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EXPLORING THE RELATIONSHIP BETWEEN GSD, KNOWLEDGE MANAGEMENT, TRUST AND COLLABORATION

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Abstract

Software development requires intensive use of knowledge management (KM). Which brings the ease for Global Software Development (GSD). The GSD approach has viable advantages such as outsourcing, cost lowering, and 24/7 availability to the customers. However, the challenges are also there, due to the different levels of dispersion (language, cultural, geographic, etc.), which brings the difficulties in team coordination, trust between developer and communication. The literature on GSD considers knowledge sharing, trust, collaboration and shared understanding of requirements as key determinants of GSD success. A quantitative research model is adopted with a quantitative questionnaire, containing multiple weighted questions related to the relationship among the key determinants of GSD. A leading multinational firm having more than 200 branches in 30 countries was selected as a research site for the survey, the sample size of 195 was taken for this research. This research proposes a conceptual research model, which presents the relationship between four constructs, which have been considered as key determinants of GSD success. According to our findings, knowledge sharing in GSD environment improve trust among GSD team members. Knowledge sharing also increase collaboration among team members. This increased collaboration and trust positively affect the shared understanding of requirements that is key to the success of requirement engineering phase and overall software project. The achieved results will help the researcher to explore a better relationship between GSD, KM, trust, and collaboration.

Keywords: Collaboration, Global software development (GSD), Knowledge management (KM), Shared an understanding of requirements (SUR), Software Engineering (SE), Trust.

1. Introduction

Global Software Development (GSD) has emerged as a common operational phenomenon in today's fast-paced economy. Technical communication advancements such as interpersonal communication tools and international telecommunication have also gone hand in hand with this tremendous growth of GSD [1]. Further, the availability of skilled resources in low-cost economies such as Eastern Europe and Asia, coupled with the desire to take benefits from GSD have contributed a lot in adopting GSD. In some cases, system development and maintenance is outsourced to a remote location. In others, organisations open their sub-branches in low-cost economies and offshore all or part of their development to those locations [2].

This rapid growth of GSD means that much software developer will collaborate along geographical, socio-cultural and temporal difference in order to accomplish software project timely and successfully [1-3]. In such situations, geographical distance hinders communication and coordination, which creates the problem of collaboration [4], temporal distance limits opportunities of direct communication and information sharing [5], cultural distance negatively influence shared understanding and linguistic distance further create a barrier to communication [5, 6].

Today, software organisation is a part of knowledge-based economy and Software engineering is considered as a knowledge-based process [7] that not only depends on technology rather it is dependent on human knowledge, creativity, and intelligence. Which means, human and social factors play a vital role in the success of software development especially in GSD context; however, research addressing this aspect of SE especially in GSD context is scarce [8, 9]. In the last decades or so, researchers have paid much attention to the technical side of software engineering, this calls the need for research on the human side of SE [10].

GSD organisations nowadays are realizing the importance of knowledge as a valuable asset, which helps them in maximizing their economic value, prosper them in today's fast-paced economy and improve their effectiveness [5]. Human knowledge and creativity serve as an input for the software development process. Knowledge in isolated form has lesser value; hence, knowledge sharing is necessary to leverage its maximum potential. Importance of knowledge sharing further rises in GSD context, where stakeholders correspond to different geographical areas. Plenty of research in the field of information system has investigated Knowledge Management System (KMS). The objective of these KMS is knowledge creation, storage and transfer within and among different entities in order to get maximum benefit from it.

Organisations create a team to work on different sophisticated tasks. One advantage of team building is that it integrates knowledge scattered among team members, which helps and facilitate them in problem-solving. If teams are managed properly, complex and non-routine tasks can be solved easily [11]. GSD team members are expected to collaborate in an efficient manner in order to solve problems and to complete project related tasks timely. It is a common knowledge that the root cause of most Information System (IS) project failure is lack of communication and collaboration and developers have to spend a lot of their time on communication [12, 13]. Similarly, dividing and assigning tasks among individuals separated geographically introduce barrier of coordination and control. These problems of communication, coordination, and control leads towards conflicts, delay, time and

budget overrun, which sometimes results in failure of GSD projects [14, 15]. Binder [16] proposed that the literature on GSD suggests the importance of knowledge sharing in promoting collaboration among team members.

Various studies by Li et al. [17] have highlighted the importance of trust in GSD success, however, building and maintaining trust in GSD context is difficult as compared to collocated settings. Trust is crucial for GSD success as it facilitates communication, improve team performance and productivity and encourage team members to work in a cooperative way. In GSD context, due to the absence of direct face-to-face interaction, the members of the team have to rely on different behaviours and information technology (IT) tools to assess the trustworthiness of others. The literature on GSD highlights the importance of KM in establishing and maintaining trust and many studies have considered knowledge sharing as a critical enabler of trust [18]

Another important problem in GSD context is the lack or absence of SUR. Requirement Engineering (RE) is the most communication rich activity of software development as overall functionalities and boundaries of the software system are identified at this stage. The process of RE should be done in a very careful and efficient manner as the output of this stage serves as an input for other development activities [19]. Many researchers consider lack of SUR as a key hurdle in the success of RE in GSD organizations. Therefore, it becomes very necessary for Global Software Development teams to achieve SUR. SUR means that individual communicating on a particular topic must have the same understanding of that topic [20]. The literature on GSD team performance fosters the importance of knowledge sharing, collaboration, and trust to improve SUR [5, 18]

Above discussion shows that knowledge sharing, trust among team members, collaboration and shared understanding act as key determinants of GSD success. The purpose of this research study is to examine the hypothesized relationship between these constructs. We argue that knowledge sharing among globally distributed team members, will lead towards better collaboration and trust, this knowledge sharing along with trust and collaboration will improve SUR among GSD team.

This research paper intends to answer the following main questions:

RQ1: What is the relationship between four key determinants of GSD success (knowledge sharing, trust, collaboration, and SUR)?

RQ1.1. What is the effect of knowledge sharing on collaboration in the GSD team?

RQ1.2. How knowledge sharing effect trust within the GSD team?

RQ1.3. What is the effect of collaboration on SUR in GSD team?

RQ1.4. What is the effect of trust in mediating the relationship between collaboration and SUR in the GSD team?

A satisfactory answer to these questions will help researchers and practitioners to better understand the importance of knowledge sharing, trust, collaboration, and SUR and factors that contribute to it. Further, empirical results obtained from this study will give an in-depth analysis of relationship existing between knowledge sharing, trust, collaboration, and SUR.

The remaining part of this paper is organised as follows: section 2 discusses the background, which focuses on GSD, trust, collaboration, knowledge sharing, and SUR. Section 3 presents a conceptual model of research along with the research hypothesis. Section 4 presents the ontology representation. Section 5 discusses our research methodology. Section 6 presents results and data analysis followed by Section 7, which provides the discussion of results. Section 8 provides research and practical implications of our study followed by Section 9, which finally conclude this study. Figure 1 shows the detailed outline of our paper.

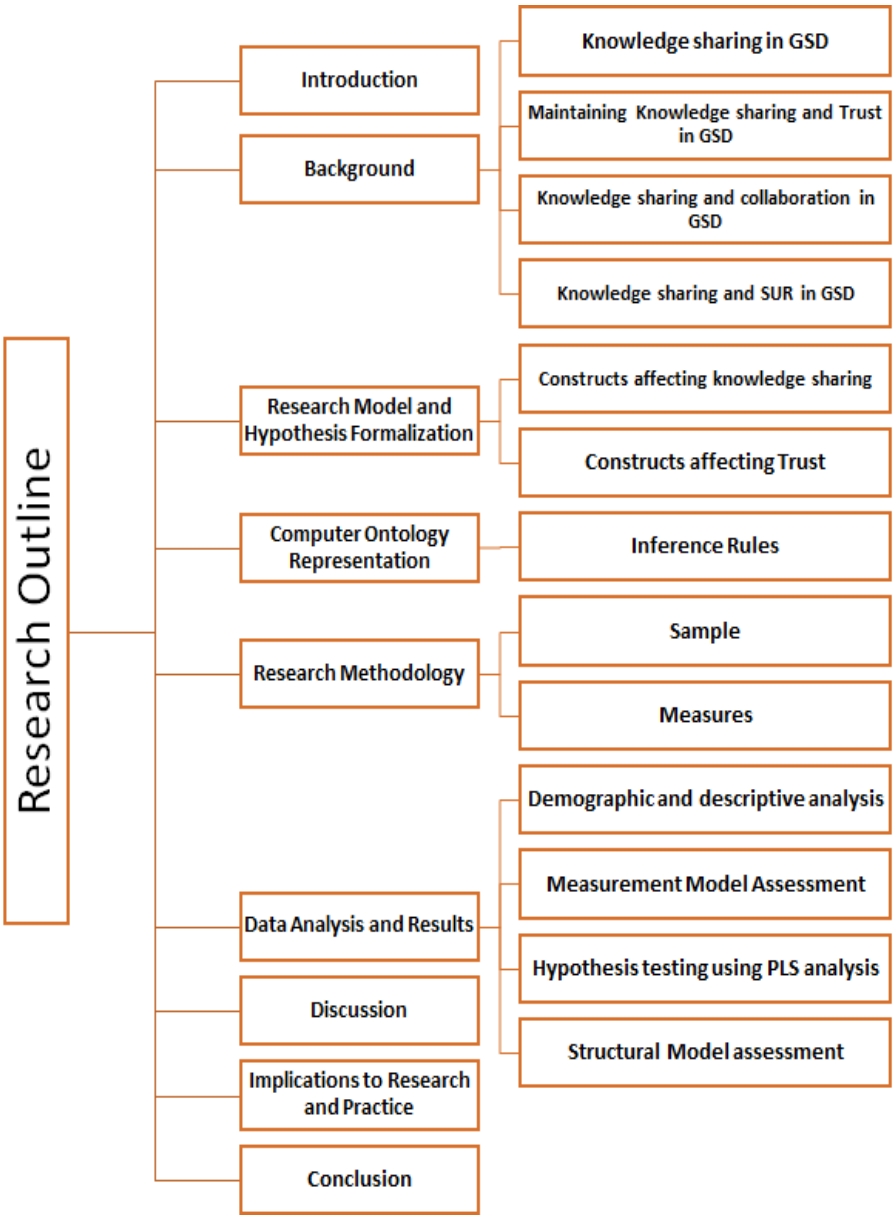

Fig. 1. Research outline.

2. Background

GSD team's issues have been widely investigated by researchers in the last few decades with trust, collaboration and SUR as crucial factors of GSD success. Similarly, the literature on KM has also been growing rapidly in the last few years. Organisations have now realized the importance of knowledge as an important asset for sustainable and competitive advantage. In this section, we will present some research from literature, which investigated trust, knowledge sharing, collaboration, and SUR in GSD settings.

2.1. Knowledge sharing in GSD

Knowledge sharing processes lie at the heart of GSD and knowledge sharing is its primary driving force in GSD context. Knowledge sharing is as crucial in online networking as in GSD. Knowledge is an essential asset of every organisation and it must be preserved and reused in order to get benefits from it and it is only possible if there is some knowledge sharing mechanism in place within GSD organisation. Practices and empirical studies show that highly qualified people in the IT industry are those who are knowledge worker; these people are the most valuable commodity in the knowledge-based economy. However, the biggest challenge is to promote effective knowledge sharing in GSD, as stakeholders in GSD corresponds to different geographical locations and there is a distance of culture and language involved between them, which hinders them in sharing knowledge. Further, people working in GSD rarely meet face to face with each other; therefore, they have fears and hesitations while sharing knowledge [21-23].

Knowledge sharing in GSD setting is inevitable, without effective information and knowledge sharing mechanism it is difficult to get desired benefits of GSD. However, knowledge sharing in GSD poses several challenges, because expertise and best practices reside at different locations. Consequently, difficulties arise in locating this knowledge and expertise due to the huge geographical distance involved. Different strategies of KM have been explored in the literature. As opposed to implementing a central KM system, researchers propose a hybrid approach, which is focused on reusing knowledge and connecting knowledge source for local project specific knowledge [1, 5].

2.2. Maintaining knowledge sharing and trust in GSD

Trust is a primary determinant in the success of GSD projects. It improves communication, coordination, and cooperation among GSD team members and has a direct positive impact on perceived outcomes. Missing trust or lack of trust reduce team performance, increase time and budget and affect product quality. If team members do not trust each other they cannot work together towards a common goal and individuals will prefer their own motives instead of working in cooperation [5, 24]. Reduced trust is associated with doubtful about information, which ultimately results in a lack of information exchange and feedback. Further, it negatively impacts teams' performance and schedule and increases monitoring, reworks, and delays [25]. Trust is inevitable in the success of GSD and knowledge sharing is suggested as the best means of building trust as trust have a direct relationship with knowledge and cannot occur without it. The literature on KM suggests that effective sharing of knowledge among GSD team members helps in building trust among team members [5, 26].

2.3. Knowledge sharing and collaboration in GSD

Collaboration is a Latin word with prefix col, which means together and elaborates, which means work [27]. It means that more than one individual work together on an intellectual effort. It is a complex and multidimensional process, which is characterized by multiple constructs such as coordination, communication, relationship and structure [28]. The significant impact of knowledge sharing in promoting collaboration has been highlighted in many past studies. Knowledge sharing is crucial in developing trust and improving collaboration. Many studies claim that without effective knowledge sharing, the project suffers from coordination problems that lead to unsuccessful collaboration. Achieving effective knowledge sharing is a problem especially in GSD context where teams have to face the challenges of cultural, geographical and temporal distances. The major challenge in knowledge sharing within GSD is the difficulty of knowing who knows what, initiating contact, and of communicating across sites, led to a number of problems related to collaboration. Several studies have acknowledged the aspect of who knows what, as the key to knowledge sharing activities [7-9, 15, 26, 28].

2.4. Knowledge sharing and SUR in GSD

Shard understanding between GSD team members is a crucial prerequisite for successful development and deployment of a software system. Shared understanding has two facets: explicit shared understanding occurs when all team members working on a project possess the same understanding of explicit specification (requirement documents, manuals etc.). On the other hand, implicit shared understanding refers to the common understanding of non-specified facts, assumptions, and values. Implicit shared understanding reduces the need for explicit communication and lowers risk of misunderstanding. As far as explicit shared understanding is concerned, research and practices in the RE field have contributed a lot in defining practices for eliciting requirements, specifying requirements and documenting them. In contrast, the value and role of implicit SUR are still not clear and need further research. Relying merely on implicit shared understanding is not enough because the real world is too complex and is very difficult to develop without any explicit documentation. Similarly, relying solely on explicit shared understanding is both unreasonable and uneconomical for any real-world software system. Although a shared understanding of requirement is crucial for the projects developed in collocated settings, the importance of shared understanding further raise in GSD context where stakeholders working on a project are far from each other and barriers of culture, time zone and geographical distances are involved between them. In such a situation, knowledge sharing, trusting working relationship and effective collaboration helps in achieving SUR [18, 29, 30].

Based on the above discussion, we argue that knowledge sharing in GSD setting influence trust among team members and thus, promote some observed behaviours, which are absent in GSD environment. Further, we argue that knowledge sharing influence collaboration among GSD team members, which ultimately influence SUR. Further, we argue that knowledge sharing affect SUR through improving coordination and trust moderates relationship between SUR and collaboration.

3. Research Model and Hypothesis Formalization

Although information and communication tools and technologies influence knowledge sharing, collaboration, and trust; social factors also affect GSD teamwork. GSD organisations are distributed knowledge-based systems, in such situation, an organisation can only lead itself towards distinctive competitive advantage; if it identifies its knowledge resources, manage them and make them accessible for its employees all the time [31, 32]. In this section, we tried to present our research model and research hypothesis to explain the relationship between knowledge sharing, collaboration, trust and their impact on SUR.

3.1. Constructs affecting knowledge sharing

In order to formulate research models, we identified constructs of knowledge sharing and Trust that we used in our research model. Below we discuss these constructs briefly.

3.1.1. Continuous intention of using KMS (CINT)

It means that the user of a system plans to use this system on a continuous basis. This usage intention of a system can be determined by two other related factors; namely, benefit obtained from using the system (i.e., perceived usefulness) and minimum efforts required to use the system (i.e., perceived ease of use) [33-35].

3.1.2. Perceived usefulness of KMS (PU)

Perceived usefulness is defined here as "the degree to which, a person believes that using a particular system would enhance his or her job performance." If a user perceives that using a particular system will rise up his performance, will give him some benefits in term of promotions, bonuses etc., then he will have a positive approach towards this system. This factor is very important in the acceptance of any information technology [31, 34-36].

3.2. Constructs affecting trust

The following subsections will brief about the constructs affecting the trust level.

3.2.1. Propensity to trust (PTT)

It is a willingness of one or more persons in a group to trust other members of that group. PTT is affected by many factors like team culture, lifestyle, experience, education, etc., it’s a general personality attribute that leads towards general expectations about credibility and trustworthiness of other persons, which remains stable across many situations. The existence of this PTT is very important for the survival and efficient working of a team especially in case of GSD [37-39].

3.2.2. Perceived trustworthiness (PTW)

It refers to the extent to which, an individual expect others to behave according to their commitments. It exists when team members behave according to the expectations of their colleagues; they are loyal and honest with their team members and nobody takes advantage of others [39-41].

3.2.3. Cooperative behaviors (CB)

It refers to the environment in which, team members work in collaboration, help others in difficult situations and share their experiences and knowledge. Cooperative behavior promotes trust and team with cooperative behavior work efficiently towards a common goal [42-44].

Figure 2 present our conceptual research model, which presents correlational research where knowledge sharing is supposed to influence trust, collaboration and SUR positively. Further, we argue that the relationship between collaboration and SUR is being moderated by trust, in which, high trust results in high collaboration impact on SUR.

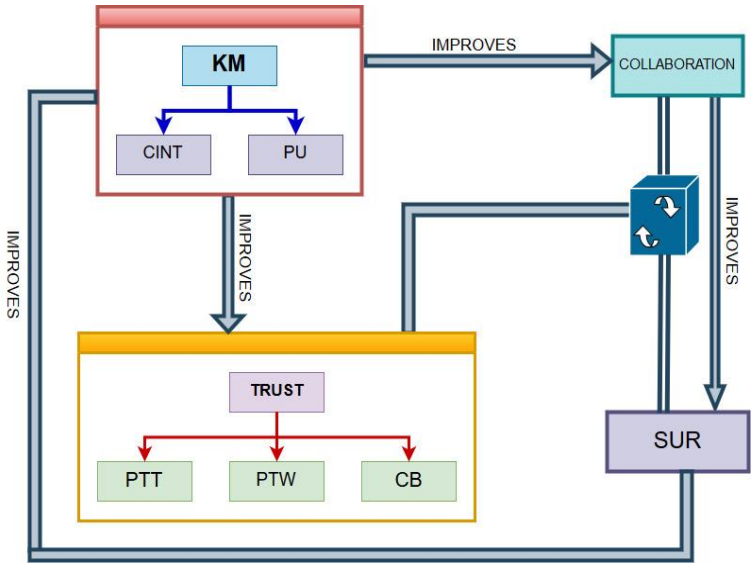

Fig. 2. Research model.

Knowledge is a valuable asset to any organisation. Individuals create knowledge and the role of the organisation should be to integrate, store and use this knowledge. According to Zheng et al. [45] and Mills and Smith [46], if knowledge is effectively utilized and integrated, it has the potential to improve organisations' productivity and competitive advantage. Sharing knowledge in GSD teams is indeed a complex issue. As on one hand, individuals consider knowledge an important personal asset and sharing it leads towards the loss of their unique personal advantage while sharing this knowledge is beneficial for others [46].On the other hand, GSD organisations form team members share knowledge for different reasons, sometimes individuals share knowledge to appear valuable in their organisation.

Trust among GSD team members affect the team's performance and coordination and it establishes an open information sharing environment and helps team members to overcome the physical barrier. It is a dynamic personality attribute, which takes time in developing and changes over time. These days, virtual teams have become part of GSD economy and are not necessarily temporary, so virtual team members have enough time for social relationships and make some

sound trust decisions [47]. The challenge is to identify such behaviors, which assist an individual to trust others. Based on the above discussion, it is argued that knowledge sharing helps in promoting these observed behaviors, which ultimately improve trust among GSD team members. This can be expressed as:

Hypothesis 1: In GSD settings, knowledge sharing positively influence trust among GSD team members

Let TR: trust

KS: knowledge sharing

$$TR = \beta_0 + \beta_1 PTT + \beta_2 PTW + \beta_3 CB + \varepsilon$$

$$KS = \beta_0 + \beta_1 CINT + \alpha_2 PU + \varepsilon$$

Then

$$TR = \beta_0 + \beta_1 KS + \varepsilon$$

Team's performance and productivity increase when it involves members with relevant expertise. When GSD teams are able to find and access required knowledge, they perform well and produce the desired outcome. According to social exchange theory, individuals exchange knowledge when they expect some unclear benefit from it. Knowledge sharing can also be considered as a form of social exchange in which, individual share knowledge with unclear benefits but in the promise of long-term mutual relationship [48]. According to Binder [16], without effective knowledge sharing, GSD projects suffer from coordination problems, which lead to unsuccessful collaboration.

In GSD settings, the main cost of knowledge sharing lies in the loss of personal advantage while the major driving force to share knowledge is effective collaboration and integration of knowledge to reach new insights. In short, GSD teams need knowledge that is distributed among different team members in order to collaborate effectively. Otherwise, GSD team will suffer from high cost of locating required information to perform their tasks. Based on this discussion we have formulated hypothesis 2, we argue that knowledge sharing in GSD settings positively influence collaboration.

Hypothesis 2: In GSD settings, knowledge sharing positively influence collaboration among GSD team

Let COL: Collaboration

KS: Knowledge Sharing.

$$KS = \beta_0 + \beta_1 CINT + \beta_2 PU + \varepsilon$$

Then

$$COL = \beta_0 + \beta_1 KS + \varepsilon$$

Whether a team is working in collocated settings or distributed globally, SUR is necessary to avoid conflicts, delays, and sometimes cost and budget overrun. However, achieving SUR becomes challenging in GSD context due to lack of face to face interaction and geographical and temporal distance involved between stakeholders. In GSD context, usually, individuals who elicit and document requirements and developers who develop a system based on these requirements are

apart from each other. In such situation communication between developers and requirement, analysts are mediated by communication technologies. Lack of collaboration among team members distributed globally hinders effective negotiation and prioritization of requirements, which create the problem of SUR [49].

As RE is the initial activity of Software Development Lifecycle (SDLC), therefore, it should be done in a careful and organized way. The output of RE phase serves as an input for remaining phases of development. Hence, if the initial input of the requirement phase is clear and correct then the resulting product will be of better quality and will meet customer requirements. On the other hand, if requirements are ambiguous and conflicting, the project will suffer from delays, cost and time overrun. Moreover, the cost of removing errors in the requirement stage is comparatively low as compared to other stages of development. RE, becomes more challenging in GSD context as developers and requirement analyst are apart from each other; in such situation GSD team members need to put more effort in collaboration through sharing more idea, knowledge exchange, and sufficiently coordination activities among each other so that SUR could be achieved and software project might not suffer from problems caused by lack of SUR [19, 50, 51]. Based on the above discussion we argue that collaboration among GSD team members positively influences shared understanding of the requirement.

Hypothesis 3: In GSD settings, collaboration among team members positively influence SUR

Let COL: Collaboration

SUR: SUR

Then

$$SUR = \beta_0 + \beta_1 COL + \varepsilon$$

GSD team members are expected to perform the common organisational task in collaboration with each other and action of an individual effect all other team members. In such situation trust act as a moderator, as for any action to take place a corresponding trust decision is made, and based on the action of other individuals trust is either authenticated or sometimes lost. The literature on GSD considers trust as a foundation of effective collaboration [16, 52]. Trust in GSD settings, reduce uncertainty and enable a positive environment of collaboration among individuals. GSD teams normally do not have a history of working together, communicate using some communication technology, and unable to observe each other directly, therefore, making trust decision is difficult for them. In such a situation, when individual trust others, they expect certain behaviors and performance.

On the other hand, team collaboration is a backbone of team success and these days abundant advance tools and technologies are available, which facilitate collaboration in GSD settings. However, in spite of the availability of these tools and technologies, trust significantly influences collaboration among GSD team member. Effective collaboration among globally distributed team members helps in clarifying ambiguities, resolving conflicts and thus, achieving SUR. Based on the preceding discussion, we argue that the relationship between collaboration and SUR in GSD settings is moderated by trust.

Hypothesis 4: (a) In a high trust environment, collaboration and SUR will be positively associated. (b) In a low trust environment, there will be a less significant association between collaboration and SUR.

Let COL: Collaboration

KS: knowledge sharing

HT: High trust

LT: Low trust

where

$$KS = \beta_0 + \beta_1 CINT + \beta_2 PU + \varepsilon$$

$$TR = \beta_0 + \beta_1 PTT + \beta_2 PTW + \beta_3 CB + \varepsilon$$

The mediating role of trust between collaboration and knowledge sharing will be

$$SUR = \beta_0 + \beta_1 HT + \beta_2 COL + \varepsilon$$

$$SUR = \beta_0 + \beta_1 LT + \beta_2 COL + \varepsilon$$

Similarly mediating role of collaboration between knowledge sharing and shared understanding of requirement as shown in our model will be

$$SUR = \beta_0 + \beta_1 COL + \beta_2 KS + \varepsilon$$

4. Computer Ontology Representation

To analyse the interrelationship between identified key determinants of GSD success we identified the factors that affect these constructs and represented them via the ontology as shown in Fig. 3.

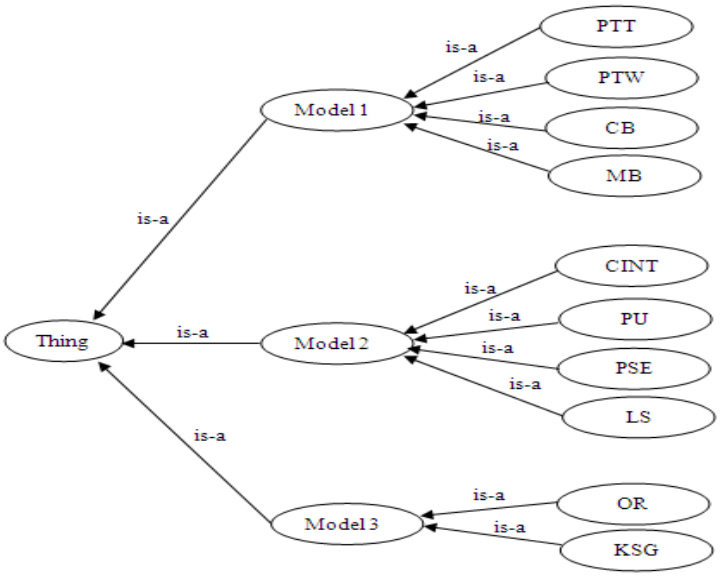

Fig. 3. Ontology structure.

Inference rules

Based on the ontology structure, we represented our hypothesis in Boolean form by using the following two inference rules

Rule1: Positive effect: *MO(a)* ^mutual complement*(a, b)⇨MO(b)*

Rule 2: Mediation effect*: MO(b)* ^partial complement*(a, b)⇨MO(b)*
where a is independent and b is the dependent variable. Using the above inference rules, there are only two kinds of relationship exist between variables. Below we state our hypothesis using ontology and in the next section, we will discuss the research methodology, which we used to test these hypotheses

Knowledge sharing (K) among GSD team members will have a positive effect on trust (T). It can be represented as

1. MO(K)^mutual complement(K,T)=>MO(T)
   Knowledge sharing (K) among GSD team members have a positive effect on SUR (S). It can be represented as
2. MO(K)^mutual complement(K,S)=>MO(S)
   Knowledge sharing (K) among GSD team members have a positive effect on collaboration(C). It can be represented as
3. MO(K)^mutual complement(K,C)=>MO(C)
   Collaboration(C) among GSD team members have a positive effect on SUR (S). It can be represented as>
4. MO(C)^mutual complement(C,S)=>MO(S)
   The relation between knowledge sharing (K) and SUR (S) is mediated by the collaboration
5. MO(K)^partial complement(K,S)=>MO(S)
   The relation between collaboration(C) and SUR (S) is mediated by trust
6. MO(C)^partial complement(C,S)=>MO(S)
   - In high trust environment collaboration and shared understanding of requirement will be positively associated
   - In a low trust environment, there will be a less significant relationship between collaboration and SUR.

5. Research Methodology

This research study can be categorised as empirical research. It is a type of research in which, conclusion is drawn from empirical evidence. To conduct empirical research, we need to collect data from a real source. One of the reliable ways to collect data from practitioners and researchers is to conduct online surveys.

We used a web-based survey methodology to collect data and to test the proposed research model. The motivation behind selecting survey method was it is suitable in the early stages of research where researcher want to collect data about something; further, it enhances the generalizability of results because it targets a wide range of audience. An online tool Survey crest was used for survey design and survey link was sent to participants by email

The steps involved in our empirical research are described in Fig. 4.

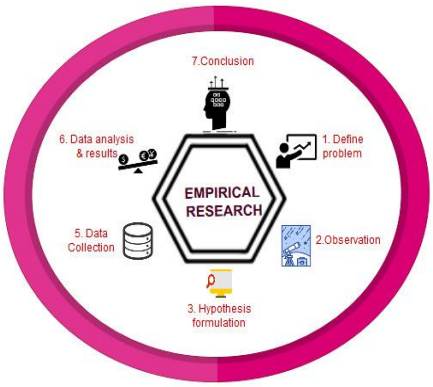

Fig. 4. Methodological framework.

5.1. Sample

The population for this study consists of individuals working in GSD settings. To avoid sampling bias, we chose a single IT industry as a research site for administering the survey. In order to obtain a representative sampling, we prepare a sample frame and sent the survey link to only those GSD practitioners who fit in the description of this study frame. According to study frame, the population will consist of those individuals only who have experience of working in GSD settings, are currently working in GSD settings, have some experience of using KMS, and share knowledge using KMS.

There exist various techniques for choosing sampling from a given population. However, we used purposive sampling in this study. The reason for choosing purposive sampling is that it focuses on particular characteristics that are of a researcher's interest. Our interest was to choose an experienced GSD practitioner who is using KMS, therefore, this sampling option was best suitable.

The target population consists of a leading IT industry XYZ of Pakistan was selected as a research site for administering the survey. This company was established in the late 1990s and deals with providing quality software services and products. The company has successfully cleared ISO 9001 and SEI CMMI Maturity Level 4. Its head office is in the USA. It is working with more than 200 companies/branches in around 30 countries. The reasons for choosing this IT industry were many. Firstly, it was a large GSD organisation with more than 15000 employees. Secondly, the organisation was using KMR (knowledge management repository) as a system of KM from last so many years. Thirdly, a senior person in this industry allowed us and helped us in identifying a sample of GSD practitioners according to our sample frame. A total of 195 subjects were selected for participation in this study.

5.2. Measures

A questionnaire was used as a survey instrument; tested questions from the prior research were selected to measure constructs, so that the validity of constructs may be ensured. If validated items were not available, we designed new questions based on literature review and experts' opinion. Chang and Chuang [31], Wang and Noe [35], Chen and Hung [36], Lucassen and Schraagen [37], Ferguson and Peterson

[38] and Trainer and Redmiles [39] adopted the items for measuring knowledge sharing. Calefato et al. [40], Marczak and Gomez [41], Humayun et al. [42], Hamayun and Cui [43] and Toth [44] adapted the items for measuring trust. Chudoba et al. [53] derived items for measuring collaboration and Khan et al. [3], Nicolas et al. [19], Hussain [20], Khan et al. [50] and Yaseen et al. [51] adopted items for measuring SUR. To ensure the validity of questions, we conducted a pilot study to ensure that the questions are satisfactory. The pilot study is just the rehearsal of the actual data collection process by applying it on a small data set before applying it on a real data set. Figure 5 describes the instrument development process in detail.

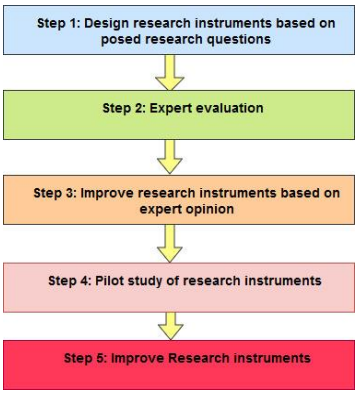

Fig. 5. Instrument development and validation process.

Definition of constructs is given in Table 1.

Table 1. Study construct's definition.

Construct	Definition
Knowledge sharing	The extent to which, knowledge seeking and contribution occurs among GSD team members, in this study knowledge sharing = knowledge acceptance +knowledge use
Collaboration	The extent to which, GSD team members work together in order to achieve organisational tasks
Trust	The belief that other team members are able and trustworthy
SUR	All team members have the same understanding of all requirements

Reliability testing of constructs

In order to test the reliability of study constructs, we performed a pilot study with a group of respondents. Reliability is used to measure the consistency of measures. It changes with time and respondents. Reliability of constructs may be assessed by using the construct on the same group of people with different intervals and results are supposed to be consistent.

6. Data Analysis and Results

As mentioned above, our questionnaire consists of two parts, first was about personal information of respondents and second part include actual items related to constructs. Hence, we used demographic and descriptive analysis. The

demographic analysis includes different techniques and methods to measure the dimensions and dynamics of the target population or sample while descriptive analysis quantitatively describes the core features of a collection of information. The research model was tested for reliability using Cronbach's alpha. Content validity, discriminant validity and convergent validity of the research model were also assessed. For hypothesis testing, we used the PLS technique. Two common techniques of hypothesis testing are PLS-SEM and CB-SEM. PLS-SEM is a suitable technique of hypothesis testing when the research is exploratory while CB-SEM is more suitable in situations where the researcher's intention is theory testing, confirmation or comparison of theories [54-56]. Based on the analysis of both testing techniques, we chose PLS-SEM, the reasons of choosing this technique were many: firstly; this technique is suggested as an appropriate technique during the initial stage of the research model where the emphasis is theory exploration and prediction. Further, it is also suitable for situations in which, the sample size is relatively small [54, 55].

6.1. Demographic and descriptive analysis

Respondents who participated in this study were asked to mention their gender and age. They were also asked to provide some information related to their work experience i.e., experience of working in GSD settings, for how long they are working in the same team, do they use KMS for knowledge sharing, if they work for the same organisation etc. This demographic and descriptive information are given in Table 2.

Table 2. Demographic and descriptive statistics.

Variables	Category	Total participant	Participant %
Gender	Male	148	76%
	Female	47	24%
Age	<=19years	0	0
	20-29 years	64	32.8%
	30-39years	89	45.64%
	>=40years	42	21.54%
Education	<=graduation	62	31.79%
	>=graduation	133	68.20%
Experience	0-6 Months	0	0
	<=3years	26	13.33%
	3-6 years	71	36.4%
	7-10years	62	31.79%
	>10years	36	18.46%
Member of current GSD team	<=1years	92	47.18%
	1-3 years	64	32.82%
	4-6years	34	17.4%
	>6years	5	2.59%
KMS usage experience	<=6 months	3	1.54%
	7-12 Months	24	12.31%
	1-3Years	78	40%
	>=3years	88	45.13%

6.2. Measurement model assessment

Below we discuss the statistical measures that were used in result analysis.

6.2.1. Convergent validity

The average variance extracted and Composite reliability are two measures used to analyse convergent validity. In this study, AVE for all constructs (as shown in Table 3) was more than 0.5 threshold value, which shows acceptable convergent validity. Similarly, composite reliability of all constructs was more than 0.7 threshold value that shows satisfactory convergent validity [57].

Table 3. Correlation and intercorrelation matrix showing convergent and discriminant validity.

Constructs	*CR*	*AVE*	*Knowledge sharing*	*Trust*	*Collaboration*	*SUR
Knowledge sharing	0.94	0.83	0.91**			
Trust	0.86	0.89	0.64	0.94		
Collaboration	0.93	0.72	0.71	0.58	0.85	
SUR	0.94	0.71	0.62	0.43	0.70	0.84

where *SUR represents Shared understanding of requirements and ** square root (AVE)

where $CR = \dfrac{(\sum_{i=1}^{n} L_i^2)}{((\sum_{i=1}^{n} L_i)^2 + (\sum_{i=1}^{n}(1 - L_i^2)^2)}$

and $\text{AVE} = \sum_{i=1}^{n} \dfrac{L_i^2}{n}$

6.2.2. Discriminant validity

Discriminant validity is evaluated using item loading and cross loading. In order to check discriminant validity, the loading of each item should be higher on its corresponding construct as compared to another construct in the model. If we observe the values of Table 4, it is clear that all item loaded higher on their respective constructs as compared to others. Further, average correlation among items of each construct, which is shown in the diagonal part of the correlation matrix in Table 3 was greater than the value of each construct's relationship with any other construct, it also provides strength to discriminant validity [58, 59].

Table 4. Items loading and cross loading.

	Knowledge sharing	**Trust**	**Collaboration**	**SUR**
KS1	**0.85**	0.42	0.54	0.48
KS2	**0.86**	0.44	0.49	0.52
KS3	**0.89**	0.39	0.46	0.54
KS4	**0.90**	0.48	0.38	0.60
KS5	**0.87**	0.42	0.50	0.39
TR1	0.43	**0.80**	0.45	0.30
TR2	0.45	**0.82**	0.39	0.34
TR3	0.49	**0.88**	0.41	0.28
TR4	0.21	**0.89**	0.44	0.26
TR5	0.14	**0.72**	0.38	0.29
COL1	0.56	0.35	**0.79**	0.48
COL2	0.54	0.43	**0.81**	0.54
COL3	0.63	0.39	**0.88**	0.56

COL4	0.51	0.44	**0.72**	0.62
COL5	0.42	0.48	**0.89**	0.60
SUR1	0.34	0.29	0.62	**0.90**
SUR2	0.46	0.27	0.59	**0.88**
SUR3	0.51	0.30	0.63	**0.79**
SUR4	0.46	0.34	0.58	**0.92**
SUR5	0.49	0.22	0.60	**0.87**

6.2.3. Reliability testing

Internal consistency and items reliability were examined to assess the reliability of the measurement model. Internal consistency is used to measure the reliability of indicators; it is represented by Cronbach's alpha, at least 70 %value of Cronbach's alpha indicates satisfactory reliability [57, 60, 61].

Indicator reliability is measured using cross loading scales, which is the proportion of indicator variance by its corresponding construct, it is described as fair (.45 to .54), good (.55 to .62), very good (.63 to .70), and excellent (0.71 and high). Cronbach's alpha values for each construct is shown in Table 5, all constructs show high and satisfactory values [62, 63].

Table 5. Cronbach's alpha.

Construct	Cronbach's alpha
Knowledge sharing	0.92
Trust	0.84
Collaboration	0.90
SUR	0.91

6.3. Hypothesis testing using PLS analysis

We used the PLS technique for hypothesis testing. PLS is a powerful analysis method due to its minimal demand on measurement scales, residual distribution and especially sample size. PLS is not only used for theory confirmation but rather it can also be used to know as for where relationships may or may not exist and to further suggest propositions for later testing. It is an extension of multiple regression method, which specifies the relationship between the dependent variable (Y) and a set of independent variables (X's).

Results of PLS analysis are represented in Fig. 6. *R* squared value of knowledge sharing is 0 because knowledge sharing was not predicted by any other variable. R squared value for trust resulted in 0.30, R squared value for collaboration resulted in 0.51 while R squared value of SUR was 0.52. Results of Fig. 6 show that 51% of the variance in collaboration and 30 %of variances in trust is explained by knowledge sharing. Similarly, 52% of the variance in SUR was explained through collaboration. Further, the value of path coefficient β between knowledge sharing, trust, collaboration, and SUR was significant at .001. However, the value of path coefficient β for trust as a mediator between collaboration and SUR was insignificant. In short, three out of four hypotheses were supported.

where $R^2 = \frac{r_{y1}^2 + r_{y2}^2 - 2r_{y1}r_{y2}r_{12}}{1 - r_{12}^2}$

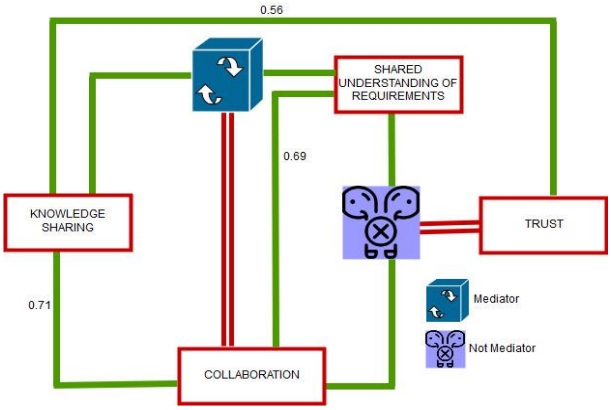

Fig. 6. PLS results.

6.4. Structural model assessment

Mediation analysis

According to our theoretical research model, collaboration was a mediator between knowledge sharing and SUR. In order to test the significance of collaboration as a mediator between knowledge sharing and trust, we used the Sobel test. Sobel test is a type of t-test, which is used to determine the impact of a dependent variable upon independent variable after including some mediator in the model.

The reason for using the Sobel test instead of other approaches are many: firstly, the intention was to test the effect of a dependent variable on the independent variable while keeping in mind the significance of mediator. In such a situation, the Sobel test is an ideal choice. Secondly; it is a widely used method of finding mediation effect [64, 65].

$$\text{sobel} - \text{test} = \frac{a \times b}{\sqrt{(a^2 \times Se_b^2) + (b^2 \times Se_a^2)}} \qquad (5\text{-}19)$$

In the Sobel test, an indirect relationship is hypothesized between the independent and dependent variable due to the influence of a mediator (third variable). Table 6 presents the result of the Sobel test, the result shows that the Sobel test for mediation is significant at 0.01 values of α. Results indicate that collaboration mediates the relationship between independent variable knowledge sharing and dependent variable SUR.

Table 6 SOBEL test results for mediation analysis

Hypothesis	*Results*
Knowledge sharing →Trust	Significant
Knowledge sharing →Collaboration	Significant
Collaboration →SUR	Significant
Trust ×collaboration → SUR	Insignificant

7. Discussion

These days GSD has become a dominant operational phenomenon and organisations are rapidly moving from collocated settings towards GSD.

Although GSD has benefited a lot, but still there exist some challenges, which are faced by almost all GSD organisations, researchers and practitioners since last one, or more decades are in search of finding some appropriate solutions of these challenges so that benefits of GSD could be utilized more efficiently. Research on GSD has identified many determinants of GSD success; some of the key determinants include knowledge sharing, trust, collaboration, and SUR. In this research study, we have investigated the relationship between knowledge sharing, collaboration, and trust and how this relationship finally affects SUR among GSD team, which is a key to the success of the GSD team. We have proposed a conceptual research model based on intensive study of literature, we have also formulated four hypotheses based on this model. To collect data, we prepared a questionnaire based on items from literature corresponding to four constructs, which include knowledge-sharing, trust, collaboration, and SUR. Obtained results show that knowledge sharing significantly impact trust and collaboration, this provides support to hypothesis 1 and 2 of our research model. Positive results of both hypothesis 1 and 2 show the importance of knowledge sharing for GSD teams, these results are also consistent with previous studies [5, 18]. Knowledge is a valuable asset of any organisation, which if managed and shared properly can benefit a lot.

Further, in this study, we extended the literature on GSD team and claimed that knowledge sharing is crucial for GSD team members for collaboration, trust and ultimately achieving SUR. The results obtained from our study shows that collaboration positively influences SUR, which supports hypothesis 3. Sobel test also indicates that collaboration mediates the relationship between knowledge sharing and SUR. It further strengthens the significance of knowledge sharing in GSD settings, knowledge sharing facilitate collaboration among GSD team members and helps them in achieving SUR. However, hypothesis 4, which states that trust, mediates the relationship between collaboration and SUR was not supported, which shows that trust has limited influence in achieving SUR.

8. Implications to Research and Practice

The results of this study have significant implications for both researchers and practitioners. For practitioners, it provides significance of knowledge sharing, trust, collaboration and SUR with a major focus on the importance of knowledge sharing in GSD settings. It also provides a relationship between these constructs by proposing a conceptual research model and formulating a hypothesis, results of hypothesis give an in-depth insight of relationships existing between these constructs. It suggests the need for implementing some effective knowledge sharing mechanism (using some tool of KM or do so) to overcome the barrier of inadequate communication and coordination and lack of SUR.

For researchers, it provides a deep analysis of the relationship existing between knowledge sharing, trust, collaboration, and SUR. Further, it suggests the need for more research to better understand the influence of trust in achieving a shared understanding of requirement in GSD settings.

9. Conclusion

Global Software Development has become a dominant operational phenomenon with current technological era to coup up with the fast-paced economy. The GSD approach

has viable advantages such as outsourcing, cost lowering, and 24/7 availability to the customers. However, the challenges are also there, due to the different levels of dispersion (language, cultural, geographic, etc.), which brings the difficulties in team coordination, trust between developer and communication. The literature on GSD considers knowledge sharing, trust, collaboration and shared understanding of requirements as key determinants of GSD success. A quantitative research model is adopted with a quantitative questionnaire, containing multiple weighted questions related to the relationship among the key determinants of GSD. A leading multinational firm having more than 200 branches in 30 countries was selected as a research site for the survey, the sample size of 195 was taken for this research. This research proposes a conceptual research model, which presents the relationship between four constructs, which have been considered as key determinants of GSD success. These constructs including knowledge sharing, trust, collaboration and SUR in GSD settings. The achieved results will help the researcher to explore a better relationship between GSD, KM, trust, and collaboration.

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