# Software Process Improvement Initiatives in Global Software Development: A Systematic Literature Review

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## Abstract

The key benefits of distributed project development are the existence of twenty four hour work cycle, cost reduction and availability of larger pool of resources. These benefits have steered software organizations around the globe to adopt the practices of global software development (GSD). The development process involved in distributed software development is different than collocated software development process (CSD). Traditional software process improvement initiatives are not very effective in distributed software development (DSD). The literature of Global Software Process Improvement (GSPI) has steadily been growing. However, it is very difficult to find a complete systematic and conclusive literature review on GSPI initiatives. We have conducted a systematic literature review on the studies, reporting global software process improvement initiatives to identify current factors and challenges involved in global software process improvement. This review is based on a selection process which comprises of three phases of study selection (i.e. primary, secondary and final). The finally selected publications are used for the data extraction based on the research questions. The primary focus of this review was to extract the data for the identification of existing GSPI initiatives (both proposed and implemented). The secondary focus was to identify the key challenges and factors involved in improvement of global software development process. This paper presents the literature overview to provide an insight to the researchers and practitioners into current GSD and GSPI initiatives. The extracted data is synthesized to report key factors and initiatives. Based on the evidence from the literature a small set of Factors is proposed. A time line is presented in the end to depict the research trend in the area of GSPI.

## Keywords

Global Software Process Improvement Initiatives, Global Software Development, Systematic Literature Review.

## 1  Introduction

The growth and progression in global communication systems has enabled organizations to utilize most suitable resources around the globe to develop high quality products. Software industry is widely using distributed development style [1, 2, 3, 4, 5, 6, 7]. The skill and cost limitations of collocated software development can be easily skipped by distributed software development. Global software development provides a larger domain of software experts from all around the world and at the same time reduces the cost of development process.

Product quality is mostly dependent upon the quality of process followed to develop it [8]. Process improvement is usually a recurrent method which is based on knowledge of current process and past experiences. The definition of process is critical for its improvement. Software development process has varied over the last decade with the concept of business process outsourcing (BPO). This paper is an effort to explore the existing research on global software process improvement.

Globalization of software development is inevitable [9] and every process needs to be improved with each project. Practitioners are widely adapting distributed development so as the research community is working to design strategies to improve this process [10, 11]. This paper is the first step as an effort to design a framework for GSPI. The data about the challenges in the process and the existing strategies has to be extracted and analyzed to identify the areas where further improvement can be achieved.

The prime objective of this research paper is the identification and classification of current initiatives used in the improvement of global software development process. The secondary objective is to highlight all factors involved in the progression or retrogression of process improvement.

The next section gives an overview of the literature covering related topics to the area of interest. Section 3 outlines the research methodology that we have used. In section 4 we have presented the analysis and results. Conclusion of the paper is paragraphed in section 5. References are provided in the last section.

## 2  Literature Overview

The prime objective of this literature review is to search for existing literature available on Global Software Process Improvement Initiatives or on global software development. The improvement of a process needs a consolidated definition of that process. In the literature there is no study which formally defines a global software development process. The only definition found is presented by Mariangela, Marcelo, and Rafael [12] which is guided by the analyses of a set of practices followed by an organization at various distributed locations. This definition is role-based and each team has a focal point defined individually for each site by the team leader. The authors have explored a case study for data collection and analysis.

Gucegliogl and Demirors [8] have developed and applied a process quality measurement model in a software process improvement initiative. Setamanit, Wakeland and Raffo have developed a model and simulated it to study the effects of Global Software Development and to highlight important factors [6]. These factors are critical to the improvement and management of the global development process. the simulation model presented in this study is hybrid in nature which combines system dynamics and discrete-event paradigms to represent GSD projects. Prikladnicki, Nicolas and Evaristo have presented a reference model (based on results of a case study to) for GSD [11]. Habra et.al has presented a methodology to initiate software process improvement in small enterprises [13]. Such initiatives can be tailored by practitioners to their needs for software process improvement on distributed sites.

Kitchenham et.al [14] has provided a very complete and reasonable definition of Systematic Literature Review, i.e. an SLR is a methodologically rigorous review of research results. An SLR should not only look for answers to the research questions, it should also provide a set of guidelines to the practitioners. Ali Babar and Mahmood Niazi [10] have conducted an empirical study of Vietnamese global software market to explore practitioner's experiences and implementation perceptions of SPI initiatives. Authors have conducted a questionnaire survey of companies and practitioners. Similar kind of work is done by Rauf, Anwar, Ramzan and Shahid to analyze the SPI efforts in Pakistan [15]. Kitchenham et.al has carried out a study to find SLR's on software engineering published from 2004 to 2008 [16]. This study has proved to be a very helpful catalogue. The results from this study highlight that only two SLRs on Software Process have been published in this time period. This focus needs to be increased in order to achieve better improvement in global software process. Siffat-ullah, Niazi and Ahmad have identified success factors for offshore software development outsourcing vendors in an empirical study [17]. This study can prove to be very helpful for practitioners (vendors) to standardize their organization for better business development.  The same authors have identified barriers in the selection of outsourcing vendors in an exploratory study [18].

The most relevant study we found is a systematic literature review carried out by Unterkalmsteiner et.al on evaluation and measurement of software process improvement [19]. Hossain, Babar and Paik have carried out a SLR covering literature on usage of Scrum in global software development [20]. They have uncovered some key factors which can be used in the improvement of GSPI. A similar study is published by Jalali and Wohlin which covers implementation of agile practices in global software engineering [21]. Harter, Kemerer and Slaughter have conducted a longitudinal field study to analyze the effects of software process improvement on severity of defects [22]. Smite, Wohlin, Feldt

and Gorschek has presented a classification scheme for describing the context of a GSE study [23]. Jung and Goldenson have provided empirical evidence in their study [24] to support a proposition that process maturity is associated with project performance and product quality. In adaptation of an initiative there are always a set of de-motivators which should be considered in design of an initiative. In persuading an organization to become accustomed to new initiatives these motivators must be brought into focus. Baddoo and Hall have presented a study which lists a set of de-motivators from practitioner's perspective [25]. Babar, Kitchenham, Zhu, Gorton and Jeffery have proposed the concept of software architecture evaluation based on Internet-based collaborative technologies [26]. The study provides preliminary findings on the viability of groupware-supported evaluation process. Wohlin, Martin and Henningsson have presented four methods of empirical research in software engineering [27] any one of them can be used in the context of global process improvement.

Krishnan and Kompali have developed and implemented a process maturity framework which they have based on 24 key process areas [3]. Software architecture plays an important role in the development process. Babar has presented a framework to support software architecture evaluation in global software development [28]. Ribeiro, Czekster and Webber have proposed a simplified process which can be used by collocated team in a global development [29].

Coordination plays an important role in the success of a globally distributed project. Research community has focused on this aspect in the recent years. Gupta and Fernandez have identified patterns of collaboration among distributed team members [4] and analyzed the effectiveness of collaboration mechanisms in specific scenarios. Supported on their analysis authors have recommended a planning based approach which can be used to enhance collaboration effectiveness. Fabinder and Henz have shared their experiences from industry in implementing global development as combination of collaboration across functions and locations [30].

Klein, Rausch and Fischer have presented an approach that bridges the semantic gap between processes by construction of syntactically correct processes [31]. The authors have elaborated their approach through the use of collaboration scenarios in globally distributed organizations. Magdaleno, Werner and Araujo have argued that the collaboration in globally developed projects can be analyzed through the use of social networks [32]. They have discussed the social network tools against the collaboration requirements which could be helpful for researchers and practitioners in tailoring processes. One of the most challenging steps in GSP is the elicitation of requirements. Gabriela, Vizcaino and Piattini have proposed a framework which analyzes the hindering factors in global software development and suggests strategies for the improvement of these factors [33]. A comparison of multi-site development processes has been presented by Avritzer and Paulish [34].

## 3 Research Strategy and Procedure

The standard procedure to carry out a systematic literature review in software engineering is outlined by Barbara Kitchenham [35, 36, 37] which is followed in this review. The procedure followed for literature review is outlined in Fig 1. This literature review doesn't follow those guidelines to the knot. We have also followed the SLR patterns presented in studies by Kitchenham, Unterkalmsteiner, Hossain and Babar [14, 16, 19 and 20].

The process is divided into three sub-processes, Pre-Review, Review and Post-Review processes. The pre-review sub process is the preparation which includes some important decisions. We started from definition of problem domain and area of interest. The motivation for selecting this research area is the increasing global trend towards distributed development processes.
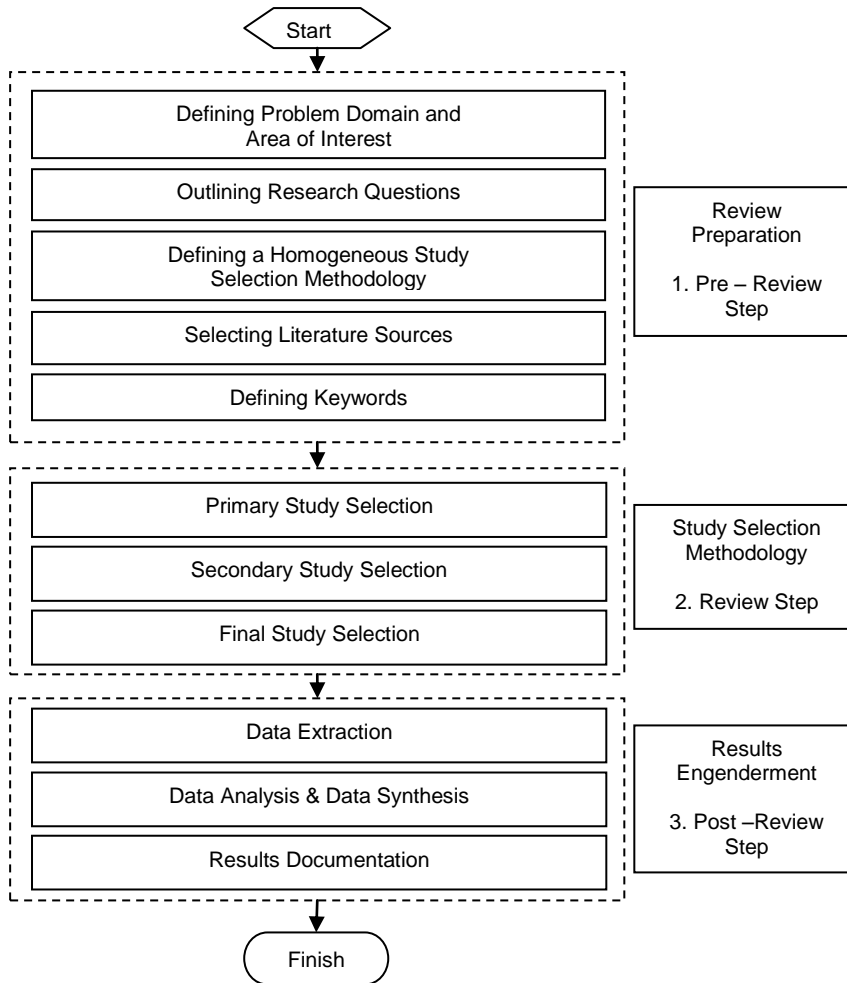
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**Figure 1:** Systematic Literature Review Procedure

An important process of planning a literature review is the definition of research questions. These questions are mapped from the problem domain and highlight the area of interest. The research questions selected for this literature review are outlined in Table 1. To review the literature a methodology (protocol) is defined. The protocol is uniformly outlined and homogeneously followed by all three authors for the literature review. The quality of the literature is critical in a review to ensure the quality the depth and breadth of the literature is very important. The depth depends on the search criteria and breadth depends on the sources.

To ensure the quality top three internationally acclaimed bodies are selected i.e. IEEE[1], Springer[2] and Elsevier[3]. Google Scholar[4] was also used to search the literature.  In the last step of preparation key phrases were derived from the keywords in different combinations using logical operators. These keywords cover research questions and the area of interest. The digital sources are searched with these key phrases.

The second sub-process is the execution of protocol. This phase is divided into three steps. The first is the primary study selection where each digital source is searched with the key phrases. English is used as language for searching and the duration is kept from year 2000 to 2011. The first step returned a large number of studies. This number is further reduced by filtering out irrelevant literature in second phase.

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[1] http://ieeexplore.ieee.org/Xplore/dynhome.jsp
[2] http://www.springerlink.com
[3] http://www.sciencedirect.com
[4] http://scholar.google.com.pk

**Table 1:** Research Questions

| ID | Research Question | Aim |
|---|---|---|
| RQ1 | What are the current global software process improvement initiatives? | Classification of the current initiatives (in the literature) used for standardization of global software process improvement. |
| RQ2 | Can Collocated Initiatives are applicable in Global? | Collocated software development process is much matured and initiatives can be found at different levels of implementation. It will be very effortless if these initiatives can be used for global processes. The purpose of this question is to look for any evidence in the literature which can prove this implementation. |
| RQ3 | Do the improvement initiatives really affect the maturity of the process? | The objective here is to find empirical evidence regarding the effectiveness of improvement initiatives. |

The second step is secondary study selection which is based on selection filters. These filters include publication year, content type, subject, and specialization area. The inclusion or exclusion of a study is based on a key factor named as "Relevance". This factor is calculated for each study and scaled as low, medium and high. Papers with medium and high relevance are only included for final study selection otherwise they are excluded. The relevance for the secondary selection study is calculated on certain factors like title, authors, content type, publication date and maturity of publisher.

The third step is final study selection where the most relevant literature is selected and other is excluded from secondary study. The criterion for study selection in this step is also 'Relevance' however the calculation of relevance is based on slightly different factors. In this step papers are reviewed in more depth i.e. abstract, introduction and result sections are overviewed by each author and then relevance is assigned to it. The final set of publications is used for data extraction and analysis. The partially reviewed studies provided a wide range of knowledge for research trends in global software development process.

## 4  Data Analysis & Results

## 4.1  Data Extraction & Research Answers

The research shows that the focused area of interest (i.e. Global Software Development Process Improvement Initiatives) is very new and pre-mature. The main digital sources were searched for the relevant literature but the initial outcome was very low number of studies. Therefore we had to broaden our area of interest. This area of global software development is developing. It needs a lot of focus from industry, academia and research communities.

There are standardized initiatives like CMMI [38] and ISO 9001: 2000 [39] for collocated software development process but no such internationally acknowledged initiative could be found for global software process improvement. The research community needs to work on the standardization of such initiative. The main outcome objective of this literature review is to look for the answers of research questions (Table 1).

**Answers to RQ1.** The literature review shows that currently there is not globally accepted standard for global process improvement. Still the initiatives found in the review are tabulated in table2. In [12] authors have presented a practice for global software process definition using data from a case study. The practice is simply based on two roles, Process Owner (PO) and Process Reviewer (PR) and a Process Change Request Documentation (PCRD). The PO defines global process and the artifacts, schedules the meetings and updates the artifacts. The PR revises and validates the process artifacts and suggests the changes. The review process achieves a level of process improvement which is restricted to the site only.

**Answer to RQ2.** Analysis of extracted data from the research literature clearly specifies that we can't use the initiatives used for collocated software process for global processes. Global software devel-

opment challenges the techniques of traditional software engineering and requires new solutions [11, 40]. The practices, organizational structures and initiatives used for collocated development are often not ample for GSD projects [9].

**Answer to RQ3**.The answer is 'Yes', and is supported by the literature. A survey result presented in [10] states that only 4% practitioners have the opinion that SPI initiatives in their organizations have not provided the desired results. This rate is further reduced in south Asian countries.

## 4.2  Data Synthesis

The main objective of this review is to highlight the existing initiatives and factors in the current literature. Table 2 classifies the initiatives found in the research. In the first part only empirically tested frameworks, models, techniques and me-thodologies are presented. Proposed or only reviewed initiatives are excluded.

**Table 2:** Initiatives

| Initiative | Classification | Reference(s) |
|---|---|---|
| Model | Process Evaluation | [8, 11, 6] |
| Model | Process Collaboration | [31] |
| Model | Process Improvement | [13] |
| Framework | Process Maturity | [3] |
| Framework | Software Architecture Evaluation | [28] |
| Framework | Requirement Elicitation | [33] |

We have identified some key factors effecting process improvement and have classified them in table 3. The three basic classifications (with respect to development process) used for these factors are Communication, Coordination and Control. These factors can be used by practitioners to help them select an appropriate improvement initiative. The researchers can benefit from the Reference column to overview the source of a certain impact factor. Impact of each factor on the globally distributed development process is specified as positive, negative and both. A factor can have a positive or negative impact based on its usage.

**Table 2:** Identified Key Factors

| Key Factors | Classification | Impact | Reference(s) |
|---|---|---|---|
| Cultural Differences | Coordination (Fundamental) | Negative | [12, 11, 41, 6, 17, 33, 18] |
| Different Time Zone | Coordination (Fundamental) | Both | [12, 11, 41, 6, 33] |
| Language Difference | Communication (Fundamental) | Negative | [12, 11, 4, 6, 17, 18] |
| Pre-Existent Processes | Control (Fundamental) | Positive | [12] |
| Communication Infrastructure | Fundamental (Communication) | Both | [12, 11, 41, 33, 18, 25] |
| Organizational Structure | Control (Organizational) | Both | [12, 11, 41] |
| Team Trust | Coordination (Organizational) | Positive | [12, 11, 5] |
| Team Size | Control (Strategic) | Both | [12, 11, 17] |
| Development Site | Control (Strategic) | Both | [6] |
| Product Architecture | Control (Strategic) | Both | [6] |
| Task Allocation Strategy | Control (Strategic) | Both | [6] |
| Distribution Overhead | Coordination (Strategic) | Negative | [6] |
| Distribution Effort Loss | Coordination (Strategic) | Negative | [6] |
| Impacts from Virtual Teams | Coordination (Organizational) | Negative | [6] |
| Team Formulation | Control (Organizational) | Both | [6] |

| | | | |
|---|---|---|---|
| Team Dynamics | Control (Organizational) | Both | [6] |
| Inertia – Laziness | Control (Strategic) | Negative | [10, 25] |
| Staff Training | Control (Organizational) | Both | [20, 10,11, 25] |
| Formal Procedures | Control (Strategic) | Positive | [10] |
| Lack of Tools | Control (Organizational) | Negative | [10, 25] |
| SPI Awareness | Control (Organizational) | Both | [10] |
| Shared availability of participants during interactions | Coordination (Organizational) | Positive | [4] |
| Shared familiarity of participant's knowledge/skills | Coordination (Strategic) | Positive | [4, 33] |
| Shared Context | Coordination (Strategic) | Positive | [11, 4] |
| Shared motivation for win-win | Coordination (Strategic) | Positive | [4] |
| Shared portal for content sharing without confusion | Coordination (Strategic) | Positive | [4] |
| Lack of knowledge on the expectations and processes of different teams | Coordination (Strategic) | Negative | [11, 4] |
| Differing Technical and Domain Vocabularies | Coordination (Strategic) | Negative | [9] |
| Coherence | Coordination (Fundamental) | Positive | [40] |
| Interpersonal Relationships between stakeholders | Communication (Fundamental) | Positive | [11] |
| Lack of Knowledge / Expertise Exchange | Communication (Organizational) | Negative | [17] |
| Hidden Costs | Control (Organizational) | Negative | [18] |
| Imposition | Coordination (Strategic) | Negative | [25] |
| Lack of SPI management skills | Control (Organizational) | Negative | [25] |

Communication Infrastructure, Cultural Differences, Time Zone and language barrier are very foundational factors of global development process. The structure of the organization has an immense impact on the process. The team size and trust are two factors which are found in multiple studies.

The knowledge of driving factors is crucial for design and implementation any improvement initiative. We have presented all the factors involved in global software development which are collected during our literature review. In [11] authors have presented factors in a conceptual map of project development.

Based on the evidence collected during the literature review we have came up with some factors that may play an important role in distributed process improvement. These factors are just proposed here. The impact of these factors can only be analyzed on implementation. The factors are presented in Table 4.

**Table 3:** Set of Proposed Factors

| | Proposed Factor | Aim |
|---|---|---|
| 1. | Different Work Ethics | Teams working in different working environment and culture may develop variant working ethics. |
| 2. | Professional & Personal priorities | People from different backgrounds usually have different professional and personal priorities. |
| 3. | Long term staff hiring | Coordination developed can be sustained for a long time. |
| 4. | Change Announcement | This factor must be considered by management. When a change occurs at one location it should be announced to all the differentially located teams. |

The research trend in global software development is depicted in table 5. The time line is constructed from the filtered literature from secondary study selection. Hence this timeline covers literature narrowed down to area of interest. This time line is restricted to the last six years because the literature available on the previous years is not very relevant. It emphasized more on global software development, global architecture and distributed requirement elicitation.

**Table 4:** Research Trend Timeline

|  | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|
| **Journal** | 08 | 09 | 09 | 07 | 10 | 14 |
| **Conference** | 07 | 07 | 10 | 17 | 13 | 13 |
| **Book Chapters** | 01 | 07 | 03 | 06 | 07 | 06 |
| **Reports          (Technical/Academic)** | 00 | 00 | 00 | 01 | 00 | 00 |
| **Total** | **16** | **23** | **22** | **31** | **30** | **33** |

## 5   Conclusion a& Future Work

The driving factors in a process are cost, quality and schedule. The improvement is usually incurred to reduce cost, increase quality and meet the schedule. The global process must be defined and this definition should be homogeneous and clearly understood by all the distributed on and off-sites involved in development.

This research paper has presented a systematic literature review carried out to find the existing initiatives for global software process improvement and key factors involved in its success or failure. The data extracted from the literature is synthesized to present the findings of the study. The outcome of this review is a guideline for the researchers and practitioners to design and implement new GSPI initiatives. A research trend time line is formed stretching over the last six years to show the increasing trend in GSD.

A questionnaire based empirical study is lining up after this review to study the key factors in the local small to medium sized organizations.

## *Acknowledgements*

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