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# Key factors that influence task allocation in global software development

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ABSTRACT

*Context:* Planning and managing task allocation in Global Software Development (GSD) projects is both critical and challenging. To date, a number of models that support task allocation have been proposed, including cost models and risk-based multi-criteria optimization models.
*Objective:* The objective of this paper is to identify the factors that influence task allocation in the GSD project management context.
*Method:* First, we implemented a formal Systematic Literature Review (SLR) approach and identified a set of factors that influence task allocation in GSD projects. Second, a questionnaire survey was developed based on the SLR, and we collected feedback from 62 industry practitioners.
*Results:* The findings of this combined SLR and questionnaire survey indicate that site technical expertise, time zone difference, resource cost, task dependency, task size and vendor reliability are the key criteria for the distribution of work units in a GSD project. The results of the *t*-test show that there is no significant difference between the findings of the SLR and questionnaire survey. However, the industry study data indicates that resource cost and task dependency are more important to a centralized GSD project structure while task size is a key factor in a decentralized GSD project structure.
*Conclusion:* GSD organizations should try to consider the identified task allocation factors when managing their global software development activities to better understand, plan and manage work distribution decisions.



## 1. Introduction

Global Software Development (GSD) is carried out by teams of knowledge workers located in various parts of the globe who develop commercially viable software for a company [1,2]. Due to its economic benefits, there continues to be an interest within the international software industry in implementing GSD [3]. A number of organizations across the globe have started adopting GSD to leverage the potential benefits of multi-site development with respect to cost and access to highly skilled resources. Client organizations, ranging from large to small companies, aim to benefit from GSD because vendors organizations in developing countries typically cost significantly less than in-house operations [4]. Furthermore, organizations also aim to take advantage of the follow-the-sun development model [5].

GSD is a complex socio-technical system where a number of geographically distributed teams collaborate with a view to produce working software [1,6]. Hence, the adoption of the GSD model is not straightforward and presents a number of challenges (e.g. cultural, temporal and communication issues [4,7–10]) including the key challenge of global project management across borders [11,12]. Poor global project management can cause chaos and can even be counterproductive by increasing the cost of sending work to low-cost regions [1,13,14].

Enabling effective global project management among GSD teams is an imperative and arduous task. Geographically distributed locations, different time zones and communication barriers present unique project management challenges in the global context. An important activity in global software development project management is task allocation which plays a fundamental role in planning GSD and is an important project control instrument [1,11,15]. In this paper, we adopt Jalote and Jain's task definition [16]: *"A task is the smallest unit of work with a well-defined functionality and external interface with other tasks"*. For example, a

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task could be developing a piece of code, writing requirements or designing technical documents, testing a software module or any other task in the process of software development [16,17].

The task allocation, being a project management activity, impacts the definition, planning and execution phases of globally distributed development projects [1,12,14,15,18]. Previous research work suggests that half of the companies that have tried GSD have failed to realize the anticipated outcomes, which has resulted in high development costs and poor services [8,19,20]. There are many reasons for these failures [19,21,22]. One of the issue is that organizations tend to struggle in task allocation activities of GSD projects because existing task allocation strategies lack depth and distribute team tasks based on limited criteria [20,23]. For example, Agerfalk et al. [24] indicated that organizations struggle to receive true benefits of GSD projects; one of the reason is lack of frameworks that allow practitioners to assign GSD project tasks horizontally with minimum interdependencies. Similarly, Lamersdof et al. [11] reported that practitioners believe their GSD projects have failed because task allocation focused too much on a single criteria (often the labor cost), while neglecting other criteria such a cultural difference, individual experience, expertise, proximity to customers and coupling between tasks. Despite the importance of this problem, little research has been done to understand the factors that influence task assignment in the context of GSD projects.

Similar to traditional software projects, GSD projects can be structured in two main ways: centralized and distributed project management structures. Some organizations may prefer to have mainly collocated teams and opt for structures with local coordinators, while others prefer a centralized structure [1,9,10]. For example, centralized structure plays an important role in projects that require intensive interaction among team members [25]. On the other hand, distributed structure has a low level of interdependence and facilitate information integration [25]. The selection of the GSD project management structure depending on the project size, organizational structure and the creation of work packages according to functional or regional criteria [1,9]. The maturity level of the organization in relation to global project management and the level of GSD experience of the project manager and team members are factors that need to be considered when choosing different GSD project structures [1,10,26]. Understanding task allocation factors with respect to centralized and distributed project management structures will help to facilitate the successful completion of projects. Therefore, the task allocation in GSD must take into account the global project structures, characteristics of sites and their relationships in terms of time zone differences and the availability of the workforce [1,15,27].

Despite the importance of this problem, little research has been done to understand the factors that influence task assignment in the context of GSD projects. Furthermore, there is no study (i.e. SLR and questionnaire based empirical study) has been conducted to analyze the factors that influence task allocation in GSD projects from centralized and distributed project management structure perspective.

The objective of this paper is to identify the factors that influence task allocation in GSD projects. We undertook a systematic literature review and surveyed practitioners. This review provides GSD scholars and practitioners with a body of knowledge by uncovering the multifaceted factors that influence task allocation in GSD. The identification of factors that influence task allocation will help to ensure that important points are not missed when considering task assignment strategies in order to find the best task allocation for a particular project. To do this, we address the following research questions:

*RQ1:* What are the factors, as identified in the literature that influence task allocation in globally distributed projects?

*RQ2:* What are the factors, as identified in the questionnaire survey, that influence task allocation in globally distributed projects?

*RQ3:* How are the factors, as identified in the questionnaire survey, related to centralized and distributed project management structures?

*RQ4:* Are there differences between the factors identified in the literature and the questionnaire survey?

We presented the initial results of the systematic literature review (RQ1) in a conference paper [28]. In this manuscript, we extend our work by adding the following details:

- Research Question # 1 – The complete set of results and analysis are presented based on the systematic literature review.
- Research Question # 2 – A questionnaire survey is developed based on the SLR results. The survey is then used to obtain feedback from 62 software industry experts from ten different countries. We present the new results and analysis based on the questionnaire-based study.
- Research Question # 3 – We present the new analysis by comparing the factors identified through the questionnaire survey for a centralized project management structure and a distributed project management structure.
- Research Question # 4 – We present new analysis by comparing the factors identified through the literature and the questionnaire survey.

We combined the SLR and questionnaire survey based approaches to compare theory with industrial practices for the following reasons:

- The SLR process was used as a method for data collection from literature (RQ1). To support our findings for RQ1 and to find the state-of-the-art industrial practices, the survey was developed to collect data from GSD practitioners based on their experience (RQ2).
- Furthermore, it is important to note that the primary studies used in RQ1 do not show how different factors are considered in centralized and distributed GSD project management structures. This gap in the literature has motivated us to gain insight into industry practice with reference to task allocation in different GSD project management structures. Hence, the questionnaire survey was used to collect data from GSD practitioners for centralized and distributed GSD project management structures (RQ3).
- The two-phase approach helps compare findings from the literature with the industrial practices (RQ4).

The remainder of this paper is organized as follows: Section 2 describes the background and related work. In Section 3, we discuss our research methodology. Section 4 describes the research results. In Section 5, we discuss the overall study results and limitations. Finally, Section 6 provides the conclusion and discusses how the findings from this study can be further used in future research endeavors.

## 2. Background and related work

### 2.1. Global project management background

Globally distributed projects involve team members working in different locations across the globe in different organizations. Globalization in the software industry has resulted in new challenges in the management of GSD projects [29]. Reported problems encountered in managing GSD projects include challenges associated with inter-site communication [26], coordination [26], knowledge sharing [1] and issues related to inter-personal relationships in global

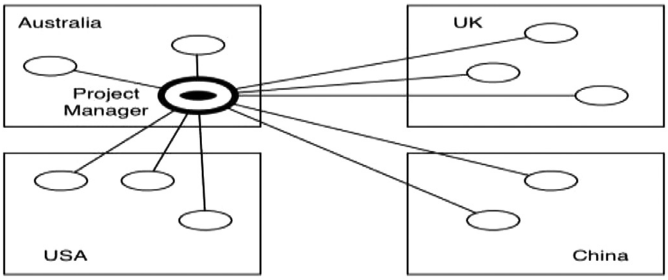


**Fig. 1.** Centralized Global Project Structure adopted from [1].

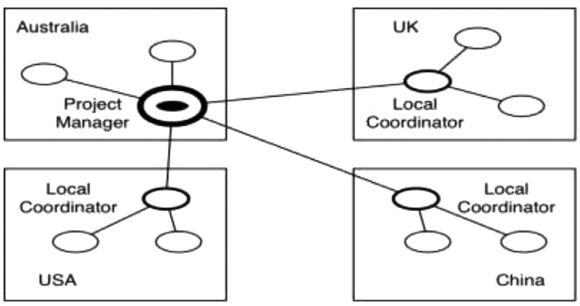


**Fig. 2.** Distributed Global Project Structure adopted from [1].

teams [1]. The literature, in some cases, also discusses the practices that help overcome such challenges [29].

Global project structure is another important aspect that has an impact on managing projects in global teams. The maturity level of the organization in undertaking global project management and the level of experience of the project manager and team members are factors that need to be considered when choosing the different project structures. GSD projects can be structured in different ways, depending on the project size, organizational structures and the creation of work packages according to functional or regional criteria [1].

According to [1], there are two main types of global project structures, namely, the centralized project management structure and the distributed project management structure. In the centralized project management structure, as shown in Fig. 1, team members report directly to the project manager, who performs most of the coordination and control tasks using collaborative tools. On the other hand, in the distributed project management structure, team members report directly to local coordinators, who are responsible for the planning and execution of work packages and reporting at regular intervals to the project manager, as shown in Fig. 2.

### 2.2. Task allocation technique related work

In this section, we present an overview of both theoretical and empirical supported task allocation models for GSD projects.

*Theoretical models:* Goldman et al. [30] propose a meta-model and identified that technical expertise and familiarity with development process are potential factors for work distribution across GSD sites. Setamanit et al. [31] develop a simulation model and identified social and technical factors for task allocation in GSD environment. Social factors include language difference, cultural difference, communication problems, and time shift while technical factors include team formulation, and GSD site expertise. Similarly, Gupta et al. [32] discuss the work distribution model with respect to 24 h knowledge factory paradigm and identified that resource cost, geographical distance, and commination issues are the major factor that influence work distribution in GSD environment. Pereira, et al. [33] developed framework for task allocation across GSD sites in software product lines projects and identified cultural and geographical difference as potential influencing factors. Mockus and Weiss [18] developed a model for optimizing task assignment with an aim to minimize cross site communication. Herbsleb and Perry [34] identified functional expertise and product structure as criteria for work distribution in the global context.

*Empirical supported models:* The allocation of development tasks to globally distributed sites is a critical success activity that has a direct influence on the benefits and risks associated with globally distributed projects [12,15,28,35]. A number of researchers have presented a range of multi-criteria optimization techniques to support task allocation in the global context. For example, Lamersdorf and Munch [36] used Bayesian networks to develop a planning tool, namely, TAMRI (Task Allocation Based on Multiple Criteria) to assign development tasks using weighted project goals.

Lamersdorf et al. [37] presented a risk-driven model to generate a set of task allocation alternatives, based on project characteristics. They analyze the proposed model with the potential project risks related to work distribution. Furthermore, they evaluated the proposed model by a series of semi-structured interviews in a multinational IT organization. Narendra et al. [38] presented a technique to develop a task allocation model for GSD projects. The proposed approach generates effort estimation for the new task allocation based on factors, such as effort estimation for a task at a particular site.

Lamersdorf et al. [11] presented an interview- based study aimed at identifying different task allocation criteria used in practice. The study shows that the sourcing strategy and the nature of the software to be developed have a direct effect on the applied criteria. The main task allocation criteria are labor costs, proximity to market, turnover rate and strategic planning. Wickramaarachchi and Lai [15] presented a software development life cycle phase-based work distribution technique for different locations with the aim of minimizing overhead costs. The technique uses a work dependency matrix and site dependency matrix to allocate tasks in a globally distributed project.

Refer to Section 5 for a comparison of empirical results with the theoretical models.

### 2.3. Need for an evidence-based study to identify factors for task allocation in a global context

Many GSD researchers have carried out empirical studies to better understand the success factors and challenges associated with software development in a global context. More recently, a number of systematic literature reviews and mapping studies have also been conducted in the area of GSD. For instance, Kroll et al. [39] presented an SLR to review best practice and the challenges associated with global software development processes. Similarly, Hanssen et al. [40] presented a systematic literature review with a focus on the application of agile methodologies in GSD. Carmel et al. [5] presented a mapping study to explore the challenges and best practice for project management in the global software development paradigm. Furthermore, Marques et al. [41] and Verner et al. [42] presented tertiary studies to categorize systematic reviews conducted in the GSD context. These tertiary studies identified that SLRs have been carried out for requirements design and management aspects of GSD projects.

However, the findings from these primary and tertiary studies indicate that no systematic study has been conducted on identifying the factors that influence the task allocation in GSD. Such a study is important for both practitioners and scholars to better understand the current state of the literature and industry in the context of task allocation in a GSD project. The study presented in this paper uncovers the factors that will assist organizations to better understand, plan and manage task allocation decisions in global projects. Moreover, we also provide evidence as to how the task allocation factors, as identified in the questionnaire survey, relate to centralized and distributed global project management structures.

## 3. Research methodology

In order to address the research questions in hand, we first used the SLR-based approach to survey the literature published in the public domain and identify the key factors that influence task allocation in GSD organizations (RQ1). Next, the SLR study results were used to develop a questionnaire survey to collect feedback from industry experts (RQ2 and RQ3). Finally, we compared the findings of the SLR and the questionnaire study (RQ4). We discuss the research methodology in detail in the following sections.

### 3.1. Data collection via systematic literature review

A systematic literature review (SLR) [43] is a methodology to identify, analyze and interpret primary studies with reference to specific research questions. In this study, we used an SLR for our literature data collection phase. An SLR reports evidence, based on the literature, for a given research context. Systematic reviews are formally planned and systematically executed. SLRs are recommended as a review methodology [43] because they allows researchers to systematically collect evidence from the literature, identify research gaps and provide a framework in which to position potential future research activities.

An SLR protocol was written to describe the overall plan for the task allocation literature survey in the context of our research. An SLR protocol consists of five main steps, i.e. (1) identification of research questions, (2) search strategy and search string, (3) study selection process, (4) quality assessment criteria; and (5) data extraction and analysis.

The SLR was undertaken by a team of five researchers, i.e. one student and four academic staff members. All team members participated in all the phases of the SLR process. To reduce personal bias and to improve the SLR process, inter-rater reliability tests were performed at the initial and final selection phases of the SLR process. The inter-rater agreement analysis is presented in Section 4.1.

#### 3.1.1. Search strategy and search

The search strategy for the SLR is based on the following four steps [44]:

1. Construct search terms by identifying keywords from population, intervention and outcome. We constructed the search terms based on population, intervention, outcome of relevance and experimental design [44] as follows:
   - Population: Global software development organizations.
   - Intervention: Task allocation criteria.
   - Outcome of Relevance: Factors that influence task allocation in GSD.
   - Experimental Design: Systematic literature review, expert options and empirical studies.
2. Find synonyms of the derived terms: We validated our terms in major academic databases and the following synonyms show potential relevance to the topic (as shown in Table 1).
3. Use Boolean operators
   - GLOBAL SOFTWARE DEVELOPMENT: Global Software Engineering OR Global software development OR Global software teams OR Distributed Software Engineering OR GSE OR Multisite software development.
   - TASK ALLOCATION: Task Allocation OR Work Distribution OR Software Development Management.
   - CRITERIA: Criteria OR Criterion OR Factor OR Determinants.

**Table 1**
Keywords and synonyms.

| Keywords | Synonyms |
|---|---|
| Global Software Development | Global software development, global software engineering, distributed software development, global software teams, multisite software development, global project management, GSD, GSE |
| Task Allocation | Task allocation, work distribution, software development management. |
| Factors | Factors, criteria, criterion, determinants |

4. Verify these terms in various academic databases

The data Collected Through Our Search String Was used as a reference for the development of the major search terms. In the scoping study, a few papers that were already known to be relevant (e.g. [11,15]) were used to validate the search terms.

After a trial search, we designed the final search string as follows:

[Global software development OR Global Software Engineering OR Distributed Software Engineering OR Global software teams OR Multisite software development OR GSE] AND

[Task Allocation OR Work Distribution OR Software Development Management] AND

[Criteria OR Criterion OR Factor OR Determinants]

The final search strings were applied on the following digital libraries (we tailored the search strings as per the individual search mechanisms of the following libraries):

- IEEE Explore.
- Science Direct.
- ACM Digital Library.
- Springer Link.
- John Wiley.

#### 3.1.2. Publication selection

The inclusion criteria are as follows:

- Publications with a focus on our research questions.
- Publications in English.
- In the case of duplicate publications, the most complete version published is included.
- Publications after 1995.

We applied the following exclusion criteria:

- Non-English publications.
- Papers that are not directly linked with the research questions.
- Publications without bibliographic information.

We exclude papers that are not directly linked with the research questions because there is a probability that the search engine returns irrelevant papers that contains few search string keywords.

For any paper to be included in the final selection, a quality assessment was done. A quality assessment of the selected studies was performed to evaluate the credibility and relevance of the selected studies. All papers were evaluated against a set of 9 quality criteria, as shown in Table 2. The first eight questions were adopted from the literature, while Q9 was proposed according to the scope and research question of this SLR. The scores of questions were determined using a three-point scale (i.e. yes, no and partial).

#### 3.1.3. Data extraction and synthesis

Grounded Theory-based coding scheme [50] provides an analytical approach in which concepts are identified, named and

**Table 2**
Quality assessment criteria.

| # | Questions |
|---|---|
| 1 | Is there a motivation for why the study was undertaken? [45] |
| 2 | Is the paper based on a research study? [46] |
| 3 | Is the research goal clearly reported? [46] |
| 4 | Is the proposed technique clearly discussed? [47] |
| 5 | Was the research empirically validated? [48] |
| 6 | Are the research results clearly discussed? [48] |
| 7 | Is there an explicit discussion about the limitations of this research? [49] |
| 8 | Does this study suggest solutions for task allocation in GSD? |

categorized through the close examination of data. We used the grounded theory-based coding scheme to review the literature and conceptualize the underpinning task allocation factors. We identified, labeled and grouped the related factors to general categories and calculated the frequency (the results are discussed in Section 4.1). Further, similar or related factors were semantically compared and grouped under relevant categories.

Data synthesis was performed by the project team and as a result of the extraction phase, a list of task allocation factors from the 31 papers was created. Initially, twenty-five individual task allocation factors were identified, as shown in Appendix A. Three researchers carefully reviewed each factor to minimize any particular researcher's bias and improve the validity of the identified task allocation factors. Once the twenty-five individual task allocation factors were reviewed and validated, the related factors were grouped into twelve major task allocation categories.

The grouping of the factors was done based on the context in which those factors were discussed in the primary studies. For example, the "technical expertise for GSD sites" and the "awareness about site expertise" were grouped together into one category as they were discussed in the same context of site technical expertise. Each major category represents a list of factors that influence task allocation in GSD projects.

### *3.2. Data collection via questionnaire survey*

Based on our SLR findings, we used a questionnaire survey to ask industry practitioners about the factors that influence task allocation in GSD. The questionnaire (Appendix E) was based on the task allocation factors (identified via the systematic literature review) that are important in GSD projects. The questionnaire was designed to elicit importance of the identified factors from the participants' perspectives [51,52]. The survey participants were asked to note each factor's relative importance as either 'strongly agree', 'agree', 'strongly disagree' or 'disagree'.

The questionnaire was also designed to elicit information about the global project management structure adopted in their GSD projects. The survey participants were asked to select a GSD project management structure as either a centralized structure or a distributed structure. Furthermore, the questionnaire also included an open-ended question that allowed the participants to include additional factors or comments.

The questionnaire was tested through a pilot study involving five software engineers from industry. Based on this pilot study, the final version of the questionnaire was developed. It is divided into three sections: section one collects demographic data, section two asks about factors that influence task allocation in GSD projects; and section three allows participants to include comments based on individual experiences during task allocation decisions in GSD projects. The participants were informed that the raw data would only be accessible to the research team, and the team would not share the data in a way that could reveal a participant's individual or organization's identity. Furthermore, data would be collated with other responses.

#### *3.2.1. Data sources*

In this study, the target population for the questionnaire survey was software practitioners with more than 5 years of experience in managing GSD projects. Finding a suitable sampling frame is very difficult for surveys for which no exhaustive register of the target population exists [53,54]. Hence, the participants for this study were recruited by using the snowball technique [55] that is typically used in questionnaire studies where the members of a population are difficult to locate [56–58].

Similar to other questionnaire survey based studies [59–61], an initial invitation to participate in this research was sent to potential participants via LinkedIn groups, mailing lists and industrial contacts of the research team. The software practitioners at the management level in organizations served as contact point for the study. The contact points were emailed the link for the web-based survey, which they were asked to forward the invitation to other relevant participants in their social network, as it will help provide characterization of unknown populations [56–58].The contact point also reported the total number of respondents from each organization and functioned as a checkpoint for the number of completed surveys.

Since we have used LinkedIn, mailing lists, industrial contacts and snowball technique, we acknowledge that the sample is not truly random. However, it is important to note that it is hard to find experts involved in task allocation activities in GSD, and as indicated by Coolican [62], if a truly representative sample is impossible to attain, the research should try to remove as much of the sample bias as possible. In order to make the sample representative of GSD practitioners in an organization, different groups of practitioners from different organizations were invited to participate in the research. These participants were from 10 different countries which includes Australia, India, Ireland, Malaysia, Saudi Arabia, UK and USA. The participants work for organizations that are involved in global software development projects ranging from business intelligence to data processing systems. Furthermore, the participants' roles in the organizations range from software project managers to team leaders with direct experience in GSD. Hence, we have confidence in the accuracy of their responses about factors that influence task allocation in GSD projects.

The completed questionnaires were manually reviewed for completeness and as a result of the review, four incomplete questionnaire response submissions were rejected. Finally, 62 useable questionnaire responses were included in this study for analysis. Appendix F presents a summary of participants' detail.

#### *3.2.2. Data analysis method*

We used the frequency analysis method to organize the data into group scores as it is helpful for analyzing descriptive information. The percentage of each data variable was then reported using the frequency tables. Frequencies were used to compare variables within or across groups and can be used for ordinal, nominal and numeric data [63–66]. In order to analyze the identified factors, the occurrence of each factor in each questionnaire was counted. Finally, the relative importance of each factor was identified by comparing the occurrences of each factor against the occurrences of other factors.

## **4. Results and discussion**

### *4.1. Systematic literature review findings (RQ1)*

In the SLR, the automated search resulted in 1866 papers. In the first review phase, the authors reviewed the titles, abstracts and conclusions of the selected papers and excluded studies that did not satisfy the inclusion criteria. In the second review phase, the complete texts from the papers selected in the previous step

**Table 3**
Paper selection data.

| Resource | Total results | First review selection | Second review selection | Final selection |
|---|---|---|---|---|
| IEEE Xplore | 778 | 164 | 20 | 13 |
| ACM | 73 | 22 | 6 | 0 |
| Science Direct | 349 | 35 | 8 | 2 |
| Springer | 621 | 44 | 18 | 14 |
| John Wiley | 38 | 13 | 5 | 2 |
| Total | 1866 | 278 | 57 | 31 |

**Table 4**
Factors identified via an SLR.

| Factors | Frequency (no. of papers ($n$) = 31) | Percentage |
|---|---|---|
| Site technical expertise | 21 | 68 |
| Time zone difference | 19 | 61 |
| Resource cost | 14 | 45 |
| Task dependency | 13 | 42 |
| Vendor reliability | 13 | 42 |
| Task size | 10 | 32 |
| Vendor maturity level | 8 | 26 |
| Geographic Distance | 6 | 19 |
| Local government regulations | 5 | 16 |
| Requirements Stability | 2 | 6 |
| Product architecture | 1 | 3 |
| Intellectual property ownership | 1 | 3 |

were reviewed and those that met the inclusion criteria were selected (57 papers). Finally, the authors applied quality assessment on the included papers and the papers that did not satisfy a minimum of 50% (similar to other researchers e.g. [48]) quality score were excluded. We finally selected 31 articles, as shown in Table 3. A list of primary studies selected in the SLR and their corresponding quality assessment scores are shown in Appendix B and C, respectively. The following data was extracted from each paper: authors, publication type, publication name, publisher, publication date and task allocation factors.

In order to reduce the researcher's bias, the inter-rater reliability test was performed where the three independent reviewers' selected ten publications randomly from the 'first review selection' list and performed the initial selection process. Similarly, the three independent reviewers also selected ten publications randomly from the 'second review selection' list and performed the final selection and quality assessment processes.

We used the non-parametric Kendall's coefficient of concordance ($W$) [67] to evaluate the inter-rater agreement between reviewers. The Kendall's coefficient of concordance ($W$) value has a range from 0 to 1 with 1 indicating perfect agreement and 0 indicating perfect disagreement. Kendall's coefficient of concordance ($W$) for ten randomly selected publications from the 'first review selection' was 0.87 ($p = 0.009$), which indicates strong agreement between the results of primary researchers and independent reviewers. Similarly, Kendall's coefficient of concordance ($W$) for ten randomly selected papers from the 'second review selection' list was 0.82 ($p = 0.0063$), which also indicates agreement between the findings of primary researchers and independent reviewers.

Table 4 Factors Identified via an SLR Table 4 lists twelve criteria that influence task allocation in global software development. In our study, the most highly cited criterion for task allocation in GSD projects is site technical expertise (68%). The development sites are spread across geographical boundaries and each site has particular expertise e.g. programming skills and tool usage skills that influence product quality as well as other factors that impact the project. Hence, selecting sites with appropriate domain expertise and knowledge is crucial to the success of a GSD project. This factor mainly ensures product quality within the budget and time requirements. For example, interviews with GSD project managers in [11] revealed that matching specific technical skill sets available at a vendor site is one of the most important criteria for task allocation.

The second highest frequently mentioned criterion is time zone difference (61%). Lamersdorf et al. [11] argue that time zone differences have a positive as well as negative impact on overall effort. GSD project managers typically use time zone difference to their advantage and decrease the overall delay by allowing 24 h development, that is, "follow-the-sun" [5,12] or "round the clock development" [5,36] under certain conditions, such as mature process, and ultimately decrease overall effort. On the other hand, time shift between sites increases communication and coordination problems which cause increases in delays and overall effort [31] and also time zone difference may necessitate night shifts which decrease employee motivation and ultimately decrease productivity [37].

Resource cost is another key criterion (reported by 45% of the articles selected from the SLR) for work distribution in a GSD project. In general, researchers and practitioners report that the resource cost consideration is an important factor during the development of globally distributed projects. Typically, project managers aim to assign work units to low labor cost sites.

On the other hand, GSD practitioners have also highlighted that cost alone should not be used as a sole criterion for task allocation because highly coupled tasks assigned to different sites potentially contribute to increased communication and project execution costs [68,69]. Another factor that needs consideration for choosing low cost is related to the required technical expertise on that site which directly impacts software quality [35]. For this factor, there is trade-off between cost and product quality and the project manager needs to consider which is most important - quality or low cost.

Task dependency is another key criterion for work distribution decisions in globally distributed projects, mentioned in more than 42% of the articles. Jalote et al. [16] argue that it can increase the overall development time and also limit the benefits of having multiple sites/resources. For example, a group is unable to start the next task until the previous one is finished, consequently, resources in other groups may be wasted. This factor has a positive as well as a negative influence on many other factors, such as time zone [12,36] and resource cost [68,69]. Such dependencies also need consideration in the task allocation.

Two other factors observed are vendor reliability and vendor maturity level at 42% and 26%, respectively. Researchers have discussed both factors in terms of respective past experience and provide an important insight for the task allocation. For example, [31] explain these two factors in terms of member familiarity which impacts team performance, stating that the more familiarity between team members, the better the performance of the GSD team. They also argue that distance between teams can negatively impact organizational performance as physical distance can cause communication and coordination problems. However, this effect can be mitigated by a number of factors, for example, Lamersdorf et al. [37] describe that a mature process can overcome com-

**Table 5**
Empirical study strategy used.

| Study type | Count | Percentage |
|---|---|---|
| Case study | 19 | 61 |
| Survey | 8 | 26 |
| Experiment | 4 | 13 |

munication problems which ultimately affects productivity and in [27] they discussed that a better Capability Maturity Model Integrated (CMMI) [70] level (over all site processes) can overcome this problem and results in improved productivity. In summary, researchers have cited that the perceived reliability of a particular vendor helps clients to better manage task allocation risks in global teams.

Local government regulation is another factor cited by 16% of research papers. Lamersdorf and Munch [14] discuss that the local government regulations impact the compatibility between GSD sites. Similarly, Lamersdorf et al. [12] discuss that government regulations impact reasons as determining the terms and conditions of a country in relation to their labor force i.e. what work can be assigned within the country, working hour regulations, salary rules etc.

Other factors in work distribution through task allocation in GSD teams are ‘requirements stability’, ‘product architecture’ and ‘intellectual property ownership’, with 6%, 3% and 3% of the articles mentioning these as task allocation criteria in GSD projects, respectively. Lamersdorf et al. [27] discusses it as a “degree of change in the requirements during the project” which ultimately impacts overall effort overhead. Less frequently mentioned factors are ‘product architecture’ and ‘intellectual property ownership’.

#### 4.1.1. Empirical research strategy analysis

In this sub-section, we discuss different empirical investigations used in the primary studies, as shown in Table 5. The primary studies have used three different types of empirical investigations, namely, case study, survey and experiment, which are commonly used in research strategies in empirical software engineering domain [71] . The results indicate that 61% of the primary studies have used case study for empirical investigation. Similarly, survey and experiments have been used for empirical investigation by 26% and 13% of the primary studies, respectively.

Furthermore, Table 6 shows a mapping between task allocation factors, empirical study strategies and source primary studies. For example, in our study, the most highly cited criterion for task allocation in GSD projects is site technical expertise (frequency = 21). The results indicate that 62% of the twenty-one primary studies who have cited site technical expertise as a factor have used case study for empirical investigation. Similarly, survey and experiments have been used for empirical investigation by 28% and 10% of the twenty-one primary studies, respectively. Similarly, task dependency is another key criterion for work distribution decisions in globally distributed projects, mentioned in nineteen primary studies. The results indicate that 52% of the nineteen primary studies who have cited task dependency as a factor have used case study for empirical investigation. Similarly, survey has been used for empirical investigation by 42% of the nineteen primary studies.

#### 4.1.2. Publication venues analysis

In this sub-section, we present analysis on the publication venues and source types of the published primary studies. The primary studies are published in five publication types: conferences, journals, workshop, symposium and book chapter. Table 7 shows the distribution of primary studies over publication types. Conferences and journals are two main publication types with 61% (19 studies) and 23% (7 studies).

The international conference on global software engineering and journal of systems and software are two main publication venues for task allocation research in global software development context. Furthermore, the temporal view of the primary studies in shown in Appendix D.

### 4.2. Questionnaire survey findings (RQ 2)

We have conducted initial survey to compare findings from the literature with the real world practice.

#### 4.2.1. Results

In the second step of our research, we analyzed the data received from 62 participants in our questionnaire survey. Table 8 summarizes the responses.

The responses were divided into two main categories: positive responses and negative responses. Positive refers to responses asserting that the listed factors do influence task allocation in a GSD project. On the other hand, a negative response implies that a particular factor is not perceived as an important attribute that impacts task allocation in a GSD project.

More than 90% of the participants agreed that ‘site technical expertise’, time zone difference, resource cost, task dependency and requirements stability are key factors that influence task allocation decisions in a GSD project. For example, one of the participants supported his positive response for site technical expertise with the following comment:

*“We allocate tasks, keeping in mind the required technical expertise available at different development sites”. Development Lead*

Similar to site technical expertise, task dependency is a task allocation factor that received a high percentage (96%) of positive responses from the participants. A majority of the participants also agreed that inter-dependencies between different tasks are also considered during the work distribution of a GSD project. This indicates that task allocation in a GSD project is multi-objective in nature, where task dependency is an equally important factor that is considered by GSD practitioners.

*“I have seen companies that failed with their GSD adoption due to ignoring dependencies between different work units and only considering low cost as their decision factor. My strategy is to cluster inter-dependent tasks as work packages and assign them to one team or site.” Team Leader*

Requirements stability also received a high percentage (96%) of positive responses from the participants. Focusing on achieving stable requirements is a task allocation factor that leads to a successful GSD project.

*“One factor which for sure influences the task allocation decision in a global software development project is that system requirements should be stable. I advise others who define a requirements change management process. It can help them in better managing global software development projects and also in achieving their goals.” Requirements Manager*

Furthermore, time zone difference also received a very high (95%) positive response from the participants. Time zone differences between different development sites facilitate a reduction in development time by assigning tasks to different time zone sites.

*“We intend to use GSD only because work can be carried out 24/7, thus, the development budget can be reduced”. Project Manager*

Resource cost is the fourth factor, which received more than a 90% positive response. In general, practitioners try to minimize resource cost by assigning work units to low cost sites.

**Table 6**
Factor analysis in context of empirical studies.

| Factor | Empirical studies classification | | | Primary studies |
|---|---|---|---|---|
| | Case study | Survey | Experiment | |
| Site technical expertise | 13 | 6 | 2 | A1, A2, A3, A4, A5, A6, A7, A9, A12, A13, A14, A17, A18, A22, A23, A24, A27, A28, A29, A30, A31 |
| Time zone difference | 10 | 8 | 1 | A1, A2, A3, A4, A5, A6, A7, A8, A10, A13, A15, A16, A17, A18, A20, A22, A23, A24, A26, A30 |
| Resource cost | 9 | 4 | 1 | A1, A3, A5, A6, A7, A8, A9, A12, A21, A22, A23, A24, A26, A27, |
| Task dependency | 10 | 2 | 1 | A1, A2, A3, A4, A5, A6, A7, A8, A9, A10, A11, A12, A13 |
| Vendor reliability | 8 | 4 | 1 | A1, A2, A3, A4, A8, A11, A12, A18, A20, A22, A21, A24, A28, |
| Task size | 7 | 2 | 1 | A1, A2, A3, A4, A5, A6, A8, A13, A15, A17 |
| Vendor maturity level | 5 | 2 | 1 | A1, A2, A3, A8, A11, A22, A29, A31 |
| Geographic Distance | 3 | 3 | 0 | A1, A3, A4, A20, A21, A22 |
| Local government regulations | 3 | 2 | 0 | A1, A3, A7, A22, A24 |
| Requirements Stability | 2 | 0 | 0 | A2, A14 |
| Product architecture | 0 | 1 | 0 | A22 |
| Intellectual property ownership | 0 | 1 | 0 | A1 |

**Table 7**
Distribution of selected studies over source type.

| Publication channel | Frequency | Percentage |
|---|---|---|
| Conference | 19 | 61 |
| Journal | 7 | 23 |
| Workshop | 3 | 10 |
| Symposium | 1 | 3 |
| Book Chapter | 1 | 3 |
| Total | 31 | 100 |

*"We started with GSD because our main challenge was the high labor cost in the UK market. At the beginning of our transition to the GSD approach, we only used cost as a factor to distribute project work units. It has worked well most of the time." Development Manager*

*4.2.2. Qualitative analysis for interactions between factors and their effect on task allocation decisions*

In this subsection, we present the qualitative analysis of the feedback shared by participants on the relationships between factors during task allocation decisions. The experience of the participants is collected as part of an open ended question, namely, 'how different factors affect task allocation decisions in a GSD project?'. The participants indicated three key objectives that together influence task allocation decisions of a GSD project, namely, increase work quality, decrease cost and minimize production time. These three key objectives are also core project management knowledge areas as per the PMBOK [72]. The identified task allocation factors are related to the three core project management knowledge areas.

The participants in the study indicate that the objective of increasing work quality relies heavily on "site technical expertise", "vendor reliability", "vendor maturity level", "requirements stability", and "product architecture". The feedback from the subjects also indicate that "resource cost" and "intellectual property ownership" associated with individual sites directly affect the task allocation decision as project managers' aim to minimize development cost. The participants also indicated that "local government regulations" at different sites are also considered while task allocation decisions are made to minimize overall development cost. Finally, the participants highlighted that information about "time zone differences", "task size", "task dependency" and "geographical distance" between sites are mainly considered to minimize production time and utilize round the clock capabilities of sites involved in a GSD project.

*4.2.3. Client vendor based analysis*

In the questionnaire survey, a demographic field asked for the correspondents' client and vendor perspective in GSD projects. The responses gathered reflect the experience of practitioners from client and vendor perspective. We apply the chi-square test of independence to compare the two categorical variables (i.e. client and vendor) from a single population. The chi-square test results are shown in Table 9. Our hypothesis is as follows:

*Null hypothesis:* There is no significant association between the identified task allocation factors and GSD client vendor perspective.

A comparison of task allocation factors from the client and vendor perspective indicates that there are more similarities than differences between the participants of, as shown in Table 9. The *p*-Value for site technical expertise, resource cost, task dependency, task size, geographical distance, local government regulations, requirements stability, product architecture, and intellectual property ownership is greater than 0.05. Hence, we accept the null hypothesis and conclude that these task allocation factors are independent of the client vendor perspective of GSD environment.

**Table 8**
Questionnaire survey results.

| | Positive | | | Negative | | |
|---|---|---|---|---|---|---|
| | Strongly agree | Agree | Percentage | Disagree | Strongly disagree | Percentage |
| **Site technical expertise** | 35 | 26 | 98 | 1 | 0 | 2 |
| **Time zone difference** | 28 | 31 | 95 | 3 | 0 | 5 |
| **Resource cost** | 27 | 31 | 93 | 4 | 0 | 7 |
| **Task dependency** | 36 | 24 | 96 | 1 | 1 | 4 |
| Vendor reliability | 27 | 27 | 87 | 7 | 1 | 13 |
| Task size | 22 | 32 | 87 | 8 | 0 | 13 |
| Vendor maturity level | 24 | 29 | 85 | 9 | 0 | 15 |
| Geographical distance | 25 | 28 | 85 | 9 | 0 | 14 |
| Local government regulations | 24 | 18 | 67 | 18 | 2 | 33 |
| **Requirements stability** | 26 | 34 | 96 | 1 | 1 | 4 |
| Product architecture | 16 | 29 | 72 | 13 | 4 | 28 |
| Intellectual property ownership | 16 | 32 | 77 | 13 | 1 | 23 |

**Table 9**
Chi square test results of client vendor data.

| Factors | Occurrence in survey ($n = 62$) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Client ($n = 22$) | | | | Vendor ($n = 40$) | | | | Chi-square test (linear by linear association) $\alpha = 0.05$ | | |
| | SA | A | D | SD | SA | A | D | SD | $X^2$ | Df | $p$-Value |
| Site technical expertise | 15 | 7 | 1 | 0 | 20 | 19 | 1 | 0 | 2.134 | 1 | 0.144 |
| **Time zone** | **4** | **18** | **0** | **0** | **24** | **13** | **3** | **0** | **4.874** | **1** | **0.027** |
| Resource cost | 13 | 7 | 2 | 0 | 14 | 24 | 2 | 0 | 1.541 | 1 | 0.214 |
| Task dependency | 12 | 10 | 0 | 0 | 24 | 14 | 1 | 1 | 0.015 | 1 | 0.901 |
| **Vendor reliability** | **12** | **10** | **0** | **0** | **15** | **17** | **7** | **1** | **4.131** | **1** | **0.042** |
| Task size | 6 | 11 | 5 | 0 | 16 | 21 | 3 | 0 | 2.521 | 1 | 0.112 |
| **Vendor maturity level** | **11** | **11** | **0** | **0** | **13** | **18** | **9** | **0** | **4.717** | **1** | **0.030** |
| Geographical distance | 9 | 8 | 3 | 0 | 16 | 20 | 6 | 0 | 0.004 | 1 | 0.950 |
| Local government regulations | 13 | 3 | 5 | 1 | 11 | 15 | 13 | 1 | 2.409 | 1 | 0.121 |
| Requirements stability | 9 | 11 | 1 | 1 | 17 | 23 | 0 | 0 | 0.894 | 1 | 0.345 |
| Product architecture | 5 | 9 | 7 | 1 | 11 | 20 | 9 | 0 | 1.295 | 1 | 0.255 |
| Intellectual property ownership | 8 | 9 | 5 | 0 | 8 | 23 | 8 | 1 | 0.912 | 1 | 0.340 |

**Table 10**
Summary results based on organization size based analysis.

| Respondents' organization size | No. of significant factors (cited as strongly agree by ≥50 of participants) |
|---|---|
| Small ($n = 32$) | *3 factors:*<br>Site technical expertise<br>Task dependency<br>Resource cost |
| Medium ($n = 21$) | *5 factors:*<br>Site technical expertise<br>Task dependency<br>Resource cost<br>Time zone<br>Requirements stability |
| Large ($n = 9$) | *6 factors:*<br>Site technical expertise<br>Task dependency<br>Resource cost<br>Task size<br>Time zone<br>Requirements stability |

On the other hand, the $p$-Values for time zone, vendor reliability and vendor maturity level factors are 0.027, 0.042 and 0.030, respectively. The $p$-Values for resource cost, task dependency and task size factors are less than 0.05, hence, our results are statistically significant and we reject our null hypothesis.

All the industrial practitioners belonging to client organizations either strongly agreed or agreed that time zone is an important factor for task allocation in GSD projects. On the other hand, 92% of the industry practitioners from vendor organizations either strongly agreed or agreed that time zone is an important factor for task allocation in GSD projects, while 8% disagreed.

Similarly, 100% of the industry practitioners belonging to client organizations either strongly agreed or agreed that vendor reliability is an important factor for task allocation in GSD projects. On the other hand, 20% of the industrial practitioners from vendor perspective either disagreed or strongly disagreed that vendor reliability is an important factor for task allocation in GSD projects.

#### 4.2.4. Organization size based analysis

To provide deeper insight into the findings, we analyzed the significant factors based on organization size. Table 10 shows the participants into three groups based on their organization size. Organizations with less than 20 employees are classified as 'small', a 'medium' company has between 20 and 199 employees; and a 'large' company has more than 200 employees [73]. Site technical expertise, task dependency and resource cost were reported as the significant factor across small, medium and large companies. However, participants from medium and large organizations agreed that time zone and requirements stability are also significant factors. It is important to note that the classification presented in Table 10 only shows the significance of these motivators by different viewpoints. The table does not show the relative importance of these categories by different viewpoint.

### 4.3. RQ3: how are the factors, as identified in the industry survey, related to centralized and distributed project management structures? (based on survey data)

#### 4.3.1. Results

In the questionnaire survey, a demographic field asked for the correspondents' organizational management structure (i.e. centralized or distributed) in GSD projects. The responses gathered reflect the experience of practitioners from centralized and distributed structured organizations. We apply the chi-square test of independence to compare the two categorical variables (i.e. centralized and distributed) from a single population. The chi-square test results are shown in Table 11. Our hypothesis is as follows:

*Null hypothesis:* There is no significant association between the identified task allocation factors and GSD project management structure.

A comparison of task allocation factors from the centralized and distributed project management structures indicates that there are more similarities than differences between the two GSD project management structures, as shown in Table 11. The $p$-Value for site technical expertise, time zone, vendor reliability, vendor maturity level, local government regulations, requirements stability, product architecture and intellectual property ownership is greater than 0.05. Hence, we accept the null hypothesis and conclude that these task allocation factors are independent of the two GSD project management structures.

On the other hand, the $p$-Values for resource cost, task dependency and task size factors are 0.015, 0.042 and 0.025, respectively. The $p$-Values for resource cost, task dependency and task size factors are less than 0.05, hence, our results are statistically significant and we reject our null hypothesis.

All of the industry practitioners who applied a centralized GSD project management structure either strongly agreed or agreed that resource cost is an important factor for task allocation in GSD projects. On the other hand, only 80% of the industry practitioners who applied a decentralized GSD project management structure either 'strongly agreed' or 'agreed' that resource cost is an important factor for task allocation in GSD projects, while 20% disagreed.

Similarly, 100% of the industry practitioners who applied a centralized GSD project management structure either 'strongly agreed' or 'agreed' that task dependency is an important factor for task

**Table 11**
Chi square test results of industry data.

| Factors | Occurrence in survey ($n = 62$) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Distributed ($n = 20$) | | | | Centralized ($n = 42$) | | | | Chi-square test (linear by linear association) $\alpha = 0.05$ | | |
| | SA | A | D | SD | SA | A | D | SD | $X^2$ | Df | p-Value |
| Site technical expertise | 11 | 8 | 1 | 0 | 24 | 18 | 0 | 0 | 0.243 | 1 | 0.622 |
| Time zone | 8 | 11 | 1 | 0 | 20 | 20 | 2 | 0 | 0.244 | 1 | 0.621 |
| **Resource cost** | **6** | **10** | **4** | **0** | **21** | **21** | **0** | **0** | **5.885** | **1** | **0.015** |
| **Task dependency** | **9** | **9** | **1** | **1** | **27** | **15** | **0** | **0** | **4.145** | **1** | **0.042** |
| Vendor reliability | 8 | 9 | 3 | 0 | 19 | 18 | 4 | 1 | 0.089 | 1 | 0.765 |
| **Task size** | **10** | **10** | **0** | **0** | **12** | **22** | **8** | **0** | **5.045** | **1** | **0.025** |
| Vendor maturity level | 8 | 9 | 3 | 0 | 16 | 20 | 6 | 0 | 0.004 | 1 | 0.950 |
| Geographical distance | 9 | 8 | 3 | 0 | 16 | 20 | 6 | 0 | 0.004 | 1 | 0.950 |
| Local government regulations | 6 | 6 | 7 | 1 | 18 | 12 | 11 | 1 | 1.198 | 1 | 0.274 |
| Requirements stability | 7 | 12 | 1 | 0 | 19 | 22 | 0 | 1 | 0.404 | 1 | 0.525 |
| Product architecture | 7 | 8 | 4 | 1 | 9 | 23 | 9 | 1 | 0.213 | 1 | 0.644 |
| Intellectual property ownership | 7 | 8 | 5 | 0 | 9 | 24 | 8 | 1 | 0.384 | 1 | 0.535 |

**Table 12**
Comparison of the two data sets.

| Task allocation factor categories | SLR Freq $n = 31$ | % | Rank | Strongly Agree Freq $n = 62$ | % | Rank |
|---|---|---|---|---|---|---|
| Site technical expertise | 21 | 68 | **1** | 35 | 58 | **2** |
| Time zone difference | 19 | 63 | **2** | 28 | 45 | **3** |
| Resource cost | 14 | 45 | 3 | 27 | 43 | 4 |
| **Task dependency** | **13** | **42** | **4** | **36** | **58** | **1** |
| Vendor reliability | 13 | 42 | 5 | 27 | 43 | 5 |
| **Task size** | **10** | **32** | **6** | **22** | **35** | **10** |
| Vendor maturity level | 8 | 26 | 7 | 24 | 38 | 8 |
| Geographical Distance | 6 | 19 | 8 | 25 | 39 | 7 |
| Local government regulations | 6 | 16 | 9 | 24 | 38 | 9 |
| **Requirements stability** | **5** | **6** | **10** | **26** | **41** | **6** |
| Product architecture | 2 | 3 | 11 | 16 | 25 | 11 |
| Intellectual property ownership | 1 | 3 | 12 | 16 | 25 | 12 |

allocation in GSD projects. On the other hand, 20% of the industry practitioners who applied a 'decentralized' GSD project management structure either 'disagreed' or 'strongly disagreed' that task dependency is an important factor for task allocation in GSD projects.

Furthermore, 100% of the industry practitioners who applied a decentralized GSD project management structure either 'strongly agreed' or 'agreed' that task size is an important factor for task allocation in GSD projects. On the other hand, 20% of the industry practitioners who applied a centralized GSD project management structure either 'disagreed' or 'strongly disagreed' that task size is an important factor for task allocation in GSD projects.

### *4.4. Comparison of the two data sets (RQ 4)*

#### *4.4.1. Results*

In the previous sections, we identified the factors that influence the task allocation in a GSD project from both the literature survey (through SLR) and the questionnaire survey. For each factor in the questionnaire, there are four options: strongly agree, agree, disagree and strongly disagree. In Table 12, we present the rank of each task allocation factor based on the SLR and the questionnaire survey results. We also compare the number of responses in the "strongly agree" option of the questionnaire survey with the motivation factors identified in the SLR.

The comparison shows that there are some similarities and differences between the SLR and the questionnaire (see Table 12). The majority of task allocation factors identified in the SLR received similar responses from the experts via the questionnaire. A comparison of the two data sets indicates that researchers and practitioners agree on the key factors that influence task allocation in a GSD, namely, site technical expertise, time zone difference and resource cost. It is important to note that task dependency was ranked 4th in the SLR findings while practitioners ranked it as the most important factor that influences task allocation in a GSD project. This reinforces that it is important to consider the dependency relationships among tasks because it determines the order in which activities need to be performed.

**Table 13**
Group statistics.

| | Type | N | Mean | Standard deviation | Standard error mean |
|---|---|---|---|---|---|
| Factor | SLR | 12 | 31.2728 | 22.69401 | 6.84250 |
| | Survey | 12 | 41.2727 | 10.20873 | 3.07805 |

In order to quantify the significance of the similarity in the motivation factors identified using the SLR and the questionnaire survey, we applied the independent $t$-test to compare the mean difference of the SLR and the questionnaire, as shown in Tables 13 and 14. Our hypothesis is as follows:

*Null hypothesis:* The population variances of two data sets (i.e. SLR and questionnaire survey) are equal.

Table 13 shows the descriptive statistics of the two data sets used for this study. Table 14 shows the independent sample $t$-test results. The $t$-test assumes that the variability of each group is approximately equal. If this assumption isn't met, then a special form of the $t$-test should be used. The columns labeled "Levene's Test for Equality of Variances" is used to check the assumption that the $t$-test has been met or not.

In this study, the $p$-Value for Levene's test is $0.012 < 0.05$ so equal variance is not considered an option. Hence, we check the $p$-Value to accept or reject the hypothesis. The $p$-Value for this option is $0.205 > 0.05$, so, we accept the null hypothesis. This indicates that the SLR and the questionnaire survey data sets tend to be very close to the mean (expected value) and hence to each other.

**Table 14**
Independent samples *t*-test.

| | | Levene's test for equality of variances | | *t*-test for equality of means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *F* | Sig. | *t* | d*f* | Sig. (2-tailed) | Mean difference | Std. error difference | 95% confidence interval of the difference | |
| | | | | | | | | | Lower | Upper |
| Factor | Equal variances assumed | 7.688 | 0.012 | −1.333 | 20 | 0.198 | −10.00000 | 7.50295 | −25.65087 | 5.65087 |
| | Equal variances not assumed | | | −1.333 | 13.888 | 0.205 | −10.00000 | 7.50296 | −26.10441 | 6.10441 |

**Table 15**
Summary of results.

| Research question | Summary of answers |
|---|---|
| RQ1: What are the factors, as identified in the literature that influence task allocation in GSD projects? | • Site technical expertise<br>• Time zone difference |
| RQ2: What are the factors, as identified in the questionnaire survey, that influence task allocation in globally distributed projects? | • Site technical expertise<br>• Time zone difference<br>• Resource cost<br>• Task dependency<br>• Task size |
| RQ4: Are there differences between the factors identified in the literature and the questionnaire survey? | • Researchers and practitioners agree on key factors that influence task allocation in a GSD project, namely, site technical expertise, time zone difference and resource cost |

## 5. Discussion

*Critical task allocation factors:* In this paper, we identified a set of factors that influence task allocation decisions in global software projects. To analyze the criticality of a particular factor, we use the following criterion: "The factor is considered significant if it is cited in the literature with a frequency of greater than or equal to 50%" or "the factor is considered significant if the question is answered as strongly agree in the survey questionnaire with a frequency of ≥90%." Similar criterion has been used in previous research studies [63,74,75]. Table 15 summarizes the key factors that research and industry community think have a major impact on the task allocation activity of a GSD project.

With reference to RQ1, we identify two critical task allocation factors, namely, site technical expertise and time zone difference. However, other task allocation factors which have a frequency greater than 40%, such as resource cost and task dependency can also be considered important and need to be used during the creation of work units in a GSD project. With reference to RQ2, data shows that site technical expertise, time zone difference, resource cost, task dependency and task size have a major impact on the task allocation activity of a GSD project. For RQ4, the data shows that site technical expertise is the common critical task allocation factor in the SLR and questionnaire-based survey. Other task allocation factors such as time zone difference, resource cost, task dependency, task size and requirements stability are also very important factors for global software development managers.

*Comparison of empirical results with theoretical models:* Table 16 presents the comparison of task allocation factors identified from empirical study with task allocation theoretical models. Few existing theoretical models individually consider site technical expertise, task dependency, vendor maturity level and geographic distance as factors to model task allocation in GSD projects. However, only one theoretical model considers resource cost a as factor for task allocation GSD projects. Moreover, no theoretical model considered vendor reliability, task size, local government regulations, requirements stability, product architecture or intellectual property ownership. Geographic distance and site technical expertise are two factors that have been considered by most of the existing theoretical models. We believe that there is a need to develop new task allocation models for GSD context that consider the key factors identified in this study to assist project managers and lead developers to realize the benefits associated with adopting the global software development methodology.

*Relationship between sites:* In GSD projects, the development sites are spread across geographical boundaries and each site has particular expertise. The development sites also have relationships between them in terms of familiarity with different site expertise and awareness about the knowledge of skill sets of these sites. In our study, the relationship between sites is inherently depicted in technical site expertise factor, as shown in Appendix A.

*Global project management structure based analysis:* Global software development projects can be either centralized and distributed structures, depending on the project size, complexity and the creation of work packages according to functional or regional criteria [1]. For RQ3, the questionnaire survey-based data indicates that there are more similarities than differences between the identified task allocation factors across centralized and distributed global project management structures. However, there are some differences of the two datasets such as 80% of the respondents from the distributed group and 100% of the respondents from the centralized group indicate that 'resource cost' is important. Similarly, 90% of the respondents from the distributed group and 100% of the respondents from the centralized group indicate that 'task dependency' is important.

It is important to note that the primary studies identified in the SLR discuss task allocation factors for general global project management and there is a lack of research on how the task allocation factors are impacted by different global project management structures. The questionnaire-based survey, presented in this study, is the first attempt to address the important research gap identified in the SLR by the collected feedback on the importance of different task allocation factors with reference to both centralized and distributed global project management structures.

*Limitations of the study:* This study applied a combined SLR and questionnaire-based study approach. One of the potential limitations of a SLR is incompleteness. The results depend on the keywords used and the limitations of the search engines. We mitigated this risk of incompleteness in the search terms by using alternative spellings and synonyms to build the search terms. We also used different electronic databases to reduce the inherent limitations of the existing search engines. The scope of the SLR study is limited to task allocation factors in the context of GSD.

**Table 16**
Comparison of empirical and theoretical research.

| Factors identified from empirical study | Theoretical research models | | | | | |
|---|---|---|---|---|---|---|
| | Goldmann, et al. [30] | Setamanit et al. [31] | Gupta et al. [32] | Pereira et al. [33] | Mockus and Weiss [18] | Herbsleb and Mockus [34] |
| Site technical expertise | √ | √ | ✖ | ✖ | √ | √ |
| Time zone difference | ✖ | √ | ✖ | ✖ | ✖ | √ |
| Resource cost | ✖ | ✖ | √ | ✖ | ✖ | ✖ |
| Task dependency | ✖ | ✖ | ✖ | ✖ | √ | √ |
| Vendor reliability | ✖ | ✖ | ✖ | ✖ | ✖ | ✖ |
| Task size | ✖ | ✖ | ✖ | ✖ | ✖ | ✖ |
| Vendor maturity level | √ | √ | ✖ | ✖ | √ | √ |
| Geographic distance | ✖ | √ | √ | √ | √ | √ |
| Local government regulations | ✖ | ✖ | ✖ | ✖ | ✖ | ✖ |
| Requirements Stability | ✖ | ✖ | ✖ | ✖ | ✖ | ✖ |
| Product architecture | ✖ | ✖ | ✖ | ✖ | ✖ | ✖ |
| Intellectual property ownership | ✖ | ✖ | ✖ | ✖ | ✖ | ✖ |

Another possible limitation of a SLR is the frequency calculation. The frequency of factors depends on the use of grounded theory based coding scheme which provides an analytical approach to identify, label and group task allocation factors and calculated the frequency. This might lead to researcher's bias. In order to reduce the researcher's bias, the inter-rater reliability tests were performed at the initial and final selection phases of the SLR process. The inter-rater agreement analysis is presented in Section 4.1. The results of inter-rater agreement analysis indicate agreement between the findings of primary researchers and independent reviewers.

One possible limitation of the questionnaire-based study is a potential lack of experience to respond to the questions. In our study, there is no threat of this in terms of internal validity because all the participants had either a degree in computer science or related fields and experience managing industry GSD projects. Another possible threat is potential ambiguity in the survey questions. To minimize the misunderstandings, the first author was available via Skype and email during the study to clarify any potential ambiguities in the survey. In this paper, we used standard statistical techniques to either accept or reject the null hypotheses. We used independent samples *t*-test and chi-square test to validate our results. Furthermore, the survey questionnaire was also designed using standard scales.

The inherent limitation of questionnaire-based studies lies in their external validity. This is primarily due to difficulty in achieving a true random sample of participants and low participation rates [53]. Similar to other researchers (for example, [54]), we used LinkedIn, mailing lists, industrial contacts and snowball technique to engage potential participants in the study. Finally, 62 useable questionnaire responses were included in the study for analysis. The response rate is similar to other questionnaire-based studies reported by the software engineering community [76,77]. However, as indicated by Lethbridge et al. [78], questionnaire-based surveys with low participants rates can be used to understand trends. Hence, we believe that the results of the study are at least a reasonable indicator of industrial practice for task allocation activity in GSD projects.

In our work, we mitigate potential bias by using the snowball sampling technique where GSD project managers serve as contact points in the organizations involved. The contact points are used to forward the survey to other relevant potential respondents.

*Study implications:* This study provides the state-of-the-art status of GSD task allocation research. The findings of the questionnaire are found to be in agreement with literature and provide a comparison of task allocation factors from the centralized and distributed project management structures. The study results provide a ranked set of task allocation factors, which serves as a knowledge-based for both researchers and practitioners. Ranking task allocation factors is important for researchers, so that they can focus and direct their research in high priority areas of GSD task allocation. It is also anticipated that the identified task allocation factors can be helpful to GSD practitioners for developing task allocation strategies and policies. In a nutshell, this paper provides a consolidated knowledge-base of the literature and an empirical study, which has not been done before.

Practical recommendations for GSD project managers are as follows:

1. Task allocation in a GSD project should not be assigned only on a single factor, for example, cost should not be used as the only criterion for task allocation.
2. GSD project managers should group inter-dependent tasks as work packages and assign them to one team or site.
3. GSD project managers should use task allocation tools that generate flexible schedules with an ability to absorb delays in activities without requiring substantial rescheduling.
4. Tasks should be assigned to teams based on their knowledge and skill related to the problem domain.
5. The characteristics of individual tasks, organizations and their sites should be modeled together to facilitate potential tradeoffs between different allocation scenarios.

These practical recommendations can help GSD organizations to make informed decisions on assigning tasks to sites, which can potentially improve the success of GSD projects.

## 6. Conclusion and future work

This paper presents an SLR and a questionnaire survey that was conducted to identify the factors that influence task allocation in GSD. Identifying task allocation factors will support global software development organizations to better understand, plan and manage work distribution decisions.

The results of this study indicate that the top ranked task allocation factors are: site technical expertise, time zone difference, resource cost, task dependency, vendor reliability and task size. Overall, the results of the independence *t*-test which were used to compare the SLR findings with the industry expert's feedback show that the research and software industry are aligned and share the same factors that influence task allocation in a GSD project. Furthermore, the chi-square test is used to analyze the task allocation factors, as identified in the questionnaire survey, related to a centralized and distributed GSD project management structure. The results show that resource cost and task dependency are more important task allocation factors in a centralized project management structure. Similarly, project managers in a distributed GSD project management structure are more concerned about task size. The chi-square results also indicate that site technical expertise, time zone, vendor reliability and vendor maturity level are equally important for centralized and distributed GSD project management structures.

For future work, we plan to conduct further empirical studies to understand the inter-dependencies between the identified task allocation factors and their impact on the success or failure of a GSD project. There is a need to conduct empirical studies to determine the best industry practices for managing GSD projects. We also plan to develop task allocation techniques using our study's findings which can assist project managers and lead developers to realize the benefits associated with adopting the global software development methodology.

## Acknowledgments

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## Appendix A. Task allocation categories identified Via SLR

| Final task allocation factors | Task allocation factors – sub categories |
|---|---|
| Site technical expertise | • Technical expertise for GSD sites.<br>• Familiarity with site expertise<br>• Awareness about site expertise<br>• Knowledge of skill set of distributed teams |
| Time zone difference | • Time zone difference<br>• Geographic difference<br>• Distance differences |
| Resource cost | • Resource cost<br>• Site cost<br>• Distributed team cost |
| Task dependency | • Task dependency<br>• Task inter dependency |
| Vendor reliability | • Vendor reliability<br>• Vendor past experience<br>• Vendor rating |
| Geographic distance | • Geographic distance<br>• Geographical dispersion |
| Task size | • Task size<br>• Work unit size |
| Vendor maturity level | • Vendor maturity<br>• Vendor readiness |
| Local government regulations | • GSD site's government regulations |
| Requirements stability | • Requirements stability |
| Product architecture | • Product Architecture |
| Intellectual property ownership | • Intellectual property ownership |

## Appendix B. List of articles selected in SLR

**A1:** A. Lamersdorf and J. Münch, "A multi-criteria distribution model for global software development projects," Journal of the Brazilian Computer Society, vol. 16, pp. 97–115, 2010.

**A2:** A. Lamersdorf and J. Münch, "Model-based task allocation in distributed software development," in Software Engineering Approaches for Offshore and Outsourced Development, ed: Springer, pp. 37–53, 2010.

**A3:** A. Lamersdorf, J. Münch, and D. Rombach, "A decision model for supporting task allocation processes in global software development" in Product-Focused Software Process Improvement, ed: Springer, pp. 332–346, 2009.

**A4:** J. Münch and A. Lamersdorf, "Systematic task allocation evaluation in distributed software development," in 2009 Workshop on the Move to Meaningful Internet Systems (OTM 2009), pp. 228–237, 2009.

**A5:** Y. Ye, K. Nakakoji, and Y. Yamamoto, "Measuring and monitoring task couplings of developers and development sites in global software development," in Software Engineering Approaches for Offshore and Outsourced Development, ed: Springer, pp. 181–195, 2009.

**A6:** H. Hu, B. Xu, Y. Ling, X. Yang, Z. He, and A. Ma, "Micro-estimation Based Global Collaborative Task Arrangement in Distributed Software Design," in Computer Supported Cooperative Work in Design IV, ed: Springer, pp. 64–75, 2008.

**A7:** S. Vathsavayi, O. Sievi-Korte, K. Koskimies, and K. Systä, "Planning Global Software Development Projects Using Genetic Algorithms," in Search Based Software Engineering, ed: Springer, pp. 269–274, 2013.

**A8:** A. Lamersdorf and J. Munch, "TAMRI: a tool for supporting task distribution in global software development projects," in 4th IEEE International Conference on Global Software Engineering, (ICGSE 2009), pp. 322–327, 2009.

**A9:** J. Helming, H. Arndt, Z. Hodaie, M. Koegel, and N. Narayan, "Automatic assignment of work items," in Evaluation of Novel Approaches to Software Engineering, ed: Springer, pp. 236–250, 2011.

**A10:** M. Yilmaz and R. V. O'Connor, "A market based approach for resolving resource constrained task allocation problems in a software development process": Communications in Computer and Information Science, vol. 301, Springer, pp. 25–36, 2012.

**A11:** S. Doma, L. Gottschalk, T. Uehara, and J. Liu, "Resource allocation optimization for GSD projects," in Computational Science and Its Applications–ICCSA 2009, ed: Springer, pp. 13–28, 2009.

**A12:** N. Celik, S. Lee, E. Mazhari, Y.-J. Son, R. Lemaire, and K. G. Provan, "Simulation-based workforce assignment in a multi-organizational social network for alliance-based software development," Simulation Modelling Practice and Theory, vol. 19, pp. 2169–2188, 2011.

**A13:** P. Jalote and G. Jain, "Assigning tasks in a 24-h software development model," Journal of Systems and Software, vol. 79, pp. 904–911, 2006.

**A14:** A. Lamersdorf, J. Münch, A. F. VisoTorre, C. R. Sánchez, M. Heinz, and D. Rombach, "A rule-based model for customized risk identification and evaluation of task assignment alternatives in distributed software development projects," Journal of Software: Evolution and Process, vol. 24, pp. 661–675, 2012.

**A15:** S.-o. Setamanit, W. Wakeland, and D. Raffo, "Exploring the impact of task allocation strategies for global software development using simulation," in Software Process Change, ed: Springer, pp. 274–285, 2006.

**A16:** M. Ruano-Mayoral, C. Casado-Lumbreras, H. Garbarino-Alberti, and S. Misra, "Methodological framework for the allocation of work packages in global software development," Journal of Software: Evolution and Process, vol. 26, pp. 476–487, 2014.

**A17:** D. Wickramaarachchi and R. Lai, "A method for work distribution in Global Software Development," in 3rd IEEE International Conference on Advance Computing Conference (IACC 2013), pp. 1443–1448, 2013.

**A18:** A. Lamersdorf, J. Munch, A. Fernández-del VisoTorre, and C. Rebate Sanchez, "A risk-driven model for work allocation in global software development projects," in 6th IEEE Inter-

national Conference on Global Software Engineering (ICGSE 2011), pp. 15–24, 2011.

**A19:** D. K. Mak and P. Kruchten, "Task coordination in an agile distributed software development environment," in Canadian Conference on Electrical and Computer Engineering, (CCECE'06), pp. 606–611, 2006.

**A20:** A. Lamersdorf, J. Munch, and D. Rombach, "Towards a multi-criteria development distribution model: An analysis of existing task distribution approaches," in IEEE International Conference on Global Software Engineering (ICGSE 2008), pp. 109–118, 2008.

**A21:** N. C. Narendra, K. Ponnalagu, N. Zhou, and W. M. Gifford, "Towards a Formal Model for Optimal Task-Site Allocation and Effort Estimation in Global Software Development," in 2012 Annual SRII Global Conference (SRII 2012), pp. 470–477, 2012.

**A22:** A. B. Marques, J. R. Carvalho, R. Rodrigues, T. Conte, R. Prikladnicki, and S. Marczak, "An Ontology for Task Allocation to Teams in Distributed Software Development," in 8th International Conference on Global Software Engineering (ICGSE 2013), pp. 21–30, 2013.

**A23:** A. Lamersdorf, J. Munch, and D. Rombach, "A survey on the state of the practice in distributed software development: Criteria for task allocation," in 4th International Conference on Global Software Engineering (ICGSE 2009), pp. 41–50, 2009.

**A24:** M. Cataldo and S. Nambiar, "Quality in global software development projects: A closer look at the role of distribution," in 4th IEEE International Conference on Global Software Engineering (ICGSE 2009), pp. 163–172, 2009.

**A25:** D. K. Mak and P. B. Kruchten, "NextMove: A framework for distributed task coordination," in 18th Australian Software Engineering Conference (ASWEC 2007), pp. 399–408, 2007.

**A26:** M. Ruano-Mayoral, R. Colomo-Palacios, J. M. Fernández-González, and Á. García-Crespo, "Towards a framework for work package allocation for GSD," in 2011 Workshop on the Move to Meaningful Internet Systems (OTM 2011), pp. 200–207, 2011.

**A27:** I. Richardson, V. Casey, J. Burton, and F. McCaffery, "Global software engineering: A software process approach," in Collaborative Software Engineering, ed: Springer, pp. 35–56, 2010.

**A28:** S. Imtiaz, "Architectural task allocation in distributed environment: a traceability perspective," in 34th International Conference on Software Engineering, pp. 1515–1518, 2012.

**A29:** S. Deshpande, S. Beecham, and I. Richardson, "Global Software Development Coordination Strategies-A Vendor Perspective," in New Studies in Global IT and Business Service Outsourcing, ed: Springer, pp. 153–174, 2011.

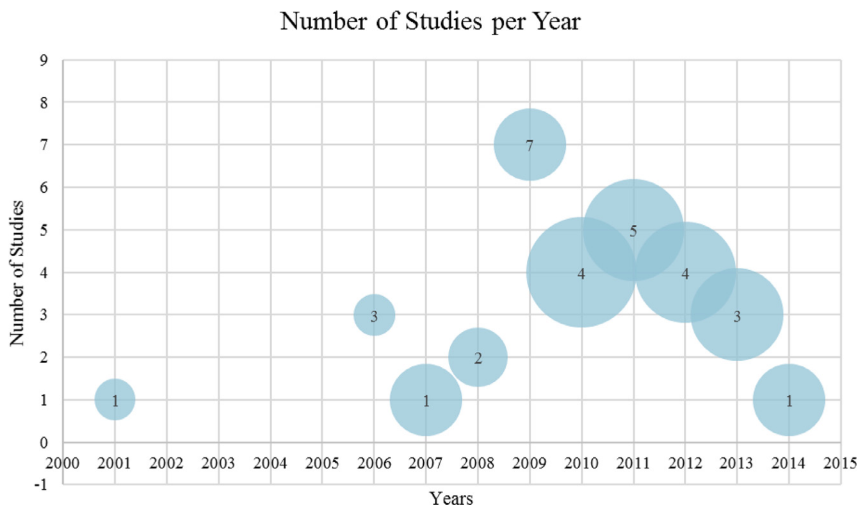
**A30:** A. Lamersdorf, J. Munch, A. F.-d. V. Torre, C. R. Sánchez, and D. Rombach, "Estimating the effort overhead in global software development," in 5th IEEE International Conference on Global Software Engineering (ICGSE 2010), pp. 267–276, 2010.

**A31:** R. D. Battin, R. Crocker, J. Kreidler, and K. Subramanian, "Leveraging resources in global software development," Software, IEEE, vol. 18, pp. 70–77, 2001.

## Appendix C. SLR primary study quality assessment results

| ID | Author | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Total score | Qual.(%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Lamersdorf et al. [A1] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.0 | 6.0 | 75.0 |
| 2 | Lamersdorf et al. [A2] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 7.0 | 87.5 |
| 3 | Lamersdorf et al. [A3] | 0.5 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 6.5 | 81.2 |
| 4 | Munch et al. [A4] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.0 | 6.0 | 75.0 |
| 5 | Nakakoji et al. [A5] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.0 | 6.5 | 81.2 |
| 6 | Hu et al. [A6] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 1.0 | 7.0 | 87.5 |
| 7 | Vathsavayi et al. [A7] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.0 | 0.0 | 5.5 | 68.7 |
| 8 | Lamersdorf et al. [A8] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.0 | 6.0 | 75.0 |
| 9 | Helming et al. [A9] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.0 | 6.0 | 75.0 |
| 10 | Yilmaz et al. [A10] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.0 | 6.5 | 81.2 |
| 11 | Doma et al. [A11] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.0 | 6.0 | 75.0 |
| 12 | Celik et al. [A12] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 7.0 | 87.5 |
| 13 | Jalote et al. [A13] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.0 | 6.5 | 81.2 |
| 14 | Lamersdorf et al. [A14] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.0 | 6.5 | 81.2 |
| 15 | Setamanit et al. [A15] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 1.0 | 7.0 | 87.5 |
| 16 | R. Mayoral et al. [A16] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.0 | 6.5 | 81.2 |
| 17 | Wickrammaarachchi et al. [A17] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.0 | 6.0 | 75.0 |
| 18 | Lamersdorf et al. [A18] | 1.0 | 1.0 | 1.0 | 0.5 | 1.0 | 1.0 | 0.5 | 0.0 | 6.0 | 75.0 |
| 19 | Mak et al. [A19] | 1.0 | 1.0 | 1.0 | 0.5 | 1.0 | 0.5 | 0.5 | 1.0 | 6.5 | 81.2 |
| 20 | Lamersdorf et al. [A20] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.0 | 6.0 | 75.0 |
| 21 | Narendra et al. [A21] | 1.0 | 1.0 | 1.0 | 0.5 | 1.0 | 1.0 | 0.5 | 0.0 | 6.0 | 75.0 |
| 22 | Marques et al. [A22] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.0 | 6.5 | 81.2 |
| 23 | Lamersdorf et al. [A23] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 7.0 | 87.5 |
| 24 | Cataldo et al. [A24] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 1.0 | 0.0 | 6.5 | 81.2 |
| 25 | Mak et al. [A25] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.0 | 6.5 | 81.2 |
| 26 | R. Mayoral et al. [A26] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.0 | 6.0 | 75.0 |
| 27 | Richardson et al. [A27] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 1.0 | 0.0 | 6.5 | 81.2 |
| 28 | Imtiaz et al. [A28] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.0 | 6.5 | 81.2 |
| 29 | Deshpande et al. [A29] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.0 | 6.5 | 81.2 |
| 30 | Lamersdorf et al. [A30] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 7.0 | 87.5 |
| 31 | Battin et al. [A31] | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 7.0 | 87.5 |

## Appendix D. Temporal view of primary studies




## Appendix E. Questionnaire survey

1. **Practitioner's Details**

   **Full Name**

   **Job Title / Position**

   **Experience (in years) –** Your experience in managing global software development projects in current/previous organizations.

   **Country**

   **Telephone No**

   **E-mail Address**

2. **Demographics**

   **In which country is your company is located? Please specify:**

**Approximately how many staff are employed by your company?**

- Less than 20
- 20-199
- Greater than 200
- Don't Know

**What is the scope of your company?**

- Client
- Vendor
- Other

**if you choose others (Please specify)**

**Approximately how many different geographically sites are used by your company?**

- 1-5
- 5-10
- Greater than 10
- Don't Know

**What type of systems are your company concerned with?**
(You may tick more than one)

- Safety Critical
- Data Processing
- Business Systems
- Telecommunications
- Windows Based
- Other

**if you choose others (Please specify)**

**What type of global software systems are your company concerned with?**
(You may tick more than one)

- Safety Critical
- Data Processing
- Business Systems
- Telecommunications
- Windows Based
- Other

**if you choose others (Please specify)**

### 3. Global Project Management Structure

**What is the global project management structure used at your company?**

- ☐ Centralized Global Project Structure
  (Team members report directly to the project manager)
- ☐ Decentralized Global Project Structure
  (Team members report directly to local coordinator, who reports to the project manager)

### 4. Factors that Influence Task Allocation in Global Software Development projects

The objective of this paper is to identify the factors that influence task allocation in the GSD project management context. Please select the appropriate box based on your experience of task allocation in global software development projects.

| Factors | Strongly Agree | Agree | Disagree | Strongly Disagree |
|---|---|---|---|---|
| Site technical expertise | ○ | ○ | ○ | ○ |
| Time zone difference | ○ | ○ | ○ | ○ |
| Resource cost | ○ | ○ | ○ | ○ |
| Task dependency | ○ | ○ | ○ | ○ |
| Vendor reliability | ○ | ○ | ○ | ○ |
| Task size | ○ | ○ | ○ | ○ |
| Vendor maturity level | ○ | ○ | ○ | ○ |
| Geographic Distance | ○ | ○ | ○ | ○ |
| Local government regulations | ○ | ○ | ○ | ○ |
| Requirements stability | ○ | ○ | ○ | ○ |
| Product architecture | ○ | ○ | ○ | ○ |
| **Factors** | Strongly Agree | Agree | Disagree | Strongly Disagree |
| Intellectual property ownership | ○ | ○ | ○ | ○ |

**Other Factors:** ☐ Yes ☐ No.

If Yes, please specify:

### 5. In light of your experience, how different factors affect task allocation decisions in a GSD project?

## Appendix F. Participant details

| Job titles | Experience | Company size | Scope of company | Number of geographic sites | Type of systems |
|---|---|---|---|---|---|
| Project Manager | 8 years | 20–199 employees | Vendor | 5–10 | Data processing and system development |
| Team Leader | 5 years | Less than 20 employees | Vendor | 1–5 | Business systems |
| Team Leader | 6 years | Less than 20 employees | Vendor | 5–10 | Windows based systems |
| Development Manager | 5 years | Less than 20 employees | Vendor | 1–5 | Business systems |
| Project Manager | 8 years | 20–199 employees | Client | 5–10 | Data processing and business systems |
| Project Manager | 9 years | Less than 20 employees | Client | 1–5 | Business systems |
| Team Leader | 6 years | 20–199 employees | Vendor | 5–10 | Data processing, financial and business systems |
| Team Leader | 7 years | 20–199 employees | Client | 5–10 | Data processing, business systems, systems software and telecommunication |
| Project Manager | 11 years | 20–199 employees | Vendor | 5–10 | Data processing, financial and business systems |
| Team Leader | 7 years | 20–199 employees | Client | 5–10 | Business systems |
| Project Manager | 6 years | Less than 20 employees | Vendor | 1–5 | Data processing and business systems |
| Team Leader | 10 years | 20–199 employees | Vendor | 5–10 | Data processing and business systems |
| Project Manager | 8 years | Greater than 200 employees | Vendor | Greater than 10 | Data processing, business systems, systems software, telecommunications, windows based |
| Project Manager | 16 years | 20–199 employees | Client | 5–10 | Business systems |
| Project Manager | 10 years | Greater than 200 employees | Vendor | Greater than 10 | Business systems |
| Team Leader | 6 years | 20–199 employees | Client | 1–5 | Business systems |
| Project Manager | 7 years | 20–199 employees | Client | 5–10 | Business systems |
| Team Leader | 5 years | 20–199 employees | Client | 1–5 | Data processing and business systems |
| Project Manager | 11 years | Less than 20 employees | Vendor | 1–5 | Business systems |
| Project Manager | 11 years | Less than 20 employees | Vendor | 5–10 | Data processing, business systems, systems software, telecommunications, windows based |
| Project Manager | 9 years | 20–199 employees | Vendor | 5–10 | Windows based systems |
| Development Lead | 7 years | 20–199 employees | Vendor | 5–10 | Data processing and business systems |
| Team Leader | 5 years | 20–199 employees | Vendor | 5–10 | Data processing and business systems |
| Project Manager | 8 years | 20–199 employees | Client | 5–10 | Data processing, business systems, systems software and telecommunication |
| Requirements Manager | 8 years | Less than 20 employees | Client | 5–10 | Business systems |
| Team Leader | 10 years | 20–199 employees | Vendor | 1–5 | Business systems |
| Development Manager | 6 years | Less than 20 employees | Vendor | 1–5 | Insurance and financial systems |
| Project Manager | 13 years | 20–199 employees | Vendor | 5–10 | Insurance and financial systems |
| Development Manager | 7 years | 20–199 employees | Client | Greater than 10 | Data processing, business systems, systems software and telecommunication |
| Requirements Manager | 11 years | Less than 20 employees | Vendor | 1–5 | Data processing and business systems |
| Project Manager | 5 years | Less than 20 Employees | Client | 1–5 | Business systems |
| Team Leader | 5 years | 20–199 employees | Vendor | 5–10 | Data processing, business systems, systems software, telecommunications, windows based |
| Project Manager | 14 years | Greater than 200 employees | Vendor | Greater than 10 | Windows based, real time systems, and embedded systems. |
| Team Leader | 8 years | Less than 20 employees | Vendor | 5–10 | Financial and data processing systems |
| Team Leader | 5 years | 20–199 employees | Vendor | 5–10 | Data processing and business systems |
| Development Manager | 11 years | 20–199 employees | Client | 5–10 | E-Governance |
| Project Manager | 6 years | 20–199 employees | Client | 5–10 | Windows based, real time systems, and embedded systems. |
| Development Manager | 5 years | Greater than 200 employees | Vendor | Greater than 10 | Windows based, real time systems, and embedded systems. |
| Project Manager | 14 years | 20–199 employees | Vendor | 1–5 | Data processing and business systems |
| Team Leader | 5 years | Less than 20 employees | Client | 1–5 | Data processing and business systems |
| Project Manager | 10 years | 20–199 employees | Client | 5–10 | Insurance systems |
| Team Leader | 13 years | 20–199 employees | Vendor | 1–5 | Financial and data processing systems |

(continued on next page)

(*continued*)

| Job titles | Experience | Company size | Scope of company | Number of geographic sites | Type of systems |
|---|---|---|---|---|---|
| Team Leader | 6 years | Less than 20 employees | Vendor | 1–5 | Data processing and business systems |
| Development Manager | 5 years | 20–199 employees | Vendor | 5–10 | E-Governance. |
| Team Leader | 6 years | 20–199 employees | Client | 5–10 | Data processing, business systems, systems software and telecommunication |
| Team Leader | 7 years | 20–199 employees | Vendor | 5–10 | E-Governance |
| Development Manager | 14 years | 20–199 employees | Vendor | 5–10 | Data processing, business systems, systems software and telecommunication |
| Team Leader | 5 years | Less than 20 employees | Vendor | 1–5 | telecommunication |
| Requirements Manager | 14 years | Less than 20 employees | Vendor | 1–5 | Data processing, business systems, systems software and telecommunication |
| Team Leader | 7 years | Less than 20 employees | Vendor | 5–10 | Data processing, business systems, windows based, real time systems and embedded systems |
| Team Leader | 13 years | 20–199 employees | Vendor | 1–5 | Business systems and data processing |
| Team Leader | 6 years | 20–199 employees | Client | Greater than 10 | Data processing, business systems, windows based, real time systems and embedded systems |
| Development Manager | 5 years | Less than 20 employees | Client | 1–5 | Business systems |
| Requirements Manager | 10 years | Less than 20 employees | Vendor | 1–5 | Business systems |
| Team Leader | 11 years | 20–199 employees | Vendor | Greater than 10 | Data processing, business systems, windows based and real time systems |
| Development Manager | 14 years | Less than 20 employees | Vendor | 1–5 | Business systems |
| Team Leader | 14 years | Less than 20 employees | Vendor | 1–5 | E-Governance |
| Team Leader | 5 years | 20–199 employees | Vendor | Greater than 10 | Windows based, real time systems, and embedded systems. |
| Development Manager | 11 years | Less than 20 employees | Vendor | 1–5 | Business systems |
| Development Lead | 5 years | 20–199 employees | Vendor | 5–10 | Data processing, business systems, systems software and telecommunication |
| Team Leader | 6 years | Less than 20 employees | Vendor | 5–10 | Financial systems |
| Team Leader | 5 years | 20–199 employees | Vendor | 5–10 | Data processing, business systems, systems software and telecommunication |

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