Framework for Task Allocation in Global Software Development

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ABSTRACT The Global Software Development (GSD) promises high-quality software at low cost. It enables round-the-clock development to achieve maximum production in a short period by utilizing expertise around the globe. GSD is only possible if tasks are effectively distributed among sites to ensure smooth development. Therefore, one of the key challenges of GSD is designing a task allocation (TA) strategy. The main objective of the present research is to develop a framework that takes into account important factors, while allocating tasks to distributed sites involved in GSD. The current allocation in plan-based software development is done on ad-hoc basis and does not follow any systematic approach or framework. The framework facilitates decision-makers in allocation of tasks in a manner that controls delay and re-allocation. The study uses a mixed method approach, where the data used to create the framework is acquired via an industrial survey (58 participants) and interviews (10 participants) with GSD practitioners. The developed task allocation framework is validated with the help of an online focus group with participants (7 participants) from around the globe. The ability of the framework to be applicable in real-world scenarios is assessed from the feedback of industry practitioners. They have highlighted the usefulness of the framework to both, practitioners involved in task allocation decision as well as researchers working in the area. The automation and validation of the framework in real-world GSD scenarios is part of future work of this research.

INDEX TERMS Computer-mediated communication, global software development, online focus group, task allocation framework.

I. INTRODUCTION

Global Software Development (GSD) is a special case of distributed development where the teams differ from each other by culture, time difference, knowledge and spatial location. Development of software across these boundaries is a challenging task. The many benefits associated with GSD make it an endeavor worth trying and it is the reason most of the multinational, medium and small-sized software organizations are going global. The objective to choose GSD varies from capturing the local market, reducing development cost to increasing product quality. The benefits can only be achieved if GSD is successfully performed. The GSD challenges or risks can be minimized through an effective task allocation (TA) decision [1]. Effective TA ensures smooth development without the need for re-allocation, as tasks are

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allocated to the most suitable sites considering the development cost, expertise, availability and temporal distance, etc. Factors highlighted as important for effective TA are labor cost and expertise [2]–[5], personal availability [4], time differences [5]–[8], cultural differences [5], [6], [8], experience of individuals, proximity to customers [5], costs of development, and coupling between tasks [6], [7], [9], [10]. Allocation is usually based on limited criteria; the reported factors are not considered altogether, resulting in project failure, as reported by practitioners [11].

Such TA framework would only be applicable in the case of traditional software development. It is not part of agile project management as the task is chosen by workers instead of task assignment; therefore, the scope of this work is limited to plan-based methods.

The research starts with the identification of information critical to the TA decision. The critical information in the form of factors is identified and validated by GSD

practitioners [12]. Moreover the detail of the TA activity that is the dynamics and tacit knowledge that go into making the decision are identified via detailed interviews with GSD practitioners; the design, execution, and result of the interview study are also discussed in this article.

The proposed TA framework is based on the data acquired via survey and interview of GSD practitioners. The TA framework is presented in planes, where each plane consists of factors critical to a TA decision in GSD. Explicit documentation of these factors raises awareness about the critical information that should be considered for an effective allocation decision. Correlation between the factors is depicted via interdependence between the planes. The explicit consideration of values of attributes (critical factors) and their correlations along with variations to the GSD situation help in reaching the final TA decision. Such an allocation decision has fewer chances of re-allocation; it results in smooth software development and does not cause project delay.

The GSD suffers from many challenges due to complexities, essential to distributed development. Difficulty of managing the project, communication and coordination overhead and decrease in team cohesion are some of the major issues that need to be resolved to gain benefits from GSD. These issues are inherent in the very nature of distributed development and can have severe consequences such as project delay and cost overrun along with other major consequences.

Therefore, managing distributed development, especially global, is a challenging task. The GSD challenges or risks can be minimized through an effective TA decision [1]. There is inconsistency in the knowledge on what information goes into making a TA decision in GSD. The literature that motivates the need for a well-informed TA decision advocates the importance of many factors [3], [4], [13]; however, strategies or approaches used for TA (both in literature and industry) do not consider them.

Organizations often only consider labor costs or expertise as a TA criterion, resulting in project failure, as reported by practitioners [11]. Moreover, factors are often considered individually, and multiple factors are not evaluated together during TA decision [15], adding to the complexity of the decision. Lack of information on what are the critical factors that are important and should be considered for an effective allocation decision makes practitioners revert to ad-hoc decision-making. This ad-hoc TA is inefficient and unable to handle management issues, leading to frequent changes in allocation, further delaying the project. Further research is needed to understand the critical information, dynamics, and variations of a TA decision.

A task allocation framework is of significant importance for the research as well as practitioners. On one hand the framework combines all the critical TA factors for evaluation. Secondly the different situations of GSD during TA decision is also highlighted in form of variations points and weights assigned to the factors. The framework is based on data from literature as well as practitioners around the globe, therefore is of significant importance and representative of the actual

TA decision. The framework is also useful for practitioners to be used during actual TA decisions in GSD.

The study is presented in eight sections, starting with Literature Review in Section 2. Research Methodology is given in Section 3. Section 4 details the Design, Execution and Results of Interview Study, where the proposed TA Framework is given in Section 5. Validation of the TA Framework via Online Focus Group is discussed in detail in Section 6. Section 7 presents the Threats to both the Interview and Focus Group Study and Conclusions and Future Work is presented in Section 8.

II. LITERATURE REVIEW

The literature presents multiple critical factors that are required for an effective and informed task TA decision. The factors are finalized via an industrial survey conducted as a first step to this research [12]. The overall list of critical factors for a TA decision in a GSD environment are given below in Table 1. The literature consisting of TA strategies, approaches, algorithms and models are given in columns, where the symbol ($\sqrt{}$) represents the presence of the factor in the study. The table 1 clearly highlights the gap where no work consists of all the factors necessary for an effective and informed decision. For an informed TA decision situational characteristics may impact the importance assigned to factors, however explicitly evaluating all the factors is necessary for effective allocation. The three composite factors i.e. site characteristics, task site dependency and site dependencies are taken from the work of Lamersdorf [11]. Since these three factors are composed of multiple sub factors their presence is highlighted in other studies even if any one of the sub factor is present. A recent study reports the following barriers to offshore task allocation process; lack of communication and coordination, trust, cultural and temporal distance, technical complexities of a site, different governmental rules and regulations, requirements instability, lack of knowledge management, delay in responses, lack of technological tools, internal politics and lack of skilled resource [27].

The literature review highlights the neglect of certain factors during task allocation such as experience of application or platform and workload etc. Moreover the usage of the identified factors is not consistent throughout the literature. The list of factors presented in table 1 are taken from literature later validated via empirical studies (survey and interview study).

III. RESEARCH METHODOLOGY

The study uses a mixed method approach to acquire data from industry practitioners. Survey and interview to acquire quantitative as well as qualitative data regarding TA decision-making. The study uses selective explanatory strategy of mixed method approaches to collect and analyze data during the research process, where each study is designed to achieve different objectives [16]. Quantitative data is collected and analyzed followed by qualitative data, analyzed and added to the results of the survey. To understand the dynamics of the

TABLE 1. Critical factors required for an effective TA decision mapped to the strategies, approaches, algorithms and models for TA.

Factors	Lamersdorf&Munch, 2009	Lings et al., 2007	Narendra,Ponnalagu, Zhou, & Gifford, 2012	Fernandez&Basbbbbn n nnnmmmm nmn n	Wickramaarachchi&Lai, 2013	Marques et al., 2013	Alsri.Almuhammadi,& Mahmood, 2014)	SimãoFilho,Pinheiro,&Albuquerque, 2017	Mahmood.Anwer.Niazi, Alshayeb, et al 2017	Edwards et al., 2008	Grinter et al., 1999	Ruano-Mavoral et al., 2011	Avritzer et al., 2010	Gorton &Motwani, 1996	Tran &Latapie, 2006)	(Mockus& Weiss, 2001	Setamanit et al., 2007	Clerc et al., 2007	Componation& Byrd Jr. 2000)	Amrit&Hillegersberg, 2007	Fernandez &Basavaraiu, 2012	Herbsleb&Moitra, 2001	Bass et al., 2007	Manuel E. Sosa,Steven et al 2004	Narendra et al., 2012	Espinosa & Carmel, 2003	Kroll, Friboim, &Hemmati, 2017	Doma, Gottschalk, Uehara, & Liu, 2009	Jalote& Jain, 2006	Gupta, Crk, &Bondade, 2011
Labour costs	√	√	√	√	√	√	√	√	√			√																		
Expertise	√	√		√	√	√		√	√	√	√	√	√	√	√	√														
Site Characteristics (Analyst Capability, Programmer Capability, Language and Tool Experience, Personnel Continuity and Customer Proximity)	√	√			√	√	√	√			√	√			√	√														
Task Site Dependency (Application Experience, Platform Experience)	√																													
Process Ownership											√																			
Task Characteristic	√							√				√																		
Product Architecture	√	√				√			√			√		√		√	√	√	√	√	√	√								
C&C Requirement	√	√										√				√		√		√	√		√	√	√					
Personnel Availability	√			√	√	√		√			√																			
Workload		√																												
Site Dependencies (Cultural and temporal Distance)	√	√		√	√	√	√	√	√			√		√	√		√	√						√	√	√	√	√	√	√

TA decision, an interview study is carried out to comprehend the trade-offs and situation specific variations. The interviews helped in gaining detailed insight into the tacit knowledge of the TA process. The impact of these factors on project success or productivity is not within the scope of this study.

The TA framework is developed based on the data from both studies and validated with the help of a computer-mediated focus group. The research process is divided into five main steps, along with forward feedback (ff) and backward feedback (f) represented diagrammatically in figure 1. The start and end of the process is also shown. The detailed design and execution of the interview study and focus group are given in sections 3 and 4, respectively.

IV. INTERVIEW STUDY

The interview study helped in comprehending the detail of the TA decision. It added further detail to the already collected knowledge by providing information related to the trade-off between factors and variance in the ranking of factors concerning different situations.

A. DESIGN

The study uses a qualitative mechanism to explore or acquire detailed knowledge from interviewees [16]. The practitioners belonged to different types and sizes of GSD organizations. The interviewees participated from Pakistan, United States, United Kingdom, and Qatar and had GSD experience ranging
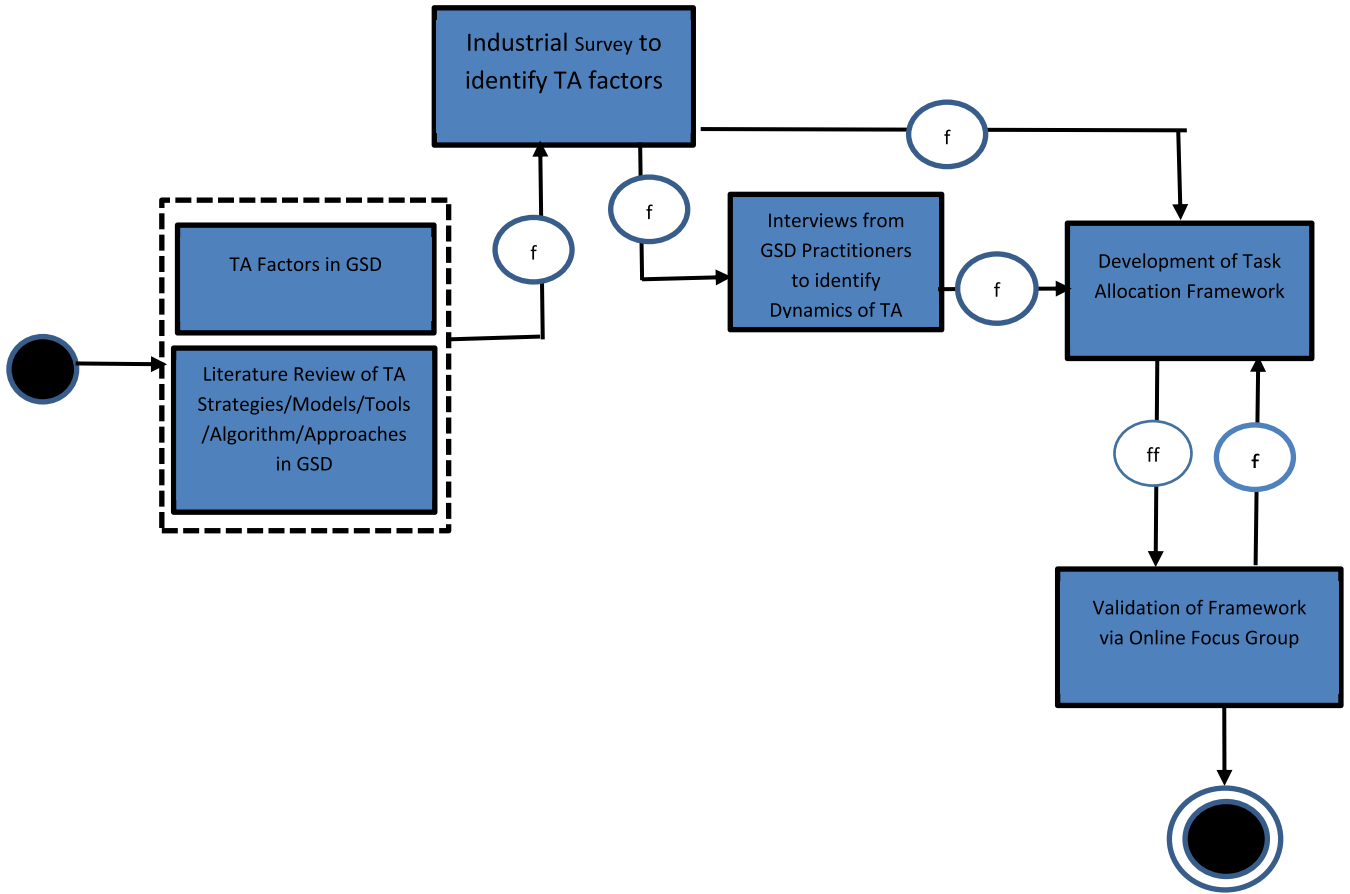
FIGURE 1. Research Process highlighting Feed Forward and Feedback Loops.

from 10–30 years. The organizations of participant practitioners are developing software solutions for business, telecom, finance, health, entertainment, automation technologies, and petroleum industry. All are mature GSD organizations with distributed offices (ranging from 2 to 8) in multiple regions or perform GSD by outsourcing. The practitioners held different roles in the organizations, such as project manager, product manager, program manager, lead principal researcher, chief system engineer, and technical consultant. The interview is designed by providing flexibilityin structured interviews. The questions and follow-up questions are formulated, since focus is to understand and elicit experience, additional questions are asked even if they are not planned initially [17]. The design is given in table 2.

B. EXECUTION
Invitation to participate is sent via email and LinkedIn. The remaining social websites are not used for interview study keeping in view the small number of responses received during the survey. The practitioners are selected on a voluntary basis. A total of 10 interviews are conducted, where all practitioners had GSD experience of about 10–30 years. Interviews are conducted via face-to-face meetings, phone call, and Skype voice calls. All interviews are recorded and

TABLE 2. Demographic information of interviews.

No. of Interviews	Roles Interviewed	Experience of Participant	Participant Countries
10	Project Manager Product Manager Program Manager Lead Principal Researcher Chief System Engineer Technical Consultant	10-30 Years	Pakistan, United States, United Kingdom, Qatar

carefully transcribed to avoid loss of information and keep the focus on the interview process rather than on writing notes.

C. RESULTS AND ANALYSIS
The interview study has given us detailed insight into the TA process and roles involved in the allocation decision. It has also highlighted the situation-specific characteristics that impact the allocation decision in GSD. The findings of the interview study are discussed in detail one by one:

1. Nature of work, which corresponds to the urgency of the task at hand or how early we need to market the product is a new factor identified during the interview. It is a task characteristic, and according to the interviewed practitioners, it holds critical importance, so much so that the decision to outsource depends on it. Some of the practitioners have shared their experience of choosing in-house development due to the urgent nature of the task at hand. Therefore, an important dimension of TA decision is to consider the nature of the task, which further depends on its timeline and criticality.

2. Trust or credibility of the distributed site to deliver quality work on time is another important factor identified during the interview. It is also highlighted as an important attribute of TA, by a survey of experts [19] and other research work [5]. Trust or credibility is gained by prior experience of working with the distributed site. This factor may not be present in case of no experience. If the task is allocated to a regional office of the same organization the importance of trust and credibility is minimized, but is given importance in case of outsourcing.

3. Political reasons or management recommendation is also highlighted as a reason to select a site for a task. Being more of a preference, as highlighted by the respondents, it is not included in the final list of factors for TA. The scope of the work is equivalent to task size factor, present in the initial list of factors identified from the literature. Many of the interview respondents' highlighted scope as an important attribute of TA decision; but, it is not included separately as it is a sub-factor of task characteristic.

4. Experience of developing a particular kind of project or application is a sub-factor of task site dependency—a factor identified from the literature and present in the initial list of factors. Organizational culture is discussed separately in the case of outsourcing organizations by interviewees, whereas this study lists culture as an important factor (comprising national and organizational cultures).Both national and organizational cultures are considered for TA by other TA literature as well [3]. Therefore, culture is later explicitly split into organizational and national cultures. Staff turnover is also highlighted as a factor impacting TA decision; it is present in the initial list identified from the literature under the site characteristic factor.

5. Cost is one factor, which incorporates labor cost. Cost of communication and coordination across sites and cost due to tax of software development are not present in the initial list of factors. The tax on software development is higher in developed countries, compared to developing countries, the task is usually off-shored to developing countries with low taxes. The initial list of factors only comprises labor cost as an influential factor in TA decision. It is renamed as development cost in the final list of factors that incorporate costs such as labor cost, cost of communication and coordination and tax of developing software at a site, along with other development costs.

6. The detailed analysis of the interview data has also emphasized the variance in a situation and its impact on the TA decision. The decision factors are almost the same across the 10 interviews, which are considered as separate cases, the importance of factors varies between situations, also highlighted in [20]. Therefore it means that a factor of critical importance in one scenario may be of minor significance in another. Some of the variation points as identified from the analysis of the interview data are: type of GSD (offshoring or offshore outsourcing), nature of project or task (criticality and timeline of a project), number of vendors in GSD, number of distributed sites, objective of carrying out GSD, and size of organizations involved in GSD. These are some of the many variation points that change the situation for a TA decision. Supporting text from the interview is given to emphasize the variance.

1) SITUATION 1: TYPE OF GSD (OffSHORING VERSUS OFFSHORE OUTSOURCING)

Organizational culture is an important attribute, present only in case of offshoring to a different organization, known as offshore outsourcing, whereas it is not a factor when work is sent to distributed office of the same organization. One organization has the same work policies, processes, norms and values across distributed site offices.

The organizational culture factor incorporates methodology used, security and other policies, processes, framework, principles, infrastructure, applications, systems, and organizational structure as mentioned in the interview. The importance of organizational culture in the case of outsourcing organization can be seen from the following excerpt from one of the interviews.

"You want to work with companies where the delta is minimized. The way that you do things the way that they do things, you want minimal differences."

Another important factor affected by the type of GSD is **Cost,** as it varies in case of offshoring only or offshore outsourcing.

"We do within reason as it may seem good to outsource but when we send a project offshore we may be spending more money on quality and logistics then if developed locally."

Similarly,

"We look at cost, but that is only a factor when you have resources available in all regions which may not always be the case."

2) SITUATION 2: NATURE OF THE PROJECT/TASK

It is also found that the nature of a project or task greatly impacts the TA decision. The significance of factors, such as **Expertise,** changes in case of a task with a strict timeline or a critical task. It is seen that in case of an urgent task, in-house development is preferred, while an expert site is preferred in case of a critical task to avoid a bigger risk of delaying the project.

"Where timeline is strict we choose a site which is expert and chances of errors are less."

Similarly, the nature of the task as well as the type of GSD affect the value given to **Cost** and **Prior Experience,** as is evident.

"Usually cost remains the same for off-shoring. Small differences don't matter because of people bargain and set rates. If the project is very critical I would make sure that the project doesn't fail. Credibility matters a lot, whether you can deliver a project. If prior experience is very good then the project is given without much thought to cost."

The volatile nature of the project also impacts the decision of whether to distribute it or keep it in-house, as mentioned.

"In case of changes, if a high volatile project we keep it in house."

It is also seen that the domain of expertise is considered in case of a domain-specific task, e.g., as mentioned by an interviewee, all finance-related work comes to them as they are a specialized team of financials. This factor is considered in both offshoring and offshore outsourcing.

"If we are looking at a specific team of people e.g. to work on portal interfaces we may look for experts, Indian teams have a skill set of designing portal interfaces so we give it to them." Similarly,

"Now we are making iPad of fountain drinks like you can customize your drink, all development work is done in India in tech Mahindra, why because India is doing a lot of work in gadgets."

Where expertise of a particular domain or requirement of a skill set is aligned with the nature of the task at hand **, Culture and Time zone Distance** are not considered important.

"If it is a critical work then you have to allocate it to a location no matter what cultural location or time zone it is in."

On the other hand, **Culture and Time zone** do become a problem when the nature of the task requires communication and coordination, as is evident from the extract of the interview transcripts. Names of the countries have been replaced with mask names to avoid offensive remarks against them.

"Time zone is a major factor, as it is very difficult to manage multiple time zones, communication and coordination is a major issue. Multiple cultures, different work habits, are very difficult to manage, ABC come after 11.30 they have tea, fun and a lot of stuff and vanish at 5 or 6. Don't prefer to work with them."

The language issue is also highlighted in case of outsourcing to XYZ.

"Depends on work, if it is only transactional work it is ok, XYZ problem of the English language makes it very difficult to get work from them."

'Once for a project in XYZ I talked for two hours and after two hours nobody had a clue what I talked about."

3) SITUATION 3: NUMBER OF VENDORS IN GSD

An interesting insight into the TA decision is with reference to multiple vendors. Internal politics makes things difficult, especially concerning **communication and coordination** and knowledge-sharing. The problems escalate and result in overall project delay. It is therefore preferred to have one vendor. The experience of a project manager is given below.

"We once had a competitive vendor in ABC and XYZ, the XYZ folks were not sharing information with ABC because they wanted to keep information with them, for me to give information from XYZ to ABC was very difficult. ABC, they record information and listen to it again and again, so much time got wasted. Internal politics between two vendors become very difficult. The problem of one module affecting the other module, and then no one owns it."

4) SITUATION 4: NUMBER OF DISTRIBUTED SITES

The number of distributed sites impacts the value assigned to **the Time Difference.** Different working hours impact communication and coordination in many ways. One problem is the difficulty to communicate due to different working hours, while another is the increase in communication and coordination and therefore, the cost, just to solve a small issue. The impact is so much so that it is preferred to keep the number of sites to a minimum of two or three. The communication and coordination overhead is the most affected factor in the case of a different time zone. Most of the practitioners have highlighted the issue; the experience of one such interviewee is shared here.

"Never wish to work again with two regions with different time zones as it is very difficult."

5) SITUATION 5: OBJECTIVE TO CARRY GSD

The objective of carrying out GSD affects TA factors. The most common objective identified from interview data is to reduce development time by taking advantage of the 24/7 development cycle. It is seen that **Temporal Difference** becomes important in case of 24/7 development because you want to assign to a temporally distant site to achieve round-the-clock development.

"Work assigned in such a way that one site delivers work to the next site for 24/7 development.

6) SITUATION 6: SIZE OF ORGANIZATIONS INVOLVED IN GSD

The GSD scenario, where more than one organization of variant size is carrying out development, organizational culture and working hours of the bigger company, is set as standard. Organizational culture is very important in the case of outsourcing work as discussed earlier, but it is adapted in case of one large organization and small organizations. The extract from one of the interview is given below.

"Big companies have made their standard so we have to adapt. Small companies adapt to the time and culture of IBM or Microsoft. you have to follow their working hours."

It is evident from the analysis of the interview data that the factors across these interviews are almost the same but their importance varies from situation to situation. It is also apparent that the characteristics of the organizations and development impact the importance assigned to the factors. A factor considered momentous in one situation may not be of

significance in another. These observations have emphasized the need for a well-thought TA process where the situation needs to be analyzed before the factors are evaluated.

While these maybe some of the variations, they have highlighted the need for a meticulous process for TA. The data from the interviews has also shown lack of any defined TA process or framework.

D. TRADEOFFS DURING TASK ALLOCATION DECISION

One more important aspect of the TA activity is the trade-off between factors, as they are related to one another and cannot be considered in isolation. One of the main motivations to conduct interviews is to identify the tacit knowledge that goes into making the TA decision, which also includes trade-offs between factors. The trade-offs as reported by the practitioners stress the intricacy of the TA process.

Labor cost is the main reason organizations decide to go global as reported in the literature, but many other factors are given priority over it in case of TA. One such factor is the availability of resources, as GSD can only be achieved if the required skill set is available. Therefore, practitioners are more interested in availability and that also of required skills, as GSD is carried by variant types of organizations. Some big organizations have regional offices in almost all regions, whereas others try to find an organization where the task can be outsourced or sent to available regional offices. Therefore, the availability of resources becomes a significant deciding factor while allocating tasks as stated below by one of the interviewees.

"Global Market today is about where you have resources available. You would look for availability. We look at cost but that is only a factor when you have resources available in all regions which may not be the case."

Similarly in situations where timely delivery is important, especially in case of publicly held organizations, labor cost is kept in the background, as quoted.

"Labour cost is why we offshore or outsource, it is the driving point but labor cost is something which can be a trade-off, as if you have a project that you plan to release by a certain date and if it is not released then you generate no revenue, so it gives a negative image to your company. If you are a publically held company it would give a negative recommendation to Wall Street since you did not meet your revenue projections."

A prior relationship is also given priority over cost to mitigate project risk.

"Prior relationship site wins over labor cost as the grass is not always greener on the other side."

Further,

"If the project is very critical I would make sure the project doesn't fail. Credibility matters a lot whether you can deliver a project. If you have prior experience then a good project is given without much thought to cost."

Expertise is a major deciding factor as highlighted in interviews. It is also given priority over cost as the main focus is on the required skillset and delivery.

"I am responsible for delivery; I will focus on capability, i.e. the one who knows technology."

In situations, such as the recommendation of a trustworthy resource, it is given more priority over expertise as highlighted.

"I may choose a low caliber person if he is coming from a trustworthy reference."

These are some of the trade-offs, found during interviews of the GSD practitioners, which emphasize the need to consider factors together. In practice, only 2–3 hours are given to the TA decision-making, which shows the ad-hoc nature of the activity. The detailed study of the TA factors and process has highlighted the fact that this ad hoc nature does not suffice in many situations and experiences are reported by practitioners where they had problems and in some cases, they had to reallocate.

"Once working with ABC developers were not good, it was not easy to reallocate project but we escalated to my manager and then we shifted to XYZ, It took us three months after a lot of escalations."

Therefore, the overall project duration can suffer due to re-allocation. There is a need to allocate in a planned and well-thought manner, minimizing the need to re-allocate.

The detailed analysis of the interview data also highlights the problems of communication and coordination across distributed sites. Bad experiences of allocating different interdependent modules to distributed sites are reported and practitioners have responded by keeping all projects within 2–3 sites. The in-depth analysis of the TA process has revealed that the architecture of the system or detailed design is not required before TA, due to the increased communication and coordination between sites, which is not manageable.

V. TASK ALLOCATION FRAMEWORK

A TA framework is developed based on empirical data obtained from the survey and interview study from the GSD industry. The framework highlights the variant situations to a TA scenario along with the important factors that need to be considered for effective TA. The variation points identified from the qualitative data are Task, Expertise, Organization, and Site. The correlations identified with help of the Spearman Rho test are also depicted in the framework. The framework also highlights the shortcomings of the already existing TA strategies along with the complexities and dynamics of the TA decision.

A. DESIGNING THE FRAMEWORK (SOCIAL TECHNICAL SYSTEMS THEORY)

The Social Technical Systems (STS) theory is useful in designing/redesigning work in different areas from manufacturing to software development. The organizational processes are carried with the help of human resources and technology, synchronization is required between the two for incorporating technology into the social structure of an organization. Software development processes can benefit from the STS by explicitly modeling the technology and social structure

together and accomplish work. The traditional method of designing technology and then incorporating it in the social structure requires a change in the social structure, which is not always successful. The STS keeps the social aspect in mind while designing technology and introducing it in the organization.

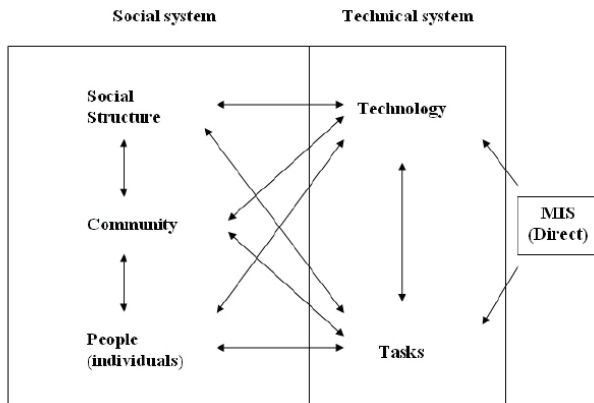The STS theory is represented in a graphical format below in figure 2 [27].

FIGURE 2. Representation of STS.

The TA is one such process that can be modeled keeping in view the STS theory. The tasks are allocated between sites, composed of teams or individuals, whereas the tasks to be performed concern technical aspects. The STS theory is very successful in the case of self-regulating groups (software development teams)—groups that perform interrelated tasks to achieve an objective and can manage different scenarios and adapt w.r.t. different situations.

A closer look at the factors reveals that the attributes/factors consist of technical aspects of tasks and technology as well as the social aspect of the organization and individuals. Factors such as component dependency, size, volatility, task budget and development cost etc. are attributes of tasks and concerned with the technical aspect of the TA decision, whereas other attributes such as trust, personnel capability, workload, availability, organizational and national culture, are the social aspects that need to be considered before making the TA decision. The social aspects are both related to individuals as well as organizations or sites, which is the group of individuals (team). Keeping in view the factors which can be differentiated as technical and social factors necessary for a TA decision, the STS theory is suitable for the development of the framework.

Objective to do GSD is an attribute of the organization participating in GSD, therefore, the explicit consideration is in alignment with the guidelines of designing work in STS, i.e. work should be organized w.r.t. the objective of the organization.

The factors on each plane are identified whereas more factors can be identified in case of different situations. Moreover, the weight of each factor varies with the situation. This is one more aspect of STS that the features should vary according to the technical and social needs.

A perfect fit between technology and social structure results in both physical products as well as psychological outcomes. This is the main concern while designing STS to ensure that the interaction between the technology and social structure yields positive outcome whether in the form of a product or psychological outcome known as joint optimization [17], [18]. The fishbone diagram presented in figure 3 organizes the factors from the STS perspective.

The process of TA in GSD is designed such that the expertise, culture, availability, and domain of work, of workers (social component) are carefully analyzed and tasks having specific budget, volatility along with the the technology of specific platform/ tool (technical component) is evaluated for a TA decision. The planes are connected via "Requires", "Belongs to" and "Situated at" relationship. Task requires expertise that belongs to an organization and the organization is situated at a site. The attributes of these planes are factors that are important for a TA decision, for example a task requires a particular skill set where the nature of task is mapped to the skill set. The proposed framework consists of four planes namely, Task, Expertise, Organization, and Site, which are thoroughly and explicitly considered for an informed TA decision. All factors are not important in all situations; some factors may not be important in a given situation at all; e.g., if an organization is not involved in any project at the moment then the workload is not applicable. Some factors may be considered but their relative importance diminishes, e.g., in a project where it is being developed for a new platform, the requirements remain the same and hence, factor-like volatility is not significant. The trade-offs taking place in a GSD situation are determined by the attributes on the four planes. The attributes/factors can also be extended based on new information.

The characteristics of the task; budget; size, criticality, and timeline are all mapped to the task present in the technical system. The expertise hold factors that can be mapped to a specific individual or team members in GSD, therefore, linked to people in social systems. The factors related to an organization such as personnel continuity, trust, the objective of doing GSD, organizational culture, size and maturity can be mapped to the community as these attributes are characteristics of groups of people. The final factors identified as critical for a TA decision are detailed one by one and the proposed TA framework is presented in figure 4.

Site:

a. Legal issues (incorporates legal issues related to the development of software at that particular site, also includes Intellectual Property rights)

b. Stability (can be measured both in cases of financial as well as political stability)

c. National culture (highlights the culture of the region, includes attributes such as culture, holidays, norms and values of people living in that region)
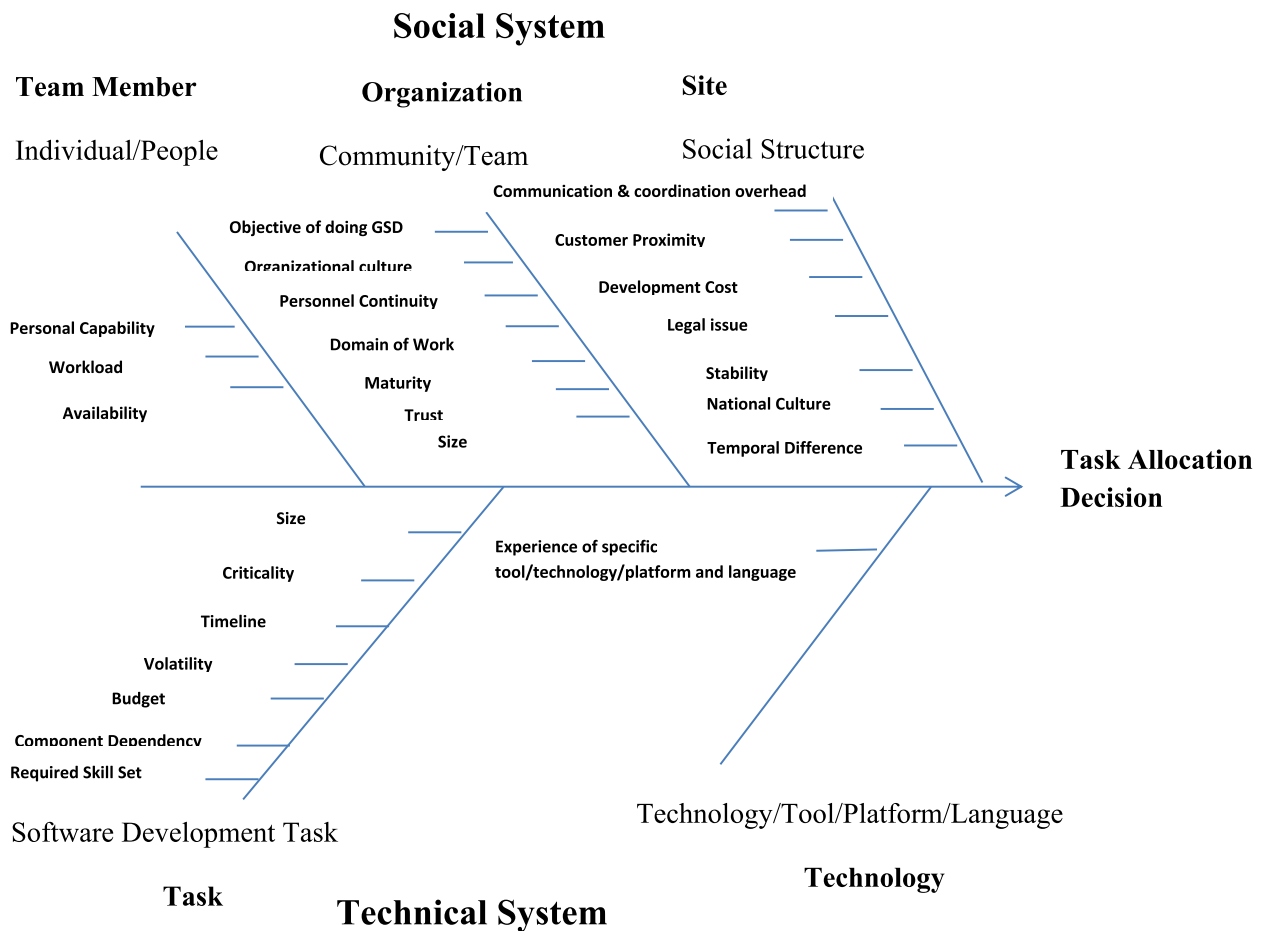
FIGURE 3. TA Factors organized w.r.t STS Design Theory.

d. Development Cost (includes labor cost and other costs such as cost of communication and coordination, infrastructure, taxes, along with other development costs)

e. Time Difference (time difference is not only measured based on the time zone of the site but the overlapping working hours (removes the breaks) and shift of time on which work is usually done at that time (e.g., in some countries evening shift is taken))

f. Communication and Coordination Overhead (measured based on national culture, organizational culture and time difference)

g. Customer Proximity (how much close the site is to the customers of the product or software being developed)

Organization

a. Size (usually measured with the help of several employees)

b. Maturity (measured based on CMMI level achieved or based on the maturity of the processes and practices)

c. The domain of work (the type of domain the organization develops software, such as Financial Systems, Healthcare Solutions.)

d. Organizational Culture (corresponds to the work ethics norms and values of the organization, includes belief towards innovation, teamwork, aggressiveness, and stability)

e. Trust (measured based on prior experience which may relate to the quality of delivered work, ability to handover on the promised timeline)

f. The objective of Doing GSD (the literature has highlighted many reasons for doing GSD such as to achieve 24-hour development, reducing development cost, increasing the quality etc.)

g. Personnel Continuity (the staff turnover is measured as a percentage of average monthly employment)

Expertise

a. Availability (measured directly irrespective of whether a resource is available due to being busy on other projects or on leave)

b. Workload (if the person is available but has heavy workload, it is concerned with the busy schedule of the selected personnel)

c. The capability of personnel (highlight the ability of the person to deliver quality work in a specific time; it will
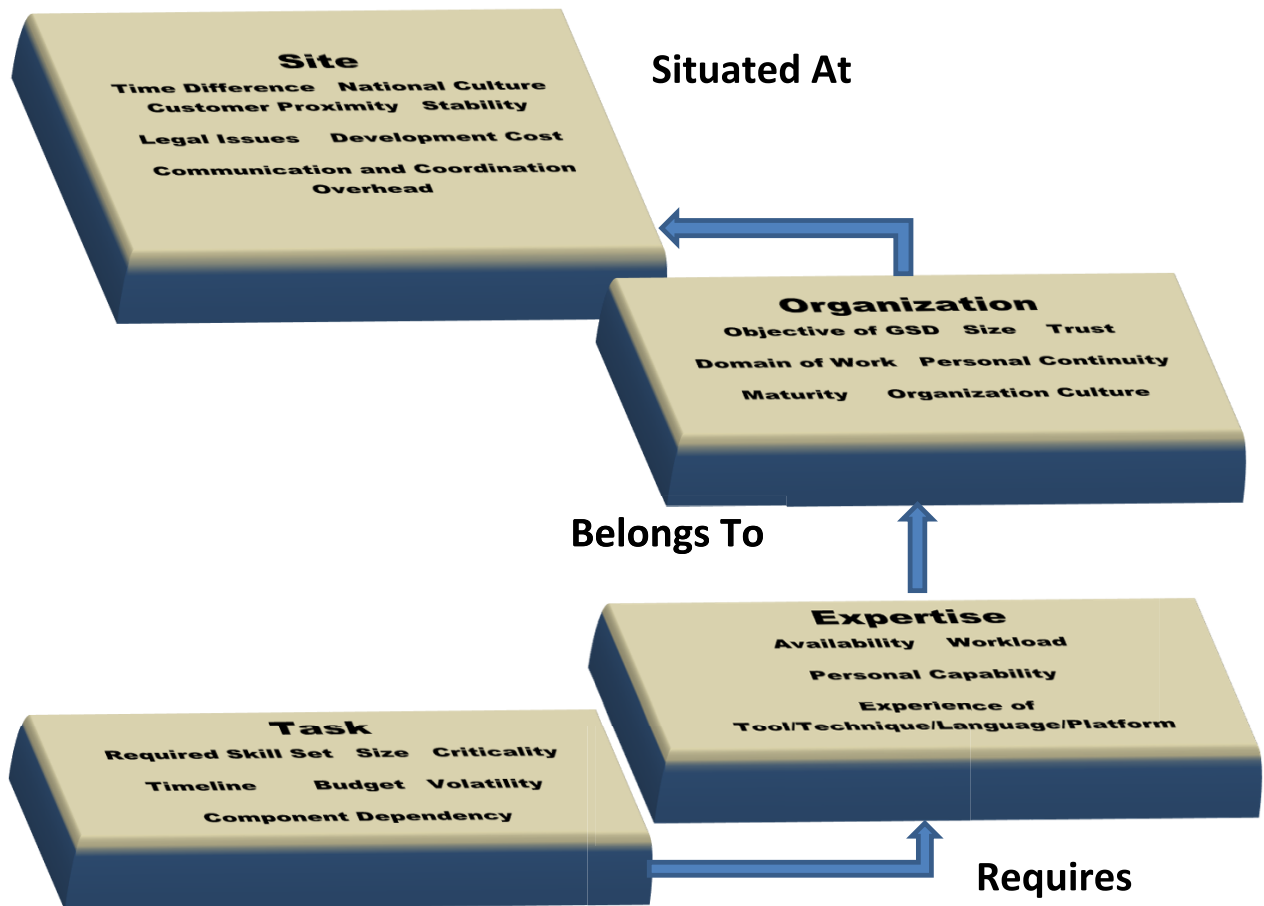
FIGURE 4. Task Allocation Framework based on STS Theory (organized in Planes).

include the capability to work under pressure, ability to solve problems and work in a team. It is also measured based on the skill set of the person)

d. Experience (measured based on experience with the specific tools, technology platform or type of application)

Task

a. Volatility (the changing nature of the task, deals with the certainty of work to be accomplished)

b. Criticality (measured based on complexity, business value or confidentiality of the task)

c. Timeline (time duration assigned for the task)

d. Budget (cost assigned to the task)

e. Component Dependency (architectural dependency between components related to the task to be allocated)

f. Required Skill Set (required skills to accomplish the task; can be specific to a language, tool or domain)

g. Size (measured based on function point or lines of code to be written)

VI. FRAMEWORK VALIDATION VIA ONLINE FOCUS GROUP

We performed validation with the help of an online focus group with GSD practitioners from around the globe. Focus groups are practically helpful in answering analytical phase questions dealing with comprehension and applicability of the model under discussion [22]. They are cost-effective and fast [23]. Online focus group [23], [24] is a variation that can be used in such situations to handle participation from temporally distant sites. The group promises many advantages [23]. The group is like a bulletin board or blog consisting of asynchronous communication [23], [24]. The group benefits from the technology as all conversation can be exported and there is no need to take notes. It is also beneficial and supports balanced conversation as shy members of the group along with individuals of such culture which restrain conversation, actively participate during the session [19]. Focus group is used in social sciences as well as software engineering to obtain insightful information on the topic under discussion [22].

The purpose of the focus group was to gather practitioners' feedback on the applicability and effectiveness of the proposed Task Allocation Framework for GSD projects. Practitioners were asked to comment on the applicability of the framework keeping in view real-world GSD TA scenarios. Feedback of the practitioners helped in determining the applicability of the proposed TA framework along with the context of use, strengths, and weaknesses of the proposed

TA framework, problems in the framework that hinder its applicability and solutions/changes. The suggestions helped improve the framework to make it more practical and useful in real-world scenarios.

A. ONLINE FOCUS GROUP DESIGN AND EXECUTION

We created the focus group on www.focusgroupit.com and sent invitations to all the participants who agreed to participate in the discussion. The invitation to participate in the focus group session was sent to practitioners actively working in the area of GSD as Project Managers or Product Managers. The framework was emailed to all the participants prior to discussion. The participants of the focus group were identified from LinkedIn keeping in view our prior experience with the social site.

The focus group participants were distributed around the globe with participation from the United States, United Kingdom, South Africa, and Sweden, as the TA decision-makers in case of GSD were not available in Pakistan. Practitioners from around the globe participated in the online focus group session by registering on the link provided. Two of the participants of the focus group were also involved in the interview study, conducted previously. Therefore, the focus group consisted of a total of seven members, where two of them were also involved in the interview study and five new members. They did not know each other and were from different organizations, and therefore, participated equally without any reservations. The participants were not intimidated by each other, as they did not know each other. The topic of the focus group was not sensitive to gender, therefore the focus group consisted of 9 male and 1 female practitioner.

Online focus group does suffer from limitations of lack of real-time groupness and interaction [24]; but the study tries to minimize this limitation by selecting practitioners from a similar background to increase groupness. Participants were encouraged to view and reply to answers and comments posted by other members within the active time period of the focus group.

To ensure discussion, all participants were communicated that the focus group will be active for three days only and that they are required to log in time and again in these three days to view answers by other participants and to comment on them. An automatic notification was also sent via email by the portal for any new submitted response or comment.

The participants were also able to view the response of other practitioners once they responded to a question. This sequence ensured individuality and eliminated chances of group thinking; to ensure interaction they were allowed to view and respond to the answers of other participants [25].

B. FINDINGS AND DISCUSSION

Qualitative analysis is performed on the feedback and discussion data of online focus group session and main points are extracted and analyzed. The analysis shows that the overall comments fall into five main categories; those related to factors, the context of use, the hierarchy of framework, the appli-

cability of framework and other suggested improvements. Keeping in view the space limitation the detailed discussion is not added here, only the major feedback and recommended changes are presented comprehensively.

The IP protection and security of code are highlighted as important deciding factors for TA.

".... IP agreements, and the practical aspects of applying the law to deal with IP issues, work? Some work may be performed in particular countries or states for IP and / or security reasons".

Keeping in view the above feedback, IP protection and security of code are incorporated inside one factor named as Legal Issues.

The focus group participants also highlighted political and government situation of the distributed site as a critical attribute, therefore, a new factor, namely, stability of the site is added in the list of final factors. The stability also incorporates economic stability.

The confidentiality aspect of the task is incorporated inside the criticality of the task; more confidential task means more criticality.

"You should also consider the confidential aspects of the project as there can be blocks of the SW/project which need to be specifically contained within a certain group and geographical location".

Prior experience with the organization or site to produce quality work is an important dimension. It is highlighted as an important factor but already incorporated as a factor by the name of the trust.

"Additional factors such as trust (in the competence, ability to deliver, and the quality of an individual's or a team's work) are important, relevant factors to consider".

Similarly, the capability of personnel is already a factor on the expertise layer along with trust that is enough to address the following concern of the focus group participants.

".... if I 'believe' the team I'm receiving the work from are at least as competent as I and my team then I'm more willing to work".

A major change is concerned with the organization of the framework. Initially, the framework was organized in layers, but a key criticism is on the constraints imposed by layered hierarchy. Therefore, the layers are changed to planes removing the topological constraint associated with layers.

"I think they'd consider some of the factors you've captured in your framework; however they're unlikely to consider these factors as part of a hierarchical framework."

Other changes and details required by the GSD practitioners are related to: alignment of the framework with Software Development Life Cycle (SDLC) phases, Detail required with respect to each plane as well as the attributes of a plane along with providing metrics for each factor, Enabling of distributed work (Installation and deployment of tools for collaboration, and familiarity with those tools across the entire team that uses them), measuring performance and appraisal of developers/ testers and conflict management. The detail required by the practitioners is added, but, the alignment

with SDLC phases, measuring performance, appraisals and conflict management is part of future work.

It is to be kept in mind that the validation is done with a focus to check the applicability of the framework in real world scenarios. The feedback of the GSD practitioners has helped in improving the framework. Future work will be on automation and application of the framework.

VII. THREATS TO VALIDITY

The threats to validity of interview study and of focus group study are given one by one.

A. THREATS TO INTERVIEW STUDY

Internal validity of the interview study was also ensured by interviewing 10 highly experienced project managers from different type and size of GSD organizations working in different domains.

External validity of interview data was ensured by collecting data from project managers of different type and sized organizations, all of them were executing GSD.

The descriptive validity of interviews is ensured by recording the interviews and listening to them again and again so that no information was lost. Open-ended interview questions were designed and piloted to ensure that they were not biased and not directed towards an answer. This helped us to ensure interpretation validity. Follow up questions were designed but were only asked in case of a positive answer. To ensure that the meaning is clearly understood, answers were reconfirmed from the interviewees. This also helped to reduce interpretation validity.

Researcher bias is also controlled as the project managers belonged to variant sized organizations working on the development of different software development via GSD. The same set of questions was asked from all practitioners regardless of the type and size of organization and region.

Theoretical validity was ensured by recording and reporting all the interview data. The conclusion of the interview is also peer reviewed. Reactivity was reduced with the help of cover letter which explained in detail that the responses will be evaluated as aggregate to ensure respondent's anonymity. The chapter presents the important factors and their inter relationship identified from both the empirical studies and highlights the similarities and differences from reported literature. The next chapter presents the proposed TA framework in detail. Comparison of the framework with the existing literature is also performed.

B. THREATS TO ONLINE FOCUS GROUP

An online focus group was conducted since face to face focus group session was not possible with participants situated around the globe. Online focus group [23], [24] is a variation which can be used in situations like these to handle participation from temporally and geographically distant sites. The online focus group promises many advantages [23]. The online focus group is like a bulletin board or blog consisting of asynchronous communication. Online focus group does

suffer from limitations of lack of real time groupness and interaction, however we tried to minimize this limitation by selecting practitioners from similar background to increase groupness.

To ensure discussion, all participants were communicated that the focus group will be active for three days only and that they are required to login time and again in these three days to view answers by other participants and can comment on them as well. An automatic notification was also sent via email automatically by the portal for any new submitted answer or comment.

The participants of the focus group belonged to different regions and sizes of GSD organizations. The conversation of focus group was exported and read to ensure descriptive validity. The protocol of the focus group was also evaluated from experts prior to execution to ensure that they are not directed.

VIII. CONCLUSION AND FUTURE WORK

The activity of TA is of critical importance to ensure successful GSD. The decision of an allocation requires information on many factors, some of which are the time difference between sites, labor cost and expertise available at a site, cultural background and temporal distance. The chances of a successful GSD are increased with the help of a meticulous TA process. It is a complex decision-making activity influenced by many factors.

The study presents a framework that highlights the situational variation and factors that need to be considered for an informed TA strategy. The careful evaluation of critical information helps in a thorough and effective TA decision. The feedback of the industry practitioners helped refine the TA framework and increased its value.

Our final goal is to determine the impact of an informed situation specific TA (one that trade-offs between important factors identified as part of this research) on communication and coordination overhead and thereby, the project duration as an extension to this research.

The framework is not applied to real-world GSD TA scenarios of variant size and type of organizations and situations. The study plans to use the framework on real TA scenarios to evaluate its applicability as part of future work to this research. There is a need to develop a tool as a first step to support the implementation of the proposed solution. A tool supporting the framework will be designed and developed in the future.

The study also aims to identify the points where TA/reallocation decision should be made during software development. It can be aligned and integrated with the software development methodology followed for software development. The TA is an activity performed in the case of traditional software development methodologies, whereas the dynamics of agile software development are very different. Moreover how the framework can help in agile methodologies will also be seen as future work, as some work in the direction of TA is already underway.

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