Requirements Engineering Techniques: A Systematic Literature Review

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Abstract: ***Requirements engineering is a torrid task to requirements engineers because requirements keep changing and this affect the project's delivery schedule and cost. Although various authors proposed numerous techniques to be used in requirements engineering, software projects still fail. The issue now lies on which technique to use to minimize project failures. The aim of the study was to identify gaps in requirements engineering techniques used. The paper used a systematic literature review of requirements engineering techniques used from January 2000 to July 2016. The study found out that a lot of techniques are used in requirements engineering and some of the techniques used are not adequately addressing the problem space but the solution space. The study identified some gaps in requirements engineering techniques that need further research in order to solve those gaps.***

Index Terms: Requirements Engineering, Project Failure, Techniques, Changing Requirements, Technique limitations.

I. INTRODUCTION

A software requirement simply put is the need of stakeholders or users that needs to be captured in a system. This is the foundation of any software project because if this soft-ware requirement is not captured correctly; the whole system development will be bound to fail since the final product will not address the needs of stakeholders. Requirements engineering is a process that encompasses the following activities namely; requirements gathering, requirements analysis, specification, requirements validation and the requirement management [2]. Requirements gathering identify the stakeholders to find the requirements for the project, requirements analysis checks for the completeness of the requirements from the requirements gathering stage, requirement specification is simply the recorded requirement that should be acted by a system and they are recorded using use cases. The requirements validation checks if the requirement truly reflects what the stakeholders want while requirement management rank requirements in terms of their priorities and also accommodate changes to requirements as suggested by the stakeholders. Reference [3] argued that there are some challenges and communication issues experienced by the requirements engineers during the requirements engineering process. The difficulties are mainly due to conflicting requirements due to functional and non-functional requirements. The functional requirement spells out what the system should do while a non-functional requirement places some constraints on how the requirement will be met by the system such as speed, security and other characteristics. Reference [5], the Standish Group reported that at least 24% of projects fail and close to 44% are challenged. The major reasons for projects failing is due to partial requirements given to the requirements engineers and constant requirements changes during the course of the project.

Requirements engineering not properly conducted will translate to project failures [7]. Requirements Engineers are often subjected to a daunting task on which technique to choose to best address the software requirements. The paper seeks to examine the various techniques being employed by requirements engineers during the requirements engineering process and any limitations of those techniques basing on the context and the domain of the project. The aim of the paper is to identify areas of further research in requirements engineering that were not adequately addressed by other authors. This will help in reducing project failures which started in 1968 with the software crisis and over the years more advances were made in requirements engineering to address projects running over budgets, projects taking longer time than anticipated and some projects failing to meet the stakeholder requirements [46]. The study looked at various techniques such as tools and frameworks used in requirements engineering by the requirements engineers.

II. RESEARCH METHODOLOGY

A systematic literature review is a secondary study that search for relevant information from the primary studies conducted; evaluate the information and do interpretations basing on the research questions or the area of study [6]. The goal of the systematic research is to identify gaps that may exist in the researches done and propose areas for further investigation. The review will be done following the guidelines postulated by [6] shown in Table I.

Table I. Literature Review Guidelines

Stage 1: Formulate Research Questions
Stage 2: Identify the Data Sources
Stage 3: Define the Search Strategy to be used
Stage 4: Indicate Information to be retrieved from the Primary studies
Stage 5: Perform Analysis

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Stage 6: Disseminate Findings
Stage 7: Future Research Areas

A. Research Questions (RQ)

RQ1. What are the techniques used in requirements engineering?
The Research question looked at the techniques that are currently being used in requirements engineering.

RQ2. What are the limitations of the existing techniques used in requirements engineering?
The limitations of the existing techniques used in requirements engineering were looked at.

RQ3. How do changing software requirements affect requirements analysis?
The research question looked at the effects of software requirements changes on requirement analysis.

B. The Data Sources

The electronic databases selected were those databases that are mostly used by authors and also some databases with restricted access and the study focused on six electronic databases shown below:

- Emerald Insight
- Science Direct
- IEEE Xplore
- Ebscohost
- Google Scholar
- Academic Search Complete

The restricted sources were chosen because they have relevant information in far as Software Engineering is concerned [1].

C. The Search Strategy

The search strategy adopted consisted of key words derived from the research questions and also utilized the Boolean expressions using the **(AND)** and **(OR)** expressions in per-forming the searches. A search was performed on the six electronic databases using the search strings derived from the research questions and consistency of search strings was adhered to in all the six electronic databases. The search considered the articles published from the period 2000 to 2016. The search keywords were confined to the research questions such as ***("requirements engineering AND techniques, requirements engineering OR limitations, changing requirements AND requirements analysis, requirements engineering frameworks OR tools, requirements engineering models OR Graphical Models".)*** A total of 420 articles were retrieved from the six electronic databases which fell in the search strings and the stated time frame. After using the exclusion strategy on the 420 articles a total of 43 articles were selected.

D. Exclusion and Inclusion Strategy

The articles that were included were those that addressed any one of the research questions such as the techniques used in requirements engineering, the limitations of the existing techniques used in requirements engineering and the effect of changing software requirements on requirements analysis. The inclusion strategy also catered for articles written in English language only and the inclusion covered articles done from 1 January 2000 to July, 2016. The exclusion strategy did not consider articles that did not address the research questions and also articles not written in English language.

E. Quality Assessment of the Study

The quality assessment of the study is crucial as it can be used to as a guide to interpret the findings from the study and any future research investigations. The study was evaluated according to the following assessment questions:

1. Aims of the research are they clearly stated?
2. Is the requirement engineering technique clearly elaborated?
3. Does the research contribute value to the body of knowledge?
4. Is the research approach clearly mentioned?

Each assessment question has got three possible answers which could be **"Yes"** or **"Partial"** or **"No".** The possible answers were assigned weights of 2 to the "Yes", 1 for the "Partial" and 0 for the "No". The assessment questions were used to compute the sum for each article basing on the weights outlined above. The reliability of the study was in-formed by finding the sum of all the assessment questions and divides the sum by 4 and an acceptable selection criterion was chosen. All articles with assessment scores from 1 (50% in percentage terms) were considered.

F. The Data Extraction

At this stage, the data was extracted for analysis and the data was extracted to a table showing the name of the journal, the author(s) name; the date of publication; the requirements techniques used; type of technique; technique application area. The framework in this paper is defined as a skeleton or an abstract that can be used to come up with a model or a graphical model, the model is derived from a framework. So the framework lays the foundation for the model. Table II shows the names of techniques and the type of techniques currently used in requirements engineering. Table II also shows the application area for each technique in the requirements engineering process.

Table II. Summary of Requirements Engineering Techniques

NO	Summary of Software Requirements Techniques				
	Author(s)	Ref	Name of Technique	Type of Technique	Application area
1	Jiang et al 2008	[7]	MRETS	Framework	Complete Requirements Process
2	Nuseibeh and Easterbrook 2000	[8]	Ethnography	Elicitation Technique	Requirements Gathering

3	Neill and Laplante 2003	[9]	Prototype (throw away)	Graphical Model	Complete Requirements process
4	Paetsch et al 2003	[10]	Focus Group	Elicitation Technique	Requirements Gathering
5	Gomes et al	[11]	MDRE	Graphical Model	Complete Requirements Process
6	Van Lamsweerde 2001	[12]	Goal Oriented analysis	Framework	Complete Requirements Process
7	Darimont and Lemoine 2006	[13]	Agent Oriented analysis	Framework	Complete Requirements Process
8	Fowler 2004	[14]	UML	Graphical Model	Analysis and Verification
9	Ghezzi et al 2002	[15]	Object Oriented Analysis	Framework	Analysis and Verification
10	Mauw et al 2000	[16]	SDL	Model	Analysis and Validation
11	Jones 2009	[17]	Joint Application Design	Elicitation Technique	Requirements gathering
12	Pandey et al 2011	[18]	Requirement Modelling Process	Framework	Complete Requirements Process
13	Brace and Cheutet 2012	[19]	CORA	Framework	Analysis and Verification
14	Hoorn and Van 2003	[20]	DUTCH	Framework	Complete Requirements Process
15	Brinkkemper and Solvberg 2000	[21]	Tropos	Framework	Complete Requirements Process
16	Bleistein et al 2006	[22]	B-SCP	Framework	Complete Requirements Process
17	Ali et al 2010	[23]	Goal based	Framework	Analysis and Verification
18	Robinson 2006	[24]	ReqMon	Framework	Complete Requirements Process
19	Yu and Liu 2001	[25]	i*	Framework	Complete Requirements Process
20	Tung and Chan 2009	[26]	UHRAF and SUM	Framework	Analysis and Verification
21	Uszok et al 2011	[27]	KAOS	Graphical Model	Complete Requirements Process
22	Thüm 2014	[28]	FeatureIDE	Framework	Complete Requirements Process
23	Lee and Gandhi 2005	[29]	Onto-ActRE	Framework	Complete Requirements Process
24	Zong-yong et al 2007	[30]	KADS	Framework	Analysis and Verification
25	Génova et al 2013	[31]	RQA	Framework	Analysis and Verification
26	Saiedian and Kumarakulasingam 2005	[32]	Use Case Scenario	Model	Analysis and Verification
27	Chatzikonstantinou and Kontogiannis 2016	[33]	ReqRV	Framework	Complete Requirements Process
28	Bachmann et al 2000	[41]	ADD	Framework	Complete Requirements Process
29	Suryn and Abran 2003	[42]	SQUARE	Model	Complete Requirements Process
30	Mead and Hough 2006	[43]	Accelerated Requirements Method	Elicitation Technique	Complete Requirements Process
31	Zowghi et al 2005	[47]	OPEN Process Framework	Framework	Complete Requirements Process
32	Beecham et al 2005	[48]	R-CMM	Graphical Model	Complete Requirements Process
33	Hull 2002	[49]	DOORS	Graphical Model	Complete Requirements Process
34	Damian and Zowghi 2003	[50]	RequisitePro	Graphical Model	Complete Requirements Process

35	Cant et al 2006	[51]	HIVE	Graphical Model	Complete Requirements Process
36	Lu et al 2008	[52]	CaliberRM	Graphical Model	Complete Requirements Process
37	Stal 2012	[53]	IRQA	Graphical Model	Complete Requirements Process
38	Delor 2003	[54]	Objectiver	Graphical Model	Complete Requirements Process
39	Lami et al 2004	[55]	QuARS	Graphical Model	Complete Requirements Process
40	Wieringa and Ebert 2004	[56]	RMTrak	Graphical Model	Management
41	Wang and Zeng 2009	[57]	Quality Function Deployment	Elicitation Technique	Requirements gathering
42	Adam et al 2014	[59]	TORE	Framework	Complete Requirements Process
43	Jiang and Eberlein 2008	[60]	FREE	Framework	Complete Requirements Process

Table II above shows the various techniques used in requirements engineering together with their application areas. The techniques chosen were those that meet our inclusion and exclusion strategy and also the quality assessment. It can be noted that various techniques have been proposed by authors and some techniques are applicable in certain areas and some are only restricted to understanding the problem domain but some techniques go as far as the solution space. Requirements engineering should focus on getting the requirements right, like what does the stakeholder really want without overstepping to the design part on how to meet the stakeholder want. Table III grouped the requirements engineering techniques.

Table III. Grouping of Requirements Engineering Techniques

Type of Technique	Name of Technique	Application Area
Framework	MRETS, MDRE, Goal Oriented analysis, Agent Oriented analysis, Requirement Modelling Process, Tropos, B-SCP, ReqMon, i* Feature IDE, Onto-Act RE, ADD, OPEN Process Framework, TORE, FREE, DUTCH	**Complete Requirements Process**
	Object Oriented Analysis, CORA, Goal based, UHRAF and SUM, KADS, RQA, Use Case Scenario,	**Analysis and Verification**
Elicitation Technique	Ethnography, Focus Group, Joint Application Design, Accelerated Requirements Method, Quality Function Deployment	**Requirements gathering**
Graphical Model	RM Trak	**Management**
	Qu ARS, Objectiver, IRQA, Caliber RM, HIVE, Requisite Pro, DOORS, R-CMM, KAOS, UML, MDRE, Prototype (throw away)	**Complete Requirements Process**
Model	SQUARE,	**Complete Requirements Process**
	Use Case Scenario,	**Analysis and Verification**
	SDL	**Analysis and Validation**

III. RESEARCH METHODOLOGY

This section presents the findings from the review and the findings were based on the Research Questions.

A. RQ1. What are the techniques used in requirements engineering?

The review identified 43 techniques used in requirements engineering but the techniques are based on our exclusion and inclusion search strategy and also the quality assessment of the study. There is no requirement engineering technique that can best solve all the issues in the software requirements domain but each issue can best address a certain problem provided it falls within that domain [58]. Choosing a requirements engineering technique can be a daunting task but factors to consider in selecting the best technique may include the size of the project, the category of the project, the funds available for the project and the complexity of the technique [61].

B. RQ2. What are the limitations of the existing techniques used in requirements engineering?

From the findings there is a striking observation that [1] concurs with that the techniques used in requirements engineering usually addresses one activity of the requirements

engineering process which cannot adequately address the dictates of the requirements engineering process as postulated by [35], which seeks to cover all the activities in the requirements engineering process. This shortfall should be addressed by coming up with a technique that addresses all the activities in the requirements engineering process.

Some of the techniques did not take into consideration some projects that are in a dynamic environment where stakeholders keep changing the requirements as also eluded by [4] who aptly suggested that requirements engineering techniques should provide support for dynamic environment. This is critical because a successful project should be delivered on time and within budget [36]. It is crucial to identify key stakeholders during requirements elicitation and many techniques are silent on this issue. If key stakeholders are not identified during the elicitation stage, the project will be bound to change requirements constantly due to stakeholders conflicts and this will ultimately affect the project delivery time and at times the project may fail [45].

C. RQ3. HOW DO CHANGING SOFTWARE REQUIREMENTS AFFECT REQUIREMENTS ANALYSIS?

Research has shown that stakeholders do not understand what they really want from the project onset hence they change agreed requirements frequently which can have a negative effect on the project cost and delivery schedule [37]. Many projects have failed due to changing requirements since one requirement change can generate many changes in the project [38] and [39]. For a change in software requirement, a proper change impact analysis has to be carried out so that the change will not cost the project in terms of the delivery time and in monetary terms. If the change request is going to have ripple effects on the project, it is crucial to consider the requirement priority ranking in the project before a change can be done.

Many techniques used in requirements engineering are too complicated making them in-applicable in a real world project. There is need to come up with techniques that are easy to follow through in a project but addressing all the activities in the requirements engineering process. Some of the techniques used in requirements engineering they go beyond the problem space into the solution space. It is important to concentrate the effort in understanding the problem and avoid moving to the solution space. Requirements engineering should focus on one central theme "what the stakeholders want" without proposing the solution in the requirements engineering phase as some techniques did.

IV. LIMITATIONS OF THE RESEARCH

A. Research Completeness

The research was focused on commonly used databases and those databases with restricted access and a total of 43 requirements engineering techniques were looked at that met our assessment questions from the primary studies done. Although some databases were not checked but however our search strategy yielded positive results, the only drawback was that articles not written in English language were not considered and articles not falling in our inclusion and exclusion search strategy and also the quality assessment of the study were not considered.

V. FUTURE RESEARCH

The review provided an eye opener on areas that have not been adequately researched on in requirements engineering. Many software projects fail because one of the stages in the requirements engineering process was not properly done [44]. So the requirements engineering process should be a holistic process so that no activity is left out otherwise the project will fail. There is need to further research on the following areas of concern:

1. To come up with a requirements engineering technique that addresses all the activities of the requirements engineering process.
2. To come up with a requirements engineering technique that should provide support for projects in dynamic environment.
3. To take into consideration factors that should be used in identifying key stakeholders in a technique.
4. To take into consideration change impact analysis in a technique.
5. To come up with techniques that are simple to follow and applicable in real projects not to be theory based.

VI. CONCLUSIONS

The research paper looked at various techniques used in requirements engineering from January 2000 to July 2016. The goal of the systematic research was to identify gaps that may exist in the researches done and propose areas for further research. The primary studies looked at came up with various techniques that address stakeholder's requirements in the following application areas: Requirements analysis, Analysis and Verification, Management and Complete Requirements Process.

There is scope for further investigation to come up with techniques to address all the activities in the requirements engineering process. There is also need to come up with techniques that are easy to follow and applicable in real projects. The review also identified that there is need to consider change impact analysis in a technique. Lastly, the technique should provide support for projects in dynamic environment.

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Prof. Nehemiah Mavetera is a Professor of Information Systems, a Masters and PhD internal and external examiner, an editor, reviewer of journal and conference papers in this field. Currently he is also a Director of the School of Economic and Decision Sciences. He is a holder of a PhD in Information Technology from the University of Pretoria, a Masters in Geoinformation Science and Earth Observation specialising in Cadastre and Land administration from ITC, University of Twente in the Netherlands and a BSc (Honours) Engineering degree in Surveying from University of Zimbabwe. Nehemiah's research interests include the Philosophy of Information Systems (IS) and their investigation, the social context of Information Technology (IT), in particular the use of ontologies in software engineering. The research also covers fields such as the semantic web, e-businesses and their e-revenue models, electronic–markets (e-markets), information technology management, business process management, scientific and business process workflow management systems. Nehemiah also researches in the fields of Social Science Research methods with special emphasis on the qualitative research paradigm. He has written and published 72 peer reviewed research papers and book chapters in these fields. Most of these publications are in Scopus, ISI, and IBSS indexed, DOE accredited national and international journals and conference proceedings. He has been awarded the Faculty of Commerce Novice Researcher of the Year Award in 2011 and one of his papers received the IBIMA 19th conference Best Paper award in November 2012, Barcelona, Spain. His work has been highly cited nationally and internationally. Nehemiah has successfully supervised more than 100 Honours research students in IT, and 25 Masters' students. Nehemiah has been an Associate Editor and Reviewer for several international journals and conferences such as the African Journal of Information Systems, European journal of Information Systems, European Conferences of Information Systems, Mediterranean Journal of Social Sciences, IBIMA, CIBIMA, IDIA, International Journal of qualitative Information Systems Research (IJQISR), Information resources management association (IRMA) now Con-firm, Conference on Electronic Commerce, Scientific research and essays (SRE), to mention but a few. His expertise has been used in NRF Grants Panel Research reviews such as Thuthuka, Thrip, SARChi and many others. For some of Nehemiah's work and publications, please visit: http://nwu.academia.edu/NehemiahMavetera.

Dr. Osden Jokonya (PhD Information Systems) is an academic with more than twenty years in the IT industry. He has held several positions invarious sectors which include mining, retail, manufacturing, financial services, insurance, utility, education and other sectors. He has presented several papers at conferences in Africa, Europe, Asia and America, in addition to publishing several papers in IT Adoption and Governance and 3rd Platforms. His current research interest is focused on 3rd Platforms or SMAC stack (Social media, Mobility, Big Analytics and Cloud). He is current employed at North-West University in South Africa as a Senior Lecturer in the Department of Information Systems.