A Risk Model of Requirements Change Impact Analysis

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***Abstract*—Software systems are critical assets to organisations as they support important business processes and workflow. To maintain the value of these assets, the requirements of software systems must evolve whenever there are changes in business needs. A key problem to organisations is implementing requirements change to the existing software systems. Such initiatives need proper analyses so that their effects could be determined before resources are spent. Impact analysis is therefore an important step in requirements change management. As a project, any change implementation involves risks. It is thus necessary for impact analysis to consider risk factors for implementing requirements change. However to date, the risk factors concerning requirement change are not much explored. This paper aims to identify the risk factors for implementing requirements change. The risk factors were identified through two qualitative approaches, namely a review of related work and a focus group study. The former involved fifty published articles and the latter concerned five domain experts. The collected risk factors from both studies were analysed by using content analysis. The risk factors form a risk model for analysing impacts of implementing requirements change. The model helps practitioners to assess the viability of requirements change requests.**

***Index Terms*—requirements change management, risk factor, impact analysis**

I. INTRODUCTION

Software is dynamic and changes rapidly in order to respond to various business needs. There are many causes of software changes. One of them is due to addition and modification of requirements. Requirements change takes place in both development and maintenance phases [1]. One fourth of requirements change occur during maintenance phase [2]. As compared to development, requirements change that happens during maintenance is more costly since the software has been put into operation and used by its users [3].

Users issue requirements change through change request forms, which information is used during impact analysis. Impact analysis analyses current environment and foresees the possible effects on the existing software when implementing the requested change. The results of impact analysis guide the Change Control Board (CCB) to decide whether the requested change should be implemented. Any approved change request is indeed a software project where its scope, cost and schedule for implementation are defined. Impact analysis therefore needs to be accurate in order to avoid the failure of such projects.

As a software project, it is necessary for CCB to assess risks during impact analysis for requirements change [3]. Risk is an event that triggers unwanted conditions that could bring harm and loss to a project. Risks are managed through a set of action plans [4]. Risk assessment in particular involves risk identification, risk analysis and risk prioritisation [5]. Despite its importance, it is uncertain how to incorporate risk assessment during impact analysis for requirements change.

The key aspect of risk assessment is the categorisation of risk factors. The aim of this paper is to explore the risk factors that should be analysed during impact analysis concerning projects involving requirements change. The individual risks are collated from theoretical and empirical work as a conceptual model that shows the interrelationships among several categories of risk factors. The model acts as a guide for assessing risks in implementing requirements change. The paper is organised as follows: Section 2 provides the related work on the subject matter. Section 3 briefly explains the methodology used. Section 4 presents and elaborates the proposed model. Finally, Section 5 concludes the paper with a summary that outlines the main findings and future work.

II. RELATED WORK

Requirements change has been a critical issue in software development projects. One particular issue in requirements change is how to deal with the requirements change before implementing them. A proper process of managing requirements change can ensure the successful implementation of the change. The critical step in managing requirements change is to decide either to accept or reject the requested change [6,7]. Such a difficult decision has to be made by a dedicated technical committee, namely Change Control Board (CCB) through impact analysis [8,9]. During impact analysis, the affected elements will be analysed [10]. To date, it is

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uncertain how CCB should analyse the impacts of those elements and subsequently decide the way forward [11].

Users issue changes in requirements through change request forms. A change request form contains change attributes such as reasons, types and sources of change, which are necessary for project team to understand the request [12]. Requirements change normally affects software and hardware of the current system. When considering a change request, source code [13,14], documentation [15], tools [16] and architecture [14] of the existing software are examined to assess the impacts. The change in software normally causes some changes in hardware and vice-versa. The changes in hardware include memory usage [17], performance [3] and platform [18]. The change is complex if it involves a new software or hardware technology that has not been used in prior projects [19,20].

Requirements change also concerns human aspects. Project team is responsible to analyse the change request forms received from users. To ensure the feasibility of the change, assessing the project team's capability such as skill, knowledge, experience and motivation during impact analysis is important [21]. On the other hand, user involvement is necessary so that the users are aware of the systems' operations after the change [22]. Furthermore, the users can also provide information about the current system and clarify the change that they requested [23].

Although requirements change provides an opportunity for a software system to improve its value, it triggers risk. Improper implementation of requirements change can cause late delivery, cost overrun, low product quality and sometimes failure to the entire software project [24]. Therefore, it is important to analyse the risk factors in implementing the requirements change through impact analysis [3]. The risk factors are indeed the affected and affecting elements of the change. The analysis of the these elements helps to reduce the ripple effects and unforeseen outcomes before the change is implemented [3].

Requirements change initiatives are considered as software projects and thus, risk factors concerning projects also apply to them. Inexperienced, lack of knowledge and skill among project team members are widely known project risks [19]. In addition, lack of commitment from team members towards the project and ineffective communication between team members and users also impede project success [20]. Besides project team and users, a project is also risky if it fails to gain support and commitment from the top management [20]; [25]. Furthermore, the number of third party involved [20] and degree of dependency on them also contribute to project risks [25].

Both technical and non-technical elements mentioned above influence the schedule and cost to implement a requirements change. A study shows that optimising the schedule can result in significant time saving to implement the change [26]. There are four factors related to cost in requirements change, namely the number of project team members and consultants as well as project duration, size and scope [27]. Inaccurate judgment of the affected and affecting elements may cause in inadequate allocation of time and cost for implementing the change [19,20].

The review above indicates that there are various elements that are deemed necessary when managing requirements change. As the elements contribute to the success or failure of a requirements change project, they are considered as risks. The identified risk however are scattered and treated discretely. It is unclear how these risks influence each other and can be classified as risk factors of implementing requirements change.

III. METHODOLOGY

The purpose of this study was to identify the risk factors of implementing requirements change. The identified risk factors could help CCB to assess the impacts of the requested requirements change and decide whether the project team should implement it. In order to ensure the identified risk factors are holistic and practical, the study employed both theoretical and empirical approaches. The former concerned a review of previous studies whereas the latter involved a focus group interview with practitioners from software industry. Fig. 1 illustrates the research design, which contains the main activities involved in the study.

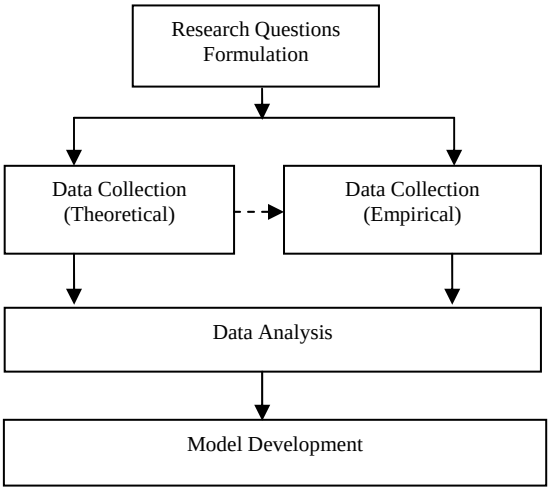

Figure 1. Research design

The following paragraphs explain each activity briefly:

- Formulate Research Questions

In general, the study aimed to answer the following research questions. The questions were generated based on a preliminary study made on the subject matter.

What are the risk factors involved in implementing requirements change? How do these factors relate to each other during impact analysis of requirements change implementation?

- Collect Theoretical Data – A Review

The objective of the review was to determine the risk elements concerning requirements change implementation as a software development project, which should be analysed during impact analysis. The keywords used in searching the articles therefore included "change impact analysis", "software change impact analysis", "requirements change impact analysis", "requirements change", "software change", "software risk" and "software development risk". There was about one hundred articles found but only fifty were selected for further analysis. The other fifty articles were rejected, as they are not relevant to the study. The searching was performed on several prominent online databases. The articles were from year 1995 until 2012 that covered both journals and conference proceedings. The findings of the review can be found in the earlier study [28].

- Collect Empirical Data – A Focus Group Interview

In order to confirm the risk elements found in the literature, a focus group interview with several domain experts and practitioners from the industry was conducted. Focus group is a planned discussion to gather information of interest in a permissive and non-threatening environment [29]. The approach was selected because it captures ideas and background regarding process and product through first degree contact and direct access to participants [30].

The focus group employed the approach suggested by [31]. The interview used semi-structured questions, which were constructed based on the risk elements found in the review. The questions also adopted the factors proposed by [32,33]. Prior to the real session, a pilot study was conducted with five software developers. The purpose of the pilot study was to validate the accuracy and completeness of the questions as well as the feasibility of the session. The feedback received from the pilot study was used to improve the planning of the real session.

Predefined selection criteria of informants were set in order to ensure the gathered data would be meaningful. The potential informants must possess more than ten years of experience in software development and must be involved in requirements change management process. To fulfill this requirement, the study employed purposive sampling [34]. The study identified and invited eight informants to the session. A formal invitation letter was sent to them, which contains information regarding the focus group session such as purpose, impact of the study, date, time and venue. Only five informants agreed to attend and thus the response rate was 62%. All of them were government servants. Table 1 provides brief background information about the informants.

The focus group session took about two hours and was video-recorded. Before the session commenced, the author explained the procedure and acquired participation agreement from the informants through consent forms.

TABLE I.
INFORMANTS' BACKGROUND

Agency	System	Informant	Designation
A	A1	I1	Head of project
	A2	I2	Head of unit
B	B1	I3	Head of project
	B2	I4	Head of unit
C	C1	I5	Head of unit

- Analyse Data and Construct the Model

The collected data from both theoretical and empirical work were transcribed and analysed by using content analysis. Content analysis is a research technique for making replicable and valid inferences from text to the contexts of their use, in a way of providing knowledge, new insights, a presentation of facts and a practical guide to action [35]. The first step was to identify the significant risk elements based on frequency analysis. The elements were grouped into several distinct risk factors. Table 2 tabulates the significant risk factors concerning requirements change management found in the review and the focus group interview respectively. Each risk factor constitutes the corresponding risk elements. Most elements were present in both work (marked with /). Nine elements (marked with X in "Theoretical-Review" column) emerged only from the empirical work. Since the experts in the focus group strongly advocated these items, they therefore were included in the model. The numbers in brackets represent the number of informants mentioned about the elements. For example, 4/5 means four out of five informants agreed on the element. In terms of importance, the informants ranked the risk factors from the most important to the least as follows: Project Team, Identification of Change, Software, Hardware, User, Top Management, Planning of Change Implementation, Strategic Planning, Technology Standard and Third Party. The risk factors were categorised into four main components, namely People, Process, Product (Existing) and Organisation. The second step was to connect the risk factors systematically and conceptualise them as a model. The detailed description of the model is included in the next section.

IV. THE MODEL

Figure 2 below illustrates a risk model of requirements change impact analysis. The model contains four essential components: People, Process, Product (Existing) and Organisation. Each component consists of several risk factors and the corresponding risk elements that need to be considered holistically during impact analysis for implementing requirements change. The risk factors are interconnected during the process. The arrows between the risk factors in the model indicate the relationships that they have on each other.

TABLE II.
RISK ELEMENTS AND FACTORS FOR REQUIREMENTS CHANGE

Component	Risk Factors and Elements	Theoritical -Review	Empirical -Focus Group (Frequency)
People	User		
	Involvement	/	/ (5/5)
	Knowledge	/	/ (5/5)
	Commitment	/	/ (4/5)
	Communication	/	/ (5/5)
	Readiness	X	/ (3/5)
	Cooperation	/	/ (3/5)
	Project Team		
	Skill	/	/ (5/5)
	Knowledge	/	/ (5/5)
	Experience	/	/ (2/5)
	Motivation	/	/ (2/5)
	Commitment	/	/ (5/5)
	Communication	/	/ (5/5)
	Top Management		
	Support	/	/ (5/5)
	Commitment	/	/ (5/5)
	Third Party		
	Number of third party involved	/	/ (2/5)
	Dependency to external agents	/	/ (4/5)
Process	Identification of Change		
	Reasons	/	/ (5/5)
	Type	/	/ (3/5)
	Source	/	/ (4/5)
	Planning		
	Effort	/	/ (5/5)
	Scheduling	/	/ (5/5)
	Cost	/	/ (3/5)
Product (Existing)	Software		
	Source code	/	/ (3/5)
	Software architecture	/	/ (5/5)
	Tools	/	/ (4/5)
	Documentation	/	/ (2/5)
	Integration	X	/ (3/5)
	Interface	X	/ (3/5)
	Hardware		
	Memory space	/	/ (3/5)
	CPU Performance	/	/ (2/5)
	Platform	/	/ (2/5)
	Integration	X	/ (3/5)
	Interface	X	/ (3/5)
Organisation	Technology Standard		
	Software	X	/ (4/5)
	Hardware	X	/ (4/5)
	Strategic Planning		
	Policy	X	/ (4/5)
	Goal	X	/ (4/5)

The *People* component consists of user, project team, top management and third party. Normally, the user issues a change request through a change request form. The project team is responsible to review and analyse the change request and estimate the change. To ensure comprehensive analysis and estimation, the project team should possess appropriate skills, knowledge and experience about the system. In addition, the project team's motivation and commitment during impact analysis are also essential. The project team also needs to communicate effectively with the user. Due to incomplete and ambiguous information in the change request form, the project team often requires further elaboration from the user. User involvement is therefore important. The user must understand the change that he or she raises. He or she also must cooperate and commit when analysing the impacts. Changes normally cause resistance among users. Consequently, it is necessary to measure users' readiness before implementing the change.

After identifying and understanding the requested change from the user, the project team has to estimate the change. When estimating the effort, cost and schedule of the change, the project team requires commitment and support from the top management. The effort may need to be adjusted based on the approved cost and permitted schedule by the top management. The number of third party involved in the project and the degree of dependency towards them also influence the planning of change implementation.

The *Process* component contains two main activities concerning impact analysis, namely identification of change and planning of change implementation. The identification of change is based on the information included in the change request form. It is important to identify the reason, type and source of the change in order to analyse the urgency and impacts that they would bring to the existing product. On the other hand, the latter concerns the planning of effort, schedule and cost based on the involvement of third party and top management, project team's capability, existing hardware and software capacity as well as organisational settings.

The *Product* component encompasses the existing hardware and software. Software comprises source code, software architecture, tools and documentation. Based on the information stated in the change request form, source code is analysed to determine the possible affected parts by the change. Changes to source code normally require software architecture and current documentation to be updated. Moreover, changes in a particular software component can affect the hardware especially the memory space, CPU performance and platform.

Subsequently, changes to hardware may entail certain software configuration. A large system may integrate and interface with other systems. The integration and interface happen at the software and hardware levels. Any changes made to these components require modification to their dependencies. Through the product analysis, the estimation of the affected elements can be determined.

The *Organisation* component contains the organisational technology standards and strategic planning. Technology standards refer to specific hardware and software criterion specified by the organisation, which have to be adhered to in any software development and maintenance projects. Each organisation possesses strategic plans such as policies that outline its roadmap and strategies to be taken in order to fulfil its vision and mission. To ensure software development strategies align with organisational strategies, any change implementation must be checked against both the technology standards and strategic plans set by the organisation. These requirements are considered when planning the effort, cost and schedule of change implementation.

V. Conclusion And Future Work

This paper has discussed the risk factors together with the corresponding risk elements concerning requirements change, which should be considered during impact analysis. They were gathered through a literature review and a focus group interview involving experts. The risk elements and factors form a risk model that could guide practitioners in assessing the risks of implementing requirements change. Rather than relying on conventional wisdom, practitioners could currently execute the impact analysis more guided and systematically.

The study was broad-brush and qualitative. The findings should therefore be refined and strengthen further by confirming the risk elements and factors quantitatively through a large scale survey. In addition, the quantitative analysis enables the generation of specific metrics for measuring the risk elements and factors. The model could then be extended as a risk measurement model for requirements change initiatives.

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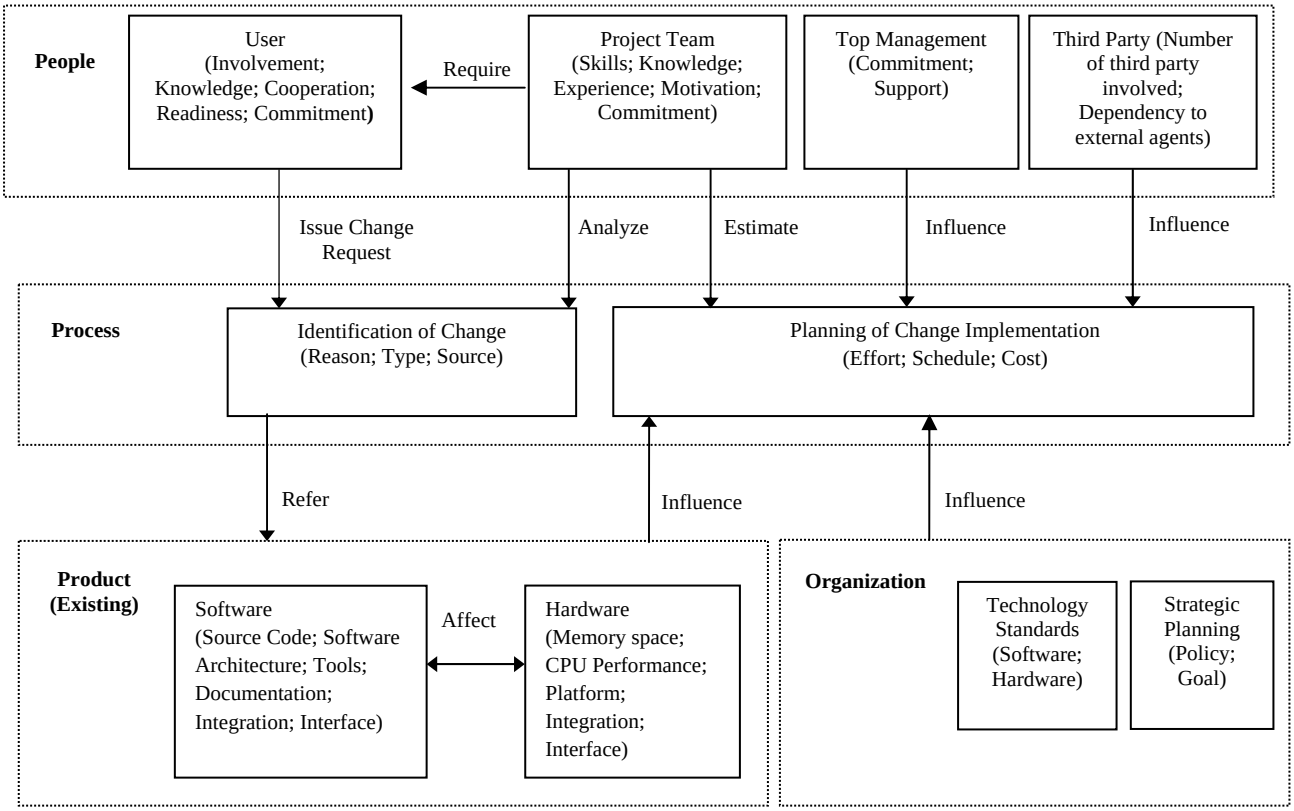

Figure 2. A Risk Model of Requirements Change Impact Analysis

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