Problems? We All Know We Have Them. Do We Have Solutions Too?

A Literature Review on Problems and Their Solutions in Global Software Development

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***Abstract*— Distribution of development processes has become common as a side effect of globalization. Working in a distributed setting brings challenges inherent to distance. The Software Engineering community has been investigating these challenges for over a decade, and issues regarding communication, coordination, and trust are frequently reported in literature. However, a few studies discuss solutions for these challenges. Frequently, best practices are described in a general context. In this paper we report our findings from a systematic literature review that aimed at identifying reported challenges and the proposed solutions to solve such challenges. In a time that distributed development has established its roots, it is important to move towards solutions to well-known problems. Our report aims to establish a baseline of problems that still need solutions. This baseline brings awareness to the global software engineering community. We finish discussing the implications for furthering the body of knowledge in the field.**

Keywords-global software development; systematic literature review; challenges; problems; solutions; mitigation strategies

I. INTRODUCTION

The globalization process the world has been living for over a decade has also imposed collateral effects in IT companies. Many organizations have been outsourcing their software development processes around the globe characterizing what we name *global software development*. Several are the reasons for such outsourcing, such as tax incentives, proximity to the customer, access to a mass of qualified professionals [1]. Despite the reason that leads a company to outsource part of or its entire development process, companies are often looking for more productive teams, better product quality, and lower costs [2]. The fast development of technology and the sophistication of communication and collaboration media made available over the last years have also motivated companies to investment in distributed software development projects [3].

Working in such distributed environment adds challenges inherent to distance, such as dealing with the impact of cultural differences in the way developers work and respect hierarchy, to those traditionally known such as managing changes to requirements in a timely and costless manner. Thus, issues such as quality, time, and cost are often amplified in distributed projects [4]. The challenges in this context are usually associated with technical issues, strategic decisions, cultural aspects, and knowledge management practices [5].

Mitigation strategies and proposal solutions are then defined aiming to reduce or to eliminate the challenges and problems faced by distributed teams. For instance, alignment of working processes among the development sites [6] and implementation of unified tools [7] are examples of strategies adopted to assist challenges associated to coordination and communication, respectively. Despite the efforts, many of the commonly reported challenges have a few modest solutions associated to them or are still reported as unsolved in literature. In a time when global software development has established its roots, it is important to move towards solutions to well-known challenges and problems.

This paper reports on a systematic literature review conducted aiming to identify which specific challenges and problems have reported solutions associated to them. The consolidated collection of challenges and problems (herein alternatively referred to challenges or problems only) and solutions listed here serve as a baseline to bring awareness for researchers and practitioners about what has already been reported. We expect the body of knowledge accumulated in this baseline to help both academia and industry to better solve the identified problems.

The remainder of this paper is organized as follows: Section 2 presents a brief background on global software development and introduces our research questions. Section 3 presents the research methodology we followed in our study. Section 4 presents the main findings of our investigation, listing the most referred problems and their solutions reported in literature. Section 5 concludes the paper discussing implications of our findings for practitioners and for future research.

II. BACKGROUND AND RESEARCH QUESTIONS

Software development is a complex activity that requires knowledge workers to be good communicators and to collaborate effectively to be successful. Distribution has increased the complexity of such activity. Over a decade ago Carmel [8] has indicated that at least five important factors, named centrifugal forces, can lead a distributed team to failure if they are not well-managed: ineffective communication, lack of coordination, geographic dispersion, loss of team spirit, and cultural differences. However, he discusses six factors that can

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minimize these challenges and, as a consequence, ensure the success of such teams: communication infrastructure, product architecture, team building strategies, developing methodologies, collaboration technologies, and management techniques [8]. Up to recent years these factors are still reported as critical to determine the success or failure of distributed projects (e.g., [3][9][6][10][11]).

Challenges in this distributed context are usually associated with technical issues, strategic decisions, cultural aspects, and knowledge management practices [5]. Human-related aspects are also considered since software development is dependent of human beings and their relationships across cultures, languages, and countries is even more complex and difficult to understand than in co-located situations [1].

Communication and collaboration are often reported as the main challenges faced by distributed teams since informal opportunities to meet are scarcer and the lack of such meetings is perceived as prejudicial [12]. Technology and infrastructure play an important role in minimizing communication and collaboration problems. The adoption of such technical resources needs special attention when multiple sites are expected to work together. The use of different tools for the same purpose, for example, can cause extra work for developers or even incompatibility of shared artifacts.

A distributed software project also calls for the alignment of working processes and methods as suggested by Carmel and later reinforced by Nidiffer and Dolan [13], and Costa [6]. Common knowledge about roles and responsibilities as well as about the expected workflow are collaboration facilitators [14]. Different technical processes and domain vocabularies, environment incompatibilities and conflicting points of view can be particularly problematic in a GSD context [15]. Overall management is another aspect that has its challenges exacerbated in distributed settings. This is because the need to manage, for example, the collaboration of stakeholders in such projects, is reduced as a function of geographic distance [16]. It is also necessary to monitor changes in the project, which becomes more difficult due to several developers working concurrently from different locations [2].

In order to develop a consolidated and more complete understanding of the problems and solutions reported in literature, we posed the following research questions:

RQ.1 Which are the problems reported in literature related to global software development?

RQ.2 Which are the solutions reported in literature related to global software development?

RQ.3 Which identified solutions are associated to each identified problem?

III. RESEARCH METHODOLOGY

We conducted a systematic review to identify problems faced and solutions adopted by distributed software teams reported in literature. This review combined two main strategies: the review of studies cited in selected literature reviews (secondary studies) and the search for primary studies to supplement the previous studies found. The study selection and data extraction processes are presented in details in this section in addition to the threats to the validity of our study.

A. Data Retrieval

The literature review we have conducted is composed of two main steps: the first sought to review the literature on any subject related to the global software development by looking for secondary literature reviews previously identified by another researcher fellows, Marques, Rodrigues and Conte [17]. Marques and colleagues have identified 27 secondary studies in GSD. Each of the 27 studies cited over 20 primary studies each. We read each of the primary studies listed in this first round of investigation. Repeated studies were disregarded at this stage to avoid duplication. We used Marques, Rodrigues and Conte study as a way to accelerate our search for papers of our interest. In the second step, in order to ensure a complete coverage of the field, we performed a specific search in the IEEE Xplore Digital Library and the ACM Digital Library, the two leading repositories for software engineering research around the world, to identify studies that have not been found in the previous step. We searched for GSD studies overall by applying the following search string: *"global software development" OR "distributed software development."* In total, after the two steps have been performed, we have over 300 candidate studies available for further investigation.

B. Study Selection

For each of the over 300 selected studies, we read the paper title, abstract and keywords as a mean to identify which paper were candidates for analysis. We wanted to narrow down from papers discussing GSD as a whole to those that discuss problems faced by and solutions proposed by distributed teams only. When reading the abstract was not sufficient to determine whether the study was of interest, then we read the introduction and skimmed through the findings section. Studies that did not present or discuss problems or solutions were removed. Out of the over 300 studies initially found, 202 were then selected for a thorough analysis.

C. Data Extraction

For each of the 202 selected studies, we extracted the following data: paper title, authors, affiliation, country of affiliation, venue, date of publication, problems, and solutions. Each problem and each solution identified were coded with a main keyword to facilitate further categorization. We categorized problems and solutions according to the categorization scheme proposed by Audy and Prikladnicki [3]. The five proposed categories are: People or Human Resources, Communication, Management, Processes, and Infrastructure. In order to remove the bias of the main researcher, two additional senior researchers (not authors of this paper) were invited to characterize the problems and solutions found according to the defined categories. To discuss discrepancies between both researchers, a face-to-face meeting was conducted with both researchers simultaneously to reach consensus. This process allowed us to eliminate bias and to increase the reliability of the findings. Due to the lack of space, we present in this paper only the challenges and solutions most cited per category. It is important to mention that the non-indication of a solution for certain challenge in this paper does not indicate the lack of a solution in literature.

Missing solutions should be interpreted as a solution that was not adopted repeatedly, thus is not presented in our study.

D. Threats to Validity

To assess the validity of our study we considered issues related to three types of validity as discussed here. First, *reliability threats* are related to the replication of the study and the identification of the same findings if other researchers conducted the research. To mitigate this issue established peer review sections of the findings for each step of our methodology. More specifically, we conducted an independent review of the data extraction and categorizations to minimize bias. Second, *internal validity* threats are related to the study design and whether the results follow from the data. We have started our investigation searching for papers in the Scopus database, which is known for its completeness. However, we have not corroborated the list of papers retrieved from this source to individual searches in the commonly used databases. To minimize this issue and to guarantee a complete coverage of the defined period, we conducted a second search at the IEEE and ACM digital libraries. Search on other databases such as Springer and Elsevier might slightly change our results. Third, *external validity* threats are related to the generalizability of results. Papers published in local venues such as the Asian Software Engineering Conference and the Experimental Software Engineering Latin American Workshop might have been ignored if these conferences are not indexed at the Scopus, IEEE, or ACM databases. Given the large amount of studies identified, we believe this might have no impact in our reported findings.

IV. FINDINGS

We summarize our findings by each of the five categories proposed by Audy and Prikladnicki [3] as previously mentioned [1]. We limit ourselves to list the problems and solutions found associated with their number of occurrences due to the lack of space to discuss each of the items in depth.

A. Problems and Solutions Associated to People

Table 1 People-related challenges and solutions

Problems	#	Solutions	#
Difficulty in establishing trust on others [E1, E4, E5, E6, E13, E14, E16, E18, E24, E26, E27, E28, E29, E37, E40, E68, E74, E83, E102, E104, E105, E106, E112, E113, E116, E125, E126, E127, E130, E137, E145, E148, E157, E159, E164, E166]	36	**To promote social activities among the team members during face-to-face visits** [E2, E3, E17, E32, E40, E79, E134, E137, E157]	9
		To promote building overall trust relationships [E28, E43, E107, E157]	4
		To promote informal meetings [E6, E37, E159, E164]	4
Fear of job loss [E3, E6, E8, E15, E21, E37]	6	-	0
Limited team spirit [E1, E112, E137, E146, E147]	5	**To foster the development of personal relationships** [E3, E12, E24, E92, E110,]	5
Lack of experience working in a distributed team [E5, E6, E22, E62]	4	-	0

B. Problems and Solutions Associated to Communication

Table 2 Communication-related problems and solutions

Problems	#	Solutions	#
Difficulty in establishing a common understanding among members who have different background and cultures [E1, E2, E5, E6, E9, E10, E14, E21, E22, E24, E25, E28, E30, E32, E37, E38, E40, E44, E46, E47, E49, E50, E52, E53, E54, E55, E56, E58, E65, E85, E87, E91, E92, E102, E103, E109, E110, E112, E115, E134, E135, E136, E137, E138, E146, E157, E167]	47	**To define a cultural ambassador for the project** [E19, E110, E148, E159, E165]	5
		To promote awareness and understanding of cultural differences [E2, E33, E40, E137]	4
Difficulty in establishing a common understanding among members who use different vocabularies and terminologies [E2, E3, E4, E6, E9, E10, E13, E15, E29, E30, E36, E37, E39, E40, E41, E42, E44, E45, E46, E47, E48, E82, E84, E92, E93, E108, E109, E110, E112, E115, E116, E117, E137, E142, E148, E157, E159, E160, E161, E162, E167, E168]	42	-	0
Limited opportunities for informal communication and establishment of interpersonal relationships [E1, E2, E3, E6, E19, E20, E29, E32, E35, E36, E37, E38, E40, E51, E85, E86, E87, E88, E109, E112, E113, E116, E117, E130, E137, E140, E141, E144, E169]	29	-	0
Limited effective forms for establishing communication [E3, E169, E109, E124, E6, E123, E10, E114, E116, E117, E122, E118, E168, E2, E6, E9, E15, E87, E144, E4, E5, E31, E32, E1, E14, E29, E30, E149, E130, E8]	30	-	0
Lack of communication caused due to geographical and temporal distances [E1, E6, E12, E29, E40, E74, E75, E79, E82, E84, E91, E92, E93, E97, E108, E110, E111, E137, E139, E148, E150, E157, E158, E163, E168]	25	**To promote an effective communication infrastructure** [E14, E19, E40, E43, E71, E73, E74, E76, E77, E78, E116, E137, E143]	13
		To define a model to guide and support communication [E2, E14, E56, E73, E74]	5
Difficult in sharing knowledge [E4, E6, E9, E19, E21, E24, E36, E37, E40, E42, E44, E47, E55, E64, E65, E112, E120, E121, E130, E137, E142]	21	**To promote a "buddy system" in which members can**	4

[1] The detailed reference for each study cited in this section can be found at http://www.inf.pucrs.br/sabrina.marczak/icgse2012_refslist.pdf

		frequently share information with each other [E2, E15, E43, E80]	
Difficulty in obtaining feedback in a timely manner [E2, E5, E6, E9, E12, E13, E14, E16, E18, E19, E20, E24]	12	**To shift work schedule** [E6, E71]	2
Difficulty for establishing an efficient information exchange and communication flow [E6, E9, E23, E33, E37, E69, E130, E170]	8	-	0
Reduced quality of the information communicated [E15, E17, E22, E24, E32, E34]	6	**To define communication guidelines and procedures** [E13, E60, E64, E79, E142]	5
		To define development processes that promote frequent collaboration [E14, E15, E17, E31, E70]	5
		To promote periodic synchronous communication [E2, E6, E68, E71, E76, E157]	6

C. Problems and Solutions Associated to Management

Table 3 Management-related problems and solutions

Problems	#	Solutions	#
Difficulty in managing the lack of cooperation from stakeholders [E3, E5, E6, E14, E37, E40, E48, E51, E54, E58, E66, E88, E90, E126, E130, E137, E141]	17	-	0
Difficulty in managing distributed projects [E1, E4, E37, E40, E58, E60, E68, E87, E130, E137, E148, E153, E154, E155, E156, E170]	16	**To define standardized work guidelines, deadlines, and commitments** [E30, E40, E44, E77, E79, E82]	6
		To communicate expectations and to establish overall rules for working together [E13, E64, E082, E142]	4
		To promote visiting trips [E2, E17, E72, E110]	4
		To consider salary equality across sites [E38, E40, E41, E50, E137]	5
Difficulty in maintaining up-to-date visibility of the project status [E1, E12, E14, E18, E19, E22, E25, E70, E74, E100, E137, E149]	12	**To define processes that require frequent report sharing and deliveries** [E15, E40, E81, E99, E100]	5
Difficulty in dealing with diverse laws and policies [E1, E3, E24, E63, E91, E101, E135, E137, E151, E152]	10	-	0
Difficulty in assigning tasks appropriately [E6, E9, E15, E37, E45, E58, E62, E64]	8	**To promote the adoption of collaborative tools to support task assignment and management** [E14, E36, E71, E73, E94, E95, E96, E97, E98, E131, E132, E133, E159]	13
Difficulty in planning an accurate effort estimation [E4, E21, E22, E48, E58, E67]	6	-	0
Difficulty for managing conflicts [E1, E85, E89, E91, E137]	5	**To define working rules and guidelines** [E3, E24, E90, E92, E111, E118]	6
Limited time for collaborating with remote colleagues [E1, E37, E86, E110, E130]	5	-	0

D. Problems and Solutions Associated to Process

Table 4 Process-related problems and solutions

Problems	#	Solutions	#
Difficulty in defining an effective configuration management and versioning control process [E4, E24, E40, E42, E51, E87, E90, E91, E109, E112, E113, E115, E116, E128, E129, E137]	16	-	0
Difficulty in establishing an understanding about the diverse work practices from different sites [E6, E9, E13, E22, E30, E37, E39, E40, E53, E58, E137, E141]	12	-	0
Difficulty in having an effective requirements engineering process [E1, E3, E4, E6, E12, E40, E51, E86, E87, E119, E138]	11	**To adopt tools to suppor collaboration among stakeholders** [E49, E79]	2
Difficult in defining a business process that attends the demands of the diverse sites [E19, E29, E40, E79, E84, E97, E110, E112, E148, E161, E164,]	11	-	0
Difficulty in defining and institutionalizing a unified process that covers the entire life-cycle [E2, E15, E21, E29, E57, E59, E137, E138, E139, E142]	10	-	0
Difficulty in defining modular architectures that diminish coordination needs [E1, E37, E86, E112, E137, E157, E161]	7	**To adopt tools to assist in the understanding and management of requirements** [E83, E97]	2

E. Problems and Solutions Associated to Infrastructure and Technology

Table 5 Infrastructure- and technology-related problems and solutions

Problems	#	Solutions	#
Limited infrastructure, tools, and techniques for supporting distributed software development [E6, E19, E29,	13	-	0

E40, E61, E87, E88, E130, E137, E149, E157, E161, E168]			
Limited telecommunication technologies [E1, E37, E110, E146,]	4	-	0

V. CONCLUSIONS AND IMPLICATIONS

Global software development has become a reality over the last decade. The challenges imposed by geographical, temporal, and cultural distance are numerous. The Software Engineering community has been studying these challenges for as long as the first discussions on the topic have been mentioned. However, many of the well-known challenges have only a few studies discussing their solutions or have not been solved at all. This paper aimed at consolidating the body of knowledge on the topic in order to facilitate the identification of future research and improvements necessary by academics and practitioners.

By performing a comparative analysis of our findings, we can see that the amount of challenges is greater than the number of solutions identified. This is a pattern found for each of the five-presented categories. It is also possible to identify that several challenges have no associated solutions at all, while only a few have more than one solution reported in literature.

An hypothesis for such low reporting of solutions is that most of the papers discuss overall best practices and mitigation strategies instead of clearly stating which solution was adopted to each problem reported. Another hypothesis is that problem solving in distributed development is quite particular to the organization and as such solutions are not shared to avoid disclaims of successful factors.

A. Implications for Practitioners

The contribution of this systematic literature review on problems and solutions in GSD helps practitioners to identify the state-of-the-art as well as the state-of-the-practice in the topic. Practitioners can identify certain challenges of their interested in focus on a more in-depth reading of related studies on such challenges saving them time and directing them to a peer reviewed knowledge of body. It can also motivate them to contact authors in order to exchange experience.

B. Implications for Future Research

Our study has revealed that a large amount of challenges still do not have solutions associated to them. Those solutions reported are often unique for a certain situation or have not been tested for a large sample of GSD projects. This confirms anecdotal knowledge that it is time for the Global software Engineering community to define strategies to move towards the investigation of solutions for such reported problems. Validation of reported solutions is also a need. The definition of such strategies will help guiding the community in improving software development processes for distributed teams and to solve some of the well-known challenges when working in distributed settings.

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