Requirements Engineering Tools for Global Software Engineering
A Feature Analysis Study

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Abstract: The demand in Global Software Engineering (GSE) is increasing every year. GSE helps the software development industry reduce development cost and provide access to resources pool; however, GSE practitioners also need to deal with numerous challenges. This impacts Requirements Engineering (RE) process in terms of teamwork, collaboration, knowledge management, time and cultural differences. RE is considered to be one of the important processes in the software development, and several studies have pointed out the need of a new RE process that supports GSE environment. We acknowledged the importance of RE tools in supporting RE process and conducted a study to discover the best way to use RE tools to solve the challenges in GSE. The study used the Feature Analysis Screening Mode approach and generated a list of features with four categories that would address these challenges, namely: (1) *Shared Knowledge Management*, (2) *Workflow and Change Management*, (3) *Traceability*, and (4) *System and Data Integration*. Four RE tools on the market are selected for investigation. We found out how these tools best support three of the categories, but have limited capability for the first category. Some suggestions were given for future development to provide the support for RE process in GSE environment.

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1 INTRODUCTION

Global software engineering (GSE) refers to distributed software development that are located in various geographical locations around the world (Niazi et al., 2016b). The concept originated from Contract Programming Outsourcing in 1970s. In 1990s, many companies started setting up globally distributed teams to low-cost countries for development (Smite et al., 2010). GSE has become more popular in recent years because it helps the software development industry reduce cost of development, achieve flexible development time, and gain access to global talents and resources (Ebert et al., 2016).

The GSE trend has projected the growth rate of 10% to 20% every year, and will become a standard engineering management method (Ebert et al., 2016). However, along with benefits and opportunities, GSE practitioners also need to deal with geographical, cultural, and temporal challenges (Niazi et al., 2016a). Several studies on GSE have tried to address those challenges. The recommendations presented solutions in communication, knowledge transfer, tools, and project management (Richardson et al., 2010).

The term *virtual teams* refers to the distributed teams in GSE that operate in different locations. In GSE distributed life cycle, the processes in different stages such as System Analysis, Design, Coding, and Testing can be shared between different virtual teams (Richardson et al., 2010). This distributed virtual structure affects the Requirements Engineering process in many ways. For this reason, GSE has cast new challenges in RE process in team coordination, knowledge management, temporal differences, and cultural differences (Zowghi, 2007).

Requirements engineering (RE) is one of the main processes that can influence the success or failure of software development (Li et al., 2015). When it comes to working in a globally distributed environment, RE process becomes more challenging compared to the process done by co-located teams. Achieving success in RE for GSE is another challenging work (Damian, 2002). There are several studies that point out the need for new RE process in GSE environment (Zowghi, 2007). To cope with the increasing demand in GSE, it is more important to look into how we can make RE process become more effective (Damian, 2002).

Our study aims to achieve the evaluation on RE tools that will help software development teams

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handle RE process more effectively in GSE environment. The study is inspired by previous studies on RE tools. Those works have produced a good understanding about RE tools capabilities which based on the standard for evaluating RE tools ISO/IEC RE 24766:2009 (Carrillo De Gea et al., 2012). However, all previous works focused on the study of the tools general capabilities, and has not pointed out how tools could address the challenges of GSE.

The objective of this study is to fill the gaps of existing studies on RE tools more specifically on RE tools capabilities that address GSE challenges.

The remainder of the paper is structured as follows: Section 2 discusses related works on RE and GSE. Section 3 describes the methodology used in the study. Section 4 presents the results derived from the evaluation. Section 5 discusses the findings. In finally, Section 6 presents conclusion of the study and future work.

2 RELATED WORKS

This section presents the related works done on RE in GSE, the study on RE Tools, and the international standards that support our study objectives.

In the study of requirements engineering in global software development, Damian (Damian, 2002) presented several challenges in RE work in GSE environment. The top four challenges included inadequate communication, knowledge management, cultural diversity, and time difference. The study also pointed out that despite the challenging work for RE in GSE, it is important that more studies are conducted on RE in regards to GSE to support the increasing demand of GSE in the industry (Damian, 2002).

In the study of the need of a different RE process for GSE, Zowghi addressed the importance of RE role in software development and the impacts of GSE on RE process (Zowghi, 2007). He claimed that GSE has brought challenges to RE in 4 main areas: (1) Team Coordination and Control, (2) Knowledge Management, (3) Time differences, and (4) Cultural Differences. The suggestion was raised during the development of a new RE process that would address these challenges impacted by GSE with the model which can deal with distance, communication, and collaboration.

With regards to RE tools, several studies have been done on the capabilities of the tools that support RE process in general, following the industry standard ISO/IEC TR 24766:2009. The results of the study on RE Tools (de Gea et al., 2011) showed that the RE tools market are facing the increasing change in demand to support the developments of technology and market. However, that study only aimed to provide the information on verification when selecting the RE tools for the development. It also stated that parts of current RE tools need to evolve to support GSE environment through the improvement of tools that support distributed virtual team and collaborative work (de Gea et al., 2011).

The work done in another study (Carrillo De Gea et al., 2012) provided a detailed capabilities study of RE tools that are currently available on the market. The work started with the list of 100 RE tools vendors with 38 respondents agreeing to participate in the study. The classification framework used for evaluation was based on the standard ISO/IEC TR 24766:2009 with some restructuring of categories. The results of the study presented the scores for all the evaluated tools in regard to all categories in the classification framework. The classification framework presented in this study added Traceability as a new category for the study of RE tools capabilities (Carrillo De Gea et al., 2012). The outcome of the study presented a good start for us to identify tools for our work.

Another quantitative study of RE tools (Carrillo de Gea et al., 2015) addressed the commonalities and differences between RE tools and put them into three groups. The study modified the classification in standard ISO/IEC TR 24766:2009 and added three other categories to the classification framework namely, Modeling, Traceability, and Collaboration & GSD. The methodology used in the study adopted the Feature Analysis method in DESMET report. The feature analysis study, qualitative or subjective, is a good way for us to conduct our study.

Our study is also inspired by the international standard that manages the RE process. The standard ISO/IEC/IEEE 29148:2011 provides the standard guideline for the process and activities for RE work. One of the 5 main processes in the standard presents the importance of requirements management as the changes of requirements in the development life cycle are inevitable (ISO et al., 2011). To achieve effectiveness in requirements management in GSE, we follow the requirements change management process from the standard which includes change proposal, review, approval, and change notification.

Another technical guideline from the international standard ISO/IEC TR24766:2009 is used as the foundation for developing a classification framework. We also consolidated the standard classification with the study on the challenges in GSE in order to fill the gaps in the standard guideline for GSE.

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3 RESEARCH METHODOLOGY

This section presents the design of the methodology and procedures used in the study.

In order to achieve the objectives of our study, we based our work on three research questions:

RQ1: *What are the features of RE tools that would address the challenges of GSE?*

RQ2: *To what extent do current RE tools conform to the list of features that support GSE?*

RQ3: *What improvements could be made with current RE tools in order to support RE process in GSE?*

The three studies on RE Tools presented in Section 2 formed the basis for developing our methodology in evaluating RE Tools using the DESMET report about the methodology for evaluating software engineering methods and tools.

Our study adopted the method presented in the DESMET report called Feature Analysis Screening Mode approach. The advantages of this approach are flexibility, simplicity, and quick process.

There are 6 steps included in conducting Feature Analysis Screening Mode approach (Kitchenham et al., 1997):

- Selecting candidate tools for the study
- Deciding on the features list base on the objective of the study
- Designing evaluation criteria
- Carry out evaluations
- Analyzing and interpreting results
- Presenting results.

3.1 Selected Candidate Tools

The tools selection techniques conducted in the 3 previous studies were based on the databases that contained the list of available RE tools on the market. To simplify the process for our study, we utilized the list of tools and their performance from the results of previous studies and selected the top 4 tools for our study based on their performance and scoring. Moreover, we replaced one of the 4 tools, Rational DOORS, with the new upgraded version Rational DOORS Next Generation (RDNG).

The complete list of the 4 selected tools is presented in the below table (Table 1):

Table 1: Selected Candidate Tools.

Tool		Vendor
T1	Cognition Cockpit ™	Cognition
T2	Cradle-7	3SL
T3	Rational DOORS Next Generation (RDNG)	IBM Rational
T4	Reqtify and Requirements Central	Dassault Systemes

3.2 Classification Framework

The foundation of the list of features for evaluating RE tools is based on the guideline in the standard ISO/IEC TR24677:2009 which is presented as follows (ISO and IEC, 2009) (Table 2):

Table 2: Features and Categories in TR Guideline.

Category(TR)	No.
Requirements elicitation	37
Requirements analysis	36
Requirements specification	16
Requirements verification and validation	34
Requirements management	17
Other capabilities	17
Total	157

However, the standard ISO/IEC TR24677:2009 only focused on the general capabilities of RE tools which does not specifically address GSE. The classification framework in our study is derived from the list of the standard guideline combined with additional features that address the challenges in GSE, such as Knowledge Management, Team Collaboration, and Communication. The following 4 categories of features are identified which aim to provide support to RE process in GSE (Table 3).

Table 3: Our Classification Framework by Category of Features.

Category		No.
CF1	Shared knowledge management	8
CF2	Workflow management	5
CF3	Traceability	4
CF4	System and data integration	4
Total		21

CF1. Shared Knowledge Management: This category of features focuses on managing the kno-

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wledge sharing among virtual teams in distributed software development in various locations around the world. We address knowledge sharing and reuse in GSE as part of our work to improve collaboration in a distributed environment (Gea et al., 2013). This category also introduces the importance of shared team knowledge in virtual teams which cover the four different types of knowledge in F1 to F4 (Moe et al., 2016). The details of these features in this category are as follows:

- *F1. Task-Related Knowledge:* This feature allows virtual team members to share their understanding about tasks, how the tasks should be accomplished, and criteria used to determine if the tasks were successfully completed.
- *F2. Team Related Knowledge:* The feature allows virtual team members to share the information about the team and members' skills, experience, strength, weakness, and knowledge about the domain.
- *F3. Process Related Knowledge:* This feature allows virtual team members to share the knowledge related to member interaction, communication process, collaboration, decision making, and discussing work process.
- *F4. Goal Related Knowledge:* This feature allows virtual team members to share the goal, vision, overall agreements of the teamwork, and understanding about customer needs.
- *F5. Architectural Knowledge Sharing:* This feature provides the option to capture, share, and manage information about the architecture process, problem domain, solution domain, and share knowledge artifacts throughout the process.
- *F6. Knowledge Transfer:* This feature provides the ability to capture and share knowledge across tools throughout the development life cycle.
- *F7. Shared Repository:* This feature presents a shared repository where it is easy for virtual team members to have access to information.
- *F8. Knowledge and Requirements Reuse:* This feature provides the option of reusing the requirements artifacts, and requirements information.

CF2. Workflow and Change Management: This category of features focuses on providing full workflow and change management to support collaboration and teamwork in GSE environment. The study on the awareness needed in GSE (Damian et al., 2003) provides the recommendation for improving collaboration in virtual teams through workflow improvement and effective communication changes. The details of these features in this category are as follows:

- *F9. Support Stakeholders Decision:* This feature provides support for decision making process such as supporting information, recording decision, assigning responsibility, managing estimation data, and impacts analysis.
- *F10. Decision Notification:* This feature provides notification to virtual team members with all decision activities and documenting the decision for tracking.
- *F11. Multiple User Access:* This feature provides multiple users an access platform with real time information update through browser-based interface which improves the awareness of other members in virtual team environment.
- *F12. Collaborative Life Cycle Management:* This feature provides real-time update about the development life cycle of all virtual team members to ensure awareness of all process updates across project life cycle.
- *F13. Global Stakeholders Collaboration:* This feature provides the management of all stakeholders based on their role and permission to access the information. This is to support collaborative workflow between all stakeholders and the awareness of requirements and needs of the customers.

CF3. Traceability: This category of features focuses on having full information about the life cycle of the requirements which link information sources that can support effective communication of requirements in globally distributed teams (Carrillo De Gea et al., 2012).

- *F14. Traceability:* This feature provides the management of requirements and documentation source, where the role and responsibility of stakeholders involved can be trace across the tools.
- *F15. Flexible Tracing:* This feature provides various types of tracing, such as one-to-one, one-to-many, or many-to-one tracing with the option of tracing of text or graphics.
- *F16. Bi-directional Tracing:* This feature provides the tracing between customer needs, requirements, source information, and element on finished product.
- *F17. Traceability Analysis:* This feature provides analysis matrices, reporting, and exporting the report of the requirements changes and requirements development throughout the life cycle.

CF4. System and Data Integration: This category of features focuses on providing full integration of data and system with the tools. In the standard guideline of RE tools capability, the system and data in-

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tegration is considered an important part of the tools as it can help with the collaboration across different parts of an organization that uses different tools and technology (Carrillo De Gea et al., 2012). The detail of the features in this category is as follows:

- *F18. Data Import:* This feature provides support for importing data in different formats from other tools or software.
- *F19. Data Export:* This feature provides support for exporting data into different formats.
- *F20. Tool Integration Vithin Vendor:* This feature provides the ability to integrate with other tools provided by the same vendor.
- *F21. Tool Integration Across Vendors:* This feature provides the ability to integrate with the tools provided by other vendors.

3.3 Evaluation Criteria

The evaluation scoring for the features included in our classification framework is based on the presence or absence of the feature. We give the Yes/No value to the feature represent by:

YES: circle with green tick

NO: empty white circle

The total value of each tools in each category represents the supporting scale for the tools in the particular category.

Each value for the feature determines the availability of the feature for particular tools.

3.4 Investigation Method

We adopted the Feature Analysis Screening Mode approach that is presented in DESMET report which provides a quick and easy assessment of the tools evaluation. The investigation process is based entirely on documentation provided by the vendors and then record into the list (Kitchenham et al., 1997).

The list of the accumulated values for the features supported by each tool is done through the investigation of three types of documentation, namely: technical paper, data sheet, and product documents. These documents are supplied by the vendors.

The study on all documentation from the vendor was done alongside with the classification of feature categories. The value ”Yes” or ”No” is given to the feature of each tool when the information on the documents provides support for the feature.

4 RESULTS

This section presents the results of the investigation on all the tool documentation retrieved from the vendor’s website. The findings are presented in four tables according to the categories of features in our classification and a figure showing how each of the tools performs in the features evaluation.

4.1 Shared Knowledge Management

Shared Knowledge Management is a new concept that we introduce into tools capability in order to address the challenges in GSE on knowledge management (Table 4). 5 of the 8 features in these categories are not available in the current tools. Team knowledge sharing and architectural knowledge sharing (F1 to F5) are also not supported in any of the 4 tools we investigated based on available technical documentation.

Knowledge transfer and requirements reuse (F6 and F8) are still not emphasized by the tools with only one tool, T3, supporting these two features.

Table 4: Supported Features for Shared Knowledge Management (CF1).

CF1	T1	T2	T3	T4
F1	○	○	○	○
F2	○	○	○	○
F3	○	○	○	○
F4	○	○	○	○
F5	○	○	○	○
F6	○	○	✓	○
F7	✓	✓	✓	✓
F8	○	○	✓	○

4.2 Workflow and Change Management

The features in this category show good support from all tools with most features supported by at least 2 out of 4 tools in our study based on the documentation. All the tools fully support decision notification using dashboard or email (F10), and provide full life cycle management (F12) (Table 5).

3 out of 4 tools provide web access to support multiple users access from different locations (F11). However there are still limitations for the tools in the

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area of supporting stakeholder's decision making (F9) and providing global collaboration for all stakeholders (F13).

Table 5: Supported Features for Workflow and Change Management (CF2).

CF2	T1	T2	T3	T4
F9	○	○	✓	✓
F10	✓	✓	✓	✓
F11	✓	✓	✓	○
F12	✓	✓	✓	✓
F13	✓	✓	○	○

4.3 Traceability

Traceability is presented as fully supported by all RE tools in our study (Table 6). Documentation shows full traceability option (F14, F15, F16) and provides a full analysis feature for traceability reports (F17).

Table 6: Supported Features for Traceability (CF3).

CF3	T1	T2	T3	T4
F14	✓	✓	✓	✓
F15	✓	✓	✓	✓
F16	✓	✓	✓	✓
F17	✓	✓	✓	✓

4.4 System and Data Integration

The integration of system and data in the tools demonstrate full support for data integration (F18 and F19) and good integration of the system within the vendor applications (F20). The integration of the system across to other vendors are supported by 2 of the 4 tools, with T2 and T4, showing some limitation on this feature (Table 7).

4.5 Tools Evaluation

The total score of each tool presents the performance in conformance to the features selected in our study (Figure 1). T3 has the highest aggregate score in the study which is 14/21, and the outstanding score is in Shared Knowledge Management (CF1).

All tools have a total score between 11 to 14 out of the maximum total score of 21. This shows that just above half of the features are present. The gaps between each tools are small with just 1 or 2 points. T1 has the highest score in CF1, while T2 and T4 have the highest score in CF4.

Table 7: Supported Features for System and Data Integration.

CF4	T1	T2	T3	T4
F18	✓	✓	✓	✓
F19	✓	✓	✓	✓
F20	○	✓	✓	✓
F21	○	✓	○	✓

5 DISCUSSION

This section discusses how this study answers the three research questions.

RQ1: *What are the features of RE tools that would address the challenges of GSE?*

The list presented in section 3.2 identified 21 features that address the challenges of the RE process in GSE. The features are classified into 4 categories based on the reviews of studies related to best practices in RE and GSE. The list of features used in this study focused on the challenges with knowledge management, teamwork and collaboration, while future work will look into temporal and cultural challenges in GSE.

RQ2: *To what extent do current RE tools conform to the list of features that support GSE?*

According to the summarized evaluation results in section 4, it shows that among the 8 features in Shared Knowledge Management, only 3 features (F6, F7, F8) are supported by current RE tools. For Traceability features, all tools provide full support to all the 4 features (F14, F15, F16, F17). The tools also sufficiently support the other 2 categories of features with at least half of the tools supporting each of the features in these 2 categories.

The evaluations of the tools are conducted using documentations provided by the vendors which consist of features description from technical papers, data sheets, and product documents. Future work will focus on looking at a more effective evaluation approach to improve accuracy.

RQ3: *What improvements could be made with current RE tools in order to support RE process in GSE?*

The results of the study suggested that RE tools need to be able to provide features for Share Know-

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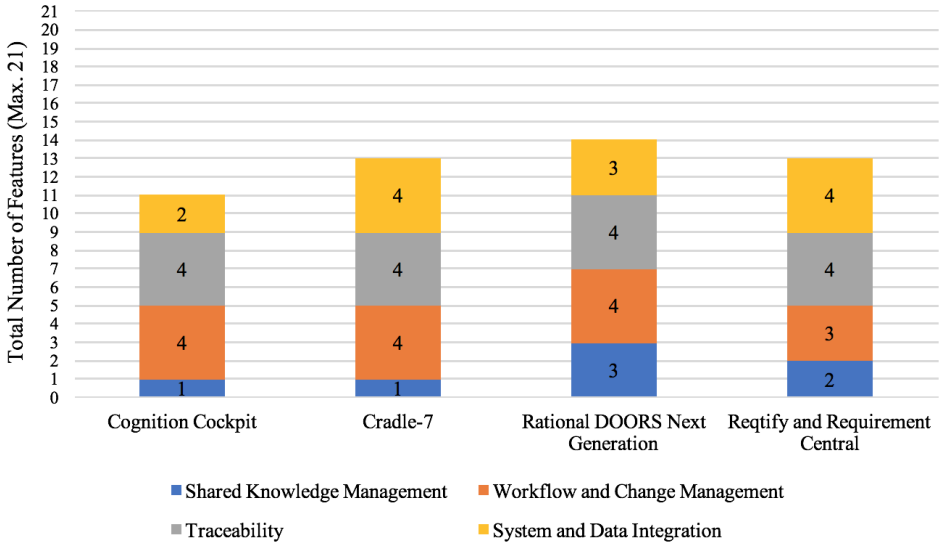

Figure 1: RE Tools Aggregated Score for All Categories.

ledge Management. 8 features in CF1 described in section 3.2 could serve as the initial suggestions for the tools. The result also suggested improving system integration feature that allows RE tools to integrate with Knowledge Management System within the same vendor or across different vendors.

We propose the use of recommended practices from studies of Knowledge Sharing in GSE. (Zahedi et al., 2016). These practices include the use of groupware, knowledge repository, wiki, discussion forum, shared repository, and blog in the virtual teams environment.

6 CONCLUSIONS AND FUTURE WORK

This paper presents the outcomes of investigating RE tools using Feature Analysis Screening Mode approach. The first outcome is the list of features identified from studies conducted by researchers addressing the challenges in GSE. The second outcome is the result of examining four RE tools and how these tools conformed to the list of identified features. The result shows that all tools fully support features under Traceability, and unsoundly support features in Shared Knowledge Management. With the gaps identified, the third outcome suggests giving more attention in putting knowledge sharing and system integration into future development to improve current RE tools.

Our future work aims to address the limitations of the current study. As Feature Analysis Screening Mode approach depends entirely on the documentation provided by vendors, future work will involve comprehensive evaluation, using case study approach that will focus on sharing knowledge in RE process among globally distributed teams. It will also address limitations of subjective evaluations. Finally, it will study RE practices that look into temporal and cultural challenges of GSE.

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