Knowledge Management Practices in GSD: A Systematic Literature Review

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Abstract—**Global software Development (GSD) is a popular software development setting that aims at developing software at low cost with geographically distributed teams. Knowledge Management (KM) is an important issue in GSD. Plethora of research is available to solve GSD issues with Knowledge management practices (KMPs).** *Evidence about the effectiveness of these practices is scattered among different studies*. **The need exists to collect, synthesize and review this research at one place. This study explores GSD issues due to lack of knowledge management (KM) and knowledge management practices (KMPs) used to solve these issues. Systematic literature review (SLR) is performed for the identification of KMPs used in GSD projects to handle GSD issues. The study has identified GSD issues due to lack of KM and KMPs used to address these issues.** *Effectiveness of knowledge management practices is seen by associating a frequency count with each practice.* **Knowledge transfer, shared understanding and communication are mostly reported problems. Collaborative technologies are widely used practice to solve GSD issues due to lack of KM.**

Keywords-Knowledge Management; Knowledge Management Practices; Global software Development; Systematic Literature Review

I.   INTRODUCTION

Knowledge management (KM) is an asset for software development organizations. It addresses different issues in software development and at the same time also contributes to software process improvement [1][2].

Global software development (GSD) is a methodology to develop software with teams at multiple locations to get the edge of round the clock development and nearness to the market. However, geographical separation introduces many issues such as communication, coordination, control and knowledge management. Knowledge, in offshore development teams is scattered across continents and GSD barriers make its coordination and synthesis difficult [2]. At the same time, effective KM plays a paramount role in solving the issues innate in offshore software development.

Knowledge management facilitates the organization operating globally to successfully integrate and coordinate knowledge resources [2]. Knowledge acquisition and sharing is helpful in achieving shared understanding in GRE [6].

The area of KM is explored to see its influence in global software engineering. Number of studies have highlighted the issues that arise in GSD due to lack of KM. Desouza et al. [2] empirically investigated different organizations and highlighted the importance of KM in their study. They identified access to skilled knowledge group as one force among the other compelling forces for global software development. They found seeking relevant knowledge, knowledge sharing, synthesis and transfer are some of the KM problems faced in GSD [1].

Damian et al. [14] focused on the impact of remote communication, knowledge management, time and culture differences on requirements engineering activities and found that ineffective knowledge management influences requirements negotiation, prioritization, specification and validation. Avram [7] focused on socio-cultural impact on knowledge exchange. During the empirical investigation they found maintaing awareness and knowledge transfer are the problems that mainly arise due to lack of informal communication.

Realizing the importance of KM, many practices are suggested to manage knowledge in GSD. Avram [3] identified the knowledge work practices that are used in the actual work setting. The focus of the study is on people, "their values and connections" to deal with issues in distributed development. The identified practices deal with the issues of knowledge transfer, mutual knowledge and knowledge sharing. Desouza [2] empirically found the strategies and models used to manage knowledge in software industry. Clerc [4] reviewed the architectural knowledge management approaches. He categorized the approaches in personalization and codification strategies and suggested to focus on hybrid approaches. Paiva

[8] narrates the experience of implementing community of practice (CoP) by Brazil Global Development Center. CoP helped in project management, information reuse, reducing time in trouble shooting, requirements specification and reverse engineering.

Despite the acceptance of knowledge management practices (KMPs) to solve GSD issues little evidence based research exists to GSD practionars to select appropriate knowledge management practice to deal with a particular issues. This paper intends to fill the gap by conducting the systematic literature review (SLR) about the state of practice of knowledge management in GSD. We followed the guidelines proposed by Barbara Kitchenham [5].The questions investigated are:

RQ1: What GSD issues occur due to lack of knowledge management (KM)?
RQ2: What KMPs are used in GSD projects?
RQ3: What GSD issues are addressed by existing knowledge management practices (KMPs)?

We have identified GSD issues due to lack of KM and KMPs to sort out these issues. We have classified the practices into predefined categories of codification and personalization. The paper is organized as follows: Section 2 describes the background. Section 3 reports the research methodology. Section 4 presents findings from the systematic literature review and analysis with some discussion. Section 5 describes the conclusion.

II. RESEARCH MEHODOLOGY

The research is conducted using systematic literature review (SLR). SLR is a well defined, thorough and fair "means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest" [7]. Barabra Kitchenham's guidelines [5] were followed to define the protocol and conduct SLR. The steps to perform review are Identification of research, primary studies selection, Study quality assessment, Data extraction & analysis.

A. Search Strategy

Search strategy consists of deriving major terms from questions, developing search strings from major terms and their synonyms using AND/OR operators. Major search terms were 'knowledge management' and 'GSD'. These terms and their synonyms are shown in table 1 below. These two terms (or their synonyms) were ANDed to form the generic search string. Initial pilot study helped in selecting the synonyms and major search terms.

TABLE I : MAJOR SEARCH TERMS AND THEIR SYNOYMS

GSD: "Global Software development" OR "distributed software development" OR "multi-site software development" OR "global software engineering" OR "global requirements engineering" OR "distributed software engineering" OR "distributed requirements engineering" OR "multisite software development" OR GSD OR GSE OR "offshore software development" OR GRE
KM: ("knowledge management" OR "knowledge sharing" OR "knowledge acquisition" OR "knowledge transfer" OR "knowledge creation" OR "knowledge capture" OR "tacit knowledge" OR "explicit knowledge" OR "knowledge retention" OR "knowledge valuation" OR "knowledge use" OR "knowledge application" OR "knowledge discovery" OR "knowledge integration" OR "knowledge theory" OR "organization knowledge" OR "knowledge engineering" OR "information management" OR "information sharing" OR "information transfer" OR "information reuse" OR "common understanding" OR "shared understanding"

A total of 525 papers were obtained from a range of databases. Databases searched and no. papers retrieved from each database were: Inspec, IET, IEEE Explore (38), ACM Digital Library(85), Science Direct (149) , Springerlink (215), EICompendex (107). Customized search strings were developed from generic string for each database. The selected databases encompass the major database in software engineering and most of the research work is published in these databases. Google Scholar was also searched for the publications at first, but later, during pilot study was excluded as it gave multiple results of the same query at different time.

B. Publication Selection

Inclusion and exclusion criteria applied to the studies are given below:

1) Inclusion Criteria: It is used to include the studies for data extraction. We included studies that
- Are about KM in GSD AND
- Are supported by some evidence in the form of case study or industrial/Experience report or experiment AND
- Are published in peer reviewed journal or conference.

2) Exclusion Criteria: It is used to screen out studies that are not included for data extraction. We excluded studies that
- Are not directly related to KM or KMPs in GSD context OR
- Lack evidence support OR
- Studies that describe GSD problems not relevant to KM

3) Selecting Primary and Secondary Resources: Primary studies selection was carried out at two levels. Level 1 screening was based on title, abstract and keywords. This excluded the papers that were not relevant to our research question. After level 1 screening of 525 papers, 51 studies were selected as candidate primary studies. In Level 2 screening, incusion/exclusion criteria was applied on full text of 51 candidate primary studies. After this step, a total of 27

studies were selected as primary studies. Data extraction and quality assessment was performed for these 27 primary studies.

Single study in multiple papers was considered only once. Most recent and comprehensive study was selected when focus of the study was same.

Secondary studies selection was based on references of primary studies; 6 secondary studies were selected for data extraction.

C. Publication Quality Assessment

Quality assessment was applied on the final selection of papers in parallel with data extraction. We consulted protocols" Agile software development" and "EPIC Case Study 2 – Extension of a Tertiary Study" and Kitchenham guidelines [5],[10],[11] to develop quality assessment criteria that consists of questions. Every quality question has three options; yes means 2 points, no means 0 point and partial means 1 point. Quality Assessment Criteria for Industrial/ Experience report are:

- Does the study clearly describe the context?
- Does the links between data, interpretation and conclusion are illustrated well?
- Does study adds value to research?

And for evidence based studies are:
- Does study clearly narrate objectives?
- Does study clearly describe context?
- Does the sampling method and its rational given?
- Does the data collection method and rational given?

D. Data Extraction

Single researcher (1st author) was responsible for the data extraction. Secondary reviewers (other authors) were consulted in case of problem or confusion.

E. Data Synthesis

We identified list of GSD issues and KMPs used to address these issues at the end of data extraction phase. The KMPs were reviewed to make their categories along the codification and personalization lines.

III. RESULTS

Results of RQ1, RQ2 and RQ3 are shown in the section below:

1) GSD issues identified through SLR (RQ1): Table II shows the list of GSD issues due to lack of knowledge management identified through SLR. Complete citation of SLR references is given in appendix A. The identified issues vary from frequently reported in different studies to the ones that are reported only once. The table shows only the most occurring issues. Issues that fall in frequency range of 3, 2 and 1 are not shown in table due to the shortage of space.

TABLE II   GSD ISSUES DUE TO LACK OF KM

#	GSD Issues due to lac of KM
1	Shared understanding
2	Knowledge sharing
3	Communication
4	Knowledge transfer
5	Relationship building or team cohesion
6	Trust
7	Finding the right people

Issues that are reported rarely (frequency less than 5) are coordination, requirements engineering, awareness, culture, cost, quality, alignment of process and tools/objectives and faster ramp-up time, knowledge reuse, mutual knowledge, knowledge creation, Knowledge externalization, knowledge exchange, information gathering, ineffective decision making meetings, cycle time, time to market, fill knowledge gap, gap in knowledge flow, face-to-face meetings difficult, codified knowledge compatibility and exchangeability, knowledge retrieval, time zone difference, outsourcing success.

2) KMPs used in GSD projects identified through SLR (RQ2): Table III shows list of Knowledge Management Practices (KMPs) applied to address GSD issues. There are many practices to solve a GSD issue which indicates that an organization must follow some guidelines to select the appropriate practice prior conducting the project. Frequently reported practices are shown in table.

Practices that are reported rarely are: Division of work, Informal communication, Guidelines or training programs, Clear project/organization structure with clear roles and responsibilities, Cross continental mini teams, Adapt scrum, Learn by watching, Direct request, Information update, Knowledge centric product life cycle management, Reverse Presentation Method, Shared team and task knowledge, Surviving the Babel tower, Mutual adjustment, Process Knowledge Tracer, Shared infrastructure, Clear project structure with clear communication responsibilities, Discussion board, Knowledge reuse.

TABLE III   KMPs USED IN GSD PROJECTS

#	KMPs used in SD Projects
1	Collaborative technology
2	Meetings or visits
3	Documentation
4	Asking the developers/boundary spanners/colleague
5	Transactive memory
6	Knowledge sharing
7	Standard tools and methods

3) KMPs used to address GSD issue (RQ3): Table IV shows the GSD issues due to lack of KM and KMPs used to address these issues along with the number of times the pair (of GSD issue and KMP used to address it) is reported together. This is different from table III, wherein we only showed the reported practices.

TABLE IV   KMPs AND GSD ISSUES

GSD Issues due to lack of KM	KMPs used to address GSD issues due to lack of KM	f
Shared understanding	1) Collaborative technology	3
	2) Meetings	3
	3) Documentation	3
	4) Standardized tools and methods	2
	5) Transactive memory	2
	6) Asking the colleague	1
	7) Guidelines/training program	1
	8) Reverse Presentation method (RPM)	1
Knowledge sharing	1) Collaborative technology	4
	2) Meetings	2
	3) Surviving the Babel tower	1
	4) Process Knowledge Tracer	1
	5) Cross continental mini teams	1
	6) Direct communication	1
	7) Division of work	1
	8) Shared infrastructure	1
	9) Discussion board	1
	10) Transactive memory	1
		1
Communication	1) Meetings/Visits	3
	2) Asking the colleague	3
	3) Collaborative technology	2
	4) Clear project/organization structure with clear roles and responsibilities	2
	5) Transactive memory	1
	6) Information update	1
	7) Adapt scrum process	1
	8) Reverse Presentation method (RPM)	1
	9) Knowledge centric product life cycle management	1
	10) Documentation	1
Knowledge transfer	1) Collaborative technology	2
	2) Meetings	2
	3) Asking the colleague	2
	4) Documentation	2
	5) Division of work	1
	6) Transactive memory	1
	7) Standard tools and methods	1
	8) Surviving the Babel tower	1
Team cohesion	1) Visits/meetings	4
	2) Mutual adjustment	1
Trust	1) Meetings/Visits	3
	2) Collaborative technology	2
	3) Adapt scrum	1
Finding the right people	1) Transactive memory	3
	2) Collaborative technology	2
	3) Meetings or Visits	1
	4) Asking the colleague	1
	5) Standard tools and methods	1

IV.   DISCUSSION

Discussion section is divided in two parts i.e., discussion on GSD problems due to lack of KM and discussion on KM practices used to address the issues.

1) Global Software Development Problems due to lack of Knowledge Management:

Lack of common understanding is the most occurring problem identified during this study. 13 papers reported lack of shared understanding as a problem in GSD. Difference in organizational culture has great impact on shared understanding and creates problems in gaining common understanding of different aspects of project because of the difference in terminologies used by organizations for the same concept, difference in standard of documentation. Research shows that successful projects implemented standard tools and methods to achieve shared understanding ([3][9]). Communication gap in GSD teams gives rise to misunderstandings and takes more time to correct misunderstandings [14]. Language difference is another reason of the lack of common understanding in distributed software development teams. Difference in time zones of teams introduces communication gap; thereby giving rise to misunderstandings among time members and also providing them less time to clear these misunderstandings ([15][16]). Cultural diversity, communication gap, difference in technical background, gap in knowledge flow also create difficulty in achieving shared understanding ([11][17][20][21][22][23] [24]). Misunderstanding of requirements can introduce delay [18].

Knowledge sharing is another important problem identified. 40% of the studies (11 papers) reported knowledge sharing as a problem. This confirms our results with the previous studies that mentioned knowledge sharing as the critical success factor for outsourcing relationships success [25]. Only one paper reported that information was not appropriately shared among team members, whereas other studies mentioned that they found sharing knowledge to be problematic. Research suggests that tacit nature of knowledge and lack of trust among team members are the reasons behind the problem of knowledge sharing(Two papers suggested that factor that contributes to problem of knowledge sharing is tacit nature of knowledge, while one paper mentioned trust among cross site team members as a reason for lack of knowledge

sharing). Tacit nature of knowledge creates problem only in sharing implicit knowledge whereas trust is the factor that is necessary for sharing both kinds of knowledge either implicit or explicit [12][14][26]. Building trust and sharing tacit knowledge both require face to face interaction that is difficult to achieve in GSD.

This SLR identifies lack of Communication; either formal or informal as another problem that arises mostly during global software development projects. 37% of the studies (10 papers) reported the problem of lack of communication. The identified studies narrate the inability of team to have appropriate communication but failed to describe the specific problem they faced. The main reasons of lack of communication are geographical, socio-cultural and temporal distance. Due to lack of communication several problems arise i.e. lack of trust, relationship building etc. which ultimately cause lack of knowledge sharing. Informal communication is also badly impacted and almost become impossible due to geographical distance.

Knowledge transfer, relationship building, and finding the right people are some other important problems that require social aspect to be considered. Various other problems are also identified but these are less important with low frequency.

2) Discussion on Knowledge Management Practices:

Collaborative technology is an important practice reported in 51% of studies, supports hybrid strategy (codification & personalization) and solves 14 problems. Use of collaborative technology reduces social distance, makes people aware of other's presence, produces the sense of being a team, synchronizes communication and reduces delay by providing in time feedback. Collaborative technology includes email, video conferencing, IM, online data bases, etc. Email, Instant Messaging (IM) and video conferencing are more frequently used among identified practices of collaborative technology. IM was mostly used when to get information about a certain problem or for interaction with experts whereas video conferencing became an interaction medium for a group most of the time, yet maintained open communication between two managers as well. Email is more frequently used for sharing artifacts, circulating logs and exchanging documents. The Pros and cons of using collaborative technology are:

- *It has the ability to deal with the problem of communication;* a major challenge in GSD projects. Geographical distance hinders *face to face communication in GSD.* The only way to communicate among team members across different locations is through the use of collaborative technology. Collaborative technology is rich media for communication. It supports formal, informal and synchronous and asynchronous communication [14]. Lack of Informal communication is found to be the reason behind many problems identified in this study such as knowledge sharing/transfer, building trust, finding the right people etc.;[11][28]. *We argue IM* and video conferencing can enable informal

communication. Collaborative technology also facilitates formal communication; thereby impacting knowledge sharing/transfer and shared understanding. Exchanging documents via email i.e.; asynchronous communication tends to cope with time zone difference. Synchronous communication via collaborative technology impacts communication and shared understanding.

- Another advantage of using collaborative technology is it supports both personalization and codification strategy [14]. Other practices supporting hybrid strategies contrary to collaborative technology are either specific to one or two organizations or some specific problems.

- However, use of collaborative technology is not without problems. Temporal distance can't be overcome by collaborative technology. Another limitation of collaborative technology is when a time slot is dedicated for informal communication but till the end of meeting formal conversation goes on leaving no room for informal communication [14].

Meetings/visits are considered more useful to cope with problems created by geographical, temporal and socio-cultural distance. Their ability to develop trust and build sense of being a team is an important factor for the wide spread adoption of this practice. Arranging visits can be costly as compared to technical meetings but these have more benefits. Research has shown that GSD projects that lack visits were unsuccessful and those supported travelling were successful [27].

Documentation is third most frequently used practice and solves seven issues among the issues identified. Documentation is beneficial in keeping the group aware of what's happening in the project and is also necessary to keep aware if new person joins the team or some expert or relevant person leaves.

Asking the colleague and transactive memory also highlight the importance of social aspect in dealing with the GSD issues. Transactive memory supports both codification and personalization strategy and indicates that both type of practices must be used to be successful in GSD projects.

Knowledge management practices are broadly categorized in codification and personalization strategy in literature. We attempted to categorize Knowledge management practices used to address GSD problems due to lack of KM identified in this SLR along these two dimensions.

Codification: This category includes practices of Documentation, Standardize tools and methods, Shared infrastructure, Information update and Knowledge reuse.

Personalization: This category includes practices of Meetings or visits, Asking the colleague, Informal communication, Cross continental mini teams, Surviving the Babel tower, Direct request, Learn by watching, Mutual adjustment, Shared team and task knowledge, Adapt Scrum processes, Information update, Clear project/organization structure with clear roles and responsibilities and Discussion board.

Hybrid: Practices in this category are Collaborative technology, Reverse Presentation Method, Transactive memory, Division of work, Process Knowledge Tracer, Knowledge centric product life cycle management, Guidelines/training programs and Knowledge sharing.

This categorization can be helpful in appropriately selecting and devising a knowledge management strategy at the start of GSD project. Managers should include practices from all categories in overall KM strategy so that the complementary nature of practices helps in tackling different types of issues in GSD projects. Following guidelines can be helpful in dealing with issues due to lack of KM in GSD:

- Encourage informal communication among team members. It will produce a sense of being a team and develop trust.
- Standardize tools /methods and procedures as it will keep all the team members at the same level of understanding
- Focus on building social interaction that is badly impacted by geographic distance. It is identified as main reason behind many problems identified.
- Arrange travelling across sites. This may be costly but has long range benefits. Research has shown that successful projects have adopted this practice.

- Use both personalization and codification strategies in the project. Regularly plan for meetings and use collaborative technology and documentation in these meetings. Use collaborative technology for communication mainly informal communication between two meetings.
- Collaborative technology is one of the most used practices and its use can be beneficial for the project. However, it is effective when accompanied by other practices such as meetings and documentation
- Be proactive in dealing with the problems that arise in GSD projects due to lack of KM. Frequency of GSD problems identified and KMPs used to addressed these problems can help you in doing so.

We are currently working on purposing a model for the selection of the appropriate practice to deal with identified problems. A brief description of the model is provided in this paper. The proposed model deals with the most frequently occurring issues and most widely used practices to handle these issues. Collaborative technology, documentation and visits are at the core of the model indicating that these practices must be used to solve different kind of problems.
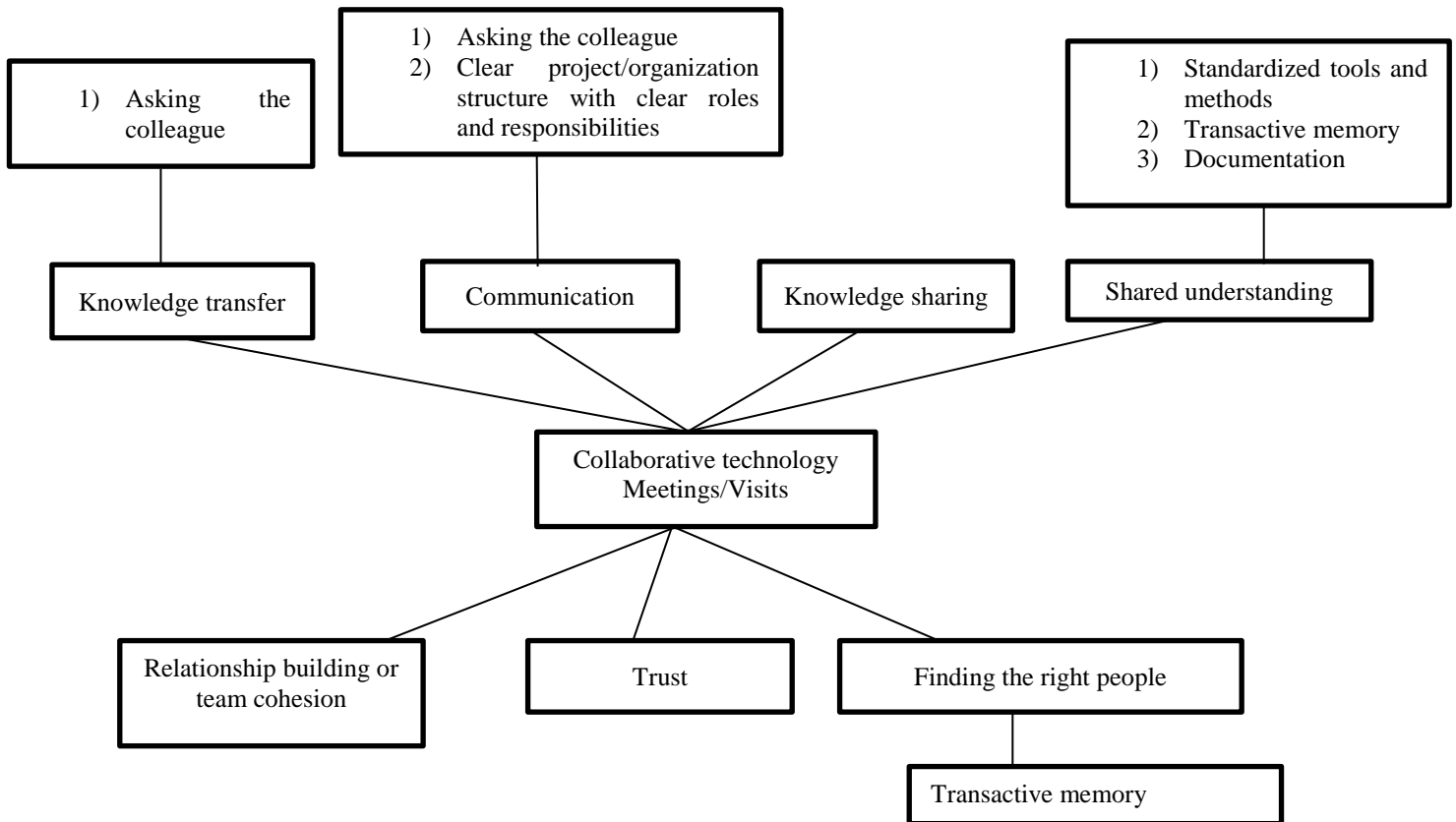

Figure 1. Model for selecting KMPs.

Team cohesion, lack of trust and relationship building are the problems that arise because of lack of social interaction or informal communication. Collaborative technology provides the supports social interaction among team members either in meetings or through direct contact. Meetings and visits also help in building sense of being a team that produces trust.

Problems at on the top require use of both codification and personalization practices. Knowledge sharing and transfer require social interaction to share tacit knowledge.. Collaborative technology and meetings/visits are the appropriate practices for this purpose. However, documentation is also required to share knowledge.

V. CONCLUSION AND FUTURE WORK

We have identified through SLR, GSD issues due to lack of KM and KMPs to solve these issues. We have identified that knowledge sharing, shared understanding and communication as most prevailing issues and use of collaborative technology and meetings or visits are mainly used practices to handle these issues. We have also found that most of the issues in GSD due to lack of knowledge management are due to lack of social interaction.

Our work facilitates the practioners in comparing which practice is better to adopt to deal with a certain issue. Frequency of each problem and practice narrates the severity of the problem in terms of its occurrence and effectiveness of a practice. This helps in identifying which problem will be confronted most and which practice is used widely to handle it. Making an aware choice by considering all the alternatives and consequences leads to better result. This piece of research helps in making an aware choice and thus leads to better results by applying this choice in offshore software development.

The following directions can be taken into account for future research:

- Relatively little empirical work has been done in software engineering. Similar situation is prevailing in the area of KM. Studies have been identified that provide only the theoretical base and lack the empirical evidence. This area requires consideration for future research.

- An important area in KM that lacks empirical evidence is KM tools. There are a lot of KM tools, but they lack the empirical ground. This area also has the potential for considering it for future research.

- This work can be extended by providing industrial perspective from Pakistan. Studies included in this SLR did not account any organization from Pakistan. A survey can be launched to identify GSD problems due to lack of KM and KMPs used to handle these issues. The results can be compared with the above

mentioned results and a model can be proposed and validated to select the best practice to solve GSD issues due to lack of KM.

VI. LIMITATIONS

The SLR incorporates the data of last ten years.

APPENDIX A: RESEARCH PAPERS INCLUDED IN THE SLR AS PRIMARY STUDIES

s1 G. Avram, ""Of Deadlocks and Peopleware - Collaborative Work Practices in Global Software Development," Global Software Engineering, 2007. ICGSE 2007.

s2 J. Bosch and P. Bosch-Sijtsema, "From integration to composition: On the impact of software product lines, global development and ecosystems," Journal of Systems and Software, vol. 83, pp. 67-76, July 2009.

s3 J. Kotlarsky, P.C. Van Fenema, and L.P. Willcocks, "Developing a knowledge-based perspective on coordination: The case of global software projects," Information & Management, vol. 45, pp. 96-108, Feburary 2008.

s4 G. Avram, "Knowledge Work Practices in Global Software Development," The Electronic Journal of Knowledge Management, vol. 5.

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s18 M.Jensen, S. Menon, L.E. Mangset, and V. Dalberg, "Managing offshore outsourcing of knowledge-intensive projects a people centric approach," International Conference on Global Software Engineering, ICGSE 2007.

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