Toward an Integrative Model of Influence Factors for Success of Global Software Development Projects

Completed Research Paper

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Abstract

In this paper, an integrative conceptual model of internal and external factors influencing the success of global software development (GSD) projects is proposed. Its intention is to provide a holistic view on factors contributing to success in GSD projects as discussed in the literature. Four external factors (cultural differences, language differences, geographical distance, and time zone difference) and four internal factors (organizational structure of the project, software development process, communication and collaboration, and knowledge transfer) are identified and put in relation to each other in the light of criteria for project success. This integrative perspective provides a framework for a future meta-analysis of isolated findings about specific GSD issues in the literature. In turn, such a meta-analysis allows an enhanced understanding of the interplay between the different factors. The integrative perspective also provides a foundation to develop theoretically grounded design propositions for the design of future GSD project organizations.

Keywords

Global software development, Project success, Influence Factors, Success factors, Project teams, Global teams, Distributed teams

Introduction

Today, large-scale software development projects often take place in globally distributed teams. Sahay et al. define global software development (GSD) as "software work undertaken at geographically separated locations across national boundaries in a coordinated fashion involving real time or asynchronous interaction" (Sahay et al. 2003 p. 1). This does not only lead to increased complexity for the project management, but also includes the additional challenge of intercultural management. Frequently cited potentials of GSD compared to traditional software development are lower costs, reduced time to market, increased flexibility, access to global resources (especially scarce professional skills), and closeness to the customer (Bird et al. 2009; Carmel and Agarwal 2001; Herbsleb and Moitra 2001). Common risks include deficits in functionality and quality of the delivered product, unexpected cost increases over the project duration, dependency on the external partners, and soft factors in project management (Amberg and Wiener 2006; Beulen 2006). Based on a study of 318 German companies, Moczadlo (2002) and Amberg and Wiener (2006) identified project management challenges and soft factors such as communication and language barriers, cultural differences, and different mental models as the most common reasons for these risks in GSD. Political or legal issues and time zone differences were found to be of lesser importance, while the technology and the IT infrastructure were rarely problematic. If these challenges are not handled adequately in a GSD project, the risks of GSD may outweigh the potentials, which in turn may lead to project failure. Often, the challenges are underestimated and the project goals are not reached (Sangwan et al. 2007).

While there is extensive literature about GSD in general, every author emphasizes different aspects. However, according to Kieser and Nicolai (2002), an isolated perspective on singular influence or success

factors is not sufficient, since they usually depend on many others, unknown factors. A focus on isolated success factors can lead to a mechanistic managerial perspective of simple cause and effect relations. But such an understanding is not suitable to manage complex and dynamic organizations, such as global software teams, and to handle phenomena such as surprises, emergence, and informal structures (Tranfield et al. 2006). As a first step toward an integrative understanding of factors with relevance for the management of GSD projects and their interplay, the goal of this paper is to develop a conceptual model based on a literature review which provides such an integrated perspective on external and internal factors influencing GSD success. The main purpose of the conceptual model is to provide a map of the overall research landscape in the context of GSD projects to conduct systematic meta-analyses and research syntheses (Cooper 2010; Cooper et al. 2009) in the future. Since there are many different factors, studies, and emphases in the existing GSD literature, even a meta-analysis and research synthesis will have to be conducted in several steps and phases. For this reason, a deliberately broad scope is chosen for this paper, and a conceptual model – and not a research model – is developed. It can be used as guidance to structure a meta-analysis process and also to develop research models aiming to explain the interplays between selected factors which have not yet been analyzed before.

In order to develop the conceptual model, in the second section external factors found to influence project success in GSD projects are discussed and systematized. Internal factors are likewise discussed and systematized in the third section. In the fourth section, the conceptual model itself is presented and the relations between external and internal influence factors are discussed. The fifth and final section provides a conclusion and an outlook toward further research.

External factors influencing GSD project success

Carmel (1999) highlights that global software teams are characterized by geographical distance, different time zones, and differences of national cultures. While he includes different languages as part of the national culture, other studies emphasize languages as a separate aspect (Rosenkranz et al. 2013; Sosa et al. 2002). These four aspects are reflected at least partially in other comprehensive studies as well (Amberg and Wiener 2006; Moczadlo 2002; Sangwan et al. 2007; Winkler et al. 2008) and no other factors could be found which do not fit to one of the four categories. Therefore, they are assessed as being comprehensive and are chosen as the four external influence factors for GSD project success.

It is of note that the four external factors are not independent. Different countries with different cultures are located in different geographical regions of the globe, may have different languages and, as long as they lie on sufficiently different latitudes, have different time zones. However, each of the four factors is a source of distinct challenges for GSD projects, and hence, warrants individual attention. The interplay between the four factors is discussed in a later section in the light of their effects on the elements of a GSD project team.

Cultural differences

Following Hofstede et al. (2010), we understand culture as "software of the mind" or mental models which are shared among a group of project members (usually within national boundaries), influencing their thinking, feeling, and behavior. Hofstede et al. (2010) differentiate between five dimensions of culture: power distance index, uncertainty avoidance, individualism vs. collectivism, masculinity vs. femininity, and long-term orientation. However, these dimensions only represent tendencies how members of a certain cultural group behave, since every individual is unique (Bronner and Jedrzejczyk 2008) and individual traits can override a person's cultural background (Carmel 1999). Furthermore, cultures cannot be planned but are subject to complex ongoing emergent change processes. Likewise, mental models of individuals cannot be externally reprogrammed – they can only be changed by the individuals themselves through internal reforming processes (Hofstede et al. 2010). For the management of GSD projects, large differences between the dimensions of team members' cultures lead to increased conflict, a reduced quality of cooperation, and increased efforts to gain trust (Winkler et al. 2008).

Language differences

Language is a critical factor for successful intercultural communication (Hofstede et al. 2010) and therefore of key importance for successful GSD (Rosenkranz et al. 2013). This is especially true for those

GSD projects where no project member communicates in their mother tongue, as Moczadlo (2002) illustrates for GSD projects in a German perspective. Limited verbal skills and strong and unusual accents have a negative effect on communication effectiveness and can lead to misunderstandings on the content level and irritations beyond it (Christiansen 2007; Hirschfeld 1998). Deviations from a familiar sounding of spoken language can also lead to reduced information absorption and concentration and even be a hindrance for acceptance on a personal level, since language skills are often related to educational level, intelligence, and even personal characteristics (Hirschfeld 1998).

Geographical distribution

Collaboration in distributed teams generally tends to be more difficult than collaboration in teams located in one place. This is therefore another key influence factor for the management of GSD projects (Carmel and Agarwal 2001; Herbsleb 2007; Siebdrat et al. 2009). Even the distribution of team members across several floors in the same building can have an effect on the quality of collaboration (Siebdrat et al. 2009). Geographical distance has a negative effect on the intensity and effectiveness of communication among project members, which in turn complicates coordination, management, and control of a project (Carmel and Agarwal 2001; Herbsleb 2007).

Time zone differences

Unlike the three other influence factors, time zone differences do not only present challenges for GSD. The distribution of team members across different time zones allows continuous project work „around the clock" and therefore shorter project times compared to traditional software development (Herbsleb 2007; Sangwan et al. 2007). However, less synchronous working hours also mean less time for spontaneous, direct, and synchronous communication between project members (Carmel 1999; Christiansen 2007). Synchronous communication has the advantage over asynchronous communication that issues can be resolved more quickly and misunderstandings can be prevented (Carmel and Agarwal 2001).

Internal factors influencing GSD project success

As opposed to the external factors, there is no unified or comprehensive perspective on internal factors that are relevant for GSD project success to be found in the literature. Therefore, we employed a top-down approach to define a framework to classify relevant internal influence factors we found in the literature. It covers formal aspects of software project management – as being responsible for 1) the organizational structure of the project and 2) the software development process – furthermore 3) communication and collaboration as abstractions over the ongoing project management and project work, and 4) knowledge management and transfer within and between distributed project teams, in order to take the knowledge-intensive nature of software projects into account.

Organizational structures

Large-scale software projects usually require a high extent of division of labor due to the diverse specialists needed in the different project phases and thus require a high coordination effort by project management. Coordinating globally distributed teams creates further management challenges in terms of transparency about task assignment and distribution as well as coordinating distributed, yet parallel and interdependent tasks and teams. Therefore, the formal organizational structure of a GSD project in terms of team distribution, role assignment, and suitable communication, coordination, and reporting structures requires special attention at the start and during a GSD project (Herbsleb and Moitra 2001; Herbsleb 2007; Sangwan et al. 2007).

Software development process

The organizational structures of a project form the formal frame, in which the actual process of software development takes place. Modern software development processes have evolved from the simple waterfall model to elaborate process frameworks such as the Rational Unified Process (RUP) (Kruchten 2003), in order to cope with the complexities of large-scale software projects in a structured and transparent way. However, formal structures and processes require their effective utilization over the duration of a project,

in order to be a factor contributing to success. Thus, effective and efficient communication is a key contributing factor to an effective software development process (Herbsleb and Mockus 2003). Therefore, it is regarded as a separate influence factor for successful GSD and discussed in greater detail in the subsequent section.

Communication and collaboration

In an abstract sense, communication is comprised of a flow of information between sender and receiver and consists of the steps of 1) selecting information to send, 2) selecting the media (both on the sender's side) and 3) the receiving and understanding of the information on the receiver's side. Since the coding and decoding of the information is dependent on the different backgrounds, experiences, and mental models of sender and receiver, it is well possible that the receiver's understanding and reaction is different than the sender expected (Baecker 2005). In the context of globally distributed teams, further factors for misunderstanding include different cultural backgrounds or different language skills. Therefore, communication in GSD is to be characterized partly as a solution (to coordination and issue resolution) and at the same time partly as a problem in terms of unambiguous understanding.

Successful communication is also a prerequisite of effective collaboration in teams. A team consists of several individuals and is characterized by a high extent of autonomy as well as a shared goal. Every member is assigned individual tasks, which are dependent on the other members' tasks and require a special form of working, the „teamwork" (Humphrey 2000). Team formation processes are commonly divided into four phases: forming (initial contact), storming (conflict over different individual norms, values, and behaviors), norming (establishing shared expectations and rules), and finally performing (Tuckman 1965). In globally distributed teams, there are additional challenges for the storming and norming phases: Diverse backgrounds among team members may lead to more intensive conflicts. The conflict over different norms and also the agreement on shared norms are emergent and communication-intensive processes which are difficult to execute over geographical and time zone distances. Thus, it is the task for the management of GSD projects, to account for these factors, in order to not only establish suitable formal structures and processes, but also enable the distributed teams to effectively communicate, collaborate, and build teams within the formal structures and processes.

Knowledge transfer

A key characteristic of software development is high knowledge intensity. Especially implicit or tacit knowledge is regarded as a decisive factor for success, since it constitutes a unique and context-dependent resource (Barney 1991). At the same time, it is difficult to capture and communicate (Davenport and Prusak 2000; Nonaka and Takeuchi 1995). But when tasks and teams in a GSD project are globally distributed, knowledge transfer between teams becomes a necessity to achieve project success. Therefore it is necessary in GSD to try to store or transfer tacit knowledge in form of data or information (Davenport and Prusak 2000). Nonaka and Takeuchi (1995) suggest four ways for knowledge transfer: socialization (observation, imitation, or exchanges of experience), externalization (dialogue and reflection), internalization (learning-by-doing), and combination. Again, it is a task for GSD project management to provide ample formal structures and processes for knowledge transfer of explicit and implicit knowledge between globally distributed teams.

An integrated model of external and internal influence factors for global software development projects

Combining the four external and the four internal influence factors with the three common criteria for project success (time, cost, and product quality) leads to the integrated model as shown in Figure 1. These three criteria for project success are chosen because they cover the input/output factors for projects. While the Project Management Institute (2009) recently proposed to consider project process factors – such as risk or resources – as well, in our model such factors are to be managed within the scope of the development process. And since the development process is treated as one of the internal influence factors in the conceptual model, the project process factors are covered already implicitly.
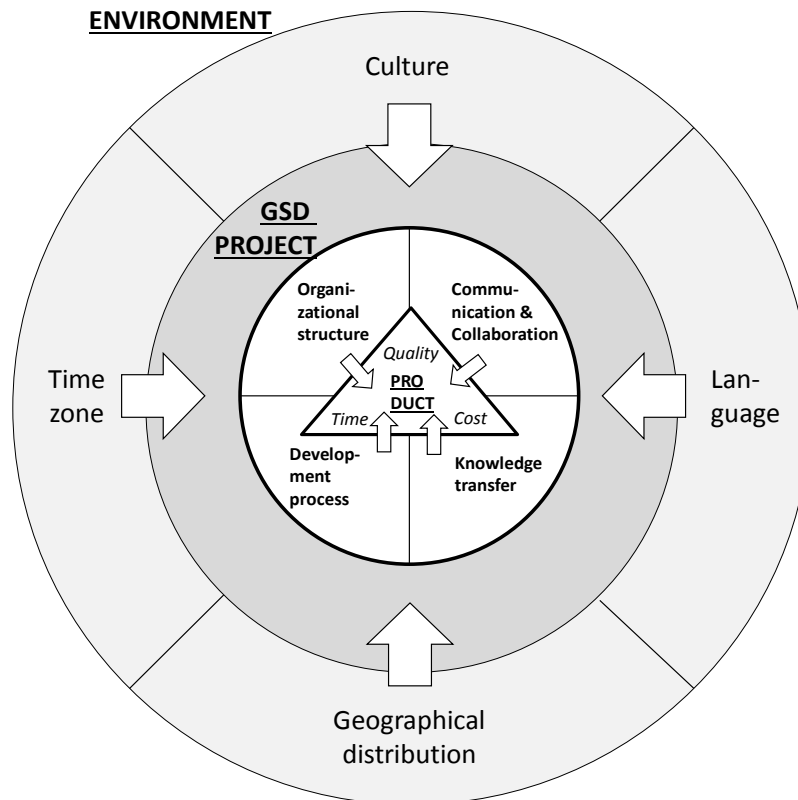
Figure 1: An integrated model of external and internal influence factors for success of GSD projects

In a project management perspective, the four internal areas are the only ones in direct control of project management. Therefore, they are now taken as foundation, in order to discuss the impact of the external influence factors on each of them in the light of the criteria for project success.

Impacts of the external factors on organizational structure

Culture

Culture-specific characteristics and values influence individual attitudes and behavioral patterns, which in turn determine ways of task fulfillment and collaboration, but also etiquette and communication and management styles (Bronner and Jedrzejczyk 2008; Hofstede et al. 2010; Jehn et al. 1999). This implies that a formal structure for a GSD project is at least partially – if not heavily – influenced by their designers' culture(s). It can be surmised, for example, that a high power distance index and masculinity of the designers' cultures is accordingly reflected in a strong hierarchy-orientation, fixed roles, and a strict reporting structure. However, GSD projects tend to suffer more coordination problems when they employ a formal networked organizational structure compared to a stronger emphasis on informal structures (Herbsleb 2007). In addition, the compatibility of the cultural values ingrained in the formal structure to the project members' values also affects its suitability. Consequently, an organizational structure determined by the designers' cultures may not always be the one best suited for the specific context and environment of a GSD project. Based on this, the major factors affected are time and cost in terms of management overheads and work efficiency.

Language

Except for the necessity to decide on one language for the project before the establishment of formal structures, no other direct influences of language differences on the project structure could be identified in the literature.

Time zone and geographical distribution

The geographical and temporal distribution of GSD project members leads to a high dependence on the communication infrastructure as part of the formal organizational structure. As mentioned above, adequate formal as well as informal pathways for communication help coping with task distribution, coordination, and execution. Therefore, the organizational communication infrastructure needs to fit the other elements of the formal organizational structure and the project environment in terms of hierarchy-orientation (such as reporting or other control mechanisms) or the extent of emphasis on informal structures (such as allowing and encouraging direct access to other team members for informal exchanges). All three factors for project success are affected here: time and cost for the communication overhead, and also quality of the outcome when an inadequate communication system leads to a lack of coordination and issue resolution.

Impacts of the external factors on the software development process

Culture

In the early phases of the software development process, many projects need to cope with volatile and ambiguous requirements or specifications which can only be resolved through communication between all participants (Curtis et al. 1988). This communication ideally takes place in a quick, uncomplicated, and informal way (Christiansen 2007). But since globally distributed teams have to use media such as telephone or video conferences or chats, cultural barriers can constitute significant obstacles. Misunderstandings may stay undetected or even increase, instead of being resolved and arriving at a common understanding of initial requirements (Herbsleb and Moitra 2001; Hsieh 2006). The same applies to the specification and the handling of changing requirements (Prikladnicki et al. 2003). Therefore, these early phases are the most critical phases of the software development process in GSD (Berkling et al. 2007; Souza et al. 2007), affecting all three factors of product quality, time, and cost.

Language

In the context of the software development process, the clarity of terminology, methods, and structure and style of the specification and documentation as part of the formal software development process is regarded as a key influence factor for success (Carmel 1999; Sangwan et al. 2007). Documenting dependencies and management of changes in requirements or specification are further seen as critical language-related coordination tasks in GSD project management (Berkling et al. 2007; Souza et al. 2007). Furthermore, clearly written scenarios can foster shared understanding. The outcome factors most affected here are quality (due to textual precision) and time (in terms of quick understanding and less need for resolution of ambiguity).

Time zone

As mentioned above, one advantage of GSD can be temporal distribution according to different time zones. This can further lead to a regular "hand-over" of work products (for example, specification documents or software modules) from one team and time zone to the next, so that effectively two or even three teams are working on work products sequentially around the clock. Common software development processes such as the Rational Unified Process (Kruchten 2003) do not explicitly account for this. Since these hand-overs happen frequently, their overall efficiency and especially clarity – since time for inquiries to the preceding team tends to be limited – are two areas of impact. The outcome factors most affected are time and cost – specifically how well the potential benefit of utilizing teams spanning time zones can be realized and how high the coordination overhead effectively is.

Geographical distribution

Besides cultural and language-related influences, the geographical distribution of the teams especially in the early phases of GSD projects is covered in the literature as well, albeit not in an unified way (Carmel 1999; Rodriguez et al. 2007; Sangwan et al. 2007): One proposal is to conduct the requirements and design phases mainly at or close to the main or customer site and work more extensively with distributed teams only during the development and maintenance phases. In contrast, it is also proposed to distribute the requirements and design phase at least to a certain extent, in order to foster knowledge distribution and transparency for more effective development later on. In addition, a unified configuration and version management system for all distributed teams, in order to allow parallel work on the work products across teams and provide every team with the same baseline of information, is also commonly mentioned (Sangwan et al. 2007). The main challenges for project management in the later stages of the software process is characterized as keeping track of emerging problems and their solutions as well the process of tracking progress for the individual teams (Sangwan et al. 2007). Therefore, the influence of the geographical distribution on the software process affects quality, time, as well as cost.

Impacts of the external factors on communication and collaboration

Culture

Different cultures tend to prefer different styles of communication and collaboration. For example, for members of more collectivistic oriented cultures, well-established personal relationships are of special importance for open communication (Konradt and Hertel 2002). Especially differences between power distance and individualism influence collaboration and trust (Winkler et al. 2008). It is recommended to prepare team members of GSD projects for intercultural collaboration by making them initially aware of cultural differences (Carmel 1999). During the phases of team building (especially storming and norming), project members of GSD projects also need ample time to get to know each other and to understand and reflect on culture-specific communication and collaboration behavior (Konradt and Hertel 2002). Here, considering the different cultural requirements for effective team building, communication, collaboration adds to the requirements for the communication infrastructure (Berkling et al. 2007) – for example, through communities and social network functionalities. In GSD projects, this factor can affect, albeit indirectly, all three criteria of quality, time, and cost.

Language, time zone & geographical distribution

Sosa et al. (2002) investigated the influence of language differences, overlapping working time, and geographical distance on project communication. They found that an increased distance led to a reduction of communication frequency across all media. Time zone and language differences are negatively correlated with the use of synchronous communication media (such as telephone) and positively correlated with asynchronous media (such as e-mail). The downsides of asynchronous media are the increased response times and a tendency to increased misunderstandings (Christiansen 2007). It can be assumed that the negative effect on collaboration is stronger when the storming and norming phases of team building also have to be conducted by asynchronous media. Therefore, the impact for GSD projects is seen as more pronounced on quality and time. In contrast, increased use of synchronous media in a GSD project (especially face-to-face meetings) is at least associated with additional cost due to travel.

Impacts of the external factors on knowledge transfer

Culture

Different cultural backgrounds in GSD projects lead to different experiences and knowledge bases of the individual team members, which in turn may not only inhibit communication, but also the knowledge transfer (Herbsleb 2007). The greater the similarity of the knowledge base and the higher the extent of a shared understanding, the more unambiguous and successful the exchanges between project members (Espinosa et al. 2007). The professional and technical knowledge to be shared is part of the written program code, part of the documentation, and part of the tacit knowledge of the developers (Ye et al. 2007). Here, Sangwan et al. (2007) speak of establishing a "collective mind" across the distributed teams,

so that all project members develop a shared understanding about their tasks and the overall project, facilitating easier knowledge transfer. Major criteria affected are quality (in terms of exchange of "lessons learned") and time and cost (in terms of reuse).

Language, time zone & geographical distribution

Since, as discussed above, direct communication opportunities for knowledge transfer are rare in GSD projects, written documentation in a shared language is a key means of exchanging knowledge (Prikladnicki et al. 2003). This includes professional and technical knowledge and also transparency about roles, responsibilities, and skills / knowledge / experience (Espinosa et al. 2007; Herbsleb and Moitra 2001). However, the use of written documentation cannot substitute face-to-face interaction (Espinosa et al. 2007; Ye et al. 2007) because both ways of transferring tacit knowledge (socialization and externalization) proposed by Nonaka and Takeuchi (1995) are grounded on direct exchanges. On the positive side, written communication can help to overcome language differences (Sosa et al. 2002). In sum, an effective knowledge transfer remains a key challenge for GSD projects, affecting all three criteria of quality, time, and cost.

Discussion and conclusion

The proposed conceptual model provides an integrated perspective on external and internal influence factors of global software development on the basis of the current literature and relates them on a conceptual level to common success criteria for GSD projects: time, cost, and quality. With the exception of the external influence factor of language, the external influence factors were found to influence all of the four internal influence factors. Also, in most cases, all three success criteria were affected for each combination of influence factors. The more detailed discussions showed selected interrelations between the external and internal influence factors, illustrating the need for the holistic perspective provided by the model. However, the limited space here did not allow a more comprehensive analysis and discussion of interrelations among the four external factors and the four internal factors. It was also not possible to consider and discuss the findings of individual studies in greater detail, relate them to underlying theory, or develop novel theoretical explanations for identified interplays.

The model itself can be used for guiding a structured meta-analysis and research synthesis (Cooper 2010; Cooper et al. 2009). This means to define a certain scope and research question, take the findings of individual studies, compare them, integrate them, or set them in relation to each other. Here, the holistic perspective of the conceptual model provides a structured way of constructing appropriate scopes combining the individual factors. This allows a more-in-depth perspective on the interplay between different factors or highlighting blind spots in current GSD research. To remedy identified blind spots, conceptually identified interrelations between influence factors can be tested empirically. During the meta-analysis, testable propositions can be formulated for specific interrelations condensing and combining the findings of the existing studies. Subsequently, several factors of the conceptual model may be integrated into more specific research models for specific interrelations. Within these research models, one influence factor may correspond to one or more constructs representing independent or moderating variables, depending on the scope and research focus. In turn, the evaluation of the partially integrated research models contributes to advancing GSD research beyond perspectives on individual influence or success factors. Here, the conceptual model developed in this paper helps integrating these findings into the overall picture of GSD project success.

In addition, some GSD research findings are now over ten years old. Since then, GSD has turned from a novel phenomenon to routine work in many contexts. Many experiences have been made and codified on the organizational and individual level, and GSD issues have also found their way into many curricula in higher education. Here, the conceptual model can also provide guidance for re-validating previous findings. Also, future design-oriented research (Gregor and Hevner 2013; Hevner et al. 2004) can take the identified influences and impacts to develop design knowledge for the theoretically-grounded design of GSD-specific organizational models or methods to cope with the identified challenges and evaluate them in practice. This further facilitates the knowledge transfer from research to practice and allows GSD research with actual impact in and high relevance for the GSD practice. In turn, it also allows evaluating the validity of the empirical findings which were used to develop the design knowledge in other settings.

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