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Architectural Knowledge Management (AKM) practices and tools for Global Software Development (GSD); A systematic literature review

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ABSTRACT

Context: The basic ground for any software system is its architecture. Those systems degenerate earlier which do not incorporate an adjustable architecture. We found an increasing interest within software research community about architectural knowledge management. The need to manage architectural knowledge becomes more crucial when it comes to globally dispersed teams and organizations. Architectural knowledge management effectiveness can help in reducing challenges imposed by GSD.
Objective: This study is a systematic literature review of Architectural Knowledge Management practices and tools for GSD. The objective of this review is to explore the AKM practices and tools being used and propose the most effective practices or tool that can overcome most of the AKM challenges faced by GSD teams.
Method: We identified the primary studies involved in this work through a selection processes and a clearly stated inclusion exclusion criteria.
Results: As the research topic indicates the study is divided into two major themes: first theme is Architectural Knowledge Management (AKM) practices and the second theme is Architectural Knowledge Management (AKM) tools.
Conclusion: As a result of this study we concluded some suggestions for further research in this topic.
KEYWORDS: Global Software Development (GSD), Architectural Knowledge Management (AKM), Software Evolveability and reuse.

1 INTRODUCTION

Software architecture explains how software system components can be arranged and how can these components work together. Usually architecture can be useful for other systems that have similar features and requirements. Architecture can promote reuse [1]. Software evolvability is to develop software that can easily evolve with time. Software evolvablity is a strong quality constraint as the world is rapidly changing. Organizations lose business opportunities if they fail to evolve the software system effectively. For this there could be many areas which can be focused such as analyzing release histories, source code. One of these areas is the architecture of the software being developed. Authors have chosen software architecture level analysis for evolvability because the basis for any software is its architecture. For example, Those systems degenerate earlier which do not incorporate an adjustable architecture. So the study mainly focuses on architectural evolvability of software systems.

The main objective of managing knowledge is to improve software development process and utilize all the available knowledge resources such as individual resources and organizational resources of knowledge. Architectural Knowledge Management support software evolve ability, sharing and reuse of architectural knowledge. Architectural knowledge management can help in improving the software systems architecture on which the organization or team is working currently as well as it can help in increasing software architecture reuse. Reusing architectural knowledge can improve the project quality with the passage of time as the architectural knowledge gets mature with the time. The second most important objective of managing architectural knowledge is to support sharing of architectural knowledge among development teams so that they can have equivalent understanding of the project on which they are working and no ambiguities occur which can increase rework on later stages of project development. Management of architectural knowledge can also support software evolveability. If any change in the requirement is received the organization should

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be able to extract knowledge from the managed architectural knowledge accommodate the changes and update their knowledge repository. Therefore, within the software architecture community, an increasing interest in architectural knowledge management is recognized [2][3][4][5].

In the last decade, we have seen dramatic transformation of software development processes. The transformation from single-site, into a multi-site, multilingual, multicultural, and globally distributed effort has marked the birth of Global Software Development (GSD) [4]. GSD has extreme benefits such as, resources from different locations can be utilized, speed of project development can be increased as work continuous twenty four hours and cost can be decreased by hiring labor from where it costs less. Software development is a complicated process and GSD has made it more complicated. But bright side of GSD has increased its importance. [6][7][8]

Architectural knowledge can be used and managed effectively to help the software development teams dispersed geographically in overcoming the challenges and issues come across a GSD environment. Whereas we have no summarized guideline to which practices can be applied to GSD setting effectively [9]. So we are interested in doing a systematic survey of all the practices and tools of architectural knowledge management.

Members of a Distributed Team can work on many different parts of the system development or develop many Components but they need to coordinate with each other in order to manage architectural and time dependencies. For allowing Distributed Teams to communicate and share knowledge some Coordination Strategies are essential. Therefore, the point of concern is what are those strategies and practices. [10][11]

In a research on setting a research agenda for GSD [12], researchers concentrated on key research areas in the field of GSD and knowledge acquisition and management is one of them. In [12], authors have shown that there is a great potential in distributed software development as far as research is concerned. They also extracted that tool support for GSD teams is a vibrant area for research. So we worked on the area of AKM for GSD as large scale data sharing and reuse definitely needs some good practices for management. Objective of this research is to answer two important questions that could help GSD teams in development of the projects that have high evolve ability factor in order to increase sharing and reusability of existing architectures for future projects.

From the literature it is shown that AKM is a hot topic of research these days but our focus is how it can help benefit GSD teams and enhancing the quality of projects developed under GSD environment. For this we have formulated two research questions that will help us to explore the AKM tools and practices present.

RQ1: What practices have been reported in GSD environment for Architectural Knowledge Management?

RQ2: Which tools have been developed for Architectural Knowledge Management?

RESEARCH METHODOLOGY

This research work has been done by means of a Systematic Literature Review (SLR). An SLR is a literature review that focuses on predefined research question(s) that tries to recognize, select and analyze all the research evidences relevant to that question or questions. The research process includes the following different stages. These steps have been explained in the subsequent sections.

i. Developing review protocol
ii. Defining exclusion and inclusion criteria
iii. Defining what search process will be followed to find relevant studies
iv. Quality evaluation
v. Data accumulating and analysis.

1.Review protocol

Following the SLR guidelines and procedures [13], we framed a review protocol. The protocol identifies the context for SLR and research questions based on that context or field of study. Basically research questions act as problem statement for the research. Review protocol also defines the search strategy, criteria for selecting studies, getting out data from the selected studies and analysis of that data. In this study section 1 describes the context of our research as well as the research questions that we are addressing in our research. Other parts of the review protocol are discussed in sections below.

2.Exclusion and Inclusion criteria

Basic reason of planning these criteria for selection of studies is finding all the relevant work/studies in this research. Papers from IEEE journals, workshops and conferences available within the range of 2006 and 2013 are considered. We set the lower search borderline on the publication year to 2006 as we wanted to consider the latest studies relevant to our topic stored in the database. We ignored studies that were not related to AKM practices used both in general and for GSD teams and organizations, and tools available for AKM. Table 1 shows the exclusion and inclusion criteria for our systematic review. The selected study must satisfy one of the inclusion criteria and studies that fulfill any condition from exclusion criteria must be excluded from the list of primary studies.

Table 1. Inclusion and exclusion criteria

Inclusion and Exclusion Criteria
Inclusion Criteria
Studies that are published from year 2006 to 2012
Studies that focus on AKM practices
Studies that focus on tool support for AKM
Exclusion Criteria
Studies that are not in English
Studies that are not related to research questions
Duplicated studies

3.The search process

We restricted our search in scientific database as most of the material in books is referenced or discussed in publications stored in electronic databases. The searched electronic database is IEEE Xplore (see http://www.ieee.org/web/publications/xplore/). There are various other electronic databases as well but due to lake of time defined for this study we only considered studies present in IEEE Xplore database. This limits the research but still it's a valid argument as IEEE Xplore is a huge data base with high impact publications covering the fields of Architectural Knowledge Management practices used in general, Architectural Knowledge Management practices for GSD teams and organizations, and tools available for Architectural Knowledge Management. Search terms used in our research to find related studies include:

S1: Architectural Knowledge Management Practices,
S2: Architectural Knowledge Management Practices AND Global Software Development,
S3: Tool support for Architectural Knowledge Management.

The selection process used for studies was based on multiple steps and these steps are shown in table 2.

Table 2. Steps in search process

Steps in search process
• Search in database to identify relevant studies by using each search term individually.
• Exclude studies based on the inclusion exclusion criteria.
• Exclude irrelevant studies based on analysis of their titles and abstracts.
• Obtain primary studies based on full text read.

At the first stage of search with first search term S1, a total of 35 publications were identified (see figure 2). Then after checking these publications against inclusion and exclusion criteria and removing irrelevant publications 29 publications were selected. Next 15 publications were selected after reading titles and abstracts. On the completion of first search process 7 studies were identified as primary studies where the contents relate to the research topic of Architectural Knowledge Management Practices.

In the search process for second search term S2, 4 publications have been identified in total (see figure 3). Then after checking these publications against inclusion and exclusion criteria no irrelevant publication was identified. After further filtering by using next steps in the search process again no publication was excluded as all 4 studies were related to the topic of Architectural Knowledge Management Practices for Global Software Development. Therefore in the end of second search process, 4 primary studies were identified.

In the last search process for the third search term S3, 34 publications have been identified in total (see figure 4). Then after checking these publications against inclusion and exclusion criteria 13 irrelevant publications were identified and excluded from the studies. After further filtering by using next two steps in the search process 3 publications were excluded as all the 13 remaining studies were related to the topic of tool support for Architectural Knowledge Management. Therefore in the end of second search process, 13 studies were identified as primary studies.

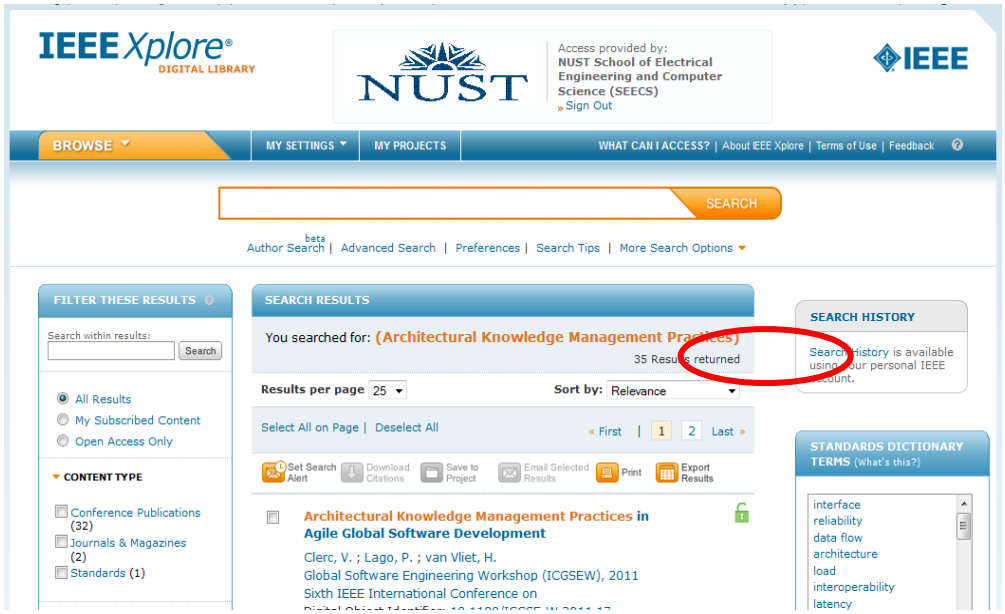

Fig. 2. Studies identified with S1

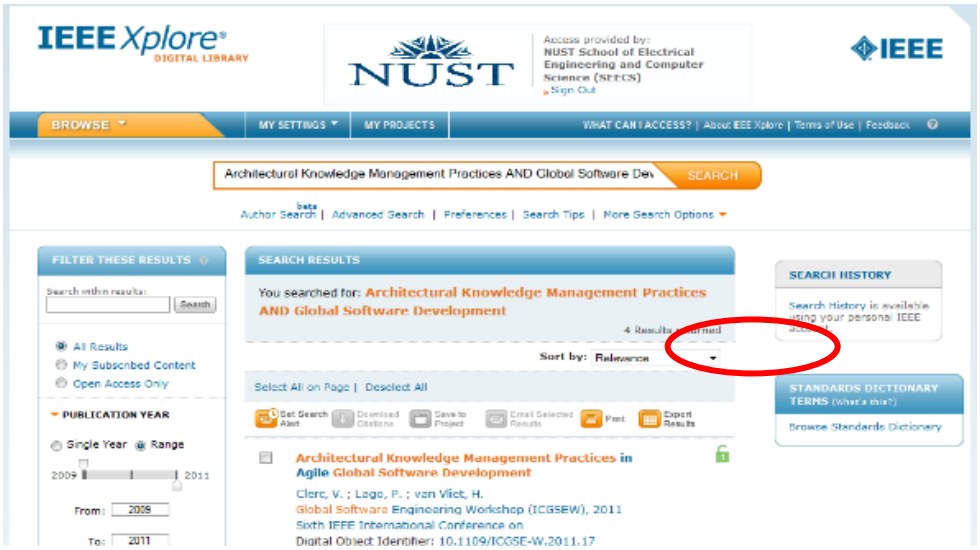

Fig. 3. Studies identified with S2

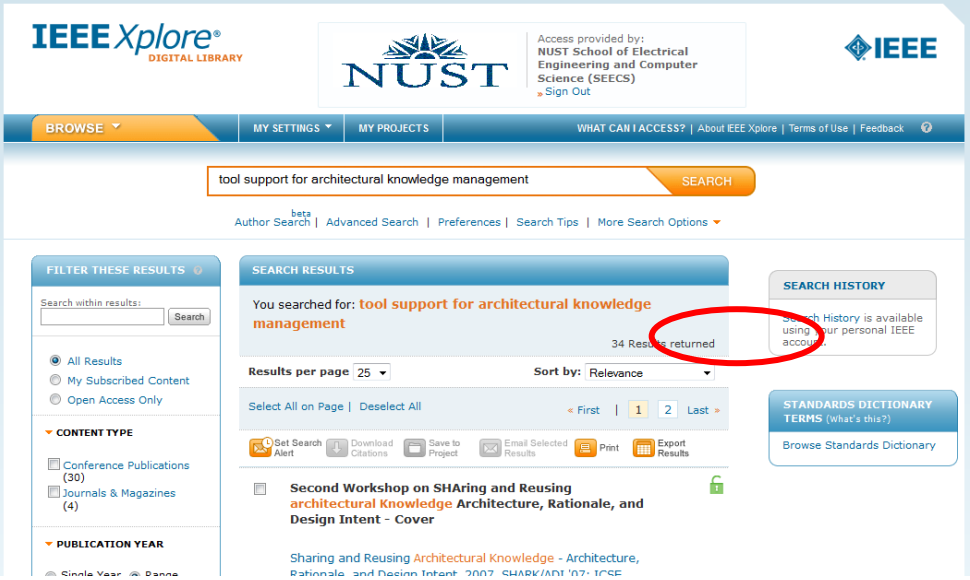

Fig. 4. Studies identified with S3

A total of the 24 studies were selected from all three search terms. Duplicate publications were removed. And at the end after removing repeating studies 20 studies were selected as primary studies for our review. Fig. 5 shows the number of publications identified at each stage of the research process.

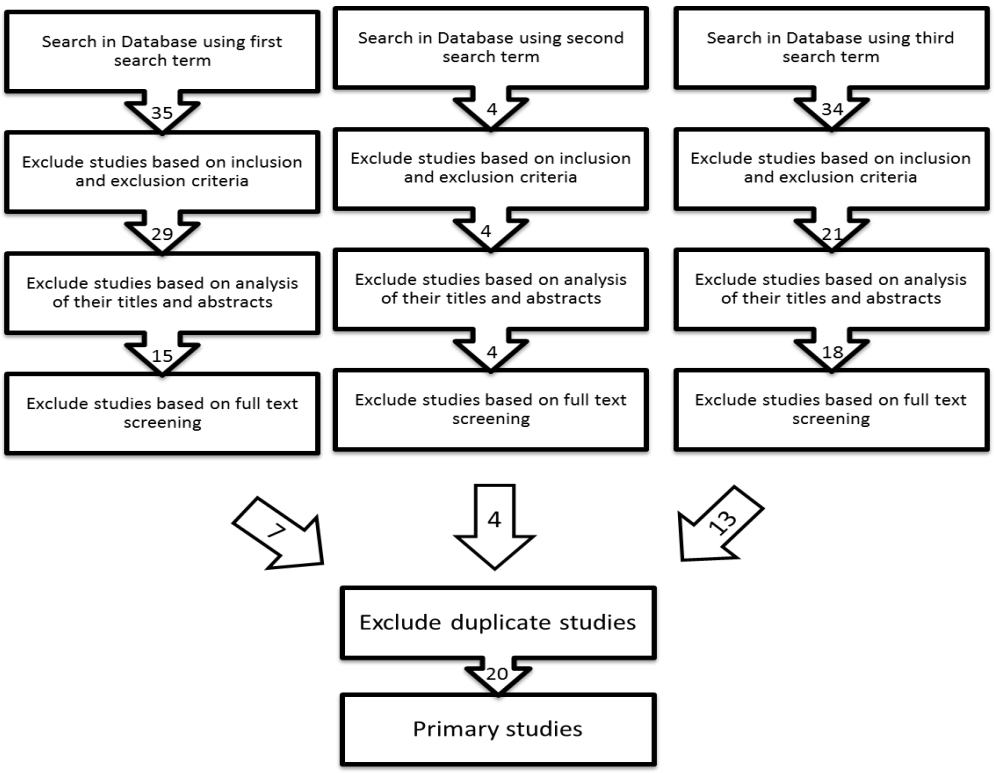

Fig. 5. Number of publications selected

4.Quality assessment

To summarize the findings of the included studies we defined a quality assessment criteria on the basis of this criteria each study has been compared. The studies have been divided into two basic themes on the

basis of the area of AKM covered. Themes are AKM practices and AKM tools. The quality assessment attributes include:

i The study includes theoretical framework/reasoning/survey results/implementation statistics instead of just studying the existing literature and writing non-justified statements.

ii The study gives background of the topic of research clearly.

iii The study clearly states the research methodology used for data collection and as well as for validation of results.

To assure the credibility and quality of selected studies all the studies must fulfil the above quality attributes.

5.Data extraction and synthesis

By reading all of the selected papers we extracted relevant material from each study. To summarize the extracted information we performed a comparison of these studies on the base of some data extraction parameters. These parameters along with the description of values for each attribute are shown in table 3. The results of our analysis will be described in the succeeding sections.

Table 3.Data extraction and synthesis

Data Extraction and Synthesis

Data Extraction Parameters	*Description*
Bibliographic Reference	Author, Title, Source and Year of publication
Type of work/study	Book, journal paper, conference paper, workshop paper
Context of work/study	Main topic area and objective of the study
Research methodology used	Included technique for the design of the study, e.g. case study, survey, experiment, interview.
Constraints and Limitations	Identified constraints and limitations in the approach as well as the identified areas for future research.

OVERVIEW OF SELECTED STUDIES

All included studies are enlisted in appendix. In this section these papers are described regarding the publication sources of the studies. A temporal view of the selected studies in the field of AKM is also presented.

1.Data sources

Most of work published; out of these 20 were conference papers and workshop papers. A few journal papers are also included in the list. Table 4 shows the summary of distribution of sources for all the publications. All papers satisfy quality assessment criteria mentioned earlier. The distribution is also mapped on a graph (figure 6) to show the results graphically. Each source of studies is mapped against number of publications under it. The graph shows the contribution of each source in the field of Architectural Knowledge Management. IEEE ICSE can be seen as the most active community in this field.

Table 4. Study distribution per publication source

Study Distribution per publication source

Source	*Studies*	*Count*
• IEEE Workshop on SHAring and Reusing architectural Knowledge Architecture, Rationale, and Design Intent (SHARK-ADI)	[1], [2], [9], [14]	4
• IEEE International Conference on Global Software Engineering (ICSE)	[3], [4], [5], [6], [8]	5
• Joint Working Conference on Software Architecture & 6th European Conference on Software Architecture	[7]	1
• IEEE Seventh Working IEEE/IFIP Conference on Software Architecture	[10], [18], [19]	3
• IEEE International Conference and Workshop on the Engineering of Computer Based Systems	[11], [16]	2
• IEEE/ACM International Conference on Automated Software Engineering	[12], [13]	2
• ICSE Workshop on Wikis for Software Engineering (WIKIS4SE)	[15]	1
• European Conference on Software Maintenance and Reengineering	[17]	1
• International Conference on Communications and Signal Processing (ICCSP)	[20]	1

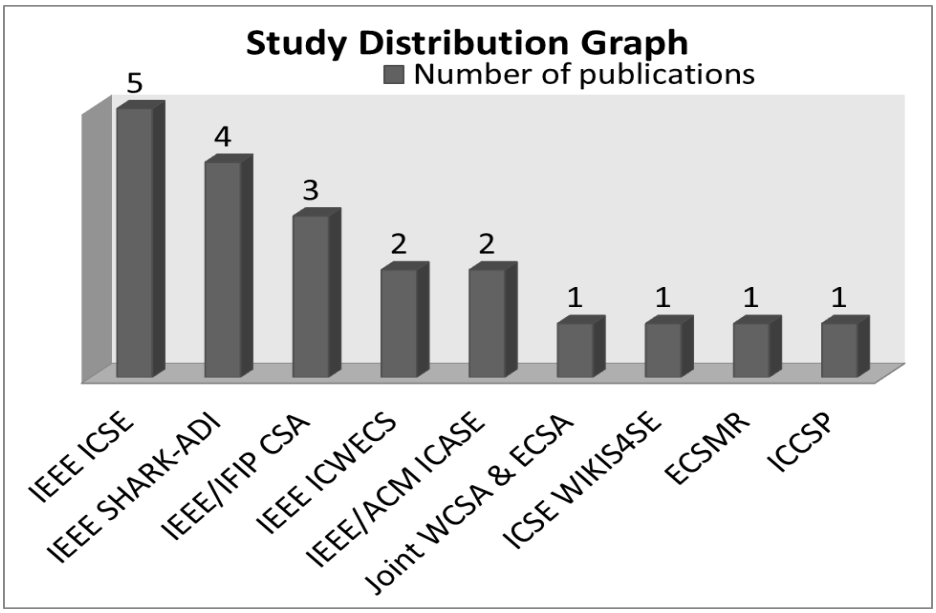

Fig. 5. Study distribution graph

2. Temporal View

We mapped the number of studies by publication year on to a graph and the graph shows an increase of interest in the field (see figure 7). During year 2006 to 2013, the number of publications on the topic of AKM practices and tools did not vary uniformly. During 2008 and 2009 more research has been done in this area then the graph goes down but in 2012 it again shows that importance of AKM has been realized. Researchers than try to minimize challenges and problems in the field they consider important.

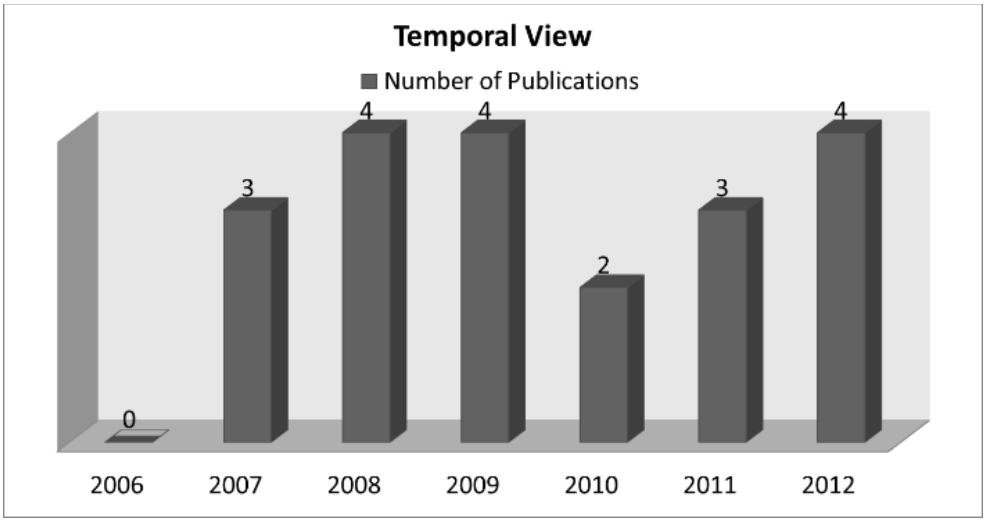

Fig. 6. Temporal view

RESULTS

1. AKM practices, Summary of Approaches

The studies included in the first theme category, that is Architectural Knowledge Management Practices are compared on some predefined quality attributes. This comparison is summarized in table 5. The comparison shows that most of the studies have been done by using different case studies. Different organizations have been considered and practices being used are identified. In some of the studies the newly proposed practices have been validated on a case study organization.

Table 5. Summary of AKM practices

Summary of AKM practices

Bibliographic Reference	*Type of work/study*	*Context of work/study*	*Research methodology used*	*Constraints and Limitations*
[S1]	Workshop paper	A preliminary review and comparison on current approaches to AKM have been presented and concluded that there appears a preference to use the codification strategy, however, the observations of the software architecture industry show that organizations tend to use a personalization strategy unintentionally. Effort has been made for awareness of this gap between intention and reality and suggest to close this gap through focusing on hybrid approaches.	Literature Review	Have not conducted an extensive literature search to identify all contributions in this area, but used the authors' knowledge of the field and experience gained in software architecture practice in three different countries.
[S2]	Workshop paper	To built up understanding on how to effectively support software architects in sharing knowledge and concluded a theoretical framework of what architects do and what they need.	Case Studies	It is based on practical findings of just one software development organization.
[S3]	Conference paper	AKM practices supporting a personalization strategy towards knowledge management are perceived to be more useful than practices that support a codification strategy.	Case Study	Conducted survey questionnaire at one organization only.
[S4]	Conference paper	Presented a summary of the Global Teaming Model (GTM) – a model that represents the key practices that software organizations should consider when operating in a geographically distributed environment.	Theoretical framework based on literature	Tried to keep the practices generic, but it is possible that they don't all apply.
[S5]	Conference paper	Performed a literature review that looks at AKM concepts, practices, tools and challenges important in GSD and attempted to synthesize these. a metamodel have been created based on literature review.	Literature Review	No validation of metamodel have been done in industry as well as no work has been done on how current tools will support it.
[S6]	Workshop paper	Presented the major AKM practices being followed in an agile environment. authors have argument that AKM practices that encourage centralization don't get much attention than those encouraging decentralization. Also they have introduced a new AKM practice, "peered sites".	Case Study and survey based on Interviews	Results can be biased as the survey is based on only one organization.
[S7]	Conference paper	Described an approach for enhancing finding, capturing, and maintaining architectural knowledge based on context information.	Experiment	Experience with the approach is limited to its application during the development of the toolkit.

1. AKM Tools, Summary of Approaches

In the first theme category, that is Architectural Knowledge Management Tools, the included studies are compared on the same predefined quality attributes. The comparison is shown in table 6. The comparison shows that most of the studies have been done by properly implementing the tools they proposed. Some studies have limitations on the lake of description to their implemented tools. A few papers have been validated by using different case studies.

Table 6. Summary of tools for AKM

Summary of Tools for AKM

Bibliographic Reference	*Type of work/study*	*Context of work/study*	*Research methodology used*	*Constraints and Limitations*
[S8]	conference paper	Highlighted the benefits and challenges in managing architecture knowledge and discussed various approaches to characterize architecture knowledge based on the requirements of a particular domain. Also included case study covering the use of AKM techniques and tools in an industrial project.	Case Study	The paper is too short. Much of the details are not discussed in the paper.
[S9]	workshop paper	A tool has been described, that is developed to support a framework for capturing and using architectural knowledge to improve the architecture process.	Tool implementation	The tool described does not support diagrammatic modelling of design decisions rather its focus is on providing a handbook of architecture knowledge.
[S10]	conference paper	An architectural knowledge sharing portal has been designed and implemented . Portal's integrated functionality supports architects in decision making, by providing easy access to right architectural knowledge at any given time.	Tool implementation	No integration with features like Wikis and Blogs allowing architects to easily produce architectural knowledge have ben done.
[S11]	workshop paper	A conceptual framework for managing architecture design knowledge have been Developed and a web-based knowledge management tool "PAKME" has been developed to support that framework.	Tool implementation with experiment	No integration with tools commonly used for managing requirements for large-scale systems.
[S12]	conference paper	How architecture design decisions can be captured and documented with specific tool support is described and provided the effort estimation in capturing such knowledge.	Tool implementation	Lake of longer experiments to estimate more accurately.
[S13]	conference paper	ADDSS tool has been described which enables capturing and documenting architectural design decisions in order to avoid knowledge vaporization.	Tool implementation	Should scale-up ADDSS to industrial applications and extend the multi-user management features.
[S14]	workshop paper	In this paper, we present a tool that captures architectural knowledge from documents and emails and stores it in more structured manner in knowledge repositories with minimum user intervention, thus minimizing the required amount of effort.	Tool implementation	Support for only MS-Word and MS-Outlook has been provided while some decisions are communicated in MS-Excel format and informally through chatting software.
[S15]	workshop paper	Describes the use of ShyWiki, a tool for Architectural Knowledge Management (AKM) and also describes how distributed stakeholders involved in software architecting can share knowledge and manage their tasks by using ShyWiki.	Tool implementation	The usability of the current version of ShyWiki has not been evaluated.
[S16]	workshop paper	A highly customizable ADD tool has been developed which can enable practitioners to define ADD models according to their preferences and working situations.	Case studies, semi structured interviews	Industrial case studies has not been conducted.
[S17]	conference paper	Supports the development of appropriate tools for automatic architecture reconstruction and reverse engineering of software systems.	Tool implementation with knowledge from case studies	Architecture visualization with change tracking is not clear.
[S18]	workshop paper	built a prototype tool (KaitoroCap) that captures users' Architectural Documents (AD) exploration paths and saves them with contextual metadata.	Prototyping and user evaluation	Information based on perceived usage in considered instead of actual AD usage.
[S19]	conference paper	Presents a reference architecture and a decision process-oriented knowledge metamodel that is synthesized from the domain specific functional requirements and quality attributes. A tool for these decision modeling concepts have also been described.	Tool implementation	Presented approach has not been applied to business domains outside IT.
[S20]	conference paper	A Web based Architectural Knowledge tool (ADUAK) has been developed and highlighted the contribution through a suitable case study.	Tool implementation and experiment with case study	Tool features has not been discussed in detail.

CONCLUSION

Software architecture is one of the basic building blocks of a software system and provides basis for the system. If the architecture of a system is not flexible enough to accommodate changes easily the software will reduce its importance and life as well. Considering this importance of architecture research community focused on managing the architectural knowledge in order to support software evolveability, sharing of architectural knowledge and reuse of architectural knowledge. The need to manage architectural knowledge in intensified when it comes to GSD because of various challenges posed due to geographically distant teams. Using architectural knowledge effectively may help in overcoming the challenges and issues encountered in GSD. For this a number of researchers have worked on the practices being followed and proposed better solutions. Need for tool support has also been identified in various papers. A number of tools have also been developed previously. We have performed a systematic literature review and divided our study into two categories of themes. First one is AKM practices and the second one is AKM tools.

FUTURE WORK

As mentioned earlier we have selected studies from only one electronic database that is IEEEXplore. This limits the range of our research and the work can be extended by exploring research studies published in various other databases. We plan to explore those and refine the systematic review in a time of next one month.

APPENDIX

Appendix includes references to all the primary studies selected for this review.

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