UNIVERSITI PUTRA MALAYSIA

EFFECTS OF HUMAN FACTOR ON REQUIREMENT VOLATILITY MEASURES FOR EFFICIENT SOFTWARE REQUIREMENT ENGINEERING

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By

ZAHRA ASKARINEJADAMIRI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

December 2016

DEDICATION

This thesis is dedicated to my lovely husband, Dr Mehdi Shabannia, my dearest parents, and family for their endless love, support and encouragement.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

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December 2016

Chairman : Professor Abdul Azim Abd.Ghani, PhD
Faculty : Computer Science and Information Technology

Software is developed based on the requirements of users which are obtained during the requirements gathering activity in the requirement engineering process in software development projects. The aim is to collect complete and unambiguous requirements. Nevertheless, not all projects are free from requirement changes or requirements volatility which involves additions, deletions, and modifications of requirements. Frequent changes to requirements are a risk factor in software development projects. Moreover, software is developed based on human activities such as problem solving, analytical thinking, communication and cognitive reasoning. Although technical skill is important to a software project's successful outcome, the human factor is a determining issue that affects most software projects. Thus, human factors are among the main challenges in requirements engineering including requirements volatility. Human as main part for software requirements gathering have an important role on requirements volatility. Changes in software requirements occur through the role of human in requirements gathering. However studies on human factors in requirements volatility are still lacking. Most of the studies have addressed the technical aspects of requirements gathering and requirements volatility in relation to productivity, software defects, and software release. A few studies focus on the factors that influence requirements volatility involving communication between users and developers, and defined the methodology for requirements analysis and modelling. Despite the maturity of human factors in many contexts, very little published literature discusses about human factors and requirements volatility. In this research, a human factors model on requirements volatility named as HF-RV model, is proposed. The constructs of the human factors model are human errors, moral capital, spiritual capital, human capital and human ability. The human factors model is derived from analysis of related literature in human factors theories which include personality theories and human errors theories. The model then had undergone further investigation to identify the relationships between human factors and requirements volatility by surveying two hundred fifteen experienced participants in requirements

gathering. The data collected from the survey was analysed using SPSS and AMOS for structural equation modelling and other analysis. The results indicated considerable confirmatory for hypothesized model. Furthermore, Exploratory Factor Analysis, Confirmatory Factor Analysis, test for reliability and validity, and model fit test conducted show the model is acceptable. To gain more insight on usefulness of the model, opinion from experts were gathered through interview sessions. The results from this research reveal the significant impact of human error, moral capital, human capital and human ability on requirements volatility. However, spiritual capital impact on requirements volatility is statistically rejected. In short, it provides new insight into impact of human factors on requirements volatility in requirements gathering.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PENGGABUNGAN EFEK FAKTOR MANUSIA KE ATAS UKURAN KETAKTENTUAN KEPERLUAN UNTUK KEJURUTERAAN KEPERLUAN PERISIAN YANG EFISYEN

Oleh

ZAHRA ASKARINEJADAMIRI

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Perisian dibangun berdasarkan kepada keperluan pengguna yang diperoleh semasa aktiviti pengumpulan keperluan dalam proses kejuruteraan keperluan dalam projek pembangunan perisian. Matlamatnya ialah untuk memungut keperluan yang lengkap dan jelas. Namun bukan semua projek bebas daripada penukaran keperluan atau ketaktentuan keperluan yang melibatkan penambahan, penghapusan, dan perubahan keperluan. Penukaran yang kerap kepada keperluan merupakan satu factor risiko dalam projek pembangunan perisian. Tambahan pula perisian dibangun berdasarkan aktiviti manusia seperti penyelesaian masalah, pemikiran analitik, komunikasi, dan penaakulan kognitif. Walaupun kemahiran teknikal penting kepada hasil kejayaan projek perisian, faktor manusia ialah isu penentu yang mempengaruhi projek perisian. Oleh itu, faktor manusia adalah diantara cabaran utama dalam kejuruteraan keperluan termasuk ketaktentuan keperluan. Manusia sebagai sebahagian utama untuk pengumpulan keperluan perisian mempunyai peranan yang penting ke atas ketaktentuan keperluan. Penukaran dalam keperluan perisian terjadi melalui peranan manusia dalam pengumpulan keperluan. Walau bagaimanapun, kajian tentang faktor manusia dalam ketaktentuan keperluan masih lagi kurang. Kebanyakan kajian menumpukan aspek teknikal pengumpulan keperluan dan ketaktentuan keperluan yang berkaitan dengan produktiviti, kecacatan perisian, dan pelepasan perisian. Sedikit kajian memfokus ke atas faktor yang mempengaruhi ketaktentuan keperluan yang melibatkan komunikasi diantara pengguna dan pembangun dan mentakrif metodologi untuk menganalisis dan memodel keperluan. Meskipun kematangan faktor manusia dalam banyak konteks, sangat sedikit literatur yang diterbit membincang tentang faktor manusia dan ketaktentuan keperluan. Dalam kajian ini, satu model faktor manusia ke atas ketaktentuan keperluan dinamakan model HF-RV, dicadangkan. Konstruk model faktor manusia tersebut ialah kesilapan manusia, modal moral, modal spiritual, modal insan dan keupayaan manusia. Model faktor manusia tersebut diterbit daripada analisis literatur yang berkaitan dengan teori faktor manusia yang melibatkan teori personaliti dan teori kesilapan manusia. Model tersebut

seterusnya menjalani siasatan lanjutan untuk mengenal pasti hubungan antara faktor manusia dan ketaktentuan keperluan dengan mensurvei dua ratus lima belas peserta yang berpengalaman dalam pengumpulan keperluan. Data yang dipungut daripada survei dianalisa menggunakan SPSS dan AMOS untuk pemodelan persamaan berstruktur dan analisis lain. Keputusan menunjukkan pengesahan yang besar untuk model hipotesis. Tambahan pula, Analisis Faktor Penerokaan, Analisis Faktor Pengesahan, ujian untuk kebolehpercayaan dan kesahan, dan ujian padanan model yang dilakukan menunjukkan model tersebut boleh diterima. Untuk mendapat tanggapan yang lebih tentang kebergunaan model tersebut, pendapat daripada pakar telah dikumpul melalui sesi temuduga. Keputusan daripada kajian ini mendedahkan impak signifikan kesilapan manusia, modal moral, modal insan dan keupayaan manusia kepada ketaktentuan keperluan. Walau bagaimanpun impak modal spiritual ke atas ketaktentuan keperluan ditolak secara statistik. Pendek kata, ia memberikan pandangan baru tentang impak faktor manusia ke atas ketaktentuan keperluan dalam pengumpulan keperluan.

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I certify that a Thesis Examination Committee has met on 29 December 2016 to conduct the final examination of Zahra Askarinejadamiri on her thesis entitled "Effects of Human Factor on Requirement Volatility Measures for Efficient Software Requirement Engineering" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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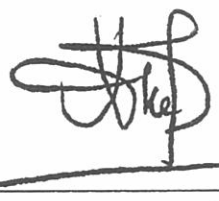

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy.The members of the Supervisory Committee were as follows:

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Declaration by graduate student

I hereby confirm that:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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Name of Member of Supervisory Committee: Dr. Koh Tieng Wei

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LIST OF ABBREVIATIONS

RV	Requirements Volatility
RE	Requirements Engineering
HE	Human Error
MC	Moral Capital
SC	Spiritual capital
HC	Human Capital
HA	Human Ability
AMOS	Analysis of Moment Structures
SPSS	Statistical Package for the Social Science
SEM	Structural Equation Modeling
AVE	Average Variance Extracted
MSV	Maximum Shared Value
ASV	Average Shared Square Variance
PCA	Principal Component Analysis
CFA	Confirmatory Factor Analysis
EFA	Exploratory Factor Analysis
CR	Construct Reliability
S.E	Standard Error
C.R	Critical Ratio
GOF	Goodness Of Fit
x^2	Chi square
DF	Degree of Freedom
RMSEA	Root Mean Square Error of Approximation
NFI	Normed Fit Index

GFI	Goodness of Fit Index
CFI	Comparative Fit Index
AGFI	Adjusted Goodness of Fit Index
IFI	Incremental Fit Index
PCFI	Parsimony-adjusted Comparative Fit Index
KMO	Kaiser-Meyer-Olkin Measure of Sampling Adequacy

CHAPTER 1

INTRODUCTION

1.1 Background

Requirements gathering is recognized as a human-intensive activity that involves one or more teams of requirements gatherer depending on the size of the project. Software is developed based on the requirements of users which are obtained during the requirements gathering activity in the requirements engineering (RE) process in software development projects. The aim is to collect as much complete and unambiguous requirements as possible. Nevertheless, not all projects are free from requirements changes or requirements volatility (RV) involving additions, deletions, and modifications (Malaiya & Denton, 1999). RV is dependent on the outcome of requirements gathering. Due to the advancing technology and heightened role of humans on its management, more researchers are focusing their attention away from the technical to the socio-technical aspects of software projects. For example, communication and cooperation among software development teams has become the focus of researchers in order to understand role of humans in software development.

As the technology grows, many scholars are focusing on the importance of RV in systems. RV refers to any change of user requirements in software project development. Communication during requirements gathering is a critical step to offsetting much RV. The needs of stakeholder should be identified through proper communications in the requirements gathering phase (Lohr, 2009). It is a critical step for the success of a project. Nevertheless, changes in requirements are inevitable due to various reasons and become issues in project development. Therefore, managing and controlling RV is vital.

Changes in user requirements are unavoidable in any project life cycle due to defects, missing user requirements, changes in project strategy, or improvements in designs. Ignoring requirements changes can lead to projects not meeting user requirements and consequently to user rejection and even project failure (Hinton et al., 2014). RV is a critical challenge in projects due to changes in software development which lead to reworking the original design and code and this leads to increases in time and costs. These are significant risk factors for projects (Ott & Longnecker, 2015). Thus, determining and measuring software RV is crucial for managers to control the system.

RV is a metric of requirements engineering and this has been identified in the literature. Requirements engineering, which involves socio-technical aspects, is a critical and complex process. It has a vital role in reducing risks to a project and consequently increasing the success of software project (Little, 1988b; Otero, 2012). Among the elements to achieve success in software projects are technology, processes, and methods, but the use of them is based on judgment and the decisions of humans (Feldt et al., 2010). Thus, human aspects are among the main challenges in

requirements engineering.

Communication between users and developers in requirements gathering is a major activity which leads to RV (Zowghi & Nurmuliani, 2002). Requirements gathering is a process in requirements engineering. The process of formulating, maintaining, and managing requirements in software project is called requirements engineering which depends on various factors. Humans, as the main part of a project, and their personality and behaviour have a vital impact on requirements engineering. There are various definitions of human factors as presented in the sciences but, in general, they refer to the physical property of a human that influences social and technical systems (Efron & Tibshirani, 1994). Overall, in this study, any factor that affects human work efficiency is considered a human factor. Humans have the capacity to control RV.

The role of humans is without doubt important to the successful development of software. For example, human reluctance to change may be important in controlling change in technically-based software processes or its tools (Lenberg et al., 2015). However, in developing software we are often faced with development problems caused by human errors just like in other domain areas (Norman, 2013; Rasmussen, 1982; Reason, 1990). Usually, requirements elicited from users are vague and incomplete and do not include adequate detailed information. Requirements are obtained through communication with stakeholders (Würfel et al., 2015) and poor communication can reduce the quality of requirements gathering (Kan et al., 1994). Undefined requirements processes and misunderstandings are signs of poor communication in software requirements gathering (Sutcliffe et al., 1999). Soft skills of human are important as well as hard skill in software development companies. Usually these companies hire person with hard and soft skills for handling tasks. Thus, both technical and social aspect of human should be considered in software project.

In this research, we present a study on RV as a means to understand the impact of human factors on requirements gathering in requirements changes. It focuses on identifying and analysing human factors on requirements gathering which impact on RV. A HF-RV model (human factors in RV model) is proposed as a result of our extensive literature review. This study attempts to establish a link between the social aspects of human activity i.e., human factors, to the technical aspects of human works which is requirements gathering.

1.2 Research motivation

Requirements gathering is a critical step in software development. In reality, requirements gathering can result in incomplete, ambiguous, and inconsistent requirements. In requirements gathering, communication between users and developers is critical. RV is one of the important risk factor of RE (Ferreira et al., 2009). Hence, organizations still consider RV as an important risk that impacts on software projects (Neyman & Pearson, 1992). Requirements changes, which include additions, deletions, or modifications, are important elements that impact on the success of projects (Byrne, 2013; Nurmuliani et al., 2004). Any changes have cost

implications for projects. RV causes cost overruns in software project(Peña & Valerdi, 2015). In fact, the decreasing costs in IT are a significant challenge for current software systems that managing and measuring RV is effective assistance. Roger Sessions has estimated the annual worldwide cost of failed projects to be "about $6 trillion a year or $500 billion per month". Also in the US the annual cost of failures in software projects is about $1 trillion (J. Curtis, 2009). Also, according to chaos survey 32% of IT projects are successful and 44% considered challenged (late, over budget, don't meet full requirements list), and the remaining 24% as completely failed (Pfahl & Lebsanft, 2000). Researches indicate that RV has a significant impact on project performance(Keil et al., 2013). Apart from that, another survey covering 4000 European companies showed that managing and controlling requirements of user is one of the main challenges of software development (Lane & Cavaye, 1998). Therefore, understanding the root of RV is an effective way for managing and controlling the system (Dalpiaz et al., 2013).

Frequent changes to requirements are a risk factor in software development projects (Wang et al., 2008). A variety of research and studies have addressed the technical aspects of requirements gathering and RV and show the impact of the latter on productivity(Kulk & Verhoef, 2008), software defects(Javed & Durrani, 2004), and software release (Nurmuliani et al., 2006). Moreover, not many studies focus on the factors that impact on RV while others focus on the communication between users and developers and define the methodology for requirements analysis and modelling (Zowghi & Nurmuliani, 2002). Also, some studies consider process management and process technique in requirement engineering impact on RV (Ferreira et al., 2011; Wang et al., 2012). A search on the ISI web of science shows that more than 70% of papers discuss the technical aspects of SE and the software development process and less than 5% study the soft or human aspects of software development. Nevertheless, not many studies have focused on the human factor as a vital component in controlling RV. Some researchers have explored some human error and requirements engineering (Embrey, 2005; Ibrahim et al., 2009; Lopes & Forster, 2013b; Walia & Carver, 2009) .They focus on some aspect of requirement volatility and classify them based on people, process and documentation. Fifty-six percent of software development effort errors can be investigated in software requirements specification(Ferreira et al., 2011). In short, the quality of requirements directly impacts RV. Thus, these above reason are main motivation for conducting this research.

1.3 Problem statement

The aim of software development project is to produce high quality software product. Software is developed based on human activities (Capretz, 2014) such as problem solving, analytical thinking, communication and cognitive reasoning. Although technical skill is important to a software project's successful outcome, the human factor is a determining issue that affects most software projects. Among the elements to achieve success in software projects are technology, processes, and methods but the use of them is based on judgment and the decisions of human (Feldt et al., 2010). Human has a vital role in reducing risks to a project and consequently increasing the success of software project (Juristo et al., 2002). Human factors are usually related to soft skill. Thus, software production demands both technical skill and social skill from

software engineers involved in the project. Furthermore, it is believe that human factor is the main root of software development challenges ((Hazzan & Hadar, 2008). Software development is dependent on not only human ability, but also their behaviour in performing their development tasks. The role of human is without doubt important to the successful development of software.

A variety of research and studies have addressed the technical aspects of requirements gathering and requirements volatility. They show the impact of on productivity(Tan et al., 2009), software defects (Zowghi & Nurmuliani, 2002), and software release (Peña & Valerdi, 2015). Moreover, not many studies focus on the factors that influence requirements volatility except that they are the communication between users and the developer and defined the methodology for requirements analysis and modelling.

In view of the importance of requirement volatility, it is beneficial to understand human factors as means to effectively control software projects. Although some research has been conducted on understanding the cause of RV, there is still lack of studies on impact of human factors in RV. Controlling humans is an issue of software development which needs understanding and requires more studies on human factors which is consists of human personality, behaviour, and other factors which impact on humans work. To better understand the causes of RV, this research study intends to propose a model involving human factors that impact on RV. This study focuses on identifying and analysing human factors on requirement gathering which impact on requirement volatility.

1.4 Research question

With regard to background and problem statement of this study, there is a need to understand the relationship between human factors and RV. Hence, below are main research questions of this study:

RQ1: What is the influencing impact of human factors on requirements volatility in requirements gathering process?
RQ2: What is the degree of relationship of human factors on requirements volatility?
RQ3: How do human factors in requirements gathering have impact on requirements volatility?

1.5 Research objectives

As mentioned above, there are some challenges in risk of RV and most do not specifically take human factors into account. As such, the main objective of this research is to propose a human factor model that impacts RV. This model will answer the above mentioned research questions. Thus, in order to achieve main objective, the followings are the sub-objectives of this study:

- To identify the human factors that impact on RV.

- To determine the relationships between the identified human factors and RV. This will involve establishing the degree of relationships between human factors constructs and RV.
- To examine how this model fits as well as validate theoretical proposition on influencing impact of human factors on RV.

1.6 Research scope

This research investigates the human factors that affect RV and propose some factors which affect RV in the requirements phase. User and developer communication for requirements gathering is conducted in the first phase. Therefore, the human factor based on requirements gatherer perspective is the purpose of this research. Thus, the research scopes are:

- Focusing on requirements-gatherer respondents whose work in software companies involves gathering user requirements. Also person having prior experience in this area can be as respondents of this study.
- This research interest is on the requirements gathering phase of the software development cycle which interacts more with RV and is crucial as a first phase.
- This study is limited to an examination of human factors in term of human errors, moral capital, spiritual capital, human capital, and human ability impact on RV. However, it is not the intention of this research to claim that human factor is only limited to these five factors.

1.7 Significant of study

RV is one of the requirements management issues in software development that involves human activity. Academically speaking, this study is significant because it makes a contribution to the human factor model on requirements gathering and expands theoretical and empirical research on RV. A better understanding of the critical factors in RV would assist software managers in their decisions in hiring requirements gatherers or improving the human factors of current requirements gatherers. For requirements gatherers and developers, understanding the crucial human factors related to RV will enable them to gather requirements more effectively as a means to enhance the quality of the inputs and to reduce the risk of RV.

Also, a search of the academic references shows that human factors, software requirements, and requirements management are major issues in the software development field today. Requirements management deals with requirements changes in software development. According to the ISI web of knowledge and the Microsoft Academia website, publications and citations on requirements engineering, software requirements, requirements specification, requirements management, and volatility have increased between 1997 and 2015. Also, much focus is currently being directed to the social science aspects in engineering. As figure in appendix A show, publications and citations on human factors have increased between 1960 and 2014.

Figures of appendix A show the importance of requirements management, engineering, and human factors for purposes of analyses. This study thus focuses on understanding the role of human factors on requirements gathering which has an impact on RV.

1.8 Research contribution

The contribution of this study is presented both theoretically and practically. The theoretical contribution relies on a model which shows the relationship between user and requirements gatherer communication during software requirements gathering, along with a proposition on the impact of human factors on RV. The HF-RV model depicts the elements of human factors which have the potential to impact on requirements change. This model provides a better understanding of RV causes from the socio-technical perspective.

The practical contribution of this research is the establishment of the questionnaires to measure RV based on human factors by using research instruments. When validity and reliability are statistically proven they can be used as significant and useful guidelines or references for prospective researchers with similar research intentions. These statistics show the impact of each human factor on RV and prioritized for use in projects.

1.9 Definition of term

Understand the meaning of keywords is essential need of each studies. It is clear that human factors, requirement volatility, moral capital, spiritual capital and human ability can be defined in various aspects, while based on aim of this study they are defined as below.

Human factors is soft skill of human for conducting requirement gathering which mentioned in different words such as personality, soft competency or human behaviour. Requirement volatility refers to any changes in requirement such as add deletion or modification. Human errors refer to any human activities in communication for requirement gathering which lead to do not achieve the goals of requirement gathering. Moral capital is set of action or morality standard which derived from morality and ethical behaviour in communication of developer for requirement gathering. Spiritual capital is defined as inherent quality of human being which impact on result of requirement gathering in communication of developer and user. Human capital refers to some factors which that contribute to development of human in requirement gathering. Human ability is defined as some mental and physical activities of human in communication for better requirement gathering. Finally, HF-RV is Model of Human factors in requirement volatility which consist set of human capital, moral capital, spiritual capital, human capital and human ability that have significant impact on RV.

1.10 Structure of thesis

This thesis is organized in accordance with the standard template of thesis and dissertations at University Putra Malaysia. It is organized in a manner to provide detailed information on how the research is carried out. This thesis is structured to provide a critical review of relevant information regarding human factors and RV. As the final report of this research, this thesis consists of six chapters as presented below.

Chapter1 presents the introduction to the background of this research. It describes the rationale for conducting this research, and outlines the researcher's motivation, research objectives, and problem statement in this research. The scope and the research contributions are also explained in this chapter.

Chapter 2 reviews the literature on different aspects of RV and human factors. It presents a discussion of past works relevant to this research. The definitions of RV, requirements engineering, requirements gathering, and human factors are also presented. In this chapter, resource materials such as journals, conference proceedings, seminar, thesis, books, and online resources are used as the main references.

Chapter 3 discusses the research methodology as well as justifies the research methodology design used in conducting this research. In addition, the research process, design, development of the instrument, pilot study, population, sample and data collection, data analysis methods are presented.

Chapter 4 presents the HF-RV models and discusses hypotheses development. It includes a description of the research model along with the justification as well as the formulation of the hypotheses.

Chapter 5 presents the research findings and discussions. It describes a summary of the key findings of this study on the human factors and RV, together with the analysis of the findings.

Chapter 6 presents the conclusion of the research and its limitations and indicates potential areas for future research.

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