Using Scrum in Global Software Development: A Systematic Literature Review

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Abstract— There is a growing interest in applying agile practices in Global Software Development (GSD) projects. The literature on using Scrum, one of the most popular agile approaches, in distributed development projects has steadily been growing. However, there has not been any effort to systematically select, review, and synthesize the literature on this topic. We have conducted a systematic literature review of the primary studies that report using Scrum practices in GSD projects. Our search strategy identified 366 papers, of which 20 were identified as primary papers relevant to our research. We extracted data from these papers to identify various challenges of using Scrum in GSD. Current strategies to deal with the identified challenges have also been extracted. This paper presents the review's findings that are expected to help researchers and practitioners to understand the challenges involved in using Scrum for GSD projects and the strategies available to deal with them.

Keywords- Global software development, agile approaches, Scrum, systematic literature reviews

I. INTRODUCTION

The trend in the recent software development industry is to move towards Global Software Development (GSD). This is driven by a number of factors such as improved network infrastructure, move towards component-based architecture and increased time-to-market pressure[1]. Despite its popularity, the question of "which agile practices are effective for GSD under which circumstances?" has not been closely researched yet [2].

Agile Software Development (ASD) paradigm has gained significant attention due to its flexible approach to managing the requirement volatility and emphasis on extensive collaboration between customers and developers [3]. Recently, we have observed that an increased number of GSD project managers are seriously considering introducing agile practices [4]. Given the increased interest in applying agile practices in GSD projects, it appears worthwhile for the practitioners and researchers to investigate the relevant experiences reported in the literature to learn how agile practices can be effectively used in GSD projects. Due to the fact that agile practices are based on the philosophy of close, frequent and collocated collaborations, the geographical distance in GSD alone can present a challenge. Through a number of reports by GSD practitioners in the literature, we have found that, despite the obvious difficulties, there are some instances of success of using agile practices with distributed teams [S1-S5]. But other researchers [5] still argue that the fundamental question on whether agile practices can be used in a distributed setting is still open to debate.

As the interest in using agile approaches in GSD projects is growing; so is the research literature on various mechanisms, challenges and strategies of deploying agile practices for GSD projects. However, there has not been any significant effort to systematically identify, synthesize, and report the literature on using agile in GSD projects. To address this research gap, this systematic literature review seeks to identify, synthesize, and present the findings reported about using Scrum practices in GSD to date. In this review, we only investigate agile practices that pertain to software project management. We chose "Scrum" as it has a focus on day to day project management and is the most widely adopted agile project management method. Recently, an increasing number of GSD project managers are also seriously considering the use of Scrum practices in their development environment [6].

The next section gives an overview of Scrum method and discusses the motivation of this research. Section 3 describes the research methods used. The results of this study are presented in Section IV. Section V discusses the findings to draw some conclusions. The limitations of the study are mentioned in Section VI. Section VII closes the paper with a brief discussion of the researchable issues on this topic.

II. BACKGROUND AND MOTIVATION

In this section, we first introduce the Scrum method, place the Scrum in the context of GSD and more concretely justify the need for this review.

A. Scrum

Scrum is an iterative and incremental project management approach that provides a simple "inspect and adapt" framework. In Scrum, software is delivered in increments called "Sprints" (usually 2-4 weeks iterations) [6]. Each sprint starts with planning and ends with a review. A sprint planning by a Scrum team is a time-boxed meeting, which could last up to 4 hours. It is dedicated to developing

175

detailed plans for the sprint. The Stakeholders of a project attend sprint review meetings to review the state of the business, the market and technology. These meetings could also last up to 4 hours. A retrospective meeting may be scheduled to assess the teamwork in the completed sprints. A daily Scrum meeting by a Scrum team is a 15-minute long and each team member addresses three questions: what did I do yesterday, what will I do today and what impediments are in my way? Scrum produces three artefacts, namely: product backlogs, sprint backlogs and burn-down charts. Backlogs contain customer requirements and daily burn down charts show the cumulative work remaining.

B. Scrum in Global Software Development

Agile approaches are usually considered effective for the projects with high uncertainty [3]. Paasivaara et al [S1] reported that distributed software development projects with volatile requirements and uncertain implementation technologies can use various agile practices for effectively organizing and managing projects. Scrum has been already found an effective approach to managing projects with many small, collocated development teams [3]. Sutherland and Schwaber [6] argue that Scrum can also be used for large and distributed teams. Indeed, from the papers reviewed in this review, we have found some distributed projects in which Scrum has been successfully used.

C. Objective of this Review

Scrum teams are self organized, are facilitated by rich communication and a collaborative environment and are usually considered effective for co-located projects with a small team size [3]. Thus, it is apparently difficult to apply Scrum practices in GSD projects because of the physical separation of the development team members [4]. There can be other GSD project contextual factors (e.g., number of distributed sites, collaboration modes, i.e., inter organizational or intra organizational, number of teams, project personnel or team size, socio-cultural distance and so on) that may also impact on Scrum team collaboration processes. A recent survey about agile practice adoption rate [7], reported that agile practices can be successfully used by significantly distributed team members. Another survey concludes that among the various agile practices, project management practices such as Scrum practices have a higher adoption rate [8]. Thus, we can argue that Scrum, as an agile method, is becoming increasingly popular and may also be used for globally distributed teams. But the actual process of using Scrum's collaborative practices instead of project stakeholder's distribution is not clearly understood [4]. For this reason we have decided to explore, investigate and explain various challenging factors that restrict the use of Scrum practices due to the global project. Current strategies to reduce these challenging factors are also be explored.

III. RESEARCH METHOD

This research has been carried out by following Kitchenham and Charters [9] guidelines for conducting Systematic Literature Review (SLR) or Systematic Review (SR), which involves several activities such as the development of review protocol, the identification and selection of primary studies, the data extraction and synthesis, and reporting the results. We followed all these steps for the reported study as described in the following sections of this paper.

The broad objective of this study is to answer the following research question.

RQ. What is currently known about the use of the Scrum practices in GSD projects?

More specifically, this study focuses on the following two questions:

RQ1. What challenging or risk factors restrict the use of Scrum practices in globally distributed projects?

RQ2. What strategies or practices are being commonly used to deal with these challenging factors to support the use of Scrum practices in globally distributed projects?

A. Data Sources and Search Strategies

We only searched for papers that are written in English and available online. The search strategy included electronic databases and manual searches of conference proceedings. The following electronic databases were used.

* IEEEXplore (www.ieeexplore.ieee.org/Xplore/)
* ACM Digital library (www.portal.acm.org/dl.cfm)
* Google Scholar (http://scholar.google.com.au/)
* Compendex EI (www.engineeringvillage2.org/)
* Wiley InterSciene (www.interscience.wiley.com/)
* Elsevier Science Direct (www.sceincedirect.com/)
* AIS eLibrary (www.aisel.aisnet.org/)
* SpringerLink (www.springerlink.com/)

We also searched the following conference proceedings for papers on the use of the Scrum practice(s) in GSD context.

* Agile Processes in Software Engineering and Extreme Programming(XP/Agile Universe)
* Agile Conference

The types of papers ranged from industry experience reports, theoretical, empirical and experimental academic papers. Figure 1 shows the review process and the number of papers identified at each stage. In stage 1, we searched the databases using the search terms listed in Table I. Category 1 has more keywords and shows many variations of the same term "Global Software Development". All these search items were combined by using the Boolean "AND" operator, which entails that an article that focuses on both Agile and Global Software Development, will be retrieved. That is, we searched every possible combination of one item from Category Type 1 AND Category Type 2. The search excluded articles that address editorials, prefaces, article, reviews, discussion comments, news, summaries of

176

tutorials, workshops, panels and poster sessions. This search strategy resulted in a total of 583 "hits' that included 366 unduplicated papers.

TABLE I.   Search Terms Used in this Review

Type	Category	Keywords
1	Global Software Development	Collaborative software development Cross continent development Distributed Software Development Dispersed teams Distributed development Geographically distributed software development Global software development Global software engineering Offshore Off shoring
2	Use of agile practices	Agile Agile practice Agile methods Scrum Scrum practice Scrum method

B. Managing Studies and Inclusion Decisions

Our study followed the citation management procedure reported by Dyba and Dingsoyr [10]. We used EndNote for storing relevant citations from stage 1 (n=366). The citations were then imported into a spreadsheet where we recorded the sources of each citation and subsequent inclusion / exclusion decision. We maintained separate Endnote library and spreadsheet for each stage. In the second stage, two of the authors sat together and went through the titles of all the 366 studies that resulted from stage 1, to determine their relevance to the systematic review. At this stage, articles with titles that indicated clearly that the articles were outside the scope of the SLR boundary were excluded and identified 123 relevant studies. However, a paper's title may not always represent the content of the paper. During the next stage, we divided 123 abstracts among three researchers in such a way so that each abstract was reviewed by two researchers independently. We found 109 abstract agreements among 123 assessments. All the disagreements were resolved by three researcher's discussions. At the end of stage 3, we were left with 77 papers for stage 4 of the selection process.

C. Final Selection

We used the following screening criteria to ensure the papers address our research topic.

1. Does a paper address the use of any Scrum practices in distributed projects?
2. Does a paper discuss any real life experience of using Scrum practices in distributed projects?
   As there is a lack of existing empirical research, we also consider "lesson learned" report based on expert opinion that address the use of Scrum practice in GSD projects. For

additional quality assessment, we included following two criteria related to the quality of each paper's description.

3. Does the objective of the paper is clearly mentioned?
4. Does the paper discuss GSD project contextual factors adequately?
   The adequacy of project contextual factors discussion was measured based on the GSE background information as shown in Appendix B. These 4 points provided a measure of the extent to which we are confident that a selected paper could make a valuable contribution to understand the current use of Scrum practices in distributed setting. Each of the 4 criteria was graded on a dichotomous ("yes" or "no") scale.
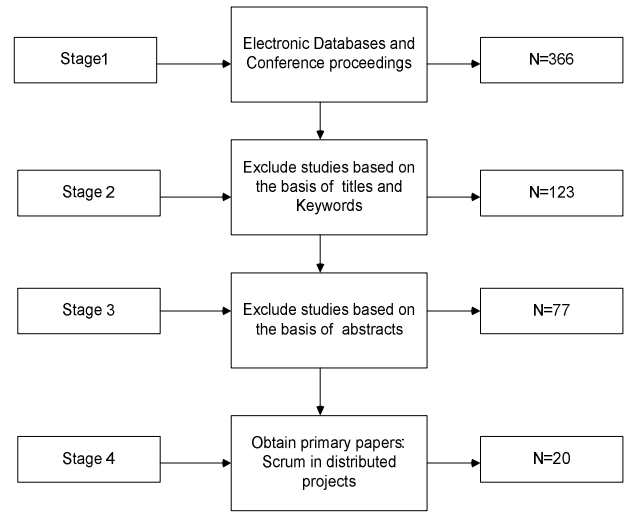

Figure 1. The selection process of primary papers.

We selected 21 papers out of the 77 articles by carrying out the quality assessment based on these four screening criteria. We accepted a paper that has satisfied 4 criteria and graded as all "yes". For example, we excluded a number of papers that discussed some other agile methods and practices (e.g. XP, pair programming). Among the 21 papers, we found that one journal paper [S1] was an extended version of previously published conference paper [S1a]. We also found that two papers [S3] and [S3a] published in two different conferences were based on the same empirical study. In both cases, we included the comprehensive recently published papers as mentioned in appendix A. In addition, one researcher went through the reference list of every selected paper of this final stage. This helped us to identify any relevant paper that was not extracted by our search strategy. In this process, we identified one journal paper [S8] that was not retrieved through our search of electronic databases but was cited by some of the selected papers [S1, S4]. The abstract was reviewed by two researchers independently and agreed that the paper [S8] appeared to be within the scope of the research. Finally we selected 20 papers (excluding two

repeated papers S1a and S3a and including one journal paper S8 from initially selected 21 papers) for data extraction and synthesis phases. We have enlisted the selected primary studies in Appendix A.

D. Data Extraction and Synthesis

From the final selected studies, we extracted data using a pre-defined data extraction form as shown in Appendix B. The detail description of the data extraction form can be obtained in the technical report [11]. During data extraction, we found it quite difficult to extract relevant and meaningful information that can answer the research questions. This is because the primary studies included in this SLR are mainly based on industry based experience reports and most of them are not described in a commonly used research paper structure. As usually a standard research report discusses research problem, related research work, research method, data analysis technique and conclusion adequately [12]. For this reason, two researchers performed data extraction independently. Extracted data from each researcher were compared and disagreements were discussed and resolved by consensus in meetings. For further disagreement, we consulted with a third independent researcher who has extensive experience in SLR. We used a qualitative data analysis tool (NVivo) to store textual data that are able to address our research questions.

We synthesized the data by identifying themes emanating from the findings reported in each of the paper reviewed in this study. In the following section, we present frequencies of the number of times each theme is identified in different studies. The respective frequencies reflect the number of times a particular challenge has been mentioned in different papers.

IV.   RESULTS

A.   Overview of Studies

Table II shows that the number of papers on the issue of using Scrum practices in GSD context are increasing over the last few years. It can be argued that the publication trend may be an indicator of practitioners and researchers' growing interest in using and reporting Scrum practices for GSD projects.

TABLE II.   SELECTED PAPERS BY YEAR INTERVAL

Year	2003	2004	2005	2006	2007	2008	2009
papers	1	1	1	3	4	9	1
%	5%	5%	5%	15%	20%	45%	5%

Table III shows that only 4 studies (20%) included in this SLR are empirical studies and all of them are industrial case studies. Rest of the 16 studies (80%) are classified as "lesson learned" or industrial experience reports. Hence, we

conclude that there is a little empirical evidence based reported on the use of Scrum practices in GSD context.

TABLE III.   TYPES OF STUDIES REVIEWED

Study Focus	Number of Papers	percentage	Reference
Empirical Study	4	20%	[S1-4]
Industrial Experience Reports	16	80%	[S5-20]

Table IV presents project frequencies that are categorized according to few distributed project contextual factors. We have found that most of the studies report the use of Scrum practices in GSD projects from intra-organizational, multi-national companies. Our findings also reveal that a limited number of distributed sites are involved while Scrum practices are used in distributed sites. However, some researchers claim that a distributed project with multiple teams can also use Scrum in their development [6]. Scrum can also be used in a distributed project with large number of project personnel or team size. In this case a number of Scrum teams are involved within the project. Some of the distributed projects can also use Scrum by minimizing the challenge of no overlap time between distributed sites. We have also found that a wide range of project domains ranging from simple web application to mission critical projects have been undertaken using Scrum in distributed development environment.

TABLE IV.   PROJECT CATOGORIZATION ACCORDING TO FEW PROJECT CONTEXT FACTORS

Collaboration Mode	Intra Organizational	16
	Inter Organizational	4
Number of Sites	Two	15
	Three	5
	Three+	0
Number of Teams	Two	6
	Two+	12
	Unclear	2
Team Size	Up to Twenty Five	5
	Twenty Five+	10
	Unclear	5
Time differences	No overlap time	10
	Overlap time	8
	Unclear	2
Application domain	Web	7
	Oil and Energy	1
	Library	1
	Logistic	2
	Public safety	1
	Airline	1
	Commercial	2
	Business service	1
	Finance	1
	unclear	3

B. Findings about Research Questions

This section discusses how the data extracted from the reviewed studied address our research questions. By investigating the two research questions, we aim to provide a synthesized overview of the literature on using Scrum practices in different distributed projects.

1) RQ1-Challenges of Using Scrum Due to Project Distribution

We have identified sixteen papers that can help us to answer the research question 1 (RQ1), "What are the challenges of using Scrum practices in distributed development?"

Our analysis of the extracted data has revealed that the temporal, geographical and socio-cultural distance of GSD projects impact on using various Scrum practices in distributed settings. We have found that communication related issues are the major challenges when using Scrum in distributed settings. Cultural differences among distributed team members may also impact on team collaboration and communication processes. Managing a large team can also be considered as one of the key challenges. A lack of dedicated meeting room for each site and Scrum team distribution at multiple sites also appear to be challenging factors that restrict the team communication and collaboration processes. Table V summarizes our findings about the key challenges of using the Scrum practices in GSD projects. Usually sprint planning or retrospective sessions can last up to four hours or sometimes even more [6]. Thus, it is very difficult to conduct such a long meeting if the distributed teams experience significant time zone differences. For this reason, lack of synchronous communication is considered as one of the most vital challenges for using Scrum in GSD context.

TABLE V.   CHALLENGING FACTORS DUE TO PROJECT GLOBAL DISTRIBUTION

Challenging factors	Paper references	Frequency (# of studies)
Synchronous communication	[S1-2,S6-7,S9-10,S16-17,S19]	9
Collaboration difficulties	[S1-3,S15-16,S19]	6
Communication Bandwidth	[S5-7,S15-16,S19-20]	6
Tool support	[S4, S10-11,S15-18]	6
Large Team	[S2,S5,S7,S10,S16]	5
Office Space	[S15-17]	2
Multiple sites	[S9]	1

A distributed project usually involves people with cultural and linguistic diversity, which may discourage offshore team members from voicing their opinions or views fully and completely [S1]. This situation usually results in miscommunication, misunderstandings or confusion among team members. This SLR has found that some Scrum teams could not conduct effective retrospective meetings due to the socio-cultural distance involved in the distributed project [S1, S7]. Communication networks can also be slow and unreliable with poor transmission quality hampering communication standards when using various communication tools (e.g. video conferencing) [S15-16, S19]. Providing better communication bandwidth and right tool in a distributed project that use distributed Scrum meeting practices is vital [S17].

Lack of effective collaborative tools, global task boards, suitable bug and issue trackers, globally accessible backlog tool are also reported to be challenging factors [S10-11, S15]. Managing a project with a team of large number of members distributed at multiple sites is considered a challenging undertaking [S2, S5, S7]. The need of a dedicated meeting room with necessary infrastructure and tool support is also considered necessary in a number of reviewed studies [S15-17]. Using Scrum in a team that is distributed in more than two sites with different time zone differences is also observed quite difficult [S9].

2) RQ2- Used Strategiesto deal with these challenging factors

Our SLR has found that Scrum teams use various practices or strategies to reduce these challenging factors to support the use of Scrum practices in globally distributed projects. This review has identified and categorized these practices as follows.

Synchronous communication: Our SLR found that Scrum teams used some strategies to provide synchronous communication when distributed team has no overlap time. From the reviewed papers, we found ten projects had distributed sites without any overlapping working hours. Thus we can argue that Scrum can be used within a distributed project that has even no overlap time between distributed sites. To address the lack of synchronous communication following practices were widely used.

Synchronized work hours: This practice is widely used by Scrum teams to ensure synchronous communication among distributed sites can be arranged. This is done by adjusting working hours, working from home, working long hours and so on [S1-2, S6, S9, S13-14, S16-17, S19-20]. Some Scrum teams used strategies to avoid the need of increased overlap time. For example, a Scrum team used strict time-boxed meeting (e.g. two hours planning meeting) to avoid late night meeting at some sites [S6]. To make the meetings short and effective, team members post their three daily Scrum questions or develop backlog (feature list) before attending the distributed meetings [S8, S10, S12, S15].

Local Scrum team: Due to the lack of overlap time, Scrum teams are formed locally and each site conducts their own scrum [S6-9, S10-11, S18]. The meeting practice Scrum of Scrums is attended by a key touch point member for each team to ensure inter-team communication. To form such a

179

Scrum team, the local team should be autonomous and should also allocate independent architectural subsystems with well defined interfaces to each team to reduce inter site communication [S6- 9, S13]. To establish multiple communication lines, Scrum team allows additional distributed meetings along with Scrum master meeting attended by technical lead or design architect of each local Scrum team [S9].

Modified practices: In some cases, Scrum team modifies or extends Scrum practices to address the communication challenges. For example, Berczuk reports that having a local "mini-scrum" in the morning after a distributed scrum meeting can be very effective to reinforce the value of the Scrum within a local team [S17]. Scrum teams also use strict communication policy (e.g. E-mail reply within 12 hours) to avoid delay due to the temporal distance of a distributed team [S9]. Instead of whole team presence in the late night (or early morning) Scrum meetings, only key members of the team attend the meetings with distributed teams [S5, S7, S13]. Moreover, the distributed daily Scrum meetings are usually cut down to twice-a-week meetings [S16]. We also found other modified practices such as asynchronous retrospective meetings (e.g., posting comments and results on Wikis, emailing the minutes of local Scrum meeting to the onshore team), conducting sprint demo by onshore team only (later onshore team briefs offshore team) [S1-3, S9, S13, S16].

Team Collaboration: Our SLR revealed that socio-cultural distance in GSD projects substantially impacts team collaboration processes and may cause ineffective Scrum meeting practices (e.g. daily Scrum meeting). GSD project managers use a number of practices that facilitate better team collaboration while using Scrum practices.

Team Gathering: To increase a project's domain knowledge and reduce the cultural distance, a Scrum team gathers and performs few initial sprints at one site before distributed development starts [S13, S15-19]. The members of a distributed Scrum team are also gathered quarterly or annually for few days [S1, S6, S10, S18]. During this gathering, a Scrum team can perform scrum planning, review meeting, retrospectives, sprint and various socializing activities, which can help to reduce cultural distance [S18].

Visit: To reduce the cultural distance and increase project vision, a Scrum team adopts the practice of exchange visits for example Product owners regularly visit offshore team throughout the development. [S15-16, S19]. Cultural exchange is also performed by maintaining planned rotation among offshore and onshore teams and cross-location visits [S14-15]. Practices like product owners organizing quarterly product roadmap meetings were also proven effective for helping team's members to fully understand a project's vision [S16].

Unofficial distributed meetings: For increased team collaboration, along with formal meetings, distributed Scrum team members may also use frequent informal meetings for clarifying various issues [S1]. These unofficial meetings may involve leadership meetings, testing, and architectural meetings, distributed team lead meetings, peer meetings, and socializing meetings (for example, virtual party or games) or even "coffee talks" for the collocated team members [S14].

Training: Our SLR also found that Scrum teams use some practices that can be categorized as "training". Practices for example "initial Scrum training," "technical Scrum" to clarify new technology issues, reinforce the value of Scrum and improve team collaboration while using Scrum practices in GSD projects [S9, S16].

Key documentation: Maintaining valuable documentation may also improve GSD team collaboration processes while using Scrum practices [S7, S9, S16, S19]. For example, supplementing user stories with Use Case diagrams in globally accessible backlogs helps reduce misunderstandings and improves team collaboration processes [S16]. Scrum teams use a number of tools, for example, issue tracker (e.g. Jira), enterprise wikis (e.g. Confluence), and project management tool (e.g. Scrum works) to maintain better documentation and project transparency [S9, S16].

Mandatory participation: To reduce "offshore silence" challenge, Scrum team can assign each site a thirty-minute mandatory demo presentation during retrospective sessions [S18]. The participation in these sessions helps make an empowered distributed team [S16]. To reduce cultural impediments, offshore teams are also encouraged to provide useful information during daily Scrum meetings [S1].

Gradual team distribution: Scrum teams may move from a collocated project to a distributed project gradually through several stages (i.e., evaluation, inception, transition and steady state) [S13]. The gradual transition helps deal with the challenges caused by cultural distances and also helps to increase project domain knowledge. Our SLR reveals that in one specific Scrum project, during initial three stages of gradual team distribution (i.e. evaluation, inception and transition phase) only a representative of an offshore team participated with onshore team in Scrum meeting practices. However, in steady state stage, all the Scrum team members located in onshore and offshore teams participated in the distributed Scrum meetings [S13]. In another project, one onshore Scrum master facilitated offshore Scrum meetings for few initial sprints and came back to onshore when the offshore team became familiar with Scrum practices [S15].

Communication bandwidth: To provide a rich communication environment and also to avoid slow, unreliable, and poor transmission, Scrum teams use the practice *"multiple communication modes"*. The practice ensures that a Scrum team with distributed project stakeholders is supported with various options of communication tools such as phone, web camera, teleconference, video conference, web conference, net meeting, email, shared mailing list, Instant Message (IM), Short Message Service (SMS), and Internet Relay chat

(IRC) [S1]. Hence, Scrum team can choose appropriate tool from a wide range of communication tools suitable to the communication bandwidth. For example, if a Scrum team found videoconferencing is not supported by the existing communication bandwidth, they may choose a teleconference in their distributed meeting sessions.

Tool Support: GSD projects that consider using Scrum need a wide range of tool support. Tools may include communication, collaborative, project management, issue tracking, bug tracking, globally accessible backlog, and burn down chart etc. We found the practice *"proactive resource management"* helps ensure that a Scrum team has the necessary tools and skills to support their Scrum practices in distributed settings. Our SLR revealed that along with communication tools, Scrum teams also use a number of collaborative tools including Wikis, Blogs, social book marking, expertise finders, whiteboards, electronic work space, desktop and application sharing, photo charts, knowledge bases, experience databases, lesson learned repositories, while using Scrum practices [S1-20]. An enterprise wiki (e.g. Confluence) has been found to be very effective while using Scrum practices [S20]. Distributed team members can communicate and publish the results of various Scrum meetings minutes in wiki [S20]. To increase project transparency and visibility and to support the Scrum practice "Backlog", our SLR has also revealed that distributed Scrum teams use a number of tools including globally accessible project management tools (e.g. "Rally"), issue tracker, bug tracker (e.g. "Jira"), backlog management tools (e.g. "Scrum works"), and tools for supporting the Scrum artifacts "Burn down charts" [S1- 4, S7, S10, S17, S19-20].

Team management: we have also found that a commonly used strategy for managing a large distributed team that considered using Scrum is to split into small manageable sub-teams [S1-2, S5]. Thus, a large GSD project may contain a number of Scrum teams (or sub teams) and some of the Scrum teams may also be geographically distributed [S1]. Scrum teams use a number of strategies to form sub teams. An autonomous sub team can be built and allocated based on features, functions and so on that ensure each sub team is allocated independent architectural subsystems with well defined interfaces [S6-8, S9, S13]. For example, highly volatile features need frequent interaction with business users and such features can be developed with a sub-team close to the customer [S3, S13]. In some cases, a sub-team has its own product owner and Scrum master and conducts their own Scrum [S1, S3, S5].

We also observed that GSD projects used following Scrum team models suitable to their development environments while considering Scrum [6].

Isolated Scrum team: GSD project teams are geographically isolated; in most cases offshore teams are not cross-functional and may not use Scrum processes. There is less empirical evidence of using this type of team model while using Scrum.

Distributed Scrum of Scrums team: In this team model, Scrum teams (or sub-teams) are formed based on local site and each team perform their site based own independent Scrum. The meeting practice, Scrum of Scrums that is attended by the key touch points (e.g. Scrum master) from each site based sub-team ensures effective inter-team communication [S1]. If the number of sub-teams increases, in some cases, a nested Scrum of Scrums meeting practice (e.g. Scrum of Scrum of Scrums) ensures effective sub-team coordination [6].

Fully Integrated Scrum team: In this team model, Scrum teams are cross-functional with team members distributed across geographical locations. This type of Scrum team should consider the risks due to geographical, temporal and socio-cultural distances. In this model, all team members should attend and participate in every Scrum meeting practice. We found in some cases, a GSD project that has several fully integrated Scrum teams follows the practice *"centrally located management team"* in which management persons of each Scrum team are located in a central site (e.g. onshore) [S1-2]. In this case frequent meetings among a centrally located product owner team, a team of Scrum masters, and architects from the sub-teams ensures effective multiple sub-team communication and collaboration [S2].

Office space: Our SLR has revealed that to support a better communication and collaborative work and meeting environment, Scrum teams use following practices:

Single room: This practice ensures each Scrum team is allocated to a single room so that they can communicate with each other [S1, S9, S11]. In this case if a person switches teams, he or she is also relocated to the new team's room [S1]. If the Scrum team is divided into multiple sub-teams, then all co-located sub-teams are able to work in a single room should be ensured [S1].

Dedicated meeting room: This practice also ensures each site has a separate meeting room with all necessary network connectivity and tools while attending a distributed meeting [S1, S3]. To make Scrum meetings visible to everyone, each site can use a video projector [S15]. In some cases, a virtual conference room can also be used as a dedicated meeting room for Scrum meetings sessions [S5].

Multi sites: It has been reported that Scrum teams usually use the following strategies while using Scrum practices in GSD projects with multi sites development.

Local Scrum team: GSD project managers build autonomous site-based local Scrum teams and allocate tasks with independent architectural subsystems and well defined interfaces to each local team [S6-8, S9, S13]. The practice Scrum of Scrums attended by a key touch point (e.g. Scrum master) of each site provides inter-team coordination [S14].

Restricted team distribution: In this practice, a fully integrated Scrum team is restricted within a limited number of sites distributions. For example, one of the studies reported on a project that was distributed over multiple sites

but each Scrum team was distributed between two sites only [S9].

V. DISCUSSION

In this section, we review various findings of our Systematic Literature Review (SLR) and draw following conclusions

Conclusion 1. There is a growing interest and literature demands more empirical study to understand the use of Scrum practices in globally distributed projects.

It is still an open debate whether or not the Scrum practices can successfully be used in distributed settings [[5]. However, the increasing number of publications on this topic, as shown in table 1, appears to be an indication that there is an increasing interest in using Scrum practices in GSD projects. We have found that most of the papers and all the empirical studies have been published after 2007. Among the reviewed twenty studies, all of the four empirical studies and few experience reports have reported some degree of success in using Scrum practices in GSD. Despite these successes, the mechanics of combining Scrum practices and GSD are not well understood [4]. These findings highlight a vital research gap that needs immediate attention of GSD and agile communities. Hence, there is a clear need of building empirically founded knowledge about using agile practices in general and Scrum practices in particular in the context of GSD.

Conclusion 2. The use of Scrum practices may be limited by various GSD project's contextual factors.

Our review has revealed that there can be several contextual factors of a project that may impact the use of Scrum practices in GSD. Some of the factors identified in the reviewed studies are shown in Table 2. Our findings also reveal that most of the distributed projects were within the same company and the team distribution was limited by the number of distributed sites. We also found that there is a limited evidence of using Scrum for safety critical applications. Though our findings reveal that the Scrum practices can be used in a distributed project that has multiple numbers of teams, very large project personnel or even no overlap time between distributed sites, but the actual process of using Scrum is not clearly understood yet. We did not consider the impact of other project contextual factors (for example: budget, complexity, criticality, team experience, time constraints, contract nature and so on) on using Scrum in GSD projects. Thus, we conclude that the use of Scrum practices may be limited by various contextual factors of a GSD project.

Conclusion 3. Globally distributed Scrum teams usually face a number of challenges as project distribution impact on communication, coordination and collaboration processes.

Our review findings reveal that the temporal, geographical and socio-cultural distances due to the project stakeholder's distribution cause a number of challenging factors that impact GSD communication, coordination and collaboration processes. The communication related challenges are identified as vital. Any cultural differences involved in a distributed team can substantially impact on the team's collaboration process. Managing a large team distributed at multiple sites is quite challenging as well. Lack of tools and insufficient infrastructure support may also make use of Scrum practices in GSD difficult.

Conclusion 4. Scrum practices need to be extended or modified in order to support globally distributed software development teams.

Our findings reveal that to support the use of Scrum practices in various distributed projects, Scrum teams need to add a number of strategies suitable to their development environments. A distributed Scrum team can choose different Scrum team models to reduce its project distribution challenges. A distributed team usually needs some overlap time between them to carry out various Scrum meeting practices. To support a distributed team that has no overlap time, Scrum teams may use some supporting distributed practices including synchronized work hours, local Scrum, additional local team meetings, strict communication policy, key persons attending all distributed meetings, reducing number of Scrum meetings, asynchronous retrospective and so on. To increase the team collaboration processes, Scrum team can also use some practices including team gathering, exchange visits, informal meetings of distributed team members, mandatory presentations, maintaining key documentation, and gradual team distribution which also help to reduce team cultural differences. A Scrum team can also use different practices such as multiple modes of communication to address the challenges caused by the lack of communication bandwidth and tools. A distributed Scrum team also needs to be supported by various tools for project management, backlog management, tracking issues, and so on.

VI. LIMITATION

Like any empirical study, this study also has certain limitations that should be kept in mind while considering the reported findings. With the increasing number of studies in this area, this review may have missed some papers that address the use of Scrum practices in GSD. However, we are confident that it would not have been a systematic omission.

The papers included in this review have undergone a thorough selection process and involved two researchers cross checking the completeness of searchers and validating the suitability of each paper for inclusion. However, the

findings of this review may have been affected by the systematic bias in describing the use of Scrum practices in various primary studies as some of the selected studies describe the use of various Scrum practices along with other agile practices (e.g. XP practices).

During the data extraction process, we found that several papers lacked sufficient details about the reported projects' contextual factors and the challenges faced and strategies used while using Scrum practices in GDS projects. We synthesized our data by identifying and categorizing the themes from the papers included in this review. Since some of the selected papers do not provide detailed information, there is a possibility that the extraction process may have resulted in some inaccuracies.

VII. CONCLUSIONS AND FUTURE RESEARCH

We have conducted a systematic review of the literature on the use of Scrum practices in GSD projects. The aim of this review was to identify various challenging factors that restrict the use of Scrum practices in projects that are globally distributed. Exploring potential strategies to deal with those challenging factors were also another research focus. We have presented our findings in two stages: initial quantitative data presentation about the number of published papers in each year starting from 2003, the types of studies reported in the reviewed papers and the contextual factors of the reported projects. In the second stage, we have analyzed and interpreted the data extracted from the primary studies included in this review in order to find the answers to our research questions. Our analysis and interpretation of the data have enabled us to draw some general conclusions in Section 5 about the current state of practice of using Scrum practices in GSD projects.

The results of this review provide information that can be useful for GSD practitioners' understanding the various challenging factors that may impact on GSD communication, collaboration and coordination processes and restrict the use of Scrum practices. Moreover, the GSD project managers can also benefit from the synthesized knowledge about the strategies that are being used to deal with the identified challenges. However, the strength of evidence found in the literature about the identified strategies is very low. That is why it is difficult to offer any specific advice to practitioners solely based on this review. This review has also identified several interesting research challenges that need to be addressed in the future research efforts by GSD and agile researchers. A clear finding of this review is that there is an immediate need of increasing the quantity and quality of empirical studies to describe, evaluate, explore and explain the use of various Scrum practices in GSD projects.

To enhance the findings of this review, we intend to conduct a comprehensive survey of practitioners to identify the key challenges involved in and the strategies to reduce these challenges to support the use of Scrum practices in GSD projects. In addition to this survey, we will also conduct multiple in depth industry based case studies to provide an empirically supported body of knowledge about the use of Scrum in GSD projects considering various contextual factors.

Appendix A. Papers included in the review

[S1] M. Paasivaara, S. Durasiewicz, C. Lassenius, "Distributed Agile Development: Using Scrum in a Large Project," *Software Process Improvement and Practice*, Vol. 13, Issue 6, pp. 527-544, 2008.

[S1a] (Excluded) M. Paasivaara, S. Durasiewicz, C. Lassenius, "Distributed Agile Development: Using Scrum in a Large Project," in Proceedings of ICGSE 2008, pp. 87-95, 2008.

[S2] J. Sutherland, A. Viktorov, J. Blount, N. Puntikov, "Distributed Scrum: Agile Project management with Outsourced Development Teams" in Proceedings of the Conference on HICSS'40, pp. 274, 2007.

[S3] J. Sutherland, G. Schoonheim, M. Rijk, "Fully distributed Scrum: Replacing Local Productivity and Quality with Offshore Teams," in proceedings of the Conference on HICSS'42, pp. 1-8, 2009.

[S3a] (Excluded) J. Sutherland, G. Schoonheim, E. Rustenburg, M. Rijk, "Fully distributed Scrum: The secret sauce for Hyperproductive Outsourced Development Teams" in Proceedings of the Conference on Agile 2008, pp. 339-344, 2008.

[S4] J. Cho, "Distributed Scrum for Large-Scale and Mission-Critical Projects," in Proceedings of the Conference on AMCIS 2007, paper 235, 2007.

[S5] W. Williams, M. Stout, "Colossal, Scattered, and Chaotic (Planning with a Large Distributed Team)," in Proceedings of the Conference on Agile 2008, pp. 356-361, 2008.

[S6] B. Drummond, J. F. Unson, "Yahoo! Distributed Agile: Notes from the World Over," in Proceedings of the Conference on Agile 2008, pp. 315-321, 2008.

[S7] M. Cristal, D. Wildt, R. Prikladnicki, "Usage of SCRUM Practices within a Global Company," in Proceedings of ICGSE 2008, pp. 22-226, 2008.

[S8] H. Holmstrom, B. Fitzgerald, P. J. Agerfalk, E. O. Conchuir, "Agile Practices Reduce Distance in Global Software Development" *Information Systems Management*, Summer, pp. 7-26, 2006.

[S9] M. Vax, S. Michaud, "Distributed Agile: Growing a Practice Together" in Proceedings of the Conference on Agile 2008.pp.310, 2008.

[S10] H. Smits, "Implementing Scrum in a Distributed Software Development Organization," in proceedings of the Conference on AGILE 2007, pp.371-375, 2007.

[S11] B. Jensen, A. Zilmer, "Cross- continent Development using Scrum and XP" in Proceedings of the Conference on XP 2003, pp.146-153, 2003.

[S12] C. Kussmaul, R. Jack, B. Sponsler, "Outsourcing and Off shoring with Agility: A Case Study" in Proceedings of the Conference on XP/Agile Universe, pp. 147-154, 2004.

[S13] K. Sureshchandra, J. Shrinivasavadhani, "Adopting Agile in Distributed Development" in Proceedings of ICGSE'08,pp. 217-221, 2008.

[S14] A. Danait, "Agile offshore techniques- A case Study" in proceedings of the Conference on Agile Development Conference, pp.214-217, 2005.

[S15] M. Summers, "Insights into an Agile Adventure with Offshore Partners," in Proceedings of the Conference on Agile 2008, pp. 333-338, 2008.

[S16] E. Therrien, "Overcoming the Challenges of Building a Distributed Agile Organization," in Proceedings of the Conference on Agile 2008, pp. 368-372, 2008.

[S17] S. Berczuk, "Back to Basics: The Role of agile Principles in Success with a Distributed Scrum Team," in Proceedings of AGILE 2007, pp. 382-388, 2007.

[S18] P. Karsten, F. Cannizzo, "The Creation of a distributed Agile Team," in proceedings of XP 2007, pp.235-239, 2007.

[S19] M. Cottmeyer, "The Good and Bad of Agile Offshore Development," in proceedings of the Conference on AGILE 2008, pp.362-367, 2008.

[S20] M. Paasivaara, C. Lassenius, "Could Global Software Development Benefit from Agile Method?" in proceedings of ICGSE 2006, pp. 109-113, 2006.

Appendix B. Data Extraction form

Paper description:

1. Paper identifier: Unique id for the paper
2. Date of data extraction:
3. Bibliographic reference: Author, year, title, source
4. Type of article: Journal article/conference paper/ workshop paper/unclear
5. Paper aims: what were the aims of this paper?
6. Paper Evidence: empirical study/experience report/unclear

GSD Background:

1. Collaboration mode: inter organizational/intra organizational/unclear
2. Number of Sites: ……./unclear
3. Number of Teams:……/unclear
4. Project personnel:……/unclear
5. Time zone differences:……/unclear
6. Application Domain: ……./unclear

Study Findings:

1. Scrum team scenario (model): Isolated Scrum team/Scrum of Scrum meeting used for site based team coordination/Fully integrated (e.g. Scrum team contain onshore and offshore personnel)/unclear
2. Challenges: challenging factors that impact GSD communication, coordination and collaboration processes and restrict the use of Scrum practices.
3. Strategies: Used various strategies to reduce project stakeholder's distribution challenges to support the use of Scrum practices.
4. Subjective evaluation: a small summary of the findings from the paper.

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[3] P. Abrahamsson, O. Salo, J. Ronkainen, and J. Warsta, *Agile software development methods - Review and analysis*, VTT Electronics ed.: VTT Publications, 2002.

[4] P. J. Ågerfalk and B. Fitzgerald, "Flexible and distributed software processes: Old petunias in new bowls?" *Communications of the ACM,* vol. 49, Oct 2006, pp. 26-34.

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[10] T. Dyba and T. Dingsoyr, "Empirical Studies of Agile Software Development: A Systematic Review," *Information and Software Technology,* Vol. 50, Issue 9-10, 2008, pp-833-859.

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