. According to [P11], the use of XP helped them in reducing complexity of code and made it easy for developers to read, write and maintain code.

4.5.1.4.3 Cost

Base on the evidence found it literature, it has also been stated in a couple of research articles that the introduction of XP in GSD projects helped in solving some issues related to cost of software development. According to [P1], XP helps in reducing the cost of software development when adopted as a development methodology in a GSD environment. Also according to [P4], XP helps in making the project estimation easier. The reduction of cost and easier project estimation has not been reported in literature too often.

4.5.2 Severity of Challenges

From the systematic review we have identified several different challenges related to the application of XP in GSD. We thought it might be interesting to classify the identified challenges on the basis of their severity. From the systematic review it was difficult to identify the severity of the challenges. Despite revisiting the selected primary studies multiple times we did not find about the impact or severity of reported challenges. However, we could determine the severity of the reported challenges on the basis of two factors, first the frequency of the reported challenges in literature and second the challenges affecting the core values of XP i.e. communication, simplicity, feedback and courage. We got a total of 23 challenges related to communication, coordination and control from our systematic review. We used numerical assignment (grouping the challenges into three categories) for determining the severity of the challenges [49]. The three groups are high, medium and low. The challenge reported more frequently and/or affecting one or more XP values had high severity, challenges which were either mentioned by few papers or had little impact on XP values had medium severity and challenges which were not mentioned too frequently or had little or no impact on XP values had low severity.

Table 9 shows the severity of challenges based on the criteria mentioned in the previous paragraph. From the table it is obvious that most of the challenges having high severity had been negatively affecting the XP values of communication, courage, simplicity and feedback. Lack of frequent informal communication is one of the most reported challenges of XP reported in literature [P4] [P15] [P16] [P17] [P18] [P19] [P20] [P21]. Besides informal communication is one of the most important requirements of XP. The challenge has been reported more frequently in the literature and is a major threat to the application of XP. Similarly the availability of on-site customer for answering the queries of the developers is also an important requirement of XP. The availability of on-site customer encourages communication and feedback but if on-site customer is not available in a development environment it becomes difficult for the teams to communicate and have frequent feedback on different artifacts. Similarly if an organization is looking forward to adopt collective code ownership, but the team members located in different sites or locations do not accept the idea or have issues and concerns about the practice, it can have a negative impact on the application of XP in that particular environment. In order to successfully adopt the practices such as continuous integration and short releases in a geographically distributed software development environment, there should be tools and technologies available to the teams for configuration management and if the team members do not have the right tools available to them they may have difficulty following XP processes in their development environment. Similarly lack of coordination, lack of communication with the customer and lack of trust also negatively affects XP values and

hinders the successful execution of software development process. Although some practices having high priorities have not been discussed too frequently but they are still very important because they are affecting some very important aspects of XP such as communication.

Those challenges which had little impact on XP values and/or were discussed by few research papers were considered to have medium severity. Despite the fact the some challenges having medium severity have been reported more than once but they do not have a major impact on values of XP. On the other hand the challenges having low severity have both been reported in few papers and most of them have very little impact on the values of XP. Most of the low severity challenges have been reported in identified research papers only once. From the challenges it is clear that challenges having high severity are mostly relevant to XP and they are affecting the core values of XP. On the other hand, challenges with medium or low severity have very little or no relevance to core values of XP. Most of the challenges having medium or low severity are typical GSD challenges caused by temporal, geographical or socio-cultural distances [14] [39]. **Table 9** presents a summary of the severity of the reported challenges. Detailed description of the reported challenges can found in **Table 6**.

Severity of Challenges – Extracted from Literature			
No	**High**	**Medium**	**Low**
1	SLR_Com_Chlg3	SLR_Com_Chlg1.1	SLR_Com_Chlg1.2
2	SLR_Com_Chlg4.1	SLR_Com_Chlg2	SLR_Com_Chlg6.2
3	SLR_Com_Chlg5.1	SLR_Com_Chlg4.2	SLR_Coord_Chlg1
4	SLR_Coord_Chlg3	SLR_Com_Chlg6.1	SLR_Coord_Chlg5.2
5	SLR_Coord_Chlg4	SLR_Coord_Chlg2	SLR_Coord_Chlg6
6	SLR_Coord_Chlg5.3	SLR_Coord_Chlg7	SLR_Coord_Chlg8.1
7	SLR_Coord_Chlg7	SLR_Coord_Chlg8.2	SLR_Ctrl_Chlg3
8	SLR_Ctrl_Chlg1	SLR_Ctrl_Chlg2	

Table 9 Severity of Challenges

4.5.3 Solutions/Practices Adopted to Cope with the Challenges

In order to cope with the challenges related to the combination of XP and GSD, different solutions or practices have been proposed in literature. The following sections present a discussion of the solutions related to different challenges. The pattern followed for discussing the benefits and challenges has been followed for the solutions as well. A grouping of the solutions with their description and according to their corresponding challenges can be found in **Table 10**.

4.5.3.1 Temporal Distance

4.5.3.1.1 Communication

In order to improve communication, the development team used XP in [P15]. Two development groups (reverse engineering and forward engineering) were made among the distributed development teams. The reverse group played the role of an on-site customer. Since, the project was a reverse engineering project of a legacy system, the reverse engineering group would analyze the legacy system, specify the requirements and confirmed it from offsite customer. After confirmation from the offsite customer, the forward engineering group worked on the development. The development team did not just rely on asynchronous communication. The development team directly communicated with

the customer in case of any ambiguity. The system was developed iteratively, within time and cost saving of about 60%. In [P8], the authors have proposed XPairtise, an Eclipse plugin for supporting social practices in distributed pair programming. XPairtise had the ability to support multiple communication channels. XPairtise also had an embedded Skype control for having an audio session. Students on a six-month project successfully used XPairtise. The problem with XPairtise is that it can only be used in situations where the two teams have some overlapping working hours.

4.5.3.1.2 Coordination

According to [P23], each of the three distributed sites were having a time difference of 8 hours. In order to take advantage of this time zone difference the organization used the strategy of daily handover from one region to another. The UK region would hand over the work done to the US region which was at a distance of 8 hours. The US office would hand over the work done to the Singapore office at 5 in the evening. The Singapore office would then hand over to UK office at the end of their work day. This practice helped all the three regions in having successful coordination and taking advantage of the time zone differences. According to [P17], team members should adjust their working hours so that they can have a maximum time overlap. In [P29], when adopting XP in a distributed settings, sites having maximum time overlap should be selected. The solutions given in [P17], [P29] having only provided suggestions and no empirical background has been provided to support these arguments. Therefore, these solutions have not been considered valid in the context of this study.

4.5.3.2 Geographical Distance

4.5.3.2.1 Communication

In order to cope with the issues of communication due to geographical distances, different solutions have been proposed in the literature. According to [P23], in order to make the communication effective and more informal they made use of video conferencing as much as possible. Video conferencing tools were used at the time of handing over the work done in one region to another and at the time of requirement gathering from the customer. This made the software development process efficient and effective and the involved sites did not face problems in communicating with each other. The use of video conferencing tools had also been suggested as a solution to communication related issues by [P4], [P21], but they have not provided any empirical background where video conferencing has been used as a solution to lack of communication.

In [P24], the development team preferred face-to-face communication with the customer for requirement gathering. When the customer was not available for face-to-face communication, communication was done through phone plus special tools like Microsoft Net Meeting. These tools helped the developing organization in clarification of requirements up to a large extent. Since, the customer and the development organization did not speak the same languages, the project manager of the development team played the role of a translator and communicator. The use of multiple communication mode has also been discussed in [P18], [P19], [P29], but they have not provided any background where it has been used.

According to [P20], the project was faced with significant difficulties because of only two hours overlap between the development and project management teams. Due to cost related issues, telephone and face-to-face communication was very difficult. Another option the teams thought about was installing voice over Internet Protocol (VoIP) on all the management teams' computers, but it was also a very expensive option. Instant messages could not serve the purpose efficiently, because it was at that time a one-to-one option and the development team wanted all the stakeholders involved when a problem

related to requirements was being discussed. This made synchronous collaboration very difficult for the teams. The team came up with an informal way of communication using email instead of normal face-to-face communication. After about one month into the project the development team started using a mailing list for their primary communication. The emails were sent to all the members of the development and project management teams. The developers would create a log of queries during their workday in Czech Republic and sent it the project management teams in the United States. The project management teams would answer the queries of the development teams and they would work accordingly the next day. The email messages sent in this manner were mostly clarification messages for clearing a particular requirement or issue. These kinds of messages made the customer continuously involved in the development process and communication between the customer and the developers was occurring continuously. It means that in case of difficulty in having face-to-face or telephonic communication emails can serve as means of communicating informally.

In [P2], the central team was encouraged to used email, chat and Skype for communicating with the customer. The results showed that the use of these tools helped the teams in communicating effectively. According to [P24], they used daily phone conference call to communicate with the customer regarding the requirements which were not clear. The calls were mostly made in the middle of the day with the project manager of the development team and customer involved in it. The developers would gather all the questions regarding unclear requirements before the phone call. After the call the developers would start working on clearing those issues and making the cleared requirements into artifacts.

In co-located extreme programming, informal meetings and interactions in lunch and coffee breaks help the team members become a single group [P23]. This shared knowledge and understanding helps the team members solve any complex idea or design issue when it occurs. But achieving this understanding and trust is very difficult in distributed context. According to [P23], they created remote pairings among the team members to help them create a group mind. In order to do so they started remote pairing sessions between two developers from different regions using VNC, teleconferencing and a common IDE. Adopting this practice helped them in collaborating on ideas, sharing experiences, removing misunderstandings and fostering a shared memory between pairs and remote teams. Also in case related stories/artifacts were to be developed, they were developed in an around-the-clock manner across all the regions. This sharing the development of related artifacts and stories helped the remote teams build a common understanding and increase mutual trust [P23].

4.5.3.2.2 Coordination

While using XP, the customer role is extremely important for activities related to requirements management. In on-site customer, the customer should always be present and physically available (in ideal situation). The role of the customer is to answer developers' question regarding requirements of the system and to make decisions related to planning. But the customer role becomes even more important in case the development is done in a global software development environment. In [P20], persons involved in project management were initially providing the developers with high level goals but they had no well-defined customer. It was not clear how the system to be developed was used. This situation made the identification of important and concrete features difficult. In this situation a development lead and one proxy customer pointed out problems in the defined project scope. But due to unavailability of customer and ambiguity of requirements, the developers could not proceed further. After an initial month of trouble, a new customer having a well-defined purpose and interest in the system got involved in the project. This made the goal of the project clear. Involvement of a new customer helped in the creation of well-defined and well-scoped user stories and improved the project team focus.

According to [P15], the customer was available at the development site in the initial two weeks of development at the development site. During these two weeks everything was going smooth and the development team did not face any difficulty. After the first two weeks, the customer left the development site and replied only once to email enquiries. The lack of frequent communication and unavailability of on-site customer caused problems in the system being developed and the defect rate increased to a great extent.

In [P8], XPairtise, an Eclipse plugin has been proposed which allows driver and navigator to work simultaneously on the same artifact. By using XPairtise, the driver and navigator can cooperate with each other as soon as the session starts. All the actions performed by the driver are also shown to navigator. It makes the navigator aware of the changes made by the driver thus helping in avoiding any conflict of work. XPairtise also had the ability of supporting synchronous collaboration. It helped the users in starting, joining, leaving and terminating a particular session.

According to [P23], the source control used by the UK team used to take 40 minutes to synchronize changes from a remote region. As a result a new source control system (Perforce) was implemented. The performance issues were dealt by using local proxies on the system. In [P13], a common configuration management tool was used for version control and documentation management of the software. This tool was accessible to both on-site and offshore team members. It also helped in storing unit tests and daily builds. The use of shared version control system has also been proposed by [P17]–[P19], but they have not provided any information about the background and deployment of the system.

According to [P2], [P23], in order to cope with the issues concerning lack of experience, XP coaches were hired. In [P23], USA and Singapore regions did not have experience in XP and object oriented programming. In order to make the teams at these regions familiar with XP, XP coaches were hired. The USA coach was hired from Seattle USA, while the Singapore coach was hired from UK, these coaches recruited more team members with the passage of time. Coaches played a very important role in the success of the team. The weekly meetings held between the coaches yielded to consistent results. In [P2], a coach was hired to answer the development teams' questions. It was observed that the performance of the team was severely impacted when the coach was absent for two weeks. It was also observed that the motivation and productivity of the remote team increased significantly with hiring of XP coach.

In order to cope with the issues of weak infrastructure such as low bandwidth, the bandwidth was increased [P23]. Shared common environment was provided across all the teams. Same tools and environment were set up in all the machines in all the three regions. The configurations were checked into a shared source control system, this helped all the developers to have the same configuration at the start of their day.

4.5.3.2.3 Control

According to [P17], [P18], for encouraging and promoting the concept of shared ownership a single build server and single shared code base should be used. A shared source control system with collective code ownership has also been proposed for promoting collective ownership. No empirical or contextual information has been provided for promoting these solutions. Therefore, these solutions have not been considered reliable.

4.5.3.3 Socio-cultural Distance

4.5.3.3.1 Communication

In [P23], three different sites UK (main site), USA and Singapore, were involved in the development. The UK team was the main site and they had prior experience in XP. In order to resolve issues related to cultural differences and trust a boot camp was organized in which developers from USA and Singapore spent time with the original team in a boot camp type in the UK office. This helped the team members understand each other and understand the cultural values followed in each organization. Another strategy adopted for coping with cultural differences and lack of trust was round-the-world program. In round-the-world program, a member from one region spent around four weeks in another region in order to understand the norms and traditions adopted in that particular region. These solutions can help the organizations solve the problems related to lack of trust and cultural differences but they require large budgets on behalf of organizations. In [P2], the remote teams sent cultural ambassadors to the central team. The cultural ambassador could speak both the languages of the central team and the remote teams. In case of any conflict the remote team would communicate with the ambassador and discuss the problem with him who would further communicate with the central team. The presence of cultural ambassador minimized the cultural issues up to a large extent because the ambassador understood the cultural values of the remote teams.

4.5.3.3.2 Coordination

According to [P4], [P17], [P25], the use of wikis, issue tracking tool and version control system has been proposed to cope the issues of transferring and maintaining tacit knowledge. No empirical background has been provided in support of these solutions. Therefore these solutions are considered as weak.

Table 10 provides a grouping of the identified solutions extracted from literature. The solutions have been grouped based on the similarity between them. The corresponding challenges have also been mapped with each solution. For a description of the corresponding challenges see **Table 6**.

Solutions – Extracted from Literature			
No	**ID**	**Description**	**Corresponding challenges**
1	SLR_Com_Sol1	Do not just rely on asynchronous communication and encourage direct communication [P15]	SLR_Com_Chlg1
2	SLR_Com_Sol2	Integrate a quick synchronous collaboration tool to your cooperative application [P8]	SLR_Com_Chlg1
3	SLR_Com_Sol3	The use of video conferencing tools [P23] [P4] [P21] Use multiple forms of technology and communication media [P18] [P29] [P19] [P24] Make a daily phone conference call with the customer [P24]	SLR_Com_Chlg3
4	SLR_Com_Sol4	Use email list and encourage useful, quick and conclusive responses to email [P20] Encourage the teams to use more frequent and direct style e.g. email, Skype etc. [P2]	SLR_Com_Chlg3
5	SLR_Com_Sol5	Form pairs between the remote members to improve trust and understanding [P23] Encourage the team members to share a related story [P23]	SLR_Com_Chlg4
6	SLR_Com_Sol6	Boot camp held for the developers from different sites and round the world program [P23]	SLR_Com_Chlg6
7	SLR_Com_Sol7	Cultural ambassadors for the remote teams should be sent to the central team [P2]	SLR_Com_Chlg6
8	SLR_Coord_Sol1	Team members should adjust their working hours to have maximum time overlap [P17] Select sites with some overlapping time [P29]	SLR_Coord_Chlg7
9	SLR_Coord_Sol2	Daily handover from one region to another region [P23]	SLR_Coord_Chlg7
10	SLR_Coord_Sol3	The customer role should well-defined and in case an on-site customer is not available, a person on the team should play the role of a customer and he should have complete knowledge and authority of the system [P15] [P17] [P19] [P20]	SLR_Coord_Chlg3
11	SLR_Coord_Sol4	1. Provide a shared editor where users can access and edit the shared artifacts and where the changes are reflected in all the users' editors. [P8] 2. Model the context for synchronous collaboration and support users in starting, joining, leaving and terminating the sessions [P18] [P8]	SLR_Coord_Chlg5
12	SLR_Coord_Sol5	Usage of a shared source control system [P13], [P17], [P19], [P23]	SLR_Coord_Chlg5
13	SLR_Coord_Sol6	Higher bandwidth were provided and same configuration was used on machines in all the regions [P23]	SLR_Coord_Chlg5
14	SLR_Coord_Sol8	Hire XP coaches [P2], [P17], [P23]	SLR_Coord_Chlg4
15	SLR_Coord_Sol7	Use technical and organization knowledge tools such as wikis and tracking software [P4], [P17], [P25]	SLR_Coord_Chlg8
16	SLR_Ctrl_Sol8	Using a single build server and single shared code-base in order to encourage share responsibility [P17], [P18]	SLR_Ctrl_Chlg1

Table 10 Solutions - Extracted from Literature

5 SURVEY

We conducted a survey in order to understand XP practices that were adopted by practitioners as well as their benefits and challenges. The purpose of the survey was to understand what practice/solution did the industry practitioners adopt to cope with the challenges. Compared to other research methods like experiments and case studies, survey was the best suitable method for this research. Experiment was not chosen because of its controlled nature. It is used to control and manipulate the situation precisely and directly [40]. Similarly, we did not choose case study because it is often used to examine the way things happen. Case studies are most often used to explore the actual context of things [27]. The results of case studies can be generalized to a particular context on a limited scale. It would not have allowed us to explore more about XP practices in GSD context, its benefits and challenges. The results obtained through a case study would not have been generalizable in a wider context.

With the help of a survey we can get more knowledge from practitioners and experts. It provides a large number of variables for evaluation and analysis [40]. The reason for choosing survey for this research is the fact the survey helps in understanding the opinion of the population. It also helps in generalizing the results. The following section provides a detailed description of the questionnaire design.

5.1 Questionnaire Design

After reviewing the literature we designed the questionnaire for the survey. The literature review provided a foundation for conducting the survey. The main purpose of conducting the survey was to understand which XP practices were adopted in the industry, which benefits and challenges were found and what solutions did the organizations adopt to cope with the challenges associated with the combination of XP and GSD. The survey was also aimed at collecting the information about impact of XP on existing GSD challenges. The survey was also conducted to understand whether the benefits and challenges described in literature were realized in practice or not.

We selected SurveyGizmo (http://www.surveygizmo.com/) [41] for collecting data from the respondents. The reason for selecting web survey was because the respondents were located in different geographical location and it was easy for us to collect data from them via an online platform. Another reason for choosing SurveyGizmo was that it provides almost all the enterprise features to students for free. It also provides better features for data analysis. As suggested [42] by the questionnaire was enclosed with cover letter stating the purpose of the survey, time required to complete the survey and anonymity of the information gathered. Our questionnaire consisted of the following sections:

The demographic information was used to collect the following information:

- Role of the respondent
- Total experience in software projects
- Involvement of the respondent in XP (in months or years)
- Location of the respondent(s)

The company and project information page collect the following information:

- Name of the company
- Size of the company (in number of employees)
- Location of main site
- Responsibility of main site
- Number of distributed sites

- Location(s) of distributed site(s)
- Responsibility/Responsibilities of the distributed site(s)
- Number of employee(s) at each distributed site
- Domain of the project(s)
- Duration of the project

In the next page we collected the following information about the adopted XP practices:

- Adopted XP practices(s)
- Modification (if any)
- Benefits
- Challenges
- Solution to challenges
- The effect of challenges on the software development process

In the final page we asked close-ended questions regarding the effects of XP on the communication, coordination and control related challenges due to geographical, socio-cultural and temporal distances. A detailed questionnaire can be found in Appendix 8.3.

5.2 Survey Piloting

Based on the data collected from SLR we started planning and designing the survey. A questionnaire was designed with the help of data collected from the systematic review. The questionnaire was initially sent to around 10 MSc Software Engineering/Computer Science students for piloting. We received feedback from 7 students regarding different questions in the questionnaire. Based on their recommendation and feedback we redesigned the questionnaire to make it easier for the respondents to answer the questions. After re-designing the questionnaire, it was sent to the supervisor for review. The supervisor continuously provided her comments and feedback on the questionnaire design until it was ready for online distribution. We had continuous collaboration and communication with the supervisor until she was satisfied with the questionnaire. Although it would have been beneficial to conduct survey piloting with industry practitioners instead of the students but due to lack of resources and time the piloting was restricted to students only. Only those responses were considered for analysis in which the respondents had answered all the questions. **Figure 8** shows piloting of the questionnaire design process.

5.3 Survey Execution

After finalizing the survey we distributed the questionnaire to a pre-compiled list of respondents. The respondents were selected based on their current/prior experience with XP and GSD. The survey was also distributed on a Yahoo group of professional software developers and different agile, XP and GSD groups on LinkedIn. All the questions on the questionnaire, except the company name, were important. We did not make any question mandatory. The reason for this was to make sure we do not lose any respondents in the process. The respondents were humbly requested to fill in all the questions and send their responses as soon as possible. We also requested the respondents to distribute the survey to their contacts as well.

5.4 Sampling of Survey Population

We utilized a convenient sampling process for survey in this research [22]. The reason for choosing this process was because most of the respondents of the survey were contacts of the authors. These contacts were also requested to send the survey link to their colleagues who had experience of applying XP practices in GSD projects. Besides, the population also consisted of practitioners who had voluntarily participated in the survey. However the authors selected the population based on their present or past experiences of using XP in GSD projects. Hence the sample of our survey population was based on random or convenient sampling.

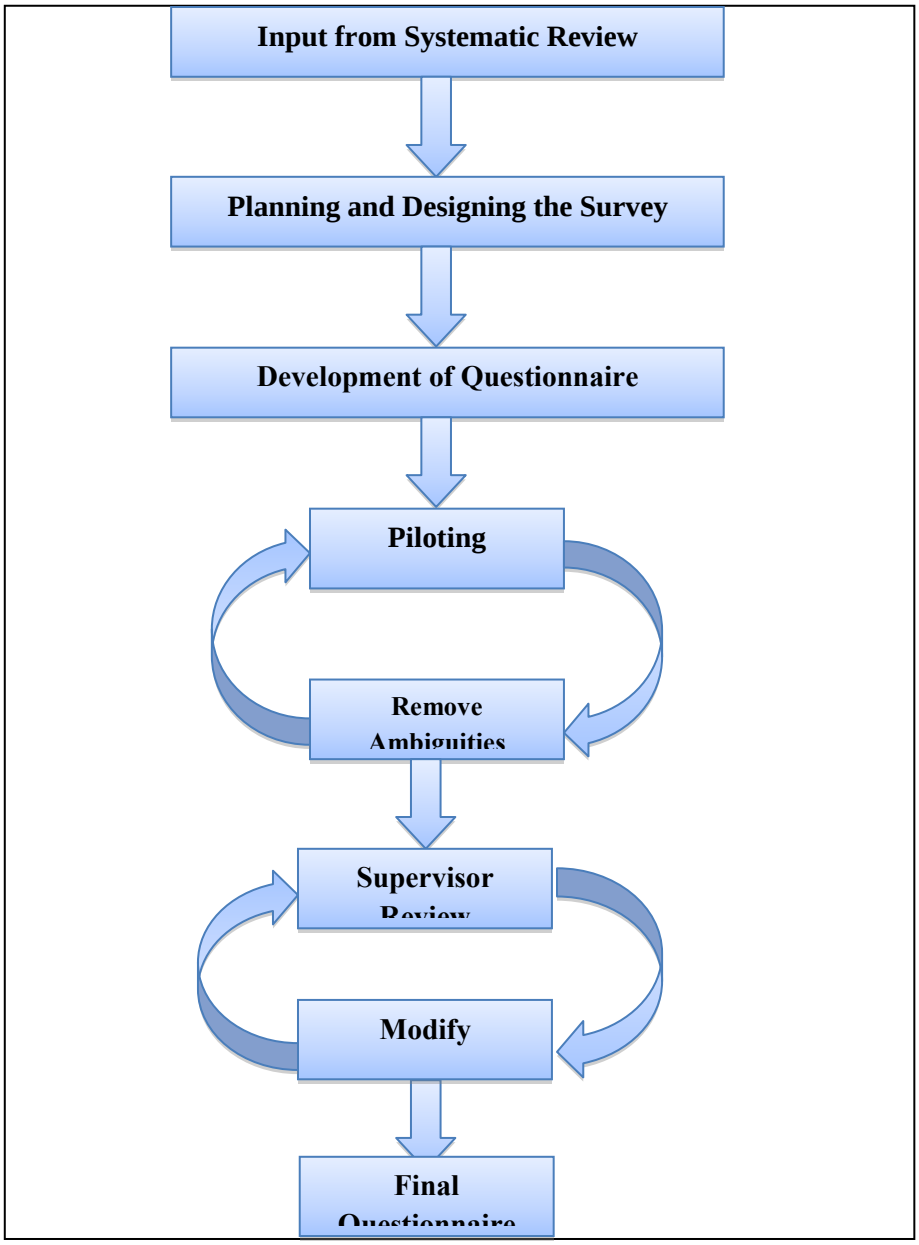

Figure 8 Survey Piloting

5.5 Reporting the Survey

We received a total of 63 responses to our questionnaire. We checked the responses for validity as suggested by [40]. Incomplete responses or responses with incorrect demographic information were discarded. The total number of completed responses were 51. The following sections describe different information gathered from questionnaire.

5.5.1 Roles of Respondents

We have identified 9 different roles from the results of the survey. Among the 51 respondents, 7 (13.7%) were project managers, 11 (21.6%) were team leads, 2 (3.9%) were system analysts, 7 (13.7%) were system designers, 13 (25.5%) were developers, 4 (7.8%) were testers and 7 (13.7%) were others including development manager, architect and consultant. **Table 11** shows roles and responsibilities of respondents and their percentage in overall responses.

S. No	Role	No of Respondents	Percentage
1	Project Manager	7	13.7 %
2	Team Lead	11	21.6. %
3	System Analyst	2	3.9 %
4	System Designer	7	13.7 %
5	Developer	13	25.5 %
6	Tester	4	7.8 %
7	Others	7	13.7 %

Table 11 Roles and Responsibilities

5.5.2 Software Development Experience of Respondents

The respondents of our survey had different levels of experiences. The experience levels have divided into four categories as shown in **Table 12**. Among the respondents, 7.8 % had less than one year experience, 52.9 % had experience between 1 and 5 years, 31.4 % had experience between 5 and 10 years and 7.8 % had more than 10 years of experience.

S. No	Experience	No of Respondents	Percentage
1	Less than 1 year	4	7.8 %
2	More than 1 year but less than 5 years	27	52.9. %
3	More than 5 Years but less than 10 years	16	31.4 %
4	More than 10 years	4	7.8 %

Table 12 Experience of Software Projects

5.5.3 Involvement with XP Projects

In order to have an idea about the respondents experience with XP, we asked the survey respondents about their experiences regarding XP. Among the respondents, 11.8 % had been involved with XP practices for more than 6 months, 35.3 % had experience between 6 and 12 months, 37.3 % had experience between 1 and 2 years, 7.8 % had experience between 2 and 3 years and 7.8 % had more than 3 years of XP experience. **Table 13** shows classification of XP experience of the respondents.

S. No	Experience in XP	No of Respondents	Percentage
1	0 to 6 months	6	11.8 %
2	More than 6 months but less than 1 years	18	35.3. %
3	More than 1 Year but less than 2 years	19	37.3 %
4	More than 2 Years but less than 3 years	4	7.8 %
5	More than 3 years	4	7.8 %

Table 13 Involvement with XP

5.5.4 Locations of the Respondents

We received responses from different parts of the world. Among the 51 respondents, 10 (19.6 %) were from Sweden, 6 (11.76 %) from India, 5 (9.8 %) each from Pakistan and USA, 4 (7.8 %) from UK and 21 (41 %) from different countries in the world. The details of locations of respondents are given in Figure 9.

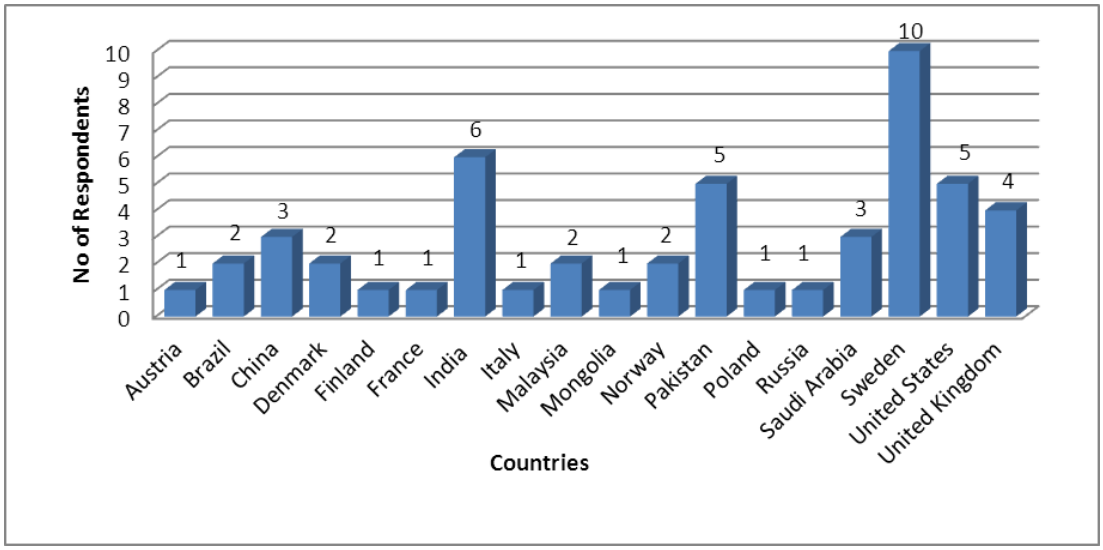

Figure 9 Geographical Location of Respondents

5.5.5 Respondents' Organization Size

The survey respondents belonged to organizations with different sizes (in terms of number of employees). 3.9 % of the respondents were from organizations having 1 to 10 employees, 15.7 % were from the organizations having 11 to 50 employees, 23.5 % were from organizations having 101 to 1000 employees and 21.5 were from organizations that had more than 1000 employees.

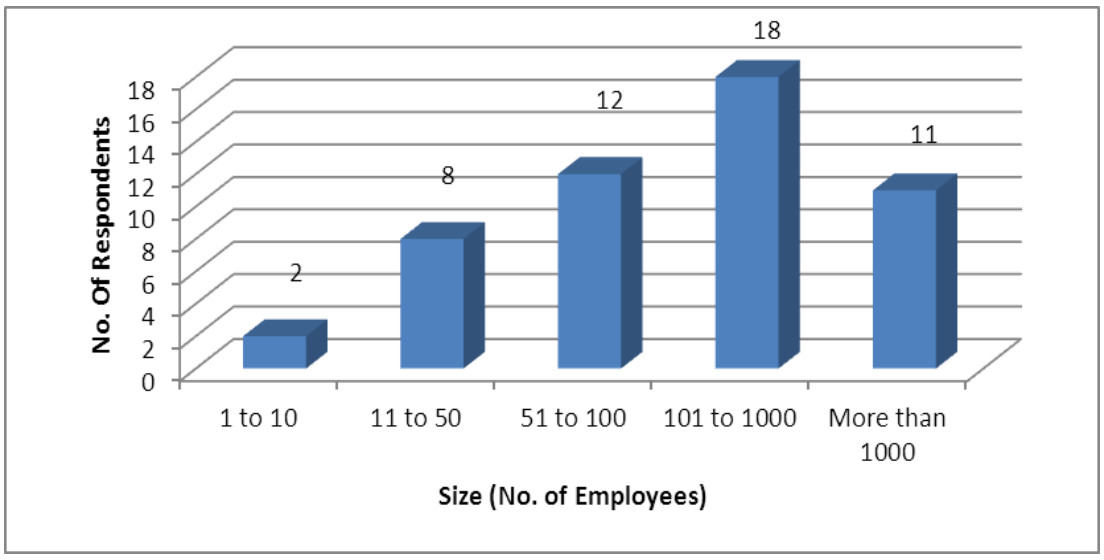

Figure 10 Respondents' Organization Size

5.5.6 Onshore Locations

We had multiple locations for the onshore sites of the survey. Of all 51 responses, 12 (23.5 %) organizations had their onshore sites located in the United States, 10 (19.6 %) were located in Sweden, 9 (17.6 %) were located in the United Kingdom, 6 (11.7 %) were located in India and 15 (29 %) were located in different parts of the world. Detail on the onsite locations is given in **Figure 11**.

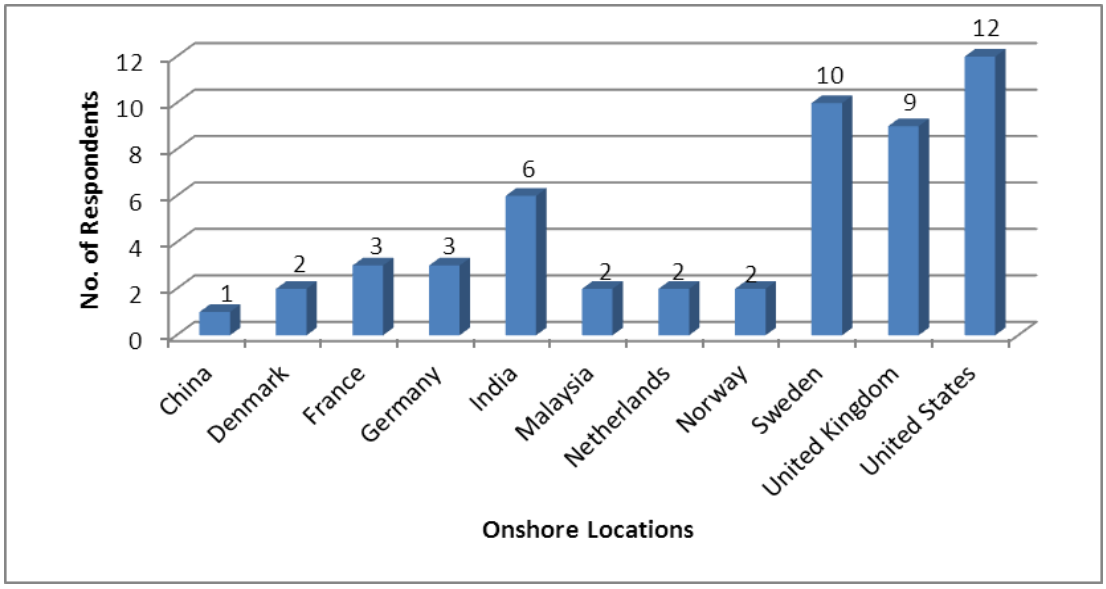

Figure 11 Onshore Locations

5.5.7 Offshore Locations

From the survey 76 offshore locations have been collected. 18 (23 %) were in India, 13 (17 %) were in China, 11 (14.5 %) were in Pakistan, 7 (9.2 %) were in Brazil, 5 (6.6 %) were in Ireland and 22 (29 %) were in different countries in the world. Detail of offshore locations and their occurrences have been given in **Figure 12**.

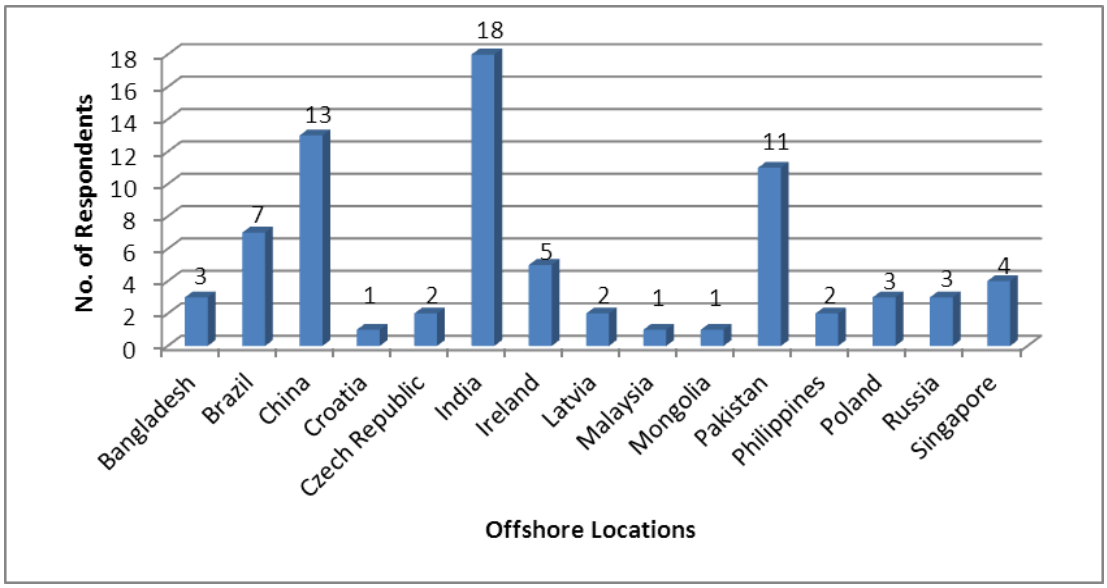

Figure 12 Offshore Locations

5.5.8 Project Domains

The respondents of the survey had been involved in different kinds of projects. 31.5 % of the projects were related to telecommunication, 17.9 % were related to finance, 16.8 % were commercial projects, 15.8 % were web projects and 17.9 % were related to other domains. **Figure 13** provides a detail of the domains of the projects.

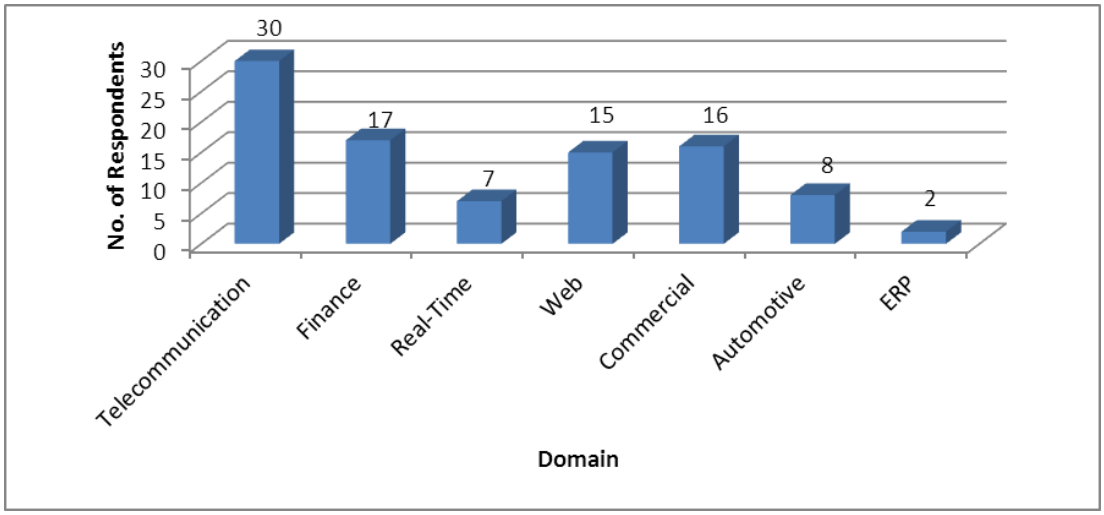

Figure 13 Project Domain

5.5.9 XP Practices Adopted

We asked the survey respondents about XP practices adopted in their projects. Adopted XP practices and their frequencies have been given in **Figure 14**. The frequency of the XP practices adopted has been more or less the same. Small releases have been mentioned most with 35 occurrences and 40-hour week is the least mentioned practice with 10 occurrences.

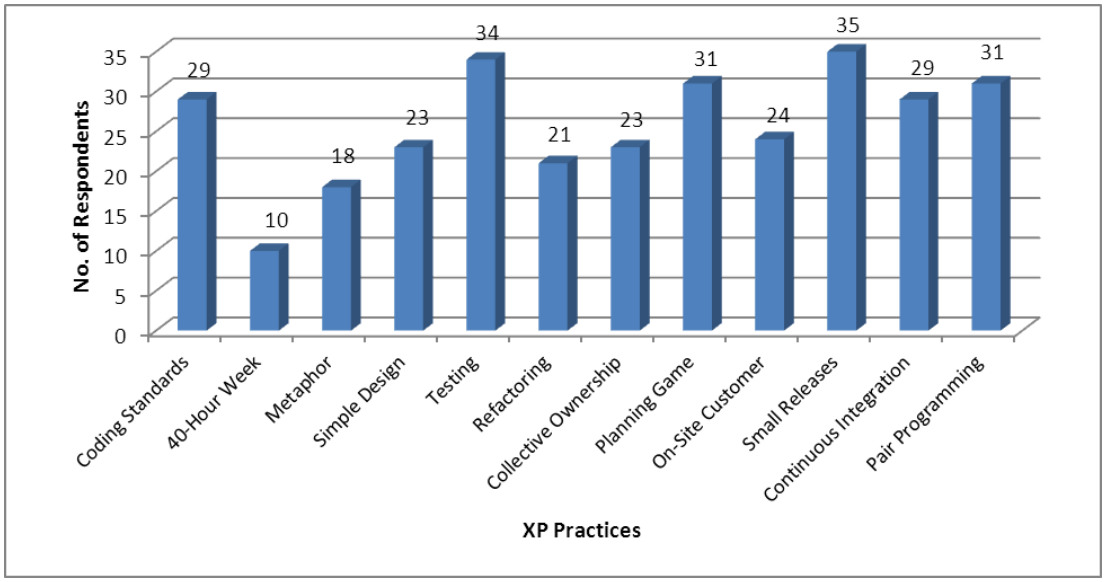

Figure 14 XP Practices Adopted

5.5.10 Identified Benefits and Challenges

We have identified different benefits and challenges associated with the application of XP in GSD from the survey. The benefits and challenges are identified in relation to different XP practices. We have also explored during the survey how each practice had been adopted in particular organizational setting. The solution or strategy adopted to cope with each of these challenges has also been identified. A similar pattern has been followed for the classification of benefits and challenges extracted from survey. Grouping and classification of the reported benefits and challenges has been presented in **Table 14 & Table 15**. The benefits have mainly been classified into three categories, i.e. communication, coordination and general.

Benefits – Extracted from Survey		
No	**ID**	**Description**
1	SUR_Com_Ben1	Despite temporal distance team members efficiently communicated
2	SUR_Com_Ben2	Despite geographical distance the application of XP practices helped in improving communication between the remote teams
3	SUR_Com_Ben3	**1.** Increased trust and cohesion among teams **2.** XP encouraged team members to communicate with remote team members
4	SUR_Com_Ben4	Increased informal communication
5	SUR_Com_Ben5	Increased mutual understanding and trust between team members and reduced socio-cultural distance
6	SUR_Coord_Ben1	In case of reduced time overlap the coordination between teams improves
7	SUR_Coord_Ben2	**1.** Makes the software development process transparent and visible **2.** Makes the decision making easier
8	SUR_Coord_Ben3	Continuous integration helps in following the progress on the project
9	SUR_Coord_Ben4	Customer satisfaction and earlier client feedback
10	SUR_Coord_Ben5	Some XP practices such as pair programming improves and eases knowledge transfer
11	SUR_Coord_Ben6	Helps in understanding the way of working in different sites
12	SUR_Coord_Ben7	Increased team motivation and satisfaction resulting in improved coordination
13	SUR_Coord_Ben8	Improved social and technical relationship among the team members
14	SUR_Gen_Ben1	Helps in understanding, managing and analyzing the requirements
15	SUR_Gen_Ben2	Improved quality, increased productivity and quick product development
16	SUR_Gen_Ben3	Helps in understanding and removing problems at an early stage
17	SUR_Gen_Ben4	Increased code readability and maintainability
18	SUR_Gen_Ben5	Reduced tasks' complexity

Table 14 Benefits - Extracted from Survey

The challenges have been grouped according to communication, coordination, control and general category. Like the results of SLR, survey also has some contradictory benefits and challenges but these challenges also come from multiple sources.

Challenges – Extracted from Survey		
No	**ID**	**Description**
1	SUR_Com_Chlg1	Little or no time overlap made it difficult for the team members to communicate
2	SUR_Com_Chlg2	Dependency on asynchronous communication due to temporal distance made informal communication for the teams difficult
3	SUR_Com_Chlg3	Delayed feedback on artifacts being developed
4	SUR_Com_Chlg4	**1.** Lack of frequent informal face-to-face communication **2.** Reduced frequency of communication
5	SUR_Com_Chlg5	Reduced communication quality
6	SUR_Com_Chlg6	Cultural and language differences caused a decrease in trust among remote team members
7	SUR_Coord_Chlg1	Team members found difficult to coordinate efficiently and effectively due to increased temporal distance
8	SUR_Coord_Chlg2	Lack of coordination due to geographical distance results in conflicting work
9	SUR_Coord_Chlg3	Absence of on-site customer negatively impacts coordination
10	SUR_Coord_Chlg4	**1.** Lack of configuration management tools and version control systems **2.** Difficulty in editing shared data simultaneously **3.** Difficulty in change management
11	SUR_Coord_Chlg5	Decreased productivity caused by geographical distance
12	SUR_Coord_Chlg6	Lack of experience of XP
13	SUR_Coord_Chlg7	**1.** Lack of accessibility of information **2.** Geographical distances and socio-cultural differences makes it difficult to transfer and maintain organizational knowledge
14	SUR_Coord_Chlg8	Lack of understanding of the ways of work of others
15	SUR_Ctrl_Chlg1	Difficulty in integrating remotely developed components
16	SUR_Ctrl_Chlg2	**1.** Difficulty in managing and organizing project artifacts **2.** Lack of project management activities
17	SUR_Gen_Chlg1	Lack of confidence due to language difference or little experience
18	SUR_Gen_Chlg2	Degraded performance and wastage of time explaining problems
19	SUR_Gen_Chlg3	Increased time consumption

Table 15 Challenges - Extracted from Survey

5.5.10.1Temporal Distance

The introduction of XP has both positively and negatively impacted different important factors such as communication, coordination and control. From the survey we have found out that introduction of XP has helped in coping with some of the traditional challenges of GSD. In other situations the traditional challenges of GSD were not impacted by the introduction of XP. In the following sub sections we are describing how the introduction of XP impacted temporal communication and coordination.

5.5.10.1.1 Communication

The use of certain XP practices such as short releases and continuous integration helped the team members improve communication quality. Despite being in different time zone these practices helped the team members communicated efficiently. The short releases practice helps in getting immediate feedback on certain artifacts.

On the other hand the respondents have reported certain challenges related to temporal coordination. Due to limited time overlap it was difficult to use practices such as pair programming. The lack of overlapping time reduced communication between team members and reduced productivity and performance as a result. Communication and particularly informal communication is one of the most important factors for implementation of XP practices, but in GSD the teams are mostly dependent upon asynchronous tools which make informal communication between team members difficult. According to our survey respondents too much dependency on asynchronous communication tools made difficult for the team members to informally communicate with each other regarding different issues related to the product being developed. Due to little time overlap and increased temporal distance it was very difficult for the developers in the offshore teams to receive immediate and quick feedback on the artifacts being developed.

5.5.10.1.2 Coordination

Achieving efficient coordination is very difficult in GSD particularly when the teams are separated by temporal distance. From our survey we have got a rather conflicting benefit and challenge regarding temporal coordination. According some of our survey respondents, lack of overlapping working hours did not affect coordination between team members. But the reason for this was that they were following the "follow the sun" strategy which helped them efficiently coordinate with the remote team members. But in situation where the teams are not following this strategy it has resulted in lack of coordination between team members and it often caused conflicts.

5.5.10.2Geographical Distance

Due to the fact that teams do not work under one roof in GSD, geographical distance is one of the main reasons behind many challenges related to communication, coordination and control. The introduction of XP to GSD has both benefited and brought some challenging factors to GSD. The following sections present an overview of benefits and challenges in GSD brought by the introduction of XP.

5.5.10.2.1 Communication

According to the respondents of our survey, despite being in different geographical locations, the introduction of XP helped the team members in improving communication. The use of practices such as planning game, continuous integration, testing and small releases helped the team members in improving communication. The use of practices such as collective ownership, pair programming and continuous integration helped the teams in getting trust and cohesion. Applying these practices encouraged the team members to efficiently and effectively communicate with the remote team members.

Beside these benefits, the organizations also faced challenges while applying XP practices in their GSD projects. Lack of frequent informal face-to-face communication caused problems in following XP practices of on-site customer. The teams applying on-site customers were affected by both the geographical distance and lack of face-to-face communication. Reduction in communication quality has also been reported by some of the survey respondents. One of the most important requirements of XP is frequent informal communication. The frequency of communication reduced up to a large extent after XP was applied in GSD settings, which affected the whole idea of successfully implementing XP practices in a distributed context.

5.5.10.2.2 Coordination

With limited or no face-to-face interaction among distributed teams, collaboration and coordination becomes important. From our survey respondents we have got both benefits and challenges regarding the application of XP in their distributed projects. The use of on-site customer, small releases, continuous integration and pair programming make the

software development process transparent and visible to each team member. The use of these practices also helps in taking very important decision easily in such a way that team members coordination improves with it. The use of on-site customer helps in getting rapid feedback from the customer and results in customer satisfaction. As a result of this team performance improves and a sense of trust arises among the team members.

Geographical distance also negatively affects the coordination between teams. According to our survey respondents, lack of coordination caused by geographical distance resulted in conflicting work between XP teams. Availability of on-site customer is one of the most important factors for successfully implementing an XP project. In on-site customer, the customer is always available to the development teams for clearing issues and providing all kind of information inquired by the developer. On-site customer is also useful in clearing ambiguous requirements. But in GSD it is often very difficult to have an on-site customer, which makes it very difficult for the development teams to effectively collaborate on a particular artifact. Unavailability of configuration management tools and version control systems also negatively affected coordination between the team members. Editing shared data at the same time was also a problem for teams working on the same artifact. Some respondents also reported that the lack of experience among team members also affected coordination among team members. Being in a geographically different place makes it very difficult for the development teams to coordinate effectively and keep track of all the changes made.

5.5.10.2.3 Control

Managing and integrating project artifacts are more difficult in GSD. The use of XP also makes it difficult for the project team to manage and integrate project items. The basic idea and purpose of XP is to concentrate on development rather than management of the project. According to the survey respondents it was difficult for the teams to integrate the remotely developed components. Besides, the lack of project management activities and tools in XP made it difficult for the teams to manage different project artifacts.

5.5.10.3Socio-cultural

In GSD team members often belong to different cultural backgrounds. This cultural diversity often results in trust and good relationships among team members and as result improves productivity and performance of team members and helps team members understand each other's cultural background and ways of working. The socio-culture diversity sometimes adds to the challenges of a GSD teams. In the following subsections we have presented different benefits and challenges introduced by applying XP practices in GSD.

5.5.10.3.1 Communication

The introduction of XP has both positively and negatively impacted socio-cultural communication among GSD team. On the one hand, after the application of XP, increased informal communications between team members resulted in mutual understanding and trust among them and reduced the socio-cultural distance between the teams. On the other hand, since GSD teams are from different cultures, cultural and language differences reduced trust among team members.

5.5.10.3.2 Coordination

In GSD, the use of XP practices improves coordination among team members. From our survey we got the idea that the use of pair programming in GSD helps teams and particularly components of the pairs to improve coordination and knowledge transfer. The use of XP practices in the distributed teams helped the team members understand the way of working of other team members. The use of practices like shared ownership, short releases and continuous integration motivated team members and resulted in increased

coordination. The use of XP practices also resulted in an improved social and technical relationships among team members.

Beside these benefits the XP-GSD teams also faced some challenges in regards to sociocultural-coordination. Lack of trust and cultural differences among the team members resulted in lack of accessibility of important information which made difficult for the teams to develop certain artifacts. Due to lack of sociocultural coordination transfer and maintenance of organizational knowledge also becomes difficult in XP-GSD teams. It is often difficult for other team members to understand the ways of working of the remote team members.

5.5.10.4General Benefits and Challenges

Other than these dimension of GSD, the introduction of XP has also brought some benefits and challenges to software development practices in GSD. Being an agile development methodology, the use of XP helps team members in understanding, managing and analyzing the requirements easily as compared to traditional methodologies. The reason for this is that in XP the duration of artifact and deliverables is limited and the product is normally developed and released in the form of small artifacts. XP also helps in improving the quality of the product and increases productivity of the team. The agile nature of XP helps in understanding and removing problems and errors earlier on in the project. Client satisfaction is easily achieved because the developing organization has to communicate with the client regarding the unclear and ambiguous requirements. The use of XP also improves program visibility, reduces complexity and improves code readability and maintainability.

Beside these benefits we have also got some challenging factors regarding the application of XP in GSD context. Language difference and little or no experience of XP can result in lack of confidence of team members. Since, in case of XP product artifacts are developed in small pieces, it becomes difficult for the organizations to organize product artifacts. Due to the fact the team members cannot communicate frequently, it becomes difficult for the team members to understand problems through emails and chat. Explanation of the problems also becomes difficult which makes things difficult on both the onshore and offshore sites. These kinds of mishaps also result in increased time consumption.

The benefits and challenges have also been classified by following the classification pattern followed in [14] [39]. The reason for classifying the challenges according to this pattern is because these challenges are mostly identical to the challenges reported in [14]. Following the same pattern however can also help to specify most of the benefits. **Table 16 and Table 17** shows the classification of identified challenges in relationship to communication, coordination and control as classified in [14].

Classification of Benefits – Extracted from Survey			
	Temporal	**Geographical**	**Socio-Cultural**
Communication	SUR_Com_Ben1	SUR_Com_Ben2	SUR_Com_Ben3
	SUR_Com_Ben4	SUR_Com_Ben4	SUR_Com_Ben4
			SUR_Com_Ben5
Coordination	SUR_Coord_Ben1	SUR_Coord_Ben2	SUR_Coord_Ben4
		SUR_Coord_Ben3	SUR_Coord_Ben5
		SUR_Coord_Ben4	SUR_Coord_Ben7
		SUR_Coord_Ben5	SUR_Coord_Ben8
		SUR_Coord_Ben6	
		SUR_Coord_Ben7	
Control	?	?	?

Table 16 Classification of Benefits – Extracted from Survey

Classification of Challenges – Extracted from Survey			
	Temporal	**Geographical**	**Socio-Cultural**
Communication	SUR_Com_Chlg1	SUR_Com_Chlg3	SUR_Com_Chlg4
	SUR_Com_Chlg2	SUR_Com_Chlg4	SUR_Com_Chlg5
	SUR_Com_Chlg3	SUR_Com_Chlg5	SUR_Com_Chlg6
	SUR_Com_Chlg4		
	SUR_Com_Chlg5		
Coordination	SUR_Coord_Chlg1	SUR_Coord_Chlg2	SUR_Coord_Chlg4
	SUR_Coord_Chlg4	SUR_Coord_Chlg3	SUR_Coord_Chlg6
	SUR_Coord_Chlg6	SUR_Coord_Chlg4	SUR_Coord_Chlg7
		SUR_Coord_Chlg5	SUR_Coord_Chlg8
		SUR_Coord_Chlg6	SUR_Gen_Chlg1
		SUR_Coord_Chlg7	
Control	SUR_Ctrl_Chlg1	SUR_Ctrl_Chlg1	
	SUR_Ctrl_Chlg2	SUR_Ctrl_Chlg2	

Table 17 Classification of Challenges – Extracted from Survey

5.5.11 Severity of Challenges

In order to classify the identified challenges by severity we have used numerical assignment [49]. The challenges faced by the practitioners most frequently and were affecting the software development practices at their organizations and were also affecting the core values of XP, had high severity. While the challenges reported by the practitioners a few times and were affecting the software development practices and the core values of XP to an extent that could easily be mitigated had medium severity. On the other hand

challenges having little or no impact on the software development practices and core values of XP were low severity challenges.

Lack of frequent informal communication is one of the most reported challenges faced by the practitioners while applying XP practices in their globally distributed software development environment. Communication is one of the core values of XP [9] and is one of most important and challenging factors in GSD [14]. According to our survey respondents, lack of frequent informal communication was affected temporal, geographical and socio-cultural distances. As a result of lack of informal communication the development teams found it difficult to proceed on specific artifact. Lack of informal communication also affected other core values of XP such feedback and courage. It was difficult for the customers to provide a prompt response or feedback about any enquiry regarding requirements or a developed artifact. Therefore, lack of frequent informal communication was reportedly one of the most important and challenging factor affecting XP processes in geographically distributed software development organizations.

Socio-cultural diversity or in other words language and cultural differences are two most important factors affecting software development practices in geographically distributed teams [14]. Socio-cultural diversity among teams resulted in lack of trust which affected the application XP practices. Lack of trust among the teams resulted in lack of communication, reduced feedback and courage and made things complicated. Similarly unavailability of on-site customer made it difficult for the development teams to proceed on the project. On-site customer is an important XP practice. In on-site customer the customer has to be available on-site to the development team for requirement elicitation, clarification and prioritization [9]. In on-site customer, the customer immediately provides feedback on artifacts and any ambiguity related to requirements. But in most of the organizations due to geographical distance and budget constraints it was difficult to have the customer on-site. Temporal and socio-cultural distances made it difficult for the development teams to communicate with the customer. The unavailability of on-site customer also made it difficult for the development teams to have immediate feedback on the developed artifacts. Practitioners have frequently reported lack of version control system and configuration management tools. Organizations who adopted XP practices such as short releases, continuous integration and pair programming faced challenges due to unavailability of suitable tools for configuration management and version control system. According to practitioners organizations faced challenges editing shared data simultaneously. Unavailability of proper supporting tools resulted in conflicting work as well. Also a lack of coordination was seen among components of pairs. Organizations also found it difficult integrate remotely developed components.

Beside these challenges practitioners have also reported some challenges which were either easy to mitigate or these challenges had little impact on core values of XP. Some practitioners have reported that lack of experience and language differences resulted in lack of confidence and courage among team members. Lack of project management activities is also an important challenge of XP. The reason for this is that XP is more a development process than project management process. Lack of project management is an important issue and practitioners dealt with by using some well know project management tools. Some organizations have dealt with the issue of project management by combining scrum with XP.

The challenges having low severity have not been discussed too frequently by the practitioners and most of the issues were typical challenges related to temporal, geographical and socio-cultural distances. Some practitioners have said that distance reduced the performance of the team because it was difficult for the teams to explain issues and problems. Similarly increased time consumption, lack of understanding of the ways other people work and lack of accessibility of information were also caused by distance.

Beside these challenges increased temporal, geographical and socio-cultural distance made it difficult for the teams to coordinate efficiently, reduced productivity of the teams and made knowledge transfer difficult.

Severity of Challenges – Extracted from Survey			
No	**High**	**Medium**	**Low**
1	SUR_Com_Chlg1	SUR_Coord_Chlg2	SUR_Coord_Chlg4.3
2	SUR_Com_Chlg2	SUR_Coord_Chlg6	SUR_Coord_Chlg5
3	SUR_Com_Chlg3	SUR_Ctrl_Chlg2	SUR_Coord_Chlg7
4	SUR_Com_Chlg4	SUR_Gen_Chlg1	SUR_Coord_Chlg8
5	SUR_Com_Chlg5		SUR_Gen_Chlg2
6	SUR_Com_Chlg6		SUR_Gen_Chlg3
7	SUR_Coord_Chlg3		
8	SUR_Coord_Chlg4.1		
9	SUR_Coord_Chlg4.2		
10	SUR_Ctrl_Chlg1		

Table 18 Severity of Challenges – Extracted from Survey

5.5.12 Solutions/Practices Adopted to Cope with the Challenges

From our survey we got a list of practices adopted by different organizations to cope with the challenges discussed in the previous section. The following sections explain how different organizations coped with the challenges associated with XP-GSD projects.

5.5.12.1 Temporal Distance

5.5.12.1.1 Communication

From our survey respondents we got different solutions/practices adopted to cope with the challenges associated with temporal communication. If the sites are located in different time zones, a communication delay can always happen. In order to cope with this situation some organizations increased overlapping of working hours by shifting the working hours. This increase in the number of overlapping hours resulted in more day time available to the development teams for communication. Adjustment of working hours can also improve coordination between teams. Another problem with temporal distance is that teams most often depend upon asynchronous communication. According to our survey respondents some of them used a direct communication medium such as phone or video conferencing for doing a more informal communication. Temporal distance also caused teams to wait for feedback from the customer or onshore teams. A possible solution to this situation could be encouraging the other party to provide immediate feedback on the developed artifacts. Some of the offshore development teams could cope with the problem of delayed communication by adopting this practice. But in order to encourage direct communication and feedback from the offshore team or the customer there should be understanding and commitment between all the stakeholders involved.

5.5.12.2 Geographical Distance

5.5.12.2.1 Communication

Geographical distance is one of the major factors affecting communication between the distributed teams. We have investigated several challenges related to communication from our survey respondents. The separation of teams by geographical distance can negatively affect communication between distributed teams in GSD. The problems

between the teams occur due to lack of informal communication. A solution to this problem could be the use of video conferencing tools. Successful use of some video conferencing tools such as Adobe Connect and Skype has been reported by some of the organizations to cope with the issues of informal face-to-face communication. Since in GSD, teams do not often meet due to geographical distance they depend mostly on formal communication tools. Due to these factors the quality of communication between the teams reduces. Communication quality can be improved by using multiple forms of communication media and tools. The frequent use of communication media such as Skype, phone and email can improve the quality of communication between geographically separated teams. Frequency of communication also decreases when the teams are separated by geographical boundaries. The reason is that teams have to depend on formal communication media. In order to increase the frequency of communication between the team members they have to be encouraged to send quick and conclusive messages to the teams across boundaries.

5.5.12.2.2 Coordination

In order to cope with the issues of conflicting work the project managers should provide the organization with such project management tools where the team members are aware of each other activities. It should be clear to all team members about who is working on which artifact, module or document. The tools should have the capability to work as a repository for storing different project artifacts. Some of these tools are AccuRev, TortoiseSVN and ClearCase. On-site customer is one of the most important XP practices which require the customer to be on-site with the development. But in GSD the availability of on-site customer becomes difficult. The absence of on-site customer from the development site makes it difficult for the development team to coordinate effectively with the customer. The best solution to cope with the absence of on-site customer is to have someone with complete domain knowledge and authority over the system at the offshore site. From our survey respondents project team lead or a senior team member has played the role of an on-site customer on a number project. Another solution proposed is that the customer should always be available online for a video conferencing meeting if not in person. For version control system TortoiseSVN, Subversion and GIT could be used. Some organization faced the problem of inexperienced team members. In organizations where there are a limited number of inexperienced team members, each inexperienced team member can be paired with an experienced team member. If majority of the team members do not have experience in XP, then the organization need to invest in training the staff and XP coaches should be hired to train team members. Change management process should be properly and clearly defined in order to cope with the issues of changes management.

5.5.12.2.3 Control

Integrating remotely developed components to the system could cause problems if the teams are not geographical close to each other. In order to cope with these issues, identify the problems associated with integration and synchronization tools to integrate remotely developed components. In case of having problems with managing different project artifacts, the status of each artifact of the project should be updated regularly. In this way it would be easier for all the team members to follow the whole development process.

5.5.12.3Socio-Cultural Distance

5.5.12.3.1 Communication

Socio-cultural diversity cause different problems in GSD context and makes communication between team members difficult. It also gives rise to lack of trust among team members. In order to cope with the issues of socio-cultural differences, the senior staff members (project managers and team leads) should pay visit to each other site. This

way they will have an idea of each other organizational culture and they will not have problems communicating with the other team. To cope with the issues of language differences a project manager or team lead (who can speak and understand the languages of both the teams), should bridge the gap between both the teams.

5.5.12.3.2 Coordination

Socio-cultural differences also result in coordination issues among team members. Due to socio-cultural differences, organizations sometimes do not share necessary information which results in lack of coordination between team members. In order to cope with the issue of lack of information sharing, organizations need to make sure that everyone in the team has access to all the required information. All the required information should be stored in a central repository and should be accessible to every person who needs it. In order to cope with the issues of knowledge sharing different knowledge management tools such as wikis or word press should be used. Sometimes misunderstandings and coordination issues arise due to the team members not understanding the ways of working of the remote team members. A possible solution for this situation could be helping and training the remote teams in understanding and evaluating the capabilities and ways of working of other team members.

5.5.12.4Solutions for General Challenges

Sometime too much time is wasted in explaining issues and problems related to certain product artifacts. The reason for this is either lack of experience or the development team does not understanding the way a problem is described. Training the staff and providing cultural ambassador to the teams who can bridge the gap between both the teams can solve these issues. Lack of project management is one of the most important challenging factors associated with the application of XP, because XP emphasizes more on development rather than documentation or project management. In order to cope with the issues related to project management, globally available project management tools should be used. The organizations can also take advantage of scrum for solving the project management problems in XP. **Table 19** shows a grouping and classification of the identified solutions according to particular challenges as extracted from survey.

Solutions – Extracted from Survey			
No	**ID**	**Description**	**Corresponding Challenge**
1	SUR_Com_Sol1	In order to have some overlapping of time working hours should be shifted	SUR_Com_Chlg1
2	SUR_Com_Sol2	Instead of relying on asynchronous communication, start direct communication when needed	SUR_Com_Chlg2
3	SUR_Com_Sol3	Encourage the other party to give direct feedback when necessary	SUR_Com_Chlg3
4	SUR_Com_Sol4	Use video conferencing tools as an alternative to frequent informal face-to-face communication	SUR_Com_Chlg4.1
5	SUR_Com_Sol5	Encourage and promote useful, quick and conclusive communication	SUR_Com_Chlg4.2
6	SUR_Com_Sol6	In order to improve communication quality use multiple forms of technology and communication media	SUR_Com_Chlg5
7	SUR_Com_Sol7	For cultural differences make senior team members to visit each other and appoint a senior team members to bridge the language gap between the two teams	SUR_Com_Chlg6
8	SUR_Coord_Sol1	Provide such an environment to the teams where all the developers are aware of other activities	SUR_Coord_Chlg2
9	SUR_Coord_Sol2	In case on-site customer is not available, a team member having full domain knowledge and authority over the system should play the role of the customer	SUR_Coord_Chlg3
10	SUR_Coord_Sol3	Use a shared version control system	SUR_Coord_Chlg4.1
11	SUR_Coord_Sol4	Invest in training the staff and hire XP coaches to train team members	SUR_Coord_Chlg6
12	SUR_Coord_Sol5	The change management process should be properly defined	SUR_Coord_Chlg4.3
13	SUR_Coord_Sol6	Make sure that every team member have equal access to information	SUR_Coord_Chlg7.1
14	SUR_Coord_Sol7	Use different knowledge sharing tools for sharing and maintaining organizational knowledge	SUR_Coord_Chlg7.2
15	SUR_Coord_Sol8	Make sure that remote team members evaluate the capability of each of their corresponding team members	SUR_Coord_Chlg8
16	SUR_Ctrl_Sol1	Identify problems related to integration before they occur and use tools to integrate and synchronize remotely developed components	SUR_Ctrl_Chlg1
17	SUR_Ctrl_Sol2	Update status of each of artifact of the project on regular basis	SUR_Ctrl_Chlg2.1
18	SUR_Ctrl_Sol3	Use globally available project management tools	SUR_Ctrl_Chlg2.2
19	SUR_Gen_Sol1	Invest time and money in training the team and provide them with a culture ambassador	SUR_Gen_Chlg2

Table 19 Solutions – Extracted from Survey

6 DISCUSSION

6.1 Comparative Analysis

Qualitative comparative analysis is concerned with the increasing knowledge and understanding of substantive area [24]. We conducted comparative analysis for improving and increasing our understanding and knowledge regarding the applicability of XP in GSD. The main purpose of conducting comparative analysis was to find out similarities and differences between the evidence found in literature and in the industrial practice [48]. Finding out similarities and differences between the evidence found in literature and industry was one of main objectives of the study.

In order to conduct comparative analysis in this research study, we first listed applied XP, their benefits, challenges and the practices adopted to cope with the challenges from both literature and industrial survey and then compared both with each other. In this way, we were able to find any similarities and differences between what is reported in the state of the art and what is actually practiced.

6.1.1 Similarities and differences between state-of-the-art and state-of-practice

After completing and reporting the systematic review and survey we found out differences between the evidence found in literature and practice. Some of the benefits and challenges reported in literature were also identified in practices as well. In addition to the benefits and challenges reported in literature, some other benefits and challenges were identified in industrial survey.

Figure 14 presents a comparison of benefits found in systematic review and industrial survey. We found 28 and 20 benefits of using XP in GSD, from SLR and industrial survey respectively. Among the reported benefits 15 were reported in both SLR and survey. We found 13 and 5 unique benefits of applying XP in GSD from SLR and survey respectively. Some important unique benefits from SLR are, reduction in communication delay, increased customer feedback and decreased development time.

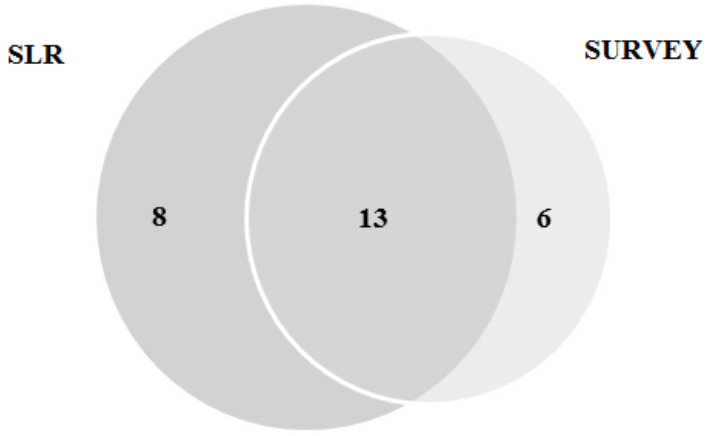

Figure 15 Benefits Reported by SLR and Survey

On the other hand we have found five unique and important benefits of using XP in GSD. Some important and unique benefits reported in survey are improved communication despite temporal distance, easier decision making and process transparency, increased

team motivation and satisfaction and improved social and technical relationship between team members.

Similarly we have found 23 and 25 challenges of applying XP in GSD from SLR and survey respectively. Among these 14 challenges had been reported by both SLR and Survey. SLR had reported 9 unique challenges associated with the combination of XP and GSD. Among these 9 challenges, lack of trust, reduced productivity, weak technical infrastructure and difficulty in accepting shared ownership were most reported and important challenges. On the other hand survey had 11 unique challenges. Among the 11 unique challenges, delayed feedback, reduced communication quality and frequency, difficulty in integrating remotely developed components, difficulty in organizing and integrating product artifacts and lack of project management activities are frequently reported by the practitioners. **Figure 15** shows similarities and differences between the challenges reported in SLR and survey.

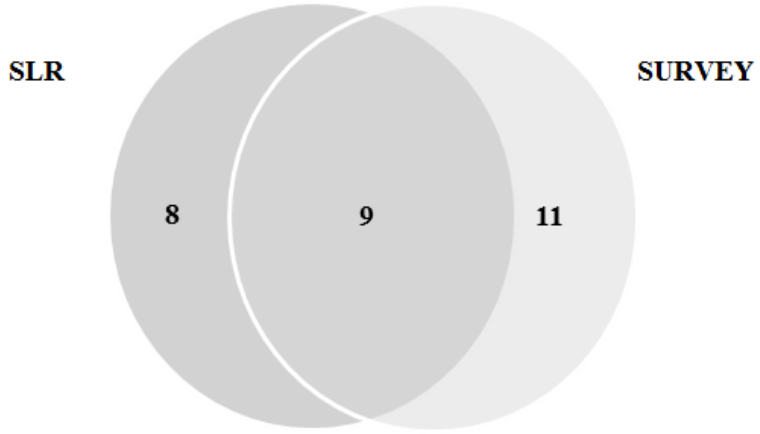

Figure 16 Challenges Reported by SLR and Survey

SLR and industrial survey had reported a total of 22 and 19 solutions/practices adopted to cope with the reported challenges respectively. Among these solutions 10 were reported by both SLR and survey.

SLR had reported 12 and survey reported 9 unique solutions to the reported challenges. Among the 12 unique solutions by SLR, the most important solutions are, encourage the teams to use a more frequent and direct communication style, make daily phone conference call, use a single build server and single shared code-base in order to encourage shared responsibility and use knowledge sharing tools such as wikis for transferring and maintaining organizational knowledge.

Among the solutions reported by survey, encourage team members to give direct feedback when needed, regularly update status of each project artifact, provide information access to every team member and use globally available project management tools.

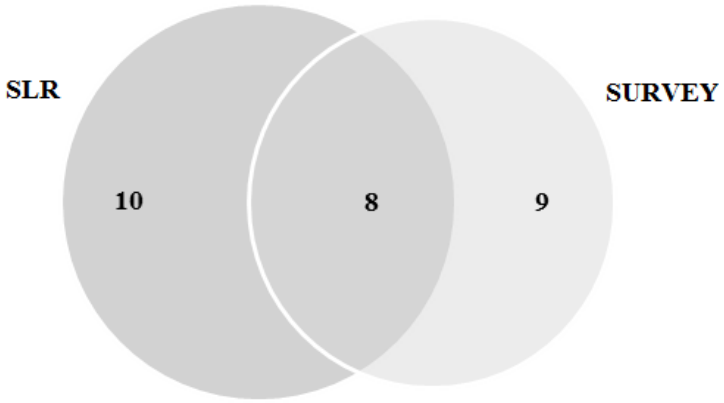

Figure 17 Solutions Reported by SLR and Survey

6.2 Overview of the Evidence found in Literature and Survey

This section presents a brief overview of the evidence found in literature and survey. We have briefly described the benefits, challenges and solutions to the challenges extracted from both literature and survey.

6.2.1 Overview of Benefits Extracted from both Literature and Survey

From the data collected from SLR and Survey we have found that most of the benefits of XP in GSD projects have been reported by both the industry and academia. We have found that most of the benefits related to communication and quality are commonly described in both the literature and survey.

All the unique benefits extracted from the survey are related to coordination. Whereas the reported benefits extracted from literature are related to multiple factors such as communication, coordination, productivity and cost. The reduction of cost in XP-GSD projects has been reported only in literature.

Table 20 presents an overview of the benefits extracted from both literature review and survey. Details of the benefits extracted from both literature and survey could be found in **Table 5** and **Table 14** respectively.

Overview of Benefits – Extracted from both Literature and Survey			
No	**SLR**	**Common**	**Survey**
1	SLR_Com_Ben1.2	SLR_Com_Ben1.1	SUR_Coord_Ben1
2	SLR_Com_Ben4	SLR_Com_Ben2	SUR_Coord_Ben3
3	SLR_Coord_Ben1	SLR_Com_Ben3	SUR_Coord_Ben4
4	SLR_Coord_Ben2	SLR_Com_Ben5	SUR_Coord_Ben6
5	SLR_Coord_Ben4	SLR_Com_Ben6	SUR_Coord_Ben7
6	SLR_Pr_Ben2	SLR_Coord_Ben3	SUR_Coord_Ben8
7	SLR_Pr_Ben3	SLR_Coord_Ben5	
8	SLR_Cost_Ben6	SLR_Pr_Ben1	
9		SLR_Pr_Ben4	
10		SLR_Qlty_Ben2	
11		SLR_Qlty_Ben3	
12		SLR_Qlty_Ben4	
13		SLR_Qlty_Ben5	

Table 20 Overview of Benefits Extracted from both Literature and Survey

6.2.2 Overview of Challenges Extracted from both Literature and Survey

A slightly different pattern has been followed in the challenges related to XP-GSD projects in both literature and survey. Most of the challenges that are commonly reported in both literature and survey are related to communication and coordination. Challenges related to control are different in both literature and survey. Challenges related to general category have only been discussed in survey. Most of the challenges which are general in nature and not specific to communication, coordination and control, are mostly relevant to productivity and quality. **Table 21** provides an overview of the challenges reported in both literature and survey. Details of challenges reported in literature and survey can be found in **Table 6 & 15** respectively.

Overview of Challenges – Extracted from both Literature and Survey			
No	**SLR**	**Common**	**Survey**
1	SLR_Com_Chlg2	SLR_Com_Chlg1	SUR_Com_Chlg1
2	SLR_Com_Chlg4	SLR_Com_Chlg3	SUR_Com_Chlg3
3	SLR_Com_Chlg5	SLR_Com_Chlg6	SUR_Com_Chlg4.2
4	SLR_Coord_Chlg1	SLR_Coord_Chlg2	SUR_Com_Chlg5
5	SLR_Coord_Chlg7	SLR_Coord_Chlg3	SUR_Coord_Chlg1
6	SLR_Ctrl_Chlg1	SLR_Coord_Chlg4	SUR_Coord_Chlg8
7	SLR_Ctrl_Chlg2	SLR_Coord_Chlg5	SUR_Ctrl_Chlg1
8	SLR_Ctrl_Chlg3	SLR_Coord_Chlg6	SUR_Ctrl_Chlg2
9		SLR_Coord_Chlg8	SUR_Gen_Chlg1
10			SUR_Gen_Chlg2
11			SUR_Gen_Chlg3

Table 21 Overview of Challenges – Extracted from both Literature and Survey

6.2.3 Overview of Solutions Extracted from both Literature and Survey

In order to cope with the challenges of XP in GSD combination different solutions have been proposed and reported in both literature and by survey participants. Some solutions proposed are common between SLR and survey while others are unique. Some challenges commonly reported by both SLR and survey have a common solution as well. The solutions common between both SLR and survey are only relevant to some communication and coordination issues. The rest of the solutions for the issues of communication, coordination and control are not common between literature and survey. **Table 22** provides an overview of the solutions reported in both literature and survey. Details of solutions in correspondence with their relevant challenges reported in both literature and survey can be found in **Table 10** and **19** respectively.

Overview of Solutions – Extracted from both Literature and Survey			
No	**SLR**	**Common**	**Survey**
1	SLR_Com_Sol2	SLR_Com_Sol1	SUR_Com_Sol3
2	SLR_Com_Sol3.3	SLR_Com_Sol3.1-3.2	SUR_Com_Sol7
3	SLR_Com_Sol4.2	SLR_Com_Sol7	SUR_Coord_Sol1
4	SLR_Com_Sol5	SLR_Coord_Sol1.1	SUR_Coord_Sol5
5	SLR_Com_Sol6	SLR_Coord_Sol3	SUR_Coord_Sol6
6	SLR_Coord_Sol1.2	SLR_Coord_Sol5	SUR_Coord_Sol7
7	SLR_Coord_Sol2	SLR_Coord_Sol8	SUR_Ctrl_Sol1
8	SLR_Coord_Sol4	SLR_Coord_Sol7	SUR_Ctrl_Sol2
9	SLR_Coord_Sol6		SUR_Ctrl_Sol3
10	SLR_Ctrl_Sol8		

Table 22 Overview of Solutions – Extracted from both Literature and Survey

6.3 Impact of XP on GSD

From SLR and survey it is obvious that XP affects GSD both positively and negatively. The introduction of XP brings with itself a number of benefits as well as challenges. Although the introduction of XP helps in coping with existing challenges of GSD it also adds to those challenges. In the following sections we have discussed the challenges which are common between XP and GSD. These challenges were both investigated in our research and had been previously reported in GSD literature. The subsequent section explains how these challenges can be alleviated with the help of XP.

6.3.1 Identified challenges which already exist in GSD

From SLR and survey we have found a total of 48 challenges in relationship to the application of XP in GSD. Among these 4 challenges did not have any relationship to traditional GSD challenges reported by [14]. These challenges appeared only due to the introduction of XP. Among the remaining 44 challenges 14 challenges were common. Therefore, we had a total of 30 unique challenges related to XP-GSD combination. Since distance is the most important factor in GSD, we classified all the challenges from SLR and survey on basis of temporal, geographical and socio-cultural distances [39]. By analyzing these challenges we found out that these challenges already existed in GSD and that they were mostly caused by temporal, geographical and socio-cultural distances and were affecting communication, coordination and control among the geographically distributed teams.

Table 42 consists of challenges common between XP and GSD. These challenges are extracted from both SLR and survey. The table consists of a total of 30 challenges. 23 of

these challenges come from SLR and 11 from survey. The challenges reported by both SLR and survey were merged together. Despite the fact that some of the challenges have a close relationship with XP, they can still be related to communication, coordination and control issues of GSD. Challenges like lack of XP experience and lack of project management activities can be associated with XP, but challenges like these can be associated with coordination and control of distributed teams. A complete classification of XP-GSD challenges due temporal, geographical and socio-cultural distances and related to communication, coordination and control can be found in the results of SLR and survey.

	Challenges common between XP and GSD		
No	**Challenge ID**	**No**	**Challenge ID**
1	SLR_Com_Chlg1	13	SUR_Coord_Chlg7
2	SLR_Com_Chlg2	14	SUR_Com_Chlg3
3	SLR_Com_Chlg3	15	SLR_Ctrl_Chlg1
4	SUR_Com_Chlg4.2	16	SLR_Ctrl_Chlg3
5	SUR_Com_Chlg5	17	SLR_Com_Chlg6
6	SLR_Com_Chlg5	18	SLR_Coord_Chlg1
7	SLR_Coord_Chlg3	19	SUR_Ctrl_Chlg2
8	SLR_Coord_Chlg2	20	SUR_Gen_Chlg2
9	SLR_Coord_Chlg5	21	SUR_Gen_Chlg3
10	SUR_Coord_Chlg4	22	SLR_Ctrl_Chlg2
11	SUR_Ctrl_Chlg1	23	SLR_Coord_Chlg6
12	SLR_Coord_Chlg7		

Table 23 Challenges common between XP & GSD

6.3.2 XP practices adopted to cope with the issues of GSD

The challenges reported in literature and survey are both related to the application of XP and GSD itself. There are different mitigation strategies reported to cope with these types of challenges in GSD as in [14]. But despite these mitigation strategies, the use of XP can also help in coping with these challenges. From the benefits reported in systematic review and survey it is evident XP helps in alleviating some of challenges. First of all the issues related to communication can be mitigated by using XP because it is one of the core values of XP. Informal communication is very important for successful implementation of XP. Hence if XP can be successfully implemented in GSD environment it can help in coping with the issues of GSD (particularly related to communication).

Each of the twelve XP practices improves the software development process in one way or another. Each of these practices has its own benefits and it is very difficult to say which one of the twelve practices can help in alleviating the challenges of GSD. However, on the basis of SLR and industrial survey we can say that these practices can help in alleviating the challenges of GSD. Collective ownership can be used to cope with the issues of socio-cultural coordination and communication because it can help in improving technical and social relationship among the team members. Pair programming and short releases improve communication between the team members and increase trust. Pair programming is also helpful in alleviating the issues related knowledge transfer. On-site customer also helps in improving trust between the team members and customer. Although due to cost issues and geographical distance this practice cannot always be affective, but if there is understanding between the team members and a senior project member at the offshore site has complete knowledge and understanding of the project, the practice can

prove to be very effective. Continuous integration helps in earlier problem identification and improves the issues related to coordination among the team members. Testing, metaphor, planning game and coding standards can be used to cope with the issues of coordination due to temporal, geographical and socio-cultural distances.

The application of different XP practices in GSD projects can help alleviate the existing challenges related to communication, coordination and control. But in order to take advantage of XP practices and to use them in alleviating the challenges of GSD, these practices have to be tailored and customized. XP practices such pair programming, short releases an on-site customer can used to improve communication. On-site customer and pair programming also help in improving trust and socio-cultural coordination and communication between team members. Continuous integration helps in improving the issues related to coordination. 40-hour week can be used to deal with the issues related to temporal coordination.

6.3.3 Successful XP practices in GSD

Evidence of XP practices gathered from SLR and survey was investigated to find out which XP practices were applied in which GSD setting. The data extracted about the project size, duration, team size and domain for both SLR and survey has been presented in chapter 4 and 5. A brief summary of each combination of XP practices and GSD as reported in literature and survey has been presented below.

Offshore: The most popular practices adopted in offshoring are short releases, continuous integration, pair programming, on-site customer, collective ownership and testing.

Outsource: The most popular practices in this combination are pair programming, collective ownership, continuous integration, small releases, planning game and coding standard.

Distributed Teams: The most popular XP practices adopted by distributed teams are small releases, simple design, testing, metaphor and continuous integration.

Virtual Teams: The most popular XP practices adopted by virtual teams are planning game, testing, coding standard, small releases are continuous integration.

The above mentioned combinations based on the results of the survey and SLR is an indication that pretty much every important XP practice can be adopted in a GSD environment provided it had to be tailored according to a particular settings. Although the data gathered from SLR and survey states that some practices such as pair programming, continuous integration, small releases, planning game and testing has been used more than the other practices the application of a particular practice for a particular GSD setting cannot be finalized. In almost all the research papers and survey responses a combination of practices has been adopted as opposed to adopting a single practice. Some research papers and survey respondents have indicated the use of scrum practices along with the XP practices.

6.4 Discussion

During the course of this research we have found that research conducted on the combination of XP and GSD is scarce. However, an increase in the number of publication over the past 6 years has been seen. The research publications are mostly in the form of experience report and case studies. But the number of publications over the last two years has declined. On other hand the industry has adopted XP in their GSD projects as reported in survey.

The main purpose of conducting SLR in this research study was to investigate the reported research literature by exploring the benefits and challenges related to applying XP

practices in GSD. Beside benefits and challenges, the SLR was also intended to investigate the reported solutions/practices adopted to cope with the reported challenges.

Many benefits and challenges of XP have been reported in the form of empirical studies. The benefits are achieved by applying one or more XP practices in a GSD environment either in its original form or in a customized form (e.g. by combining XP with scrum). The results indicate that XP can both benefit and bring challenges to GSD. The introduction of XP according to some empirical studies benefits GSD and helps in alleviating the existing challenges of GSD. XP can alleviate communication, coordination and control related challenges introduced by temporal, socio-cultural and geographical distances in GSD. The introduction of XP into GSD also improves productivity, quality and reduces cost. Beside benefits the research papers have also discussed related to communication, coordination and control which are introduced by temporal, socio-cultural and geographical distances. Almost all the reported challenges are related to traditional GSD challenges as reported by [14]. The research papers have also discussed the solutions or practices adopted to cope with the reported challenges.

A similar pattern of investigation has been followed in the survey as well. The purpose of the survey was to explore the benefits and challenges of applying XP in GSD. Like SLR the survey also investigated the solutions adopted to cope with the challenges. Most of the benefits reported in the survey improved communication, coordination and control. The challenges reported were also related to communication, coordination and control. Beside these typical GSD challenges a couple of challenges were out of these categories. The survey also helped in investigating the solutions/practices adopted to cope with the challenges.

The results of SLR and survey were combined to investigate the suitability and applicability of XP to GSD. By analyzing the data collected from SLR and survey we found out the most of challenges reported in the context of this research are traditional GSD challenges. Applying proposed solutions can however alleviate these challenges. Beside the proposed solutions, applying different XP practices in GSD projects can also alleviate these challenges. But before applying XP in GSD projects it has to be tailored according to a particular GSD setting. Beside this the application of different XP practices was also investigated in this research. But due to the application of multiple practices in different GSD settings it was difficult to conclude which XP practice can be adopted in which GSD settings.

From SLR we have found that limited number of empirical studies exist in literature. Therefore, more research work is required to investigate the projects which have successfully implemented XP in their GSD projects. Beside this some research papers have described the successful use of XP in their GSD projects but they have not specifically described which practices were adopted. The use of scrum along with XP has also been reported the context has not been clearly stated.

The contextual information for many research papers is insufficient or is not available at all, which makes it difficult for the researchers to apply this information to other projects. In order to make it easy for the researchers to explore the area and apply the findings of the research to other research areas, adequate research information should be provided.

6.5 Validity Threats

The reliability and accuracy of the research is always affected by some factors no matter how well the research is conducted. For this research study we have found some validity threats related to SLR and industrial survey. There are four different kinds of validity threats as discussed by [40]. These threats are: internal validity threats, external

validity threats, construct validity threats and conclusion validity threats. The following sections explain the validity threats associated with this work and their relevant mitigation strategies.

6.5.1 Internal Validity

The purpose of internal validity is to make sure that valid conclusion can be drawn from the collected data [40]. The internal validity threats related to our research study were the following.

The purpose of the systematic review was to find as many relevant research studies as possible. For the purpose of this study we performed backward and forward snowballing. In order to have an initial set of papers we searched IEEE and Google Scholar. We created a search string from search keywords extracted from the research questions. While performing snowballing it is possible that we may have missed important relevant studies. We may have found more studies if we had performed our search in multiple databases. But due to lack of availability of time and resources we could not conduct a database search in multiple databases. According to [43] regardless of numbers and figures, similar patterns can be found in systematic literature studies and snowballing and hence similar conclusion can be drawn. In [43], a comparison between database searches and snowballing was drawn and was conducted on agile global software development, which makes it relevant to our study. Therefore, we believe that a similar conclusion can be made.

In order to avoid the threat related to publication bias, a strict review protocol was defined and followed systematically. The papers were selected by individually on the basis of predefined protocol. In case when the authors had confusion selecting or rejecting a particular paper, both authors would discuss the issue and would either include or exclude the papers on their mutual consensus. In order to avoid ambiguities in the data extraction both the authors performed a pilot extraction. The piloting help the authors reach a consensus regarding the extraction of data from the selected papers. Also in order to check the level of agreement between the authors, kappa statistics was used [35]. The authors randomly selected 3 research papers and applied their inclusion/exclusion criteria on the selected papers. The authors also extracted the data independently from the selected papers. The level of agreement between the two authors was checked according to kappa statistics and the results shown negligible difference between the opinions of the authors.

There was also a potential threat of missing the benefits and challenges by missing some primary studies during the search. The reason for this is because in GSE or GSD different terms are used interchangeably. For example the term development in global software development may mean development phase or entire development cycle. Beside this we used Google Scholar for getting our initial set of papers for snowballing. But the problem with Google Scholar is that it does have the ability to conduct complex searches by using long search strings. In order to avoid these issues both the authors carefully developed the search string and refined it with the help of supervisor and librarian.

6.5.2 External Validity

According to [40] external validity is concerned with the generalizability of the conducted research study. We have found major threats associated to the industrial survey. Finding organizations working on XP in a GSD context was difficult. Approaching and contacting the respondents who have/had been using XP in their distributed project was difficult. In order to reach respondents in different parts of the world an online questionnaire was developed on the mutual consensus of the authors. It was also possible that we may not have access to a substantial number of respondents. For this purpose we distributed the questionnaire on a number of online XP, agile and GSD groups on LinkedIn. We also sent the links to our personal contacts and request them to send the survey link to their contacts further. The reliability of the survey respondents was also a

threat to the conclusion and analysis of the survey. But we got about 70% of responses from our contacts, which helped us cope with the issues related to the reliability of the survey.

The number of responses we got for the survey was another threat. Because it was difficult for us to make generalizable statement about the data received through the survey. We tried very hard to have as much as possible responses from participants in different parts of the world. But due to limited time and resource availability it was difficult for us to have a large number of responses. We were successful in getting responses from 51 Number of respondents. It was a threat to make any kind of generalized statement about the benefits, challenges and solutions of the challenges associated with the combination of XP and GSD. It was also possible that we may have missed any important benefits or challenges. Another threat was that some respondents did not completely fill the questionnaire and some responses were not very clear. In order to avoid those problems we ignored those responses which were either incomplete or unclear.

The types of questions asked in the survey were another threat. The questions related to demographic, company and project information were asked in close ended questions whereas the questions related to the adopted XP practices, their benefits and challenges, and solutions to challenges were asked in a combination of both close and open ended types. There was a possibility that the respondents may find these questions difficult to answer. While designing the survey we tried very hard to make these questions as easy to answer as possible. It may also have been difficult for the respondents to answer questions specific to company or project information. We made it clear in the introduction to keep the information specific to project and company anonymous.

The survey was sent to many respondents located in Europe, Asia and America. The idea was to gather information from people from different cultures, backgrounds, geographical locations and organizational structures. The idea was to generalize the results of the research to a larger context. However due to time limitation we could not keep the survey open for a longer duration.

6.5.3 Construct Validity

According to [44] construct validity is concerned with the question "How do you know that you are measuring what you think you are measuring?". The construct validity threat in our research could be the structure of the search string. The search string may not help us find all the required information and research articles. For this purpose we refined the search string with the help of librarian and our supervisor. Another threat could be the extraction of information from the research papers regarding the benefits, challenges, solution and severity of challenges. In order to avoid these threats we continuously communicated with our supervisor and sent her updates of every step we took. In case we faced any problems or difficulty we would discuss that with our supervisor and ask for her guidance.

6.5.4 Conclusion Validity

Conclusion validity is concerned with the issues affecting the ability to draw correct conclusion about relationships between treatment and outcome [40]. In order to cope with the threat of missing important benefits and challenges reported in literature, the authors strictly followed a pre-defined review protocol. The review protocol consisted of a well-defined inclusion/exclusion criteria and a data extraction form. The protocol was prepared after mutual understanding and consensus of both authors and with guidance of the supervisor. Also in order to measure the level of agreement between both the authors, kappa statistics was used. If there were any misunderstandings between the authors on a particular issue both authors would discuss the issue together until a mutual agreement was reached. In order to ensure that the data was extracted according to the review protocol we performed a pilot data extraction. Data was extracted from five primary studies initially

and was sent to the supervisor for approval. After getting the approval and acknowledgement from the supervisor data was extracted from the rest of primary studies.

There was also a risk associated with conducting the survey, because in case of misunderstanding or misinterpretation of a particular question we may miss important information from the practitioners. In order to cope with this issue we approached a senior BTH student and ask for his guidance. He had prior research experience in agile and studied global software engineering as a subject. He gave us valuable feedback regarding different questions in the survey. He advised us to make the questions simpler and easy to answer. His feedback helped us in refining our survey. After refining the survey we sent the survey questionnaire to our supervisor and discussed the potential issues with her. She continuously provided feedback on the survey until she was satisfied with the questionnaire. The small number of responses received from the survey was another threat to the generalizability of the conclusion. It would have been much better if we had conducted interviews alongside the survey but limited time and resources did not allow us to conduct an interview.

7 CONCLUSION

In this research work we have investigated the suitability of eXtreme Programming in Global Software Development. We have conducted a systematic review and an industrial survey to investigate and explore the benefits and challenges of XP in combination with GSD. We have also investigated different solutions adopted to cope with the challenges of XP. In addition to the benefits and challenges, it is investigated which challenges are typical GSD problems, and how GSD benefits from XP practices. The results indicate that XP practices can actually alleviate traditional GSD challenges to a good extent. However, in order to successfully implement XP in GSD, it has to be customized and tailored according to the organization setting and distribution of responsibility across different sites.

7.1 Research Questions Revisited

RQ1. What is reported in the available research literature about XP practices in GSD?

RQ1.1. What are the benefits and challenges?

In order to investigate the benefits and challenges of XP in GSD we have conducted a systematic review. After conducting the systematic review we classified the identified benefits and challenges in relationship to communication, coordination and control on the basis of temporal, geographical and socio-cultural distances. The data gathered in this step indicate that GSD can benefit from XP and that it can help in alleviating the challenges of GSD. A detail of the benefits and challenges investigated through systematic review can be found in section 4.5.1.

RQ1.2. Which challenges are severe and require more attention than others?

In order to find answer to this question we analyzed the data gathered from SLR. We determined the severity of the challenges by using numerical assignments. The challenges reported more in literature and which were affecting one or more core values of XP were considered more severe. Detail of severity of challenges can be found in section 4.5.2.

RQ1.3. What strategies are adopted to deal with the challenges?

The answer to this question was also investigated from the data gathered through SLR. The selected primary studies had proposed different solutions or practices to cope with the challenges reported in literature. Section 4.5.3 provides detail of the identified strategies adopted to cope with the reported challenges.

RQ2. What is being done in software organizations that utilize XP practices in their GSD projects?

RQ2.1. What are the benefits and challenges?

In order to investigate the benefits and challenges of XP in GSD we conducted an industrial survey. We received 51 responses from the respondents. A total of 20 benefits and 25 challenges were reported in survey. The benefits and challenges reported in survey were also classified according to communication, coordination and control and were based on temporal, socio-cultural and geographical distances. The results of the survey also indicated the same pattern as SLR. Most of the benefits helped in improving communication, coordination and control and most of the reported challenges were traditional GSD challenges. Section 5.4.10 provides a detail discussion on the benefits and challenges reported in survey.

RQ2.2. Which challenges are severe and require more attention than others?

In order to classify the identified challenges on the basis of severity we applied a three-step process. Challenges that were reported the most, had an impact on the software development processes in the investigated organizations and were affecting one or more core values of XP had a higher severity. The challenges reported by relatively less respondents and did not have a huge impact on software development process and were not affecting the core values of XP had medium severity. Whereas the challenges which were reported very little number of respondents, had very little impact on software development process and were not affecting one or more core values of XP had low severity. Section 5.4.11 provides additional information.

RQ2.3. What strategies are adopted to deal with the challenges?

The survey respondents provided different solutions to the challenges reported. Details of reported solutions can be found in section 5.4.12.

RQ3. Does GSD benefit from XP practices?

RQ3.1. Which of the identified challenges are traditional GSD problems?

In order to find answer to this question we analyzed data related to challenges from both SLR and survey. After a thorough analysis of the gathered data we found out that the challenges identified during SLR and survey were mostly traditional challenges of GSD. A detail of this question can be found in section 6.2.1.

RQ3.2. Which of the identified practices or typical XP practices can alleviate those issues?

The results from both the survey and SLR indicate that almost all XP practices have been used. These practices although customized according to the requirements of organization benefited and helped in alleviating the problems associated with GSD. A detail discussion can be found in section 6.2.2.

RQ3.3. Which XP practices are applied in which GSD settings?

Data gathered from SLR and survey indicates that multiple XP practices have been applied in different GSD setting. However it is difficult to specify conclusively which particular XP can be applied in which GSD setting. Section 6.2.3 provides a complete detail of RQ3.3.

7.2 What Have We Done Differently?

In [P9], the authors have investigated the proposed benefits and challenges of agile methods in global software development based on the existing literature. They have also presented a plan for conducting a case study in the future. The authors have discussed XP in general and no discussion about particular practices has been given.

Similarly Layman et al [P20] have conducted a case study on the communication practices in XP in GSD. The authors have discussed only XP and the issues that could arise due to lack of informal communication in an XP team in GSD. In another study conducted by Holmström et al [P22], the authors have conducted a case study on the usage of agile methods in global software development. The authors have mainly focused the challenges of global software development. Two different agile methodologies i.e. scrum and XP have been explored during the course of this extensive case study and only few of XP practices such as pair programming, simple design, refactoring and coding standard and its impacts on GSD have been discussed. In [P18], a case study on the application of XP in GSD has been conducted. The authors have discussed some challenges of GSD and stated how the use of agile methods such XP can help in solving the problems.

Unlike previous studies, this research aimed at investigating the applicability of XP in GSD through collecting all reported benefits and challenges of this combination in the literature complementing with a survey targeting practitioners. We also wanted to find out

what solutions are adopted to deal with the challenges. We wanted to find out these factors from both the state-of-art and state-of-practices perspectives. The main objective of this thesis report was not to find out the challenges and/or solution to the existing challenges of GSD. We have made the following contribution to the research area.

- We have investigated the benefits and challenges related to the application of XP in GSD from both the literature and practice perspective. We have also found out what practices or solutions have been adopted to deal with these challenges.
- In this study we have found that almost all XP practices have been applied in GSD, although some of them are applied with modifications.
- We have found out that most of the challenges related to XP-GSD combination are basically GSD challenges. The challenges were mostly relevant to communication, coordination and control and were introduced by temporal, geographical and socio-cultural distances. Based on the classification of GSD challenges previous investigated by other researchers [14] we classified the challenges of XP-GSD. We did the same classification for the benefits and that these benefits improve software development in distributed environment.
- Based on the population sample of our survey we believe that our results are more generalizable because our survey population consisted of respondents having multiple years of experiences, from different location and were working on software development projects in different domains.

7.3 Future Work

- **Lack of project management**

During this research study we have found that XP is more a development methodology rather project management methodology. Although some research papers have discussed the use of scrum practices in XP to cope with project management challenges in XP. It would be interesting to investigate how project management activities are performed in XP projects.

- **XP in large scale distributed projects**

XP can reportedly be adopted small to medium sized projects. It is not evident from both survey and SLR if XP has been successfully adopted in large-scale projects or not. Conducting research on large scale XP project could be important for future research.

- **Knowledge management in distributed XP projects**

Since extreme programming was developed for co-located environment, it emphasizes more on practice than documentation. In co-located environment it is easy to transfer and maintain organizational knowledge. But in GSD since there is limited informal and face-to-face communication, knowledge transfer becomes limited. We did not find any evidence of organization knowledge management in XP-GSD projects in the existing literature. Therefore, it would be interesting to see how organizational knowledge is transferred and maintained in XP-GSD projects.

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8 APPENDIX

8.1 Data sources with search strings and search results

The following table contains search strings created from the keywords in table 1. The table also consists of the names of data sources searched and the results obtained from the search.

Database	Search String
IEEE	(agil* OR "extreme programming" OR xp OR xp2 OR flexible) AND ("distributed software development" OR "global software development" OR "collaborative software development" OR "global software engineering" OR "globally distributed work" OR "collaborative software engineering" OR "distributed development" OR "distributed teams" OR "global software teams" OR "globally distributed development" OR "geographically distributed software development" OR "dispersed teams" OR "multi-site software development" OR software offshor* OR software outsourc* OR software onshor* OR software insourc*)
Google Scholar	(agile OR "extreme programming" OR xp OR xp2) AND ("distributed software development" OR "global software development" OR "global software engineering" OR "dispersed teams" OR offshore OR outsource OR onshore OR insource)

Table 24 Electronic databases with search strings

8.2 Data Extraction Form

General Information About Research Study/Article	
Title of article	
Name of author(s)	
Year of publication	
Type of Article	☐Journal ☐ Conference
Database source	
Research Methodology	
Empirical Background	☐Yes ☐No ☐Unclear
Research Method	☐Case Study ☐Multiple Case Studies ☐Experiment ☐Surveys ☐Literature Review ☐Mixed ☐Others
Research Background	☐ Academia ☐ Industrial ☐Mixed
Global Software Engineering Attributes	
Collaboration Mode	☐ Inter-Organizational ☐ Intra-Organizational ☐ Unclear
Characteristics	Number of Sites: ……./Unclear Number of Teams: ……./Unclear Location(s): ……./Unclear Time Zone Difference: ……./Unclear
XP Attributes	
XP Practices adopted	☐XP ☐Planning Game ☐Small Release ☐Metaphor ☐Simple Design ☐Testing ☐Refactoring ☐Pair Programming ☐Collective Ownership ☐Continuous Integration ☐40-Hour Week ☐On-Site Customer ☐Coding Standards
Customization of XP Practice(s)	☐Yes ☐No (If Yes Please state how?)
Project Features	
No. of Projects	……./Unclear
Size	☐Large (More than 2 Years) ☐Medium (1-2 Years) ☐Small (4-6 Months) ☐Unclear
Duration	…….Months/Unclear
Participants	☐ Students ☐ Industry ☐ Mixed ☐ Unclear
Success	☐ Yes ☐ No ☐ Partially
Product Features	
Application Domain	……../Unclear
Size	LOC: ……../Unclear Function Points: ……../Unclear
Highlighted Benefits/Challenges/Solutions	
	Highlighted challenges, proposed solutions/strategies/frameworks and lessons learnt etc.
Results	

Figure 18 Data Extraction Form

8.3 Survey Questionnaire

The Benefits and Challenges of XP in Global Software Development

Personal Info

1. Role

- ○ Project Manager
- ○ Team Lead
- ○ System Analyst
- ○ System Designer
- ○ Developer
- ○ Tester
- ○ Other (Please Specify) _____

2. Total experience in software projects

- ○ Less than 1 year
- ○ More than 1 year but less than 5 years
- ○ More than 5 Years but less than 10 years
- ○ More than 10 years

3. For how long have you been involved in XP?

- ○ 0 to 6 months
- ○ More than 6 months but less than 1 years
- ○ More than 1 Year but less than 2 years
- ○ More than 2 Years but less than 3 years
- ○ more than 3 years

4. Where are you located?

-- Please Select --

Company & Project Info

5. Name of the company

6. Size of the company (number of employees)

- ○ 1-10
- ○ 11-50
- ○ 51-100
- ○ 101-1000
- ○ More than 1000

7. Location of the main site

-- Please Select --

8. What was the responsibility of main site?

- ☐ Requirement Analysis
- ☐ Design
- ☐ Development
- ☐ Testing
- ☐ Other (Please Specify) _____

9. How many distributed sites does the company have?

- ○ Up to 2
- ○ 3-6
- ○ 7-10
- ○ More than 10

10. Where were the distributed sites located? What responsibility and size did the team have at each location?

Location

-- Please Select --

Responsibility

☐ Requirement Analysis ☐ Design ☐ Development ☐ Testing

☐ Other (Please Specify)

Size of the team (no of employees)

○ 1-10 ○ 11-50 ○ 51-100 ○ More than 100

Add Another

11. What was the domain(s) of the project(s) you were involved in?

☐ Telecommunication ☐ Finance ☐ Real-time ☐ Web ☐ Commercial ☐ Automotive

☐ Other (please specify)

12. For how long the project is/had been under development?

○ Up to 6 months ○ 7-12 months ○ More than 1 year but less than 2 years

○ More than 2 years but less than 4 years ○ More than 4 years

XP Practices

In the following questions, definition each XP practice has been provided according to Kent Beck*. For each practice:

-Please indicate whether it has been adopted in your project or not?
-If it was utilized differently than the given definition, please specify the modification.
-Please write down it's perceived benefits and challenges on your project.
-For each challenge, please specify how you alleviated it.

* K. Beck, Extreme Programming Explained: Embrace Change, Addison Wesley Longman, Reading, Mass., 2000.

13. Planning Game: Determine the scope of next release and update the plan when the previous part is accomplished

		Modification	Benefits	Challenges	Solutions to Challenges
Planning Game	☐				

14. Small Releases: Quickly putting a simple system into production and releasing new versions in short cycles.

		Modification	Benefits	Challenges	Solutions to Challenges
Small Releases	☐				

15. Metaphor: Developing a common/shared vision of how the system works.

		Modification	Benefits	Challenges	Solutions to Challenges
Metaphor	☐				

16. Simple Design: Designing the system in the simplest possible way and removing any complexity as soon as it is discovered.

		Modification	Benefits	Challenges	Solutions to Challenges
Simple Design	☐				

17. Testing: Programmers write the test for development to continue and customers write test for accomplishing particular features. Also each feature must be tested thoroughly before release.

		Modification	Benefits	Challenges	Solutions to Challenges
Testing	☐				

18. Refactoring: Restructuring the system without changing its behavior in order to remove duplication, improve communication and to add flexibility.

		Modificaiton	Benefits	Challenges	Solutions to Challenges
Refactoring	☐				

19. Pair Programming: All the code is written by two programmers working on the same machine.

		Modification	Benefits	Challenges	Solutions to Challenges
Pair Programming	☐				

20. Collective Ownership: No single person is responsible for a piece of code. Every person can change the code everywhere and at any time.

		Modification	Benefits	Challenges	Solutions to Challenges
Collective Ownership	☐				

21. Continuous Integration: Integrating the system many times a day every time a task is completed.

		Modification	Benefits	Challenges	Solutions to Challenges
Continuous Integration	☐				

22. 40-Hour Week: Follow the rule of working no more than 40 hours a week. Never work overtime a second week in a row.

		Modification	Benefits	Challenges	Solutions to Challenges
40-Hour Week	☐				

23. On-Site Customer: Include a live, real user on the team. He should be available to answer questions related to the system any time.

		Modification	Benefits	Challenges	Solutions to Challenges
On-Site Customer	☐				

24. Coding Standards: The code must be written in the same way following the same style and format to improve communication and knowledge sharing.

		Modification	Benefits	Challenges	Solutions to Challenges
Coding Standards	☐				

25. If you have specified one or more challenges regarding the combination XP & GSD, please tell us how these challenges affected the software development process in your organization?

The effect of XP on GSD

26. To what extent do you think the introduction of XP affects the existing GSD challenges related to communication, coordination and control?

	Much Worse	Worse	Same	Better	Much Better
Communication related challenges due to Temporal Distance	○	○	○	○	○
Communication related challenges due to Geographical Distance	○	○	○	○	○
Communication related challenges due to Socio-Culture Distance	○	○	○	○	○
Coordination related challenges due to Temporal Distance	○	○	○	○	○
Coordination related challenges due to due to Geographical Distance	○	○	○	○	○
Coordination related challenges due to Socio-Culture Distance	○	○	○	○	○
Control Related Challenges due to Temporal Distance	○	○	○	○	○
Control Related Challenges due to Geographical Distance	○	○	○	○	○
Control Related Challenges due to Socio-Culture Distance	○	○	○	○	○

Additional Comments

27. Would you like to add anything we have not covered in the questionnaire? Please fill in the essay box below

Thank You!

Thank you for taking our survey. Your response is very important to us and we hope your participation will help us contribute to software engineering research.

Figure 19 Survey Questionnaire