A SEMI-AUTOMATED REQUIREMENTS PRIORITISATION TECHNIQUE FOR SCALABLE REQUIREMENTS WITH STAKEHOLDER QUANTIFICATION AND PRIORITISATION

FADHL MOHAMMED OMAR HUJAINAH

DOCTOR OF PHILOSOPHY

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____

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Full Name : DR. MANSOOR ABDULLATEEF ABDULGABBER

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FADHL MOHAMMED OMAR HUJAINAH

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ABSTRAK

Salah satu cara untuk memastikan kualiti sistem aplikasi adalah dengan mengambilkira proses penentuan keutamaan keperluan perisian. Proses pengutamaan keperluan perisian selalunya dijalankan untuk memilih kerperluan perisian yang penting sebagaimana yang dinyatakan dan dihasratkan oleh pihak berkepentingan sesuatu sistem. Ini menjadikan proses ini adalah satu proses yang penting dalam memastikan kualiti dan kejayaan pembangunan perisian tersebut. Proses kuantifikasi dan keutamaan pihak berkepentingan perisian dilaksanakan adalah dengan tujuan untuk mengenalpasti dan memberi keutamaan kepada senarai pihak berkepentingan berdasarkan pengaruh yang mereka ada dalam memilih keperluan utama aplikasi. Oleh itu, penyelidikan ini memfokuskan kepada kaedah kuantifikasi keutamaan pihak berkepentingan dan juga senarai keperluan didalam sesuatu projek pembangunan aplikasi. Dalam masa yang sama, ianya juga mengambilkira isu yang dihadapi oleh teknik-teknik semasa seperti isu berskala besar, kelemahan didalam proses kuantifikasi keutamaan pihak berkepentingan, kekurangan dalam penjelasan bagaimana proses pemilihan ini dilakukan, ketiadaan kriteria penilaian pihak berkepentingan dan kebergantungan yang kuat kepada kepakaran manusia didalam memastikan kejayaan proses-proses ini. Isu-isu ini menjadi motivasi utama didalam penyelidikan yang dirancang dan dijalankan. Oleh itu, teknik untuk penyenaraikan keutamaan perisian yang berskala besar dan bersifat separa automatik (SRPTackle) dengan mengintegrasikannya bersama teknik baru untuk proses kuantifikasi keutamaan pihak berkepentingan yang dinamakan sebagai StakeQP telah dicadangkan untuk menyelesaikan masalah yang dinyatakan diatas. StakeQP berkeupayaan untuk melakukan proses kuantifikasi keutamaan pihak berkepentingan berasaskan atribut penilaian baru yang dengan menggunakan teknik kepelbagaian atribut pembuat keputusan yang bernama TOPSIS. Manakala, SRPTackle yang dicadangkan akan menghasilkan nilai keutamaan keperluan perisian dengan menggunakan algoritma K-Means, K-Means++ dan carian pokok binary. StakeQP pula telah diuji dengan mengunakan data penanda aras RALIC dengan menunjukkan StakeQP berupaya untuk mencapai ketepatan sebanyak 89.69% dalam proses kuantifikasi keutamaan pihak berkepentingan pihak berkepentingan. Manakala, SRPTackle telah dinilai dengan menggunakan data penanda aras dari sistem pembangunan perisian yang sebenar yang berskala sederhana dan besar dari segi senarai keperluan sistem dan juga pihak berkepentingan dengan menjalankan sebanyak tujuh (7) set eksperimen. Keputusan pengujian menunjukkan SRPTackle berupaya untuk memberi ketepatan kepada penilaian dan keputusan keutamaan keperluan aplikasi pada minimum 93% dan maksimum 94.65%. Kesemua keputusan yang didapati menunjukkan StakeQP dan SRPTackle berupaya untuk melaksanakan proses kuantifikasi keutamaan pihak berkepentingan dan penyenaraian keutamaan keperluan aplikasi dengan lebih baik dan berkesan berbanding teknik yang sediada dengan penggunaan masa yang lebih sedikit dan lebih efektif dalam mengatasi masalah yang dibincangkan diatas. Pada masa hadapan, kajian ini boleh difokuskan untuk menambahbaik prestasi SRPTackle dan StakeQP dalam mengendalikan keperluan system yang bergantungan dan juga mengelasan pihak berkepentingan dengan set data yang berbeza dari projek perisian sebenar.

ABSTRACT

One of the gatekeepers of quality software systems is requirements prioritisation (RP) that is often used to select the most important requirements as perceived by system stakeholders. RP is considered as a vital role in ensuring the development of a quality system with defined constraint. Stakeholder quantification and prioritisation (SQP) is executed to quantify and prioritise the stakeholders of the system based on their impacts. The SQP plays a crucial role in identifying and selecting the most essential requirements to produce a successful system. Thus, this research mainly focuses on the RP and SQP domains. Although, the useful of the existing RP and SQP techniques, a close look discloses that these techniques face key challenges with respect to the scalability, shortage of SQP process, lack of low SQP implementation detail with respect to the non-existence of attributes measurement criteria and heavily need of highly professional human intervention in quantifying and prioritising the participating stakeholders and specifying priority value of each requirement in RP process, and lack of automation along time consumption in performing the SQP and RP processes. Hence, a new semi-automated scalable prioritisation technique (SRPTackle) integration with a new SQP technique (StakeQP) are proposed to address the reported key limitations. The StakeQP introduces new low-level implementation details to perform SQP automatically. The StakeQP is on the basis of the newly proposed new measurement criteria for each SQP attribute and using the multi-attribute decision-making method, namely, technique of order preference similarity to the ideal solution (TOPSIS). Furthermore, the proposed SRPTackle is based on the combination of the proposed StakeQP technique, the constructed requirement priority value formulation function and the employing of classifying algorithm (K-means and K-means++) and binary search tree. The effectiveness of SRPTackle and StakeQP are evaluated using a benchmark dataset of the actual software project (RALIC). Experimental implementation of the proposed StakeQP technique and comparative analysis against the existing SQP techniques have been conducted in order to evaluate the StakeQP performance. On other hand, seven experiments are conducted using the large sets of requirements with purpose of assessing the SRPTackle and comparing the SRPTackle performance results with other alternative techniques. The experiments show that StakeQP can produce accurate result of 89.69 %, while accuracy results of the SRPTackle are 93.0% and 94.65% as minimum and maximum accuracy, respectively, which are better than other existing SQP and RP techniques. Also, the findings demonstrate that the StakeQP and SRPTackle perform the SQP and RP process, respectively with less time consumption and are more effective in addressing the reported key limitations compared with other alternative techniques. Future research can dig deeper in improving the SRPTackle and StakeQP performance in terms of catering the requirements independencies and stakeholder classifications, respectively, along with extending the implication of the StakeQP and SRPTackle with different dataset of global software projects practices for better applicability.

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LIST OF SYMBOLS

$\sum$	Summation
%	Percentage
≥	Greater than or Equal to
≤	Less than or Equal to
PIS	Positive Ideal Solution Value
NIS	Negative Ideal Solution Value
S^*	Separation Value of Stakeholder from the Positive Ideal Solution
$S^{'}$	Separation Value of Stakeholder from the Negative Ideal Solution
RC	Relative Closeness Value
h	Hour
s	Second
∈	Element of
—	Division

LIST OF ABBREVIATIONS

AMC	Attribute Measurement Criteria
ASD	Agile Software Development
AWV	Attribute Weight Value
BST	Binary Search Tree
CD	Cognitive Driven
EA	Experience Attribute
EBA	Educational Background Attribute
GRQE	Goal-Oriented Requirement Engineering
IA	Interest Attribute
KA	Knowledge Attribute
MCV	Measurement Criteria Value
MDSD	Market-Driven Software Development
PPA	Power Position Attribute
QAC	Quality Assessment Criteria
RALIC	Replacement Access, Library and ID Card
RCCD	Real-Client Custom Development Projects
RCWV	Requirement Cost Weight Value
RE	Requirements Engineering
RIA	Role Influence Attribute
RIWV	Requirement Importance Weight Value
RP	Requirements Prioritisation
RPV	Requirement Priority Value
RQ	Research Question
SA	Software Architecture
SAV	Stakeholder Attribute Value
SDOW	System Development Organisational Work
SE	Software Engineering
SLR	Systematic Literature Review
SNSD	Social Network System Development
SPV	Stakeholder Priority Value
SQP	Stakeholder Quantification and Prioritisation

SREP	Software Release Planning
SRPTackle	Semi-automated Scalable Requirements Prioritisation Technique
StakeQP	Semi-automated Stakeholder Quantification and Prioritisation Technique
TOPSIS	Technique of Order Preference Similarity to the Ideal Solution
VBSD	Value-based Software Development

CHAPTER 1

INTRODUCTION

1.1 Overview

Software engineering (SE) is a domain that aims to produce good quality software by concentrating on the phases of developing a system (Ian Sommerville 2013; Kneuper 2017; Pohl 2010). The aim of the phases is to plan, analyse, design, develop, and test the developed system (Hull et al. 2011; Misaghian & Motameni 2018); thus, SE is more than just the programming side of the system development lifecycle (Achimugu et al. 2014d; Babar et al. 2015c). Each of these system development phases is associated with critical activities that should be accurately executed to unerringly accomplish the phase (Ian Sommerville 2013).

Requirements engineering (RE) is one of the most essential phases in software development. RE is mainly concerned with the process of eliciting, documenting and maintaining stakeholders' requirements (Lim 2010; Misaghian & Motameni 2018). Often, meeting and securing stakeholders' core requirements is one of the main reasons for producing a good-quality software system (Babar et al. 2015c; Keshta et al. 2017; Lim & Finkelstein 2012). One important aspect of RE is requirements prioritisation (RP). As the name suggests, RP relates to the process of identifying the most essential requirements for the implementation of a successful system (Achimugu et al. 2014a; Babar et al. 2015c; Shao et al. 2017).

In line with the ever-increasing demands for software functionalities, most recent system projects include many requirements. As such, implementing all of the requirements with limited resources (e.g. insufficient budget, time and technical staff is extremely difficult (Khan et al. 2017; Lehtola et al. 2004; Port et al. 2008)). Therefore, development teams tend to deliver system requirements to stakeholders in stages (i.e. with a number of small releases); each release contains an incremental number of requirements from all the extracted requirements. Selecting the important requirements to be implemented and delivered first in the early releases is important in meeting stakeholders' demands (Achimugu et al. 2014b; Babar et al. 2015c; Misaghian & Motameni 2018). The requirements that are less essential are left for latter releases.

RP is an iterative process that involves critical and complex decision-making activities that facilitate the development of a high-quality system within defined constraints (Babar et al. 2015c; Shao et al. 2017). Specifically, RP ensures the correct ordering of requirements' implementation as perceived by stakeholders by rearranging the requirements according to importance using various prioritisation criteria, such as importance, cost, penalty and risk (Achimugu et al. 2014a; Li et al. 2012; Racheva et al. 2010a). Nonetheless, RP is a challenging task. Different features of software requirements have to be taken into consideration in prioritising the requirements such as dependency, time, cost, value, and other features (Ibriwesh et al. 2018; Karlsson & Ryan 1997; Misaghian & Motameni 2018). Various techniques have been proposed to execute the RP process such as PHandler (Babar et al. 2015c), StakeRare (Lim & Finkelstein 2012), Drank (Shao et al. 2017), etc.

Furthermore, the prioritisation process is performed based on by stakeholders' preferences of the software project (Babar et al. 2015c; Misaghian & Motameni 2018). The term 'stakeholder' is defined as any person or organisational group with interest in or ability to affect the system or its environment (Alexander & Robertson 2004; Freeman & McVea 2005; Kakar 2015). Selecting the core and complete requirements can only be accomplished with the involvement of core stakeholders (Anwar & Razali 2016; Babar et al. 2015b). The impact on a certain system differs from one stakeholder to another, and the number of participating stakeholders of different types can be massive, with each one construing their needs differently (Bendjenna et al. 2012; Razali & Anwar 2011). This difference will create difficulties in making the decision on which stakeholder has more impact on the requirements prioritisation project than others (Babar et al. 2014a, 2015b; Bendjenna et al. 2012). Thus, the stakeholder quantification and prioritisation (SQP) process is conducted to identify the impact (priority) value of each stakeholder and prioritising them according to the identified impact values, where the stakeholders are quantifying and prioritising based on certain attributes such as power, influence, role (Babar et al. 2015b; Bendjenna et al. 2012; Lim et al. 2010). The SQP process assists in determining the stakeholders who more significantly influence the project's success, which leads to selecting the most essential requirements for the significant stakeholders (Babar et al. 2015a, 2015b; Zedan & Miller 2018)

This research focuses on requirements prioritisation along with stakeholder quantification and prioritisation. The following section presents a detailed explanation of the motivation of the specified research focus.

1.2 Research Motivation

According to reports in (Standish Group 2014, 2015a, 2015b), Figure 1.1 summarises the percentage of unsuccessful system development projects from 2011 to 2015 (the projects are not completed on-budget and on-time, with offering fewer stakeholders' requirements than originally specified along with projects that are impaired and ultimately cancelled). The percentage of unsuccessful projects in 2011, 2012, 2013, 2014, and 2015 was 61%, 63%, 59%, 64%, and 64%, respectively.

Figure 1.1 Percentage of Unsuccessful System Development Projects From 2011 to 2015

Table 1.1 shows the list of causative factors of system development project failure as reported in (Standish Group 2014, 2015a, 2015b). Each causative factor is reported with its percentage degree, which reflects the extent of the impact that factor can induce to project failure. The involvement of inadequate stakeholders and identification of the incomplete requirements (that have to be implemented) are ranked at the top of the list as considered the most prevalent factors that that leads to the failure of project development

(Standish Group 2014, 2015a, 2015b). Prioritising requirements is essential to capturing the core and complete requirements based on the stakeholders' preferences. Selecting the most essential and complete requirements can only be achieved with the involvement of appropriate and core stakeholders which can be revealed by the SQP process. Hence, Ignoring RP for prioritising the requirements and SQP lead to involvement of inadequate stakeholders increases the possibility of missing the correct and core requirements, which will lead to system failure (Achimugu et al. 2014d; Babar et al. 2015c; Ibriwesh et al. 2018; Lim et al. 2010).

Table 1.1 Causative Factors of System Development Projects Failure

Factor	Percentage in causing project failure in terms of being impaired and ultimately cancelled	Percentage in causing project failure in terms of not completed on-budget and on-time with not achieving the satisfactory result
Incomplete requirements	13.1%	12.3%
Lack of user involvement	12.4%	12.8%
Lack of resources	10.6%	6.4%
Unrealistic expectations	9.9%	5.9%
Lack of executive support	9.3%	7.5%
Changing requirements	8.7%	11.8%
Lack of planning	8.1%	-
Did not need it any longer	7.5%	-
Lack of IT management	6.2%	-
Technology illiteracy	4.3%	-
Unclear objectives	-	5.3%
Unrealistic time frames	-	4.3%
New technology	-	3.7%
Technology incompetence	-	7.0%

- : no percentage reported

Additionally, detecting the stakeholders' influences and prioritising their importance accordingly can assist the project manager in providing a clear view about the expectations, roles and needs of the stakeholders who have a potential influence on a certain activity of the project development process, which assists managers in factoring in the planning project in order to win support from the most influential stakeholders (Carroll et al. 2018; Lehtinen et al. 2018; Li et al. 2017; Mascena et al. 2018; Zedan & Miller 2018). Obtaining such support will bring more potential resources to the project development, which will induce an increase in the possibility of producing a successful project (Lehtinen et al. 2018; Mascena et al. 2018; Zedan & Miller 2018).With prioritising the requirements, the project manager can reveal the requirements with high level of importance to be implemented at the early stage of the project development process. This consequently assists the project manager in optimizing the limited resources usage effectively during the development process, and constructing an effective plan of financial implications of the requirements and staged deliveries, allowing for the expansion of projects with excellent outputs and increasing the likelihood of securing a successful system project (Achimugu et al. 2014d; Babar et al. 2015c; Ibriwesh et al. 2018; Lim et al. 2010).

On the basis of the aforementioned significance of evaluating the stakeholders' influences and prioritising the requirements in the development of the software system projects, this research concentrates on the RP and SQP with identifying and addressing the key challenges. A detailed elaboration of these key challenges is given in the problem statement that will be presented in the following section.

1.3 Problem Statement

From the literature, various RP techniques have been proposed to execute the RP process such as StakeRare (Lim & Finkelstein 2012), and Drank (Shao et al. 2017), etc. Although useful, the existing RP techniques suffer from key issues of scalability (inability of dealing with large number of requirements) (Achimugu et al. 2014a; Ahl 2005; Babar et al. 2015c; Inayat et al. 2015; Ling Lim et al. 2011; Vestola 2010), being not cost effective in term of time utilization especially in prioritising the large set of requirements, lack of SQP process, heavily credence on the involvement of the experts in specifying the requirements priority values, and lack of automation (Achimugu et al. 2014c; Babar 2011; Babar et al. 2015c; Kukreja et al. 2012).

The scalability issue has a significant impact on the implication of the prioritisation process in industrial projects, as most current projects include large number of requirements to be prioritised (Achimugu et al. 2014d, 2014e; Ahl 2005; Babar et al. 2015c; Inayat et al. 2015; Ling Lim et al. 2011; Vestola 2010). Although most of the software products became more complex in terms of containing large set of requirements, most of the RP existing techniques can only work well with small number of requirements such AHP technique (Achimugu et al. 2014d; Babar et al. 2015c).

Performing the SQP process by identifying the impact value of stakeholders and prioritising the stakeholders plays a key role in producing accurate result of an ordered list of requirements from prioritisation process (Anwar & Razali 2016; Babar et al. 2015b;

Lim et al. 2010; Ling Lim et al. 2011; Mok et al. 2015). Whereas, most of the existing RP techniques are lack of executing SQP process. While few techniques in stakeholder analysis have been proposed with aim of performing the SQP process such as Razali and Anwar (Anwar & Razali 2016), Bendjenna et al. (Bendjenna et al. 2012), ,Ballejos & Montagna (Ballejos & Montagna 2011). At a glance, these techniques have usefully emphasized the process of quantifying and prioritising the stakeholders.

Nonetheless, a close look reveals that these SQP techniques still also suffers from certain challenges with respect to lack of low-level implementation details, heavy reliance on the involvement of experts in performing the SQP process, and non-existence of measurement criteria for the SQP attributes used to quantify and prioritise the stakeholders, lack of automation level due to most of them perform the SQP process manually with issue of time consumption as well (Babar et al. 2014a, 2014b, 2015b; Ballejos et al. 2007; Ballejos & Montagna 2011; Bendjenna et al. 2012). Thereby, the adoption of the techniques difficult in real cases of prioritising the requirements and affects the accuracy performance with respect to produce an accurate result of quantifying and prioritising the stakeholders (Babar et al. 2014a, 2015b).

Regarding the issues of the deficiency of the automation level , not being cost-effective with respect to time utilisation, conducting the RP and SQP process without employing the automation influences the efficiency of the technique with respect to it being more time consumption and complex when evaluating the stakeholders' impacts and prioritising the requirements due to the manual process that will be required to execute the computational calculation to measure the impact value of each stakeholder and complexity of implementing prioritisation that can be related to the high number of comparisons to obtain the relative priority value of each requirement (Achimugu et al. 2014d; Babar et al. 2015b, 2015c; Forouzani et al. 2012; Lim et al. 2010). This manual computational complexity requires more effort in terms of time and increases the likelihood of human errors, indicating that the technique is impractical in a real scenario of being adopted in executing the SQP and RP process (Achimugu et al. 2014d; Babar et al. 2015b, 2015c; Ma 2009; Shao et al. 2017).

Additionally, the necessity of the experts' participation in performing the SQP and RP process (in term of assigning the priority value for each requirements or/and the evaluating the participating stakeholders in the prioritisation by identify the impact value of each stakeholders) leads to the issue of bias being induced by the experts and unavailability of human experts that consequently can impact the accuracy of the technique (Aasem et al. 2010; Babar et al. 2015c).

As a result, the core motivation of this research is to address the limitations with respect to the scalability, shortage of SQP process, lack of low SQP implementation detail with respect to the non-existence of attributes measurement criteria and heavily need of highly professional human intervention in specifying the priority value of the participating stakeholders in RP process and requirements priority values, and lack of automation along time consumption in performing the SQP and RP processes.

1.4 Research Objectives

The core aim of this research is to propose a new RP technique along with a new SQP technique to solve the RP and SQP limitations elaborated in the problem statement section. This ambition can be clarified by following particular research objectives(RO):

1. RO1: To study the RP and SQP in terms of SQP attributes, RP criteria and techniques with their challenges.
2. RO2: To propose a new SQP technique (StakeQP) based on new attributes' measurement criteria.
3. RO3: To propose a new semi-automated scalable RP technique (SRPTackle) with integration with the new StakeQP technique.
4. RO4: To evaluate the proposed StakeQP and SRPTackle techniques with respect to the accuracy and time effectiveness.

The first objective aims to study the RP and SQP with in terms of providing a comprehensive analysis of the SQP attributes, RP criteria and existing RP and SQP techniques with their limitations. The second objective aims to develop a SQP technique for quantifying and prioritising the participating stakeholders in the RP process by identifying their priority values. Thus, StakeQP is proposed in such a manner as to solve the SQP issues of low implementation details with respect of non-existence of SQP attribute measurement criteria, higher time consumption, and heavy need for expert participation in conducting the SQP process. The StakeQP technique depends on the development of semi-automated SQP process (in which the semi-automated refers to the ability to automate one more steps in conducting the process) which is executed based on new measurement criteria for SQP attributes used to evaluate the stakeholders and reduce the need for the expert participation. This proposed StakeQP assists in quantifying and prioritising the stakeholder by providing low process details and minimising the need for expert participation in conducting the SQP process along with improving the time utilization to perform the SQP process.

Additionally, the third objective is to propose a new RP technique (named as SRPTackle) with integration with the proposed StakeQP technique, in which the generated the stakeholders priority values by the StakeQP is also the part of prioritisation process to address the specified RP limitations of scalability, lack of automation, time cost effectiveness, and heavy reliance on the expert's involvement, and lack of SQP process developed SQP technique. In addition, forth objective of this research intends to evaluate the performance of the StakeQP and SRPTackle (in terms of the accuracy and time consumption).

1.5 Research Questions

This research will attempt to answer the following main question:

"How can a technique be proposed to quantify and prioritise the stakeholders with the ability to prioritise large set of requirements based on the stakeholders' preferences?"

In order to answer of the above mentioned question, the following secondary research questions (RQ) are stated as follows:

1. RQ1: What is the importance of the RP and SQP in the software development and requirements prioritisation process, respectively?

2. RQ2: What are the current techniques used for process of RP / SQP and their current advantages, limitations, attributes for SQP process and prioritisation criteria for the RP process?

3. RQ3: How can the limitations of the current existing RP and SQP techniques be addressed?

4. RQ4: How can the proposed SQP and RP techniques be evaluated?

Figure 1.2 depicts the linking structure among the defined research questions and objectives. RQ1 and RQ2 are related to literature exploration and analysis of the RP and SQP with specifying the challenges in RP and SQP, in which two systematic literature reviews (SLRs) are conducted (SLR-RP and SLR-SQP) in order to address the first research objective (RO1). Meanwhile, RQ3 is associated to the specified second and third objectives (RO2, and RO3) in order to propose new SQP and RP techniques to handle the defined challenges. RQ4 is mapped to the forth objective (RO4), in which the performance of proposed SQP and RP techniques are evaluated with respect to accuracy and time effectiveness.

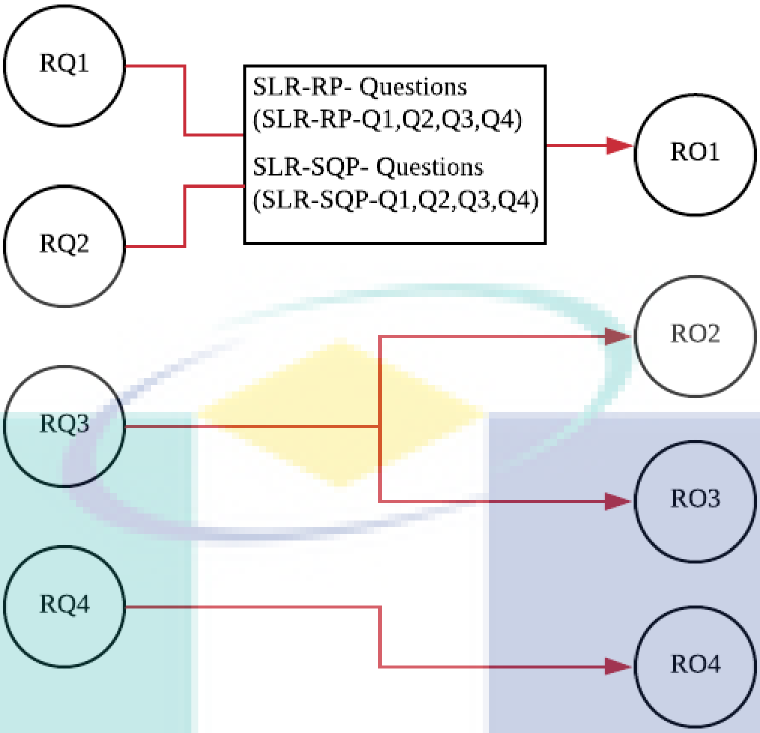

Figure 1.2 The Linking Structure among the Research Objectives and Questions

1.6 Research Scope

In requirements prioritisation, the sets of requirements are categorized into three different sets, which are small set of requirements (number of requirements in < 15), medium set (15 <= number of requirements <50), and large set (number of requirements >= 50) as defined in (Babar 2015; Babar et al. 2015c; Ma 2009). In order to select the benchmark dataset to be used in the evaluation phase of this research, various resources are explored. However, the benchmark dataset of software large scale project, known as replacement access, library and ID card (RALIC) (Lim 2010) is used to evaluate the proposed SQP and RP techniques. The RALIC dataset includes detailed information of the RALIC project in terms of the stakeholders and requirements (that are assumed to be independent requirements) of the system by providing the profile details of the stakeholder and the stakeholders' ratings for each requirement. This makes the RALIC dataset to be suitable to be used in this research.

1.7 Thesis Organization

This thesis is structured into 6 chapters; a brief explanation of each chapter is given as follows:

In chapter 2, two systematic literature reviews (SLRs) are conducted to explore and critically analyse the RP and SQP existing works. The importance of the RP along with its meaning are illustrated. In order to identify the currently and latest issues with the existing RP, the researcher discussed the RP aspects, the involved stakeholders in prioritisation process, benefits, and limitation of each existing RP technique. Also, the detailed discussion of the importance of SQP in RP process, existing SQP attributes, process is discussed along with identification and analysis of the existing used techniques in SQP domain.

Chapter 3 illustrates a detailed explanation of the research methodology used in order to achieve the identified research objectives. Various identified components and a detailed explanation of these components is presented. Chapter 4 presents the proposed StakeQP technique. A detailed explanation of the proposed StakeQP along with its evaluation performance are discussed along with the full description of the automated tool that are developed in order to implement the proposed StakeQP technique.

In chapter 5, the proposed SRPTackle is presented and discussed in detail. The explanation of the automated tools developed to execute the process of the proposed SRPTackle is also provided. The performance evaluation of the proposed SRPTackle is also conducted and elaborated in this chapter. Lastly in chapter 6, the conclusion, different achievements from this research, and future recommendations are presented.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review presents the existing related studies to this research (Kitchenham & Charters 2007). In this research, a comprehensive literature exploration is conducted to provide a clear view of the current status of the requirement prioritisation domain along with stakeholder quantification and prioritisation.

This chapter starts by providing an overview description on the RP and SQP. Then, critical literature analysis is presented through conducting two systematic literature reviews (SLR): SLR-RP, and SLR-SQP on the basis of the standard SLR guidelines by Kitchenham (Kitchenham & Charters 2007).

The SLR-RP is conducted to provide a comprehensive review on RP domain via selecting and critically studying published studies by the current research studies that are relevant to the specified area. While SLR-SQP focus on SQP as the first study to carry out SLR on this specific research domain. The details of the results for each conducted SLR are elaborated in the following section, while the used review methodology is going to be explained in the chapter3 (Research Methodology). Figure 2.1 shows the map structure of literature review.

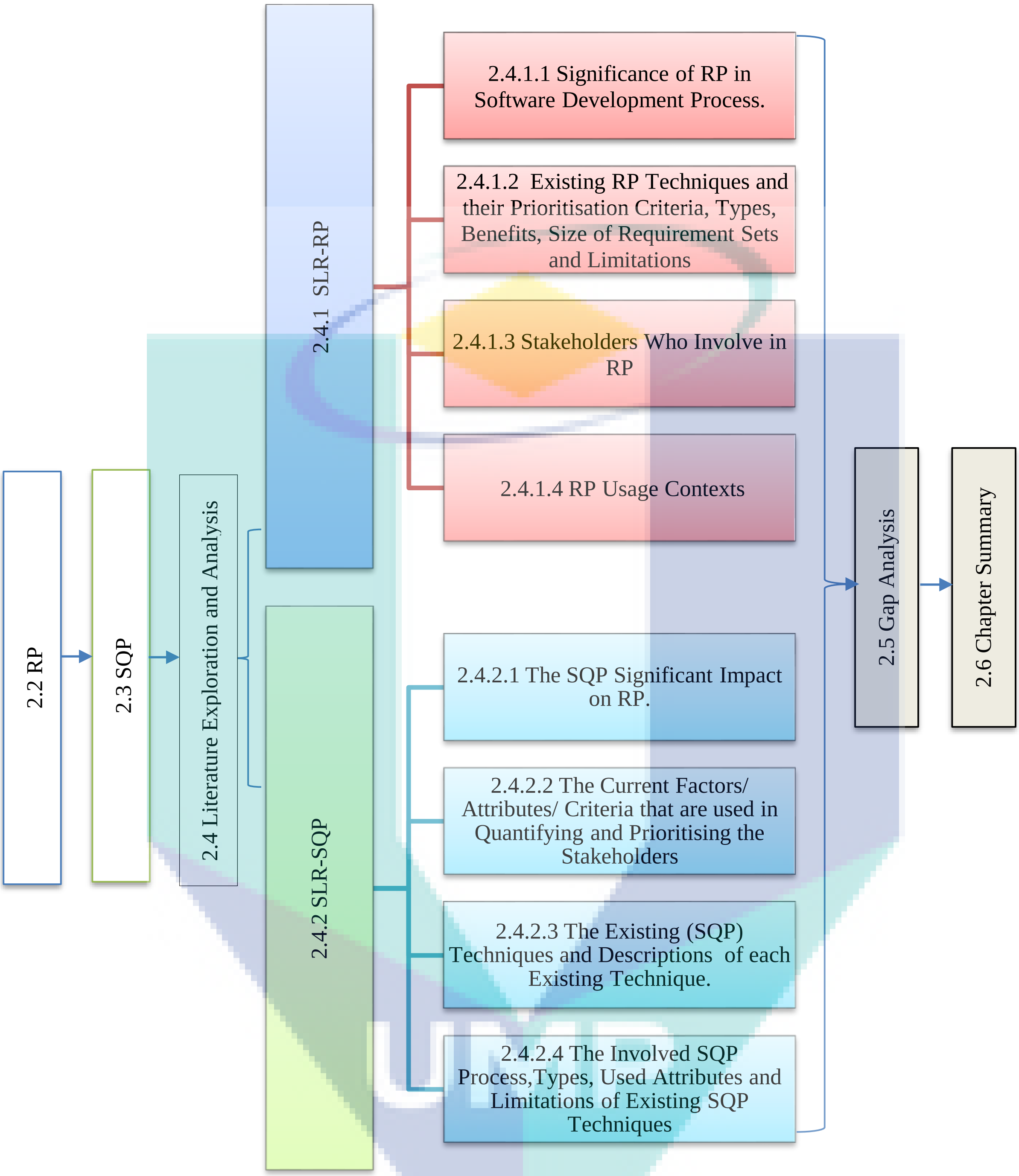

Figure 2.1 The Map Structure of the Literature Review

2.2 Requirements Prioritisation

Meeting and securing the stakeholders' core requirements is one of the main reasons for producing a good quality software system (Gomariz-Castillo et al. 2019; Misaghian & Motameni 2018). Additionally most of the system projects include a large number of requirements and it is extremely difficult to implement all of the requirements with limited resources such as insufficient budget, time, technical staff, quality (Ibriwesh et al. 2018; Khan et al. 2017; Misaghian & Motameni 2018). Thus , RP is executed to assist the requirement engineers in determining the order of requirements' implementation as perceived by stakeholders of the system with selecting the most significant or high risk requirements to be implemented in order to produce a quality system (Al-Ta'ani & Razali 2016a; Shao et al. 2017). However, performing RP process is a complex decision making process (Achimugu et al. 2014a).

A certain number of elements that should be considered in designing and introducing an efficient RP technique: process, implementation, requirements criteria, stakeholder elements (Babar et al. 2015c; Carod & Cechich 2009). The process element refers to the process structure of the technique used in prioritising the requirements. This process reflects the method used in dealing with different priorities of the requirements and calculating the final priority or importance order, or classification rank of each requirements based on the stakeholders' preferences (Achimugu et al. 2015; Babar et al. 2015c; Carod & Cechich 2009).

The existing RP techniques perform the prioritisation process in different ways, such as some techniques prioritize the requirement by comparing pair wise for all possible requirements such as Analytic Hierarchy Process (AHP), and pairwise comparison techniques. Whereas, other techniques carry out the prioritisation process by categorize the requirements into different groups such as critical, standard, and optional, where each requirement that are in the same group have same priority such as numerical assignment and priority groups (Achimugu et al. 2015; Lehtola et al. 2004) techniques.

Requirements criteria element indicates to the criteria of the requirements that are considered by the technique in prioritizing the requirements, in which each requirement is assessed and prioritized based on one or more prioritisation criteria such as the importance, cost, penalty, risk. Specifying the prioritisation criteria that will be used to prioritize the requirements is an essential part in RP process (Alawneh 2018; Babar et al. 2015c; Sher et al. 2014a, 2014b). This is due to; the used criteria in the prioritising the requirements will specify the objectives of the prioritisation and affect the final prioritised list of the requirements (Sher et al. 2014a, 2014b). However, prioritising the requirement based on various criterion is challenging task as one criteria can affect and impact another one. Consequently, it is significant to figure out the conflicts among the used criteria during the prioritisation (Shao et al. 2017; Sher et al. 2014a, 2014b)

Regarding the stakeholder element, The prioritisation process is performed by stakeholders of the system, where the stakeholder is participated in assessing and prioritising on the basis of defined prioritisation criteria (such as cost, penalty, risk) using certain execution process such as requirements ordering, or initial weights of each requirement, or classification rank, selecting the most essential requirements (Babar et al. 2015c; Khan et al. 2017; Misaghian & Motameni 2018). Thus, the RP technique should contain information regarding the participating stakeholders with respect to the execution process that the stakeholder can use in prioritising the requirements. Also, in the case of the technique consider the SQP during the prioritisation process, the execution steps of performing the SQP process should be covered in the technique (Babar et al. 2015c; Lim & Finkelstein 2012) .

Implementation element concerns to the dynamism of the technique with respect to its usability and ability in dealing with the sets of requirements (small, medium, large sets) (Babar et al. 2015c; Carod & Cechich 2009). The execution type used by technique (in terms of automation or manual) along with the existence of the implementation details of the technique in pilot study are also covered in the element of the implementation (Babar et al. 2015c; Carod & Cechich 2009).

2.3 Stakeholder Quantification and Prioritisation

Stakeholder theory was established by Freeman in recognition of the significance of the stakeholder management in securing the success in the development of the firm's projects (Freeman 1984). This theory was then grown to include a variety of fields, such as organisational management (Donaldson & Preston 1995), business society and ethics (Carroll et al. 2018; Majoch et al. 2017), as it is evident that organisations' projects generally have an extensive variety of stakeholders, and these compete for available resources, leading to difficulty in making a decision of specifying the core stakeholders (Donaldson & Preston 1995; Li et al. 2017; Zedan & Miller 2018). Thus, identifying the strategies for managing stakeholders is an important task for managers, leading them to a better understanding of the stakeholders' project networks and the possible impacts of the stakeholders. This will induce the decision makers of the organisation to make more effective and realistic strategic decisions on the development process of the organisation's project (Carroll et al. 2018; Donaldson & Preston 1995; Freeman 2010).

Additionally, the perspective of the identifying stakeholders' influences can assist the managers in identifying the most influential stakeholders that the firm seeks support from and directs the managers to incorporate those stakeholders' concerns into the strategic plans, leading them to win more support and carry on the development of the project by increasing the chances of developing a successful project (Mascena et al. 2018; Zedan & Miller 2018).

Detecting stakeholders' influences, prioritising their importance accordingly can assist the project manager in providing a clear view about the expectations, roles and needs of the stakeholders who have the potential influence on a certain activity of project development process, which assists the mangers to factor that in planning project in order to win supports from the most influential stakeholders. Obtaining such supports will brings more potential resources during the project development, which will induce to increase the possibility of producing a successful project (Lehtinen et al. 2018; Mascena et al. 2018; Zedan & Miller 2018).Moreover, the SQP process assists to concern on the stakeholders who significantly influence project success more, which contribute to highlight the most critical requirements for significant stakeholders which will lead to the production of successful system (Babar et al. 2015a; Lehtinen et al. 2018; Mascena et al. 2018; Zedan & Miller 2018). There are certain number of basic features that should be considered in developing an efficient technique for conducting the SQP. These elements are SQP attributes, stakeholders, process (Babar et al. 2015b; Lim et al. 2010; Sadiq 2017).

Regarding the SQP attributes, the stakeholders are quantified and prioritised on the basis of certain attributes, such as power, influence and role. Hence, one of the first feature that should be covered in the development of the technique is associated to the information regarding the attributes used in quantifying and prioritising the stakeholders (Babar et al. 2015b; Zedan & Miller 2018; Zhao 2018). While, the stakeholders feature considers the stakeholders' profiles, in which the information details of each stakeholder are collected based on the defined SQP attributes (Babar et al. 2015b; Lim et al. 2010; Sadiq 2017). For instance, the information details regarding the role and experience and job scope should be collected in order to evaluate the stakeholders based on the role influence and experience attributes.

Concerning the process feature, the SQP process is executed by either classifying the stakeholders or by identifying the impact degree of the stakeholders and prioritising them (Babar et al. 2015b; Razali & Anwar 2011; Zedan & Miller 2018). The quantification and the prioritisation process is performed on the basis of the defined SQP attribute and the stakeholders' profiles collected. The low implementation details in term of providing a clear guidelines and the measurement criteria that can be used in conducting the SQP process should be also covered in the development of the technique process in order to increasing the possibility of implementing the technique in efficiently in the real scenarios (Babar et al. 2015b; Lim et al. 2010).

2.4 Literature Exploration and Analysis

In order to critically analyse the research in the domains of SQP and RP, two SLRs (SLR-RP, and SLR-SQP) are conducted. The discussion and results of each SLR are described in the following sub section.

2.4.1 SLR-RP

To investigate the strengths and limitations of existing RP techniques, many review studies have been conducted (e.g. Khan (Khan 2006), Kaur and Bawa (Kaur & Bawa 2013), Pergher and Rossi (Pergher & Rossi 2013), Pitangueira et al. (Pitangueira et al. 2015) and Achimugu et al. (Achimugu et al. 2014d)). At a glance, these review studies have usefully emphasized the performance of existing RP techniques. Nonetheless, a close look reveals two main limitations. Firstly, these existing review studies have not sufficiently focused on the analysis of RP in terms of the characteristics of decision makers, the prioritisation criteria they use, RP activity in the software development context and significance of RP in the software development process.

Secondly, given that new RP techniques have been introduced in the literature, an up-to-date analysis of existing work is needed. Such analysis is helpful for researchers and practitioners in improving the current state of the art and state of practices. To date, the most recent review is from (Achimugu et al. 2014d), in which 49 RP techniques were analysed. Unlike Achimugu et al., this SLR-RP incorporated the stakeholders' dimension as a new evaluation criteria apart from covering additional RP techniques (108 techniques). Thus, the contribution of this SLR-RP can be summarised as follows:

i. Analysis and review of the characteristics of participating stakeholders in RP

ii. A new perspective on the RP activity within software development contexts and the significance of RP in the software development process and

iii. Empirical evidence for uncovered and recent RP techniques and their limitations.

Five review studies related to the RP process were collected. Khan's (Khan 2006) was perhaps the earliest systematic literature review (SLR) on software RP. This review aimed to objectively compare RP techniques from eight selected studies. The authors concluded that most of the proposed RP techniques addressed only a small set of requirements.

Complementing the work of Khan, Kaur and Bawa (Kaur & Bawa 2013) focused on studying and comparing the performance of seven RP techniques that are based on cumulative voting, analytic hierarchy process (AHP), numerical assignment, value-oriented prioritisation, binary search tree, planning game and B-tree prioritisation. The performance of the selected techniques was evaluated on the basis of the criteria of measurement scale, time consumption, granularity, complexity and fault tolerance. The authors concluded that the area of RP still required additional work to enhance the effectiveness of RP techniques in terms of complexity, fault tolerance and time consumption.

Pergher and Rossi (Pergher & Rossi 2013) presented a systematic mapping study in software RP to highlight the RP area that had been explored by existing research studies and to clarify the state of the art in the conducted empirical research in RP. The review revealed that most of the existing studies mainly concentrated on techniques, whereas the existing empirical research was concerned with techniques and the issue of accuracy in RP.

Pitangueira et al. (Pitangueira et al. 2015) presented an SLR on RP with specific focus on search-based software engineering (SBSE). The objective of the review was to investigate, categorise, analyse and classify the SBSE techniques that had been introduced to solve the issues of software RP and selection. Thirty-nine (39) relevant studies were selected and analysed after executing the defined study selection process of the review. The review presented the requirements selection aspects, prioritisation issues and the proposed search techniques to address the specified issues.

Recently, Achimugu et al. (Achimugu et al. 2014d) conducted an SLR of RP techniques; the review focused on measurement scales, descriptions and limitations. The findings suggested that the existing techniques still faced a number of challenges related to time consumption, requirement interdependencies and scalability.

Table A.1 in Appendix A summarises the findings (in terms of similarities and differences) of the related studies. The table indicates that the main concern of most of the related studies was to provide an overview of RP techniques' performance. With the exception of Achimugu et al. (Achimugu et al. 2014d), which covered 49 RP techniques, most existing studies focused on only a few RP techniques. Although useful, the work of Achimugu et al falls short in terms of not giving sufficient consideration for the stakeholders' dimension within RP contexts. Additionally, recent developments in terms of newly developed RP techniques have also not been covered. This SLR-RP aimed to close this gap and address these issues by considering a large number of RP techniques. The present study not only focuses on an overview of RP techniques but also investigates the characteristics of decision makers and the prioritisation criteria they use. Complementing existing work, this SLR-RP also analysed the important impacts of implementing RP on system development, particularly emphasizing the extent to which the execution of RP can generate high-quality systems in real scenarios. Different questions (SLR-RP-Q) are formulated based in order to conduct this SLR-RP in assessing the research in the RP process, which are as follows:

i. SLR-RP-Q1: What is the significance of conducting RP in the software development process?

ii. SLR-RP-Q2: What are current techniques used in executing RP and their prioritisation criteria, types, benefits, size of requirements to be prioritised and limitations?

iii. SLR-RP-Q3: Who are the stakeholders involved in RP, and how can these stakeholders be classified?

iv. SLR-RP-Q4: What are the usage contexts of the identified RP techniques in Q2 and the selected studies?

By answering these defined questions, the SLR-RP aims to identity and emphasize the significance of conducting RP in system development; that is, SLR-RP-Q1 is structured to provide a clear understanding and discussion regarding the reasons of prioritising requirements and how they can help in producing high-quality systems within real industrial practices. SLR-RP-Q2 intends to collect information about the available techniques that can be used to perform RP and analyse them with respect to their limitations, prioritisation criteria, types, benefits, size and sets of requirements to be prioritised. Additionally, the SLR-RP-Q3 aims to report and classify the stakeholders that should participate in the RP process. SLR-RP-Q4 is articulated to reveal the contexts of the RP techniques and the selected studies in this SLR-RP that are proposed or applied in the system development context.

2.4.1.1 SLR-RP-Q1 Significance of RP in Software Development Process

The main factor in determining the success of developed software systems is achieving and satisfying the expectations of stakeholders (Berander & Andrews 2005; Şen & Baraçli 2010). Identifying the requirements that are most important to stakeholders from large numbers of elicited requirements is a challenge. Thus, identifying the most essential requirements is a major step towards software system success (Achimugu et al. 2014a, 2014d; Berander & Andrews 2005; Logue & McDaid 2008; Şen & Baraçli 2010).

In industry, any development of a software system project usually encounters constraints in resources, including restricted human capital expertise, budget, technology and timelines (Lehtola et al. 2004; Port et al. 2008). The RP process is an effective means of addressing this issue; it enables developers to deliver systems on time and ensures that stakeholders' needs are fulfilled within the time and budget constraints (Achimugu et al. 2014b; Berander & Andrews 2005; Garg & Singhal 2017; Karlsson et al. 1998). The execution of the RP process produces an order list of the requirements that will be used by a development team for implementation in successive releases within resource constraints. Therefore, the chance of developing a successful system is increased because the most critical requirements are implemented and delivered first, thereby ensuring stakeholder satisfaction (Achimugu et al. 2014b; Karlsson et al. 1998).

Figure 2.2 shows the success percentage rates of system project development in 2015 from a recent study (Standish Group 2015a). A total of 29% of all system projects were considered successful systems and delivered within project constraints, whereas 52% of projects were presented as challenging because they were not delivered on time, over the budget or/and did not implement sufficient features of the required stakeholders' needs. In addition, 19% of the projects were considered failed because of cancellation or delivery without use. Complying with stakeholders' expectations, needs and time constraints are major challenges in producing successful systems (Babar 2011). The impact of these challenges can be reduced or eliminated with the execution of RP, which identifies the most important requirements to stakeholders and thus assists development teams in concentrating on delivering the most critical requirements (Achimugu et al. 2015; Berander & Andrews 2005).

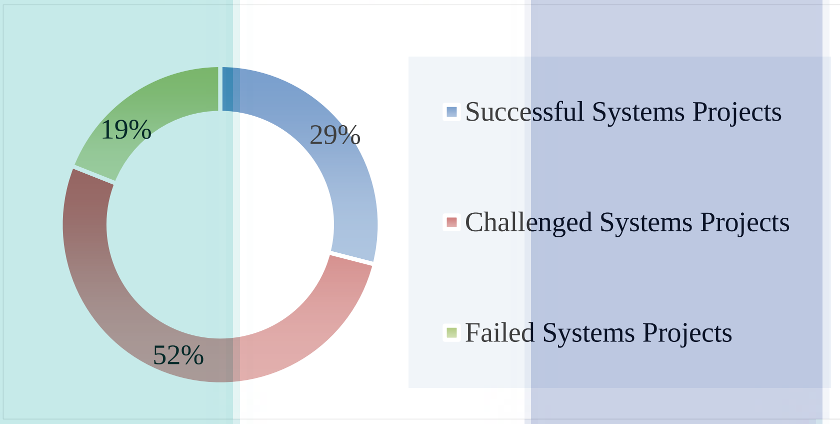

Figure 2.2 Successful Rate of the Systems Project Development in 2015

Amongst the prime reasons behind the failure of software systems are lack of user involvement, lack of user expectations and short timelines (Lim et al. 2010; Ling Lim et al. 2011; Razali & Anwar 2011). RP can potentially help lower the risk of project cancellation and increase the success rate of projects when the stakeholders are actively involved (Achimugu et al. 2014b, 2014c; Berander & Andrews 2005; Ling Lim et al. 2011). With RP, the order of requirement implementation is executed on the basis of the prioritised list of requirements, which is defined by the stakeholders' preferences.

Inevitably, RP also reduces the work effort because time is not wasted on implementing requirements that are not considered important to stakeholders. Thus, RP promotes plan stability (Berander & Andrews 2005; Iqbal 2012).Additionally, given that most organisations require their development teams to conduct cost–benefit analyses prior to undertaking any development project, RP can help optimise and manage resource usage (Babar et al. 2015c; Berander & Andrews 2005; Logue & McDaid 2008).

Ignoring RP activity will lead to many challenges (Achimugu et al. 2014d; Berander & Andrews 2005). For example, a project team may fail to satisfy customers mainly because deciding which requirements are essential to the customers will be difficult. This issue may lead to project failure (that is failed to be delivered on the budget and time constraints, or failed to implement the sufficient requirements of the core stakeholders' needs defined) because of the delivery of non-significant (i.e. 'nice-to-have' versus 'must-have') requirements to stakeholders.

Furthermore, balancing the cost of each requirement against its business benefits without conducting the RP process will be challenging for the projects' stakeholders (especially the development team) (Babar et al. 2015c; Lehtola et al. 2004). Often, the prioritisation process can be used to identify the priority value for each requirement according to its business benefits and cost involved. Thus, the RP process will help balance the benefit of each requirement and its cost. Consequently, the probability of producing a high-quality software system will be increased accordingly (Babar et al. 2015c; Lehtola et al. 2004).

In software development, it is it vital to prioritize requirements owing to that information on priorities is critical to allow project managers to resolve conflicts, plan for staged deliveries, and make necessary trade-offs. Thus, the influence of requirement prioritisation cannot be overstated (Achimugu et al. 2014b; Babar et al. 2015c). Furthermore, the elicited requirement relative necessity was determined by requirement prioritisation, in that even though all requirements are mandatory some are more important than others. This is evidenced in that the non-delivery of only some requirements would have devastating business consequences (Babar et al. 2015c; Lehtola et al. 2004).

The execution of RP in the software development lead to have an efficient negotiation of precise requirements (Berander & Andrews 2005; Iqbal 2012). These precise requirement negotiations assist software engineers eliminate unnecessary or contradictory requirements (Achimugu et al. 2014d; Iqbal 2012). Also, RP process can assist to secure an effective implementation schedules that allow project managers to modify project resources and delivery dates based upon environmental circumstances (Babar et al. 2015c; Duan et al. 2009). They also improve stakeholders' satisfaction by making it more likely that their preferred requirements are implemented. Hence, RP makes the rejection of projects after development less likely through the creation of clear and precise requirements (Achimugu et al. 2014d; Lim & Finkelstein 2012) .

Concerning the aspect of the judicious fund utilization, RP allows for stakeholders to develop a rough estimate of the financial implications of each requirement, allowing for the expansion of projects with excellent outputs. (Achimugu et al. 2014d; Alawneh 2018).

2.4.1.2 SLR-RP-Q2 Existing (RP) Techniques and their Prioritisation Criteria, Types, Benefits, Size of Requirement Sets and Limitations

SLR-RP- Q2 aims to identify and analyse existing RP techniques. Thus, the present techniques were identified. Each identified technique was critically analysed on the basis of certain parameters: prioritisation criteria (criteria that are used by each technique to prioritise requirements), limitations, types (execution type or automation level used by the technique to execute prioritisation; three types are present: manual execution, which means manual performance of RP steps; semi-automated execution, in which one or more RP steps are automated and fully automated execution, wherein the entire RP process is fully automated), benefits and sets of requirements to prioritise. These sets are categorised into three: small (number of requirements < 15), medium (15 <= number of requirements < 50) and large (number of requirements >= 50), as defined in (Babar et al. 2015c; Ma 2009).

From the selected primary studies of this review, 108 RP techniques were identified to be relevant to the current work. Figure 2.3 presents the outcome of classifying all the identified RP techniques. The RP techniques were classified according to execution type, which pertains to the automation level that is used to perform the prioritisation process.

i. Manual execution: These techniques perform all steps of the RP process manually.

ii. Semi-automated execution: These methods automate one or more steps in the RP process.

iii. Fully automated execution: These techniques provide full automation of the whole RP process.

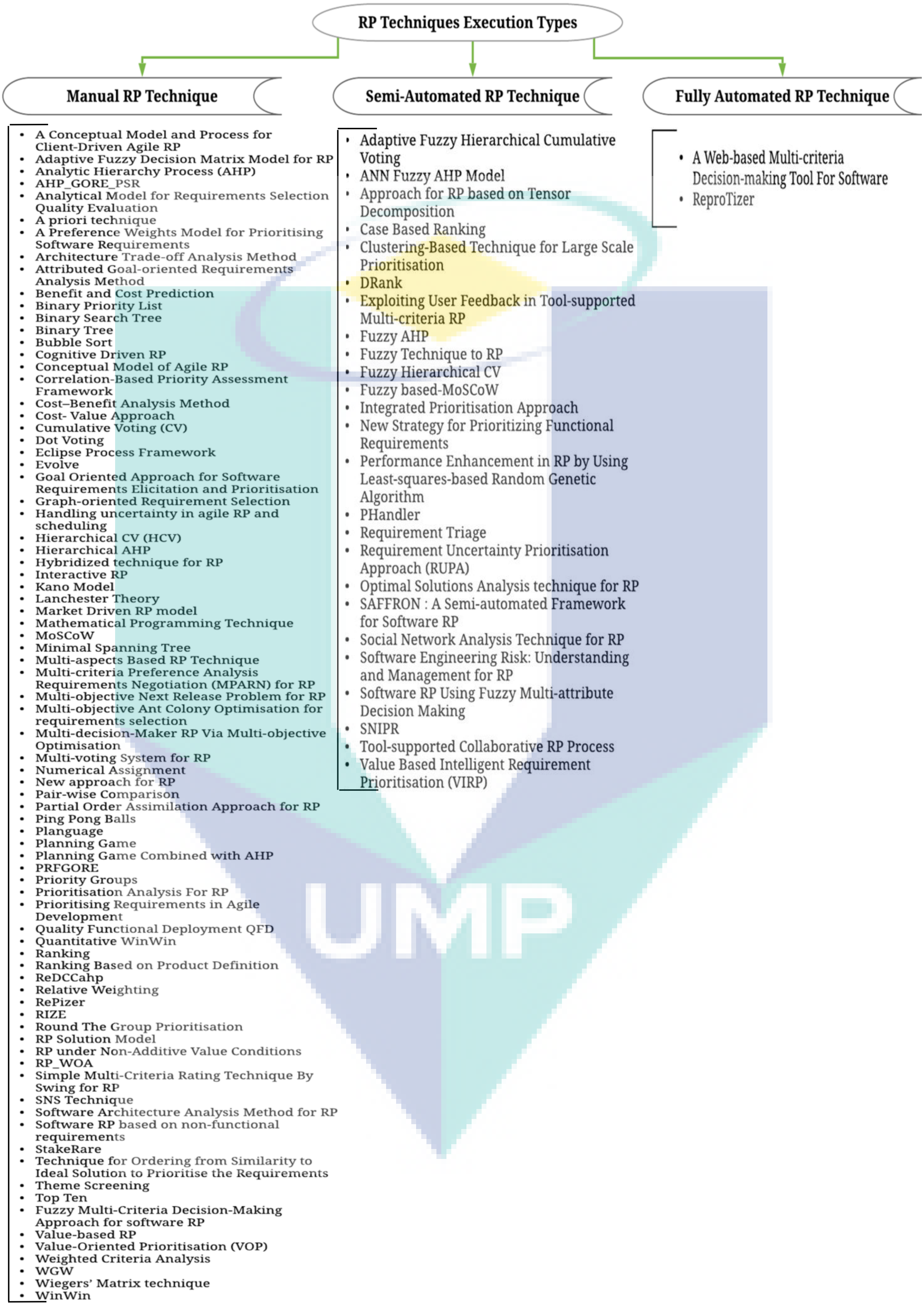

Figure 2.3 Classification of RP Techniques based on the Execuation Type

From the defined classification types, 81 RP techniques were categorised as manual execution. These techniques require human experts to undertake the RP process manually, and no tool support is involved. A human expert refers to a person who has particular knowledge and relevant experience in related domains, such as software system development, project software practices and software marketing and business (Almaliki et al. 2014; Babar et al. 2015c; Creplet et al. 2001).

Table A.2 in Appendix A depicts the result of analysing the existing techniques in terms of prioritisation criteria, benefits, limitations and size of requirement sets that are prioritised. Figure 2.4 presents the numbers of the techniques against the size sets of requirements.

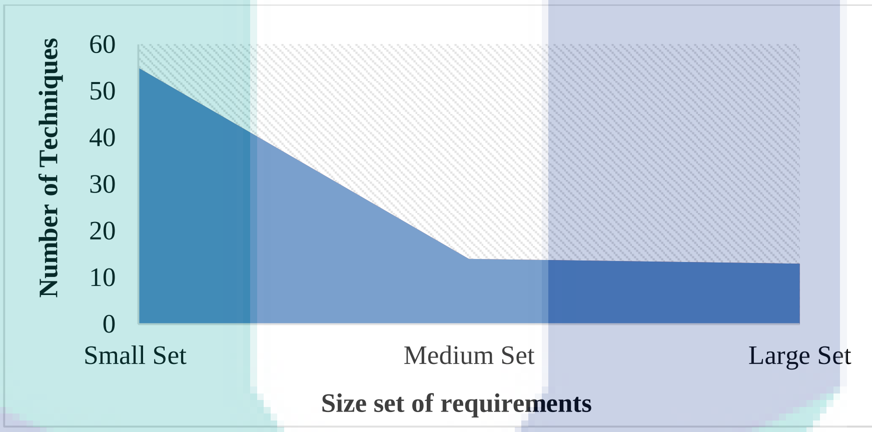

Figure 2.4 Techniques that Address Size of Requirement Sets

In the Figure 2.4, 54 existing techniques are shown to prioritise a small set of requirements. The medium and large sets of requirements are considered by 14 and 13 existing techniques, respectively. Finally, 30 techniques have either not indicated the size of the requirement set or have not been adopted for prioritising any set of requirements. The findings indicated that most of the existing techniques were applied to projects with small sets of requirements (i.e. not exceeding 20 requirements). In fact, these techniques do not sufficiently consider prioritising large numbers of requirements (partly because they are mainly evaluated as mere proof of concepts).

The existing RP techniques use various criteria for prioritising the requirements, as shown Table A.2 in Appendix A. The selection of the criteria in the prioritisation process was based on the type and the aims of the technique for prioritising the requirements. For instance, to produce an ordered list of requirements that is based on the required implementation cost for each requirement, cost analysis is needed per requirement (Lehtola et al. 2004; Sher et al. 2014a). Forty– eight (48) prioritisation criteria were retrieved from the identified techniques. Figure 2.5 depicts the reported prioritisation criteria with their frequency usage from the identified techniques. The usage frequency indicates the number of times each prioritisation criteria is used for prioritising requirements.

The importance of requirement implementation to stakeholders' criteria yielded a usage frequency of 51. The cost criteria amounted to a usage frequency of 22, whilst business value and value criteria had usage frequencies of 9. The dependency and risk had a usage frequency of 8 and 7, respectively. Next, the benefit and effort criteria indicated a usage frequency of 5 and 4, respectively. The penalty and software goal criteria had a usage frequency of 3. Furthermore, the business goal, completeness, modifiability, performance, schedule and time criteria produced a usage frequency of 2. Finally, the remaining criteria each showed a usage frequency of 1. Here, the importance and cost prioritisation criteria were associated with the highest rank of the usage frequency in the existing techniques. This finding is in line with the need to prioritise requirements on the basis of their importance to stakeholders' needs.

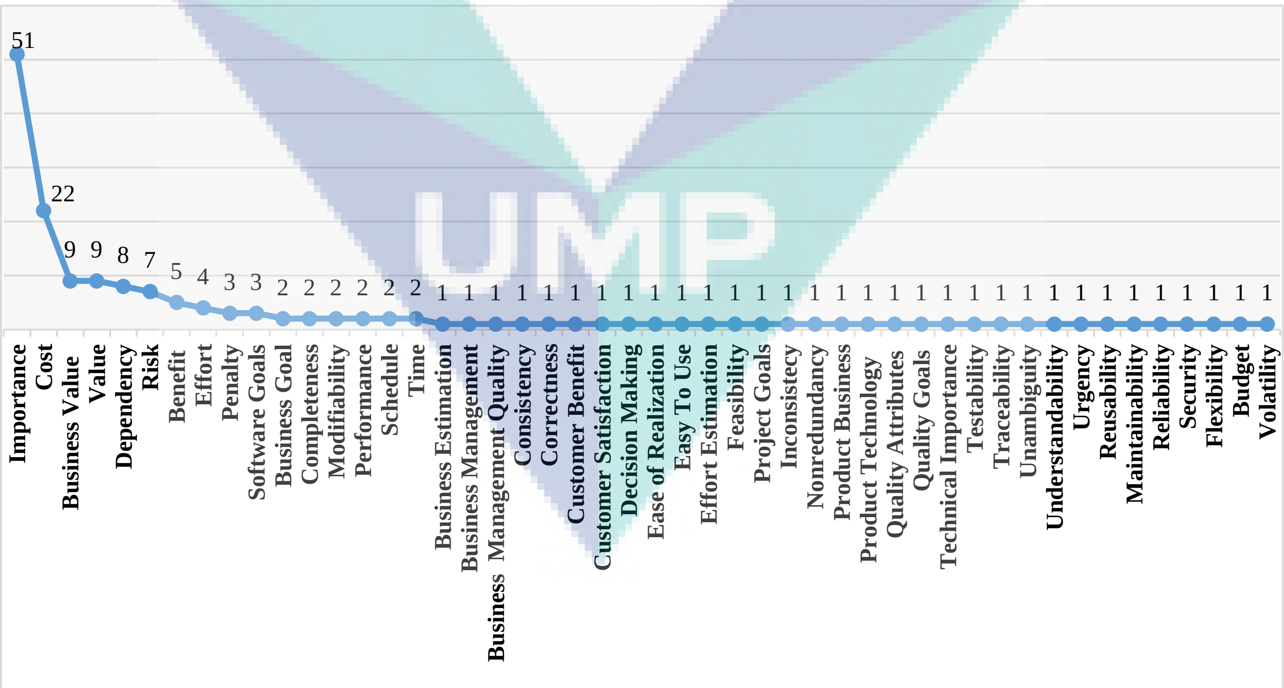

Figure 2.5 Requirements Prioritisation Criteria and their Usages Frequency

As shown in Table A.2 in Appendix A, each technique has quality benefits and limitations. The identified limitations are discussed in the following paragraphs.

Scalability can be a limitation to many existing techniques. Scalability is the capability of these techniques to handle a large set of requirements. An evaluation of the relative priorities between pairs of requirements is one of the common ways for conduction RP process in most of the existing techniques such as bubble sort (Berander & Andrews 2005), AHP (Berander & Andrews 2005; Karlsson et al. 1998), and pairwise comparison techniques (Achimugu et al. 2014d; Karlsson 1996; Karlsson et al. 1998, 2007). The number of comparisons increases dramatically as the number of requirements grows, which makes the prioritisation process to be highly tiring and leads to introduce mistakes with respect to the comparisons. This will undoubtedly induce the scalability of the prioritisation process (Achimugu et al. 2014d; Avesani et al. 2005; Berander et al. 2006; Ma 2009; Tonella et al. 2010).For instance, pairwise comparisons technique has been proven to have scalability as main issue in their prioritisation processes due to the high growth in pair-wise comparisons that exist in handling the large set of requirements. Thus, this technique is not scalable and only suitable to be used with small set of requirements (less than 20 requirements) (Achimugu et al. 2014d; Babar et al. 2015c).

The SQP process aims to identify the most critical stakeholders by measuring the degree of impact of each stakeholder and prioritising them based on their importance. From this research, it is found that SQP plays a vital role in identifying and selecting the core requirements of the system. In system development, the involvement of critical stakeholders is essential to elicit and identify the most important requirement to be implemented (Babar et al. 2015b; Razali & Anwar 2011). In system development, extracting and prioritising the requirements must be performed based on a sufficient range of critical stakeholders, which will assist in capturing the core requirements and lead to the development of a high-quality system (Babar et al. 2015b; In et al. 2002; Razali & Anwar 2011). However, based on the finding of Table A.2 in Appendix A, it is noticed that most existing RP techniques lack of SQP process in their requirement prioritisation process. Out of 108 RP techniques, only 6 techniques perform the SQP process in their RP process: evolve, mathematical programing, VIRP, RUPA, PHandler and StakeRare techniques. These techniques suffered from the issue of being heavily reliant on the involvement of experts, lack of providing measurement criteria for each SQP attributes used in evaluating the stakeholders along with time consuming issue, since this techniques execute the SQP process manually with the non-existence of the measurement criteria of each SQP attributes used in evaluating the stakeholders.

As can be noticed from findings Table A.2 in Appendix A, most of the existing RP techniques are heavily reliant on the experts in performing the prioritisation process by specifying the priority value of each requirements and undertaking the SQP process for the participating stakeholders. Supporting automated prioritisation may alleviate repetitive mundane processes, yet it must not hinder the judgement and creativity of human experts. However, excessive reliance on human experts intervention can also be counter-productive and lead to the following issues: human nature's bias parameters and unavailability of human experts (Aasem et al. 2010; Babar et al. 2015c). To minimise human intervention, AHP-based methods are adopted in undertaking the weighing process for stakeholders and requirements (e.g. Fuzzy AHP (Chan et al. 2012; Kwong & Bai 2002), RUPA (Voola & Babu 2012) and hierarchical AHP (Karlsson et al. 1998)). However, employing the AHP-based method can introduce time consumption and scalability issues (i.e. AHP-based methods do not work well with large projects that contain hundreds of stakeholders and requirements (Achimugu et al. 2014d; Vestola 2010; Yousuf et al. 2016)).

Besides automation issues, the time consumption complexity of implementing prioritisation can be problematic for some existing RP techniques such as AHP, cost–value approach, Evolve, pairwise comparison, Hierarchy AHP. For instance, the time utilization complexity of and cost–value approach, Hierarchy AHP, Evolve, AHP techniques increases with the increase in the number of requirements (Achimugu et al. 2014d; Avesani et al. 2004; Forouzani et al. 2012; Ma 2009). In the case of RUPA, the employed IER algorithm is resource demanding because it adopts a computationally complex calculation (Voola & Babu 2012). Such complexity considerably affects time efficiency in the handling of large sets of requirements (Achimugu et al. 2014d; Babar et al. 2015c; Forouzani et al. 2012).

2.4.1.3 SLR-RP-Q3 RP Stakeholders

The participation of the adequate stakeholders is crucial in producing an accurate RP result (Achimugu et al. 2014a; Ling Lim et al. 2011; Voola & Babu 2012). Thus, involving the right stakeholders is essential during prioritisation (Babar et al. 2015c; Lim et al. 2010; Majumdar et al. 2013). The aim of RQ3 is to identify and categorise stakeholders involved in the RP process. Table A.3 in Appendix A presents the stakeholders involved in the prioritisation process according to the selected studies.

Selecting stakeholders who participate in the prioritisation is impacted by the criteria used to prioritise the (Berander & Andrews 2005; Sher et al. 2014a). For instance, if the requirements are prioritised on the basis of the importance and cost prioritisation criteria, then the customers, project managers, requirements engineers and experts are chosen to participate (Berander & Andrews 2005; Karlsson & Ryan 1997). The customers then prioritise the requirements on the basis of the importance of requirements from a non-technical view. Simultaneously, the project managers, requirement engineers and/or experts evaluate the requirements on the basis of their technical knowledge (e.g. with respect to the cost of the prioritisation criteria).

The findings in Table A.3 in Appendix A indicate that the users and customers are highly participating stakeholders during prioritisation. As such, most of the existing RP techniques aim to satisfy users and customers. This goal is realised by prioritising the requirements on the basis of the importance criteria, which enables users and customers to specify the most essential requirements from their points of view. Meanwhile, the product manager, development teams (developers), requirement engineers/specialists, analysts and software architects are other stakeholders who participate in prioritising the requirements on the basis of technical prioritisation criteria (e.g. cost, time and penalty criteria). The experts and professional analysts are also involved in prioritisation. They specify the priority value of each requirement. These priority values are assigned on the basis of technical prioritisation criteria and the impact value for each participating stakeholder.

In accordance with the findings, the participating stakeholders' types could be categorised into three categories, as shown in Figure 2.6: functional beneficiary, commercial and technical stakeholders. The functional beneficiary stakeholders include stakeholders who foresee other stakeholders' satisfaction (e.g. the importance of requirements for system functionalities). Typically, the functional beneficiary stakeholders are those who pay for the system, specify the system functions to be developed and use its services. They are the customers and users of the system.While, the commercial stakeholders are those who participate in terms of commercial prioritisation criteria, such as product business, commercial goals, business estimation and business management. These stakeholders are business analysts, marketing managers and business experts. The technical stakeholders comprise stakeholders who participate on the basis of the technical prioritisation criteria, such as dependency, efforts, time and cost criteria. These stakeholders include requirement engineers, project development teams, software architects, project managers and experts, professional analysts, software developers, programmers, design teams, requirement specialists and professional team leaders.

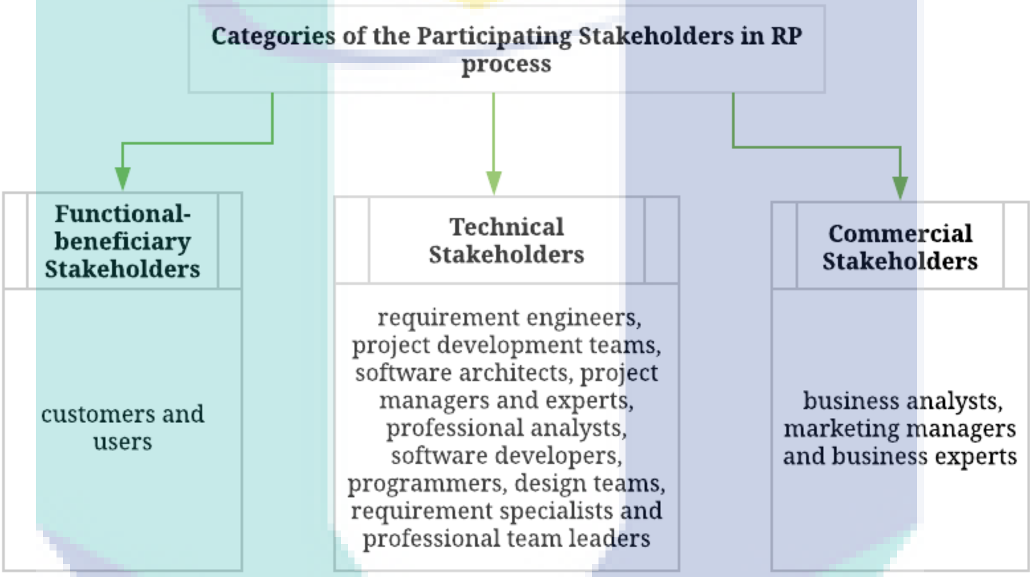

Figure 2.6 Categories of RP Stakeholders

2.4.1.4 SLR-RP-Q4 RP Usage Contexts

The participation of the adequate stakeholders is crucial in producing an accurate RP result (Achimugu et al. 2014a; Ling Lim et al. 2011; Voola & Babu 2012). Answering RQ4 involved two stages. Firstly, the contexts of the identified techniques and selected studies were revealed. Secondly, the usage frequency percentage of each context in the existing techniques was quantified. The usage frequency was measured by the number of times the RP techniques were proposed or applied in each identified context. As such, the selected studies and the study focus are categorised in accordance with the publication years and their contexts, respectively. The implication of the RP process through the identified techniques concerns few contexts of software development. These contexts are software release planning (SREP), agile software development (ASD), value-based software development (VBSD), software architecture (SA), social network system development (SNSD), real-client custom development projects (RCCD), cognitive driven (CD), system development organisational work (SDOW), market-driven software development (MDSD) and goal-oriented RE (GRQE). An additional context (not specified [NS]) also included to contain cases where the RP technique does not specify any context.

Figure 2.7 presents the usage frequency percentage of each context of the listed RP techniques. The usage frequency percentage is measured by calculating the number of times the RP techniques were proposed or applied in each identified context from identified 108 techniques of the selected studies.

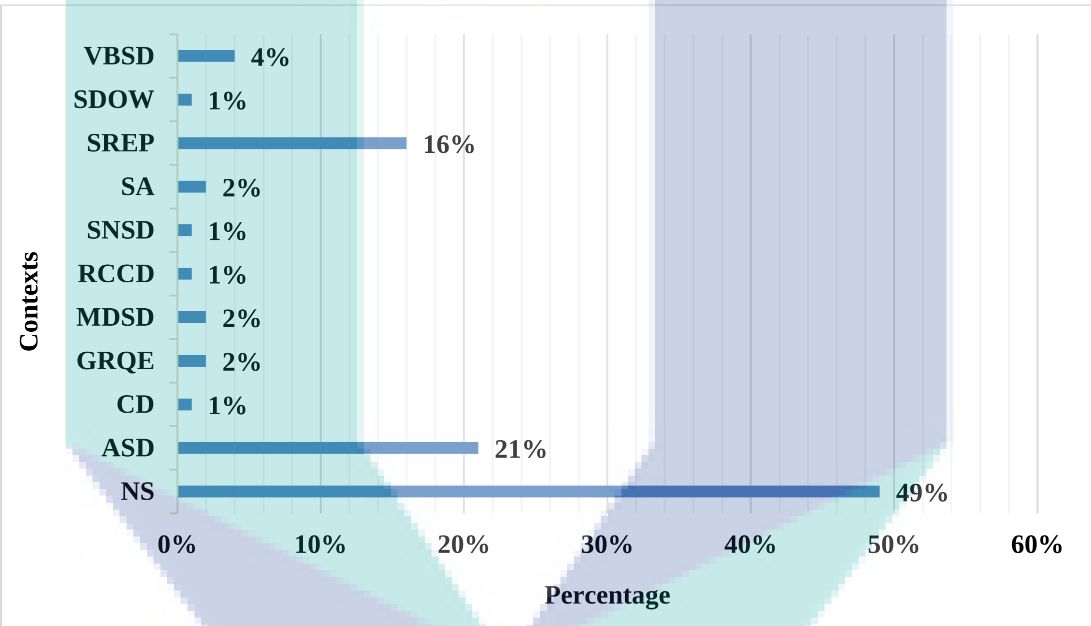

Figure 2.7 Contexts of RP Techniques

Most of the RP studies (49%) provides their RP processes for general software development (as NS context). ASD context had a usage frequency of 21%, followed by SREP with 16%, VBSD with 4%, SA, MDSD and GRQE with 2% and finally CD, SNSD, RCCD and SDOW with 1%. Placing the NS context aside, SREP and ASD yielded the top usage contexts regarding RP. This finding relates to the benefits of the environment development process within the ASD and SREP contexts. In the SREP context, the identification of the core requirements is often strictly observed within the project's constraints. As such, conduct of the RP process is necessary to select the most important requirement to be delivered (Carlshamre et al. 2001; Svahnberg et al. 2010). Similarly, prioritising the requirements is a crucial step within the ASD context. In this context, the

RP process is conducted to ensure that correct requirements are selected and included in each iteration during prioritisation (Al-Ta'ani & Razali 2016b; AL-Ta'ani & Razali 2013).

In addition to Figure 2.7, Figure 2.8 illustrates the publication tendency of the selected primary studies on the basis of their study contexts across the publication years between 1993 and 2018. In general, the number of the published studies related to RP was increasing yearly. This increase could be observed from 2005 to 2018, with a noticeable peak in 2012. This result indicated strong interests on applying RP in their relevant contexts (such as ASD, SA, GRQE and VBSD) by RP researchers and practitioners. Publication within the NS context started in 1994, with a peak in 2010. This result indicated a healthy improvement, especially in the general awareness of the RP process.

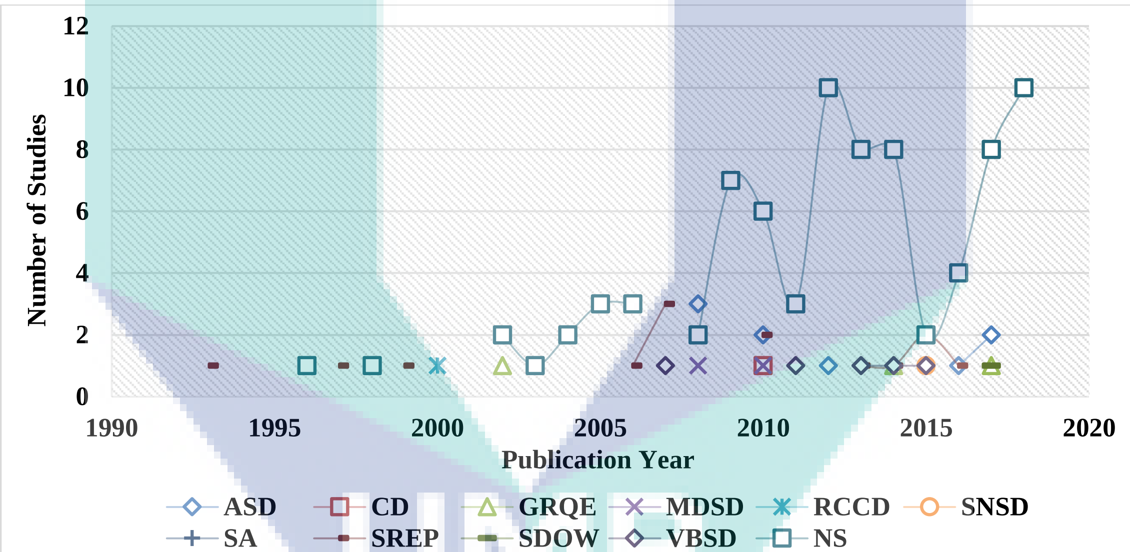

Figure 2.8 Publication Tendencies of Selected Primary Studies by Publication Year and Study Focus with Contexts

Meanwhile, the focus of the selected studies on the ASD context started from 2008, coinciding with the practices of the agile development process (Bhatti et al. 2015; Inayat et al. 2015; Moniruzzaman & Hossain 2013), which began in 2005. The publication of the selected studies on ASD context was steady until now due to the popularity of the agile development process. Regarding the SRP and VBSD contexts, the ranges of publication were from 1993 to 2016 and from 2007 to 2015, respectively. Regarding the GRQE context, the publications were sparsely distributed in 2002, 2014 and 2017. This result indicated little work in the field of GRQE. Similarly, the published studies within the context of MDSD were also sparsely distributed in 2003 and 2010. Finally, the SA, CA, RCCD, SDOW and SNSD contexts each had one published study in 2013, 2010, 2000, 2017 and 2015, respectively.

2.4.2 SLR-SQP

Various elements motivated the author to conduct this SLR-SQP. First, on the basis of the conducted search of the relevant literature, there are no research papers, either SLRs or systematic mapping reviews, that are conducted specifically on SQP; although a few review research studies exist on stakeholder analysis in general, none of them particularly concentrate on the SQP area as their focus was on stakeholder identification. The second element which influenced the decision to conduct this study is that SQP is the forthcoming research trend in the analysis of stakeholders of a system. Hence, this makes SQP an important topic to be investigated thoroughly. Third, the literature study plays an essential role in providing a clear view about the current and certain challenges in SQP. Table B.1 in Appendix B presents the summary of focus and findings in related studies in comparison to this SLR-SQP.

Pacheco and Garcia conducted the first systematic review in stakeholder identification. The aim of their review was to investigate stakeholder's identifications in the requirements elicitation(Pacheco & Garcia 2012). Forty-seven (47) related studies were selected for primary study after the specified studies selection process of the review was executed.

This review is useful as it could present stakeholder identification methods in the requirements elicitation, report the aspects of the stakeholder identification, and discuss consequences of performing an inefficient stakeholder identification process on the quality of a system's requirements. The authors of this study concluded that the methods cannot cover all aspects of stakeholder identification in conducting the process of identification. The process of SQP was not discussed at all in this study as its investigation was about stakeholder analysis in terms of the identification process for the stakeholders of the systems.

In addition, the authors in (Mok et al. 2015) presented a review study with specific focus on stakeholder management research studies in mega contraction projects (MCP). The study aimed to provide a critical analysis of existing research studies on stakeholder management that are related to the MCP. The review performed the filtering process designed to exclude irrelevant studies; hence, eighty-five (85) studies were selected as the studies most relevant to the specified domain of the review. This review could provide an explanation of the stakeholder engagement and management process in MCP as well as briefly highlight the stakeholder analysis method in MCP that focused on the stakeholder identification process based on their influence and interest.

Another systematic review of stakeholders management in the value-based software development sector was documented in (Babar et al. 2014b). The review concentrated on reporting the available stakeholder attributes and their usage context, presenting stakeholder types, and revealing the issues that are solved in value-based software development. The selection strategy of the studies yielded forty-one (41) studies as primary studies for this review. The failure to explore the stakeholder quantification attributes is reported as the main limitation in the existing studies of stakeholder management. Although this review discussed stakeholder quantification from the attributes used point of view, it is not exhaustive in its coverage of the quantification of the stakeholders and does not cover the domain of the stakeholder prioritisation.

However, the present SLR-SQP provides various characteristics as discussed previously. The focus of this SLR is on SQP as the first study to carry out SLR on this specific research domain. Therefore, the objective of this paper is to present a comprehensive review of the SQP domain by selecting and studying critically published works that are related to the specified domain. The SQP is investigated in terms of its impact on RP, reporting the SQP attributes along with revealing their degree of importance by measuring the frequency usage of each attribute in existing studies that quantify and prioritise the stakeholders, and identifying and analysing the existing techniques that proposed to perform the SQP process. The existing SQP techniques are identified and analysed based on specified parameters: involved SQP process, attribute used, and limitations. In addition, the detailed discussion of the overall limitation of SQP is presented.

To achieve the objective of this SLR-SQP, four questions (SLR-SQP-Q) were formulated as a guideline for the study. At the end of this SLR-SQP, the questions presented here should be accurately answered and discussed. These formulated questions are as follows:

i. SLR-SQP-Q1: Does SQP have a significant impact on RP?

ii. SLR-SQP-Q2: What are the current factors/attributes/criteria used in quantifying and prioritising the stakeholders?

iii. SLR-SQP-Q3: What are the existing techniques used for quantifying and prioritising the stakeholders?

iv. SLR-SQP-Q4: What are the SQP process, types, and limitations of each existing SQP technique?

SLR-SQP-Q1 aims to investigate the significant impact of the SQP on the specific process of RP. This investigation aims to identify and precisely discuss the importance of conducting the quantification and prioritisation for the system stakeholders during RP. SLR-SQP-Q2 is structured to specifically identify SQP attributes and critically investigate them with respect to their related meaning, usage impact, and degree of importance. SLR-SQP-Q3 and SLR-SQP-Q4 are specifically formulated to identify the available techniques that focused particularly in quantifying and prioritising the stakeholders, and critically analyse them by revealing the SQP process, attributes, obtained desired result, and the limitations of these techniques discussed in detail.

2.4.2.1 SLR-SQP-Q1 the SQP Significant Impact on RP

The objective of SLR-SQP-Q1 is to illustrate the importance of the SQP process in RP. To answer this question, 15 papers were identified from the final selected studies. It was found that SQP is considered as a critical process to quantify and prioritise stakeholders based on their impact on the developed system. Further details regarding the answers to this question are explained as follows.

The SQP process can acquire stakeholder needs through RP activity. The success of any system or project is evaluated by meeting the stakeholders' needs and requirements (Babar et al. 2013; Power 2010). Hence, identifying and selecting the stakeholders play a vital role in the elicitation and prioritisation of requirements (Babar et al. 2015c; Benestad & Hannay 2012; Berander 2004). Acquiring the right requirements must be executed based on identifying the most critical stakeholders, which will lead to the capture of requirements that are related to the real needs or requirements of the system (Babar et al. 2015c; Benestad & Hannay 2012; Lim & Finkelstein 2012).

In addition, the SQP process can assist in decision-making, which comprises most of the issues in science and engineering fields (Babar et al. 2015a; Bendjenna et al. 2012). The decision-making processes rely on various criteria, which require the knowledge of a diverse group of experts (Bendjenna et al. 2012). SQP is considered an important process to assist in decision-making, in which various stakeholders have competing interests, limited resources, and appropriately balanced stakeholder requirements (Benestad & Hannay 2012; Dearden, P., S. Jones 2003). When such conflicts arise, to ensure the success of an organisation, it is important to quantify and prioritise the stakeholders' requirements.

Furthermore, the SQP process helps to identify a stakeholder's impact in RP as the impact on a certain requirement differs from one stakeholder to another. On the other hand, the number of participating stakeholders of various types can be large and each of them construes their needs differently (Berander 2004; Parent & Deephouse 2007). This will create difficulties in making the decision on which stakeholder's impact is more significant than that of another. As a result, there is a need to quantify and prioritise the stakeholders in order to capture the most important stakeholders' requirements that will contribute considerably to the success of the system (Babar et al. 2014a, 2015b; Razali & Anwar 2011).

In addition, SQP can produce the accurately prioritised list of requirements; thus, it is extremely significant to prioritise or quantify the stakeholders before performing the prioritisation process for system requirements (Babar et al. 2015c; Lim & Finkelstein 2012; Voola & Babu 2012). Identifying the importance of each stakeholder among the participating stakeholders will contribute to the capture of the most critical requirements for the significant stakeholders (Babar et al. 2015c; Lim et al. 2010; Ling Lim et al. 2011; Parent & Deephouse 2007). For instance, if stakeholder A has been identified to have a higher impact on the project than stakeholder B, then the requirements of stakeholder A must be given priority over those of stakeholder B. Meanwhile, prioritising the requirement without prior identification of the stakeholders' impact would produce an incomplete and incorrect list of the stakeholders' critical requirements, which might not meet the stakeholders' needs and could endanger the quality of the produced system (Babar et al. 2015b, 2015c; Lim et al. 2012; Ling Lim et al. 2011; Power 2010).

2.4.2.2 SLR-SQP-Q2 the Current Factors/Attributes/Criteria that are used in Quantifying and Prioritising the Stakeholders

SLR-SQP-Q2 is concerned with capturing attributes that are used in the existing studies to quantify and prioritise stakeholders, while the attributes that are used only for identifying the stakeholders are declined. Stakeholders who are involved in a system development can be quantified and prioritised by certain factors or criteria, also known as attributes.

Table B.2 in Appendix B presents SQP attributes and their descriptions and usage impact along with citations for existing studies that used each attribute. These attributes are retrieved from the selected studies that used at least one of them in the process of quantifying and prioritising the stakeholders. These attributes are power or influence; interest; urgency; role, responsibility or job scope; personality; experience; knowledge; legitimacy; training; skills; managerial abilities; objectivity; risk; self-esteem; education background; environment, and instability (Babar et al. 2013, 2014a, 2014b, 2015a, 2015b; Ballejos & Montagna 2011; Bendjenna et al. 2012; Damian 2007; Dearden, P., S. Jones 2003; Jepsen & Eskerod 2009; Lim et al. 2012, 2010; Lindblom & Ohlsson 2011; Mayers 2005; McManus 2004; Parent & Deephouse 2007; Preiss & Wegmann 2001; Rawlins 2006; Razali & Anwar 2011; Seale 2003; Varvasovszky 2000; de Vivero & Alba 2007).

Figure 2.9 presents the reported attributes with their degree of importance. The importance is measured by calculating usage frequency from the selected studies. The usage frequency refers to the number of times each attribute is used in quantifying and prioritising the stakeholders: influence or power (85 %); interest (70 %); role responsibility (job scope), knowledge, and experience (60 % each); skills, legitimacy, training, skills, educational background (30 % each); and urgency, personality, managerial abilities, objectivity, risk, environment, and instability (15 % each). The degree of importance of each reported attribute is used to determine which attributes are considered as the most important in the SQP process.

Based on the reported frequently usage percentage of the captured SQP attributes, it is observed that the attributes of power or influence, interest, knowledge, and experience are more important SQP attributes compared to other attributes in the existing SQP techniques. The authors of most existing SQP studies postulated that their attributes have higher impact on the SQP process than other attributes in terms of affecting the success of a system or project (Babar et al. 2013; Ballejos & Montagna 2011; Bendjenna et al. 2012; Lim et al. 2010; Razali & Anwar 2011).

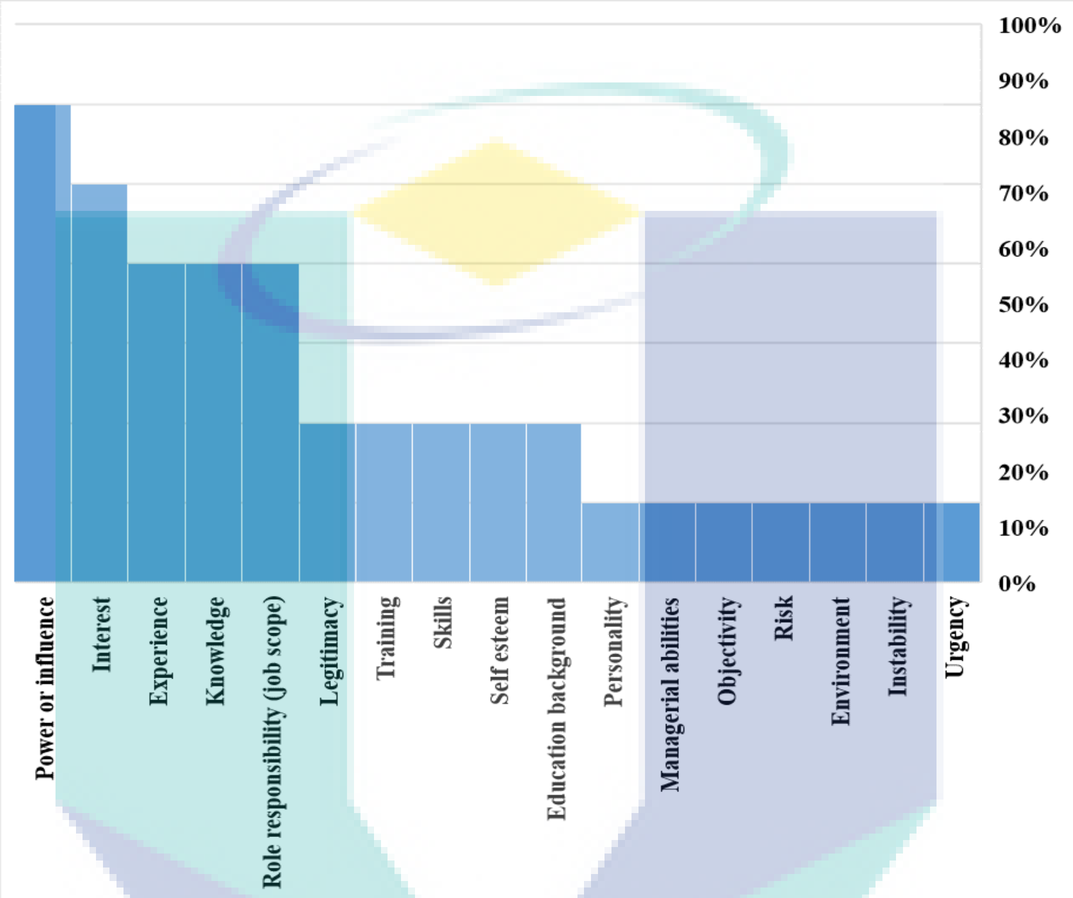

Figure 2.9 Importance Degree of SQP Attributes

However, the implementation guidelines or the usage description of the reported attributes have not been precisely provided in the existing SQP techniques or studies. The current existing SQP studies used the reported attributes only by providing high-level descriptions of the attributes. The full descriptions of how to implement these attributes in quantifying and prioritising stakeholders are not given; the existing studies relied on the involvement of experts to execute the SQP process, but the authors are vague in providing standard methods or measurement criteria for using the reported attributes in their studies.

2.4.2.3 SLR-SQP-Q3 the Existing (SQP) Techniques and Descriptions of each Existing Technique

The first part of SLR-SQP-Q3 aims to identify existing SQP techniques. Various techniques have been used for stakeholders' identification and quantification; however, most of the techniques were concerned with identifying the stakeholders while ignoring the process of quantifying and prioritising them. Thus, this study excluded a majority of the techniques and selected only those that focused on the process of quantifying and prioritising stakeholders, such as AHP, Bendjenna et al. (Bendjenna et al. 2012), and Lim et al. (Lim et al. 2010). Figure 2.10 presents the existing SQP techniques along with their citation rates.

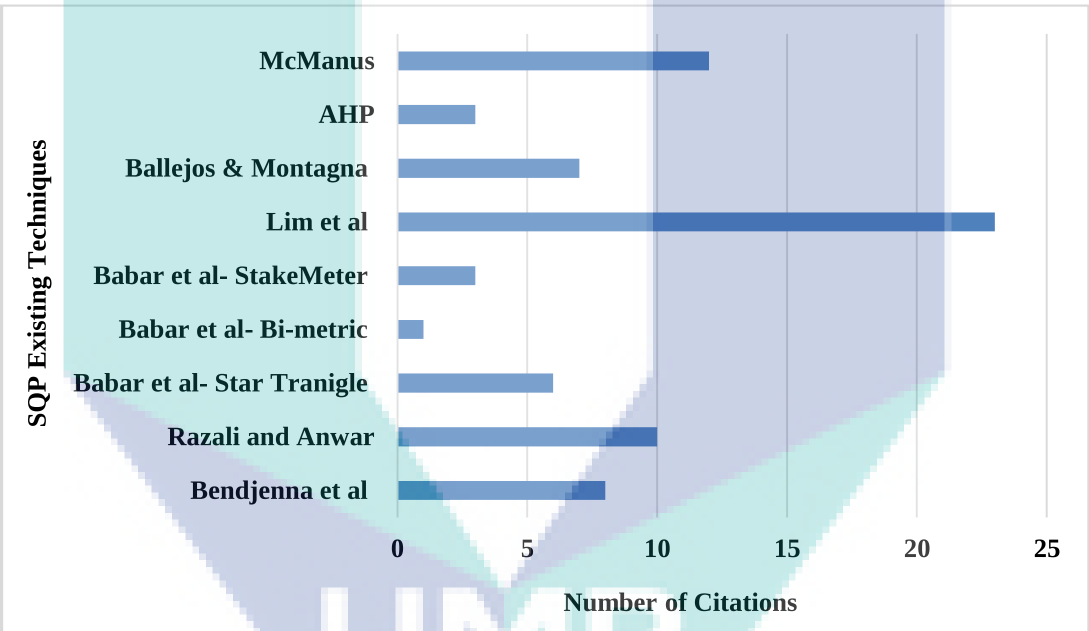

Figure 2.10 SQP Existing Techniques

The citation rates are derived based on the citation analysis via counting the number of times the existing research studies mention or use the SQP technique. Identifying the citation rate for each SQP technique is performed based on three steps, which are as follows:

1. Extracting the studies that cite the SQP technique: this step was performed starting with deriving the existing studies that cited the SQP technique from three citation analyses, which are Web of Science, Google Scholar, and Scopus. These citation analyses were selected as they are considered to be the most powerful tools that

have sufficient stability of coverage to be used for citation tracking and generating citation data, and their coverage includes almost all of the published research study types (such as journal, book chapter, and conference)(Levine-Clark & Gil 2008; Yang & Meho 2006).

2. Checking study duplication: checking study duplication among the selected citation analyses was executed to exclude the duplicated studies and include the most recent study.

3. Locating the number of studies that only use or mention the technique: the citation rates for each SQP technique was then determined by counting the number of studies that only use or mention the technique in their contents. For example, the study of the McManus (McManus 2004) technique was cited by 31 existing studies; however, it has been found that only 12 studies only used or mentioned the technique. Thus, the obtained citation rates were twelve (12).

The second part of SLR-SQP-Q3 illustrates the description of each existing technique. The description of each technique is essential to present a view of how each existing technique works. A majority of the researchers depended on industry experts in performing the process of SQP process. The AHP technique was applied with the involvement of experts in some studies such as in (Brito & Moreira 2003; Voola & Babu 2012; Voola & Vinaya Babu 2012); however, the implementation of AHP did not fully describe the process of performing quantification and prioritisation, such as detailed criteria for the importance priority of each stakeholder (Babar et al. 2014b; Bendjenna et al. 2012). Lim et al.'s (Lim et al. 2010) technique, presented in (Lim et al. 2010; Lim & Finkelstein 2012) to identify, quantify, and prioritise stakeholders, consists of three main steps: identify stakeholders and ask them to recommend other stakeholders and stakeholder roles, build a social network whose nodes are stakeholders and links are recommendations, and prioritise stakeholders using a variety of social network measures.

In addition, another conceptual framework is introduced in (Razali & Anwar 2011) that performed the selection process in quantifying and prioritising the stakeholder based on the stakeholder's role, education, experience, job scope, interest inventory, and personality test (Razali & Anwar 2011); Babar (Babar et al. 2014a) postulated that this framework provides high-level details of implementing the SQP process without explaining in full detail the process activity. In addition, another research was conducted in (Ballejos & Montagna 2011) to propose a technique in which stakeholders are manually quantified and prioritised by performing quantitative calculations in relation to their interest and influence over the project (Ballejos & Montagna 2011); the process is performed manually and requires the involvement of experts to determine the priority of each stakeholder based on the selected attributes.

Furthermore, another technique is given in (Bendjenna et al. 2012) to prioritise the stakeholder using multi-criteria analysis. The proposed technique is used in Mitchell's model to classify stakeholders based on urgency, power, and legitimacy attributes. Next, the proposed technique uses the fuzzy Choquet integral as an aggregation operator, which enables the consideration of interaction between attributes (Bendjenna et al. 2012). Babar et al.- Star Triangle (Babar et al. 2013) was presented in (Babar et al. 2013) to quantify and prioritise the stakeholder based on role, power, business process knowledge, experience, and training attributes. The involvement of experts in this technique was vitally needed to analyse and categorise the participating stakeholders based on the identified attributes (Babar et al. 2013).

In addition, another technique (Babar et al.- Bi-metric) stated in (Babar et al. 2014a) is used to execute the SQP process by using bi-metric and fuzzy means technology, in which two primary stakeholder attributes, skill and interest, are considered in this research. Each of the two attributes had sub-attributes or aspects that will help the experts to assign a value to the attributes for each stakeholder (Babar et al. 2014a). The skill attribute was divided into sub-attributes, which are domain knowledge, managerial abilities, domain training, and self-esteem; while the sub-attributes for interest were defined as domain scope knowledge, business knowledge, and objectivity. However, the fuzzy c-means (FCM) algorithm was used to define inclusion and exclusion criteria for stakeholders (Babar et al. 2014a). Although the technique is useful in quantifying and prioritising the stakeholders, it relied heavily on the participation of the experts and faced the issue of scalability (Babar et al. 2014a).

Moreover, another recent study called Babar et al.- StakeMeter was presented in (Babar et al. 2015b). This technique was proposed to quantify and prioritise stakeholders for value-based software systems. The technique was constructed based on studies conducted in (Babar et al. 2013, 2014a, 2015b), where it combined both techniques proposed in those studies; this helps in the selection of highly critical stakeholders for value-based systems with less judgemental error. Even though it provides low-level implementation guidelines, attributes, metrics, quantification criteria, and application procedures as compared to the other methods, it still fails to provide a detailed scenario on how the involved experts determine the priority value for each stakeholder. Thus, it leads to the issue of bias being induced by the experts. The framework is only applicable to a small number of stakeholders; therefore, it also needs to be tested with hundreds of stakeholders to check its performance (Babar et al. 2015b).

2.4.2.4 SLR-SQP-Q4 the Involved SQP Process, Types, Used Attributes and Limitations of Existing SQP Techniques

To find the answer to SLR-SQP-Q4, the existing SQP techniques (that have been identified SLR-SQP-Q3) are analysed with respect to the steps involved in executing the SQP process, types, the attributes used to quantify and prioritise stakeholders, and the limitation of each existing technique. The SQP process involved in each technique is highlighted to give a clear view of how the process was conducted in each existing technique.

Additionally, attributes that are used to quantify and prioritise the stakeholders are reported in order to clarify the selected criteria implemented in each technique. Table B.3 of Appendix B presents the results of the analysis from which it is found that each existing technique used specific attributes to conduct the SQP process. All the existing SQP techniques used specified attributes without presenting any standard method as to how the selected attributes are applied in assessing the priority of the stakeholder value (attribute measurement criteria). All the techniques require the involvement of experts to determine the priority value (which indicates the importance value of a stakeholder) of different stakeholders based on one of the chosen attributes. The usage frequency of each of the attributes has been discussed in SLR-SQP-Q2.

In addition, the type of each existing SQP technique is identified to highlight the automation level in the existing techniques. As presented in Table B.3 of Appendix B, the analysis results show that, out of nine techniques, the SQP processes of seven techniques were manually performed. However, the remaining two techniques which are in Bendjenna et al. (Bendjenna et al. 2012) and Babar et al.- Bi-metric (Babar et al. 2014a) automated one step of their processes.

The fuzzy Choquet integral was introduced in technique of Bendjenna et al. (Bendjenna et al. 2012) to express the interactions among the attributes used for quantifying and prioritising the stakeholders, while the remaining SQP processes were implemented manually. The clustering method of FCM was implemented by the technique in (Babar et al. 2014a). FCM was used in the last step of the stakeholders' quantification to classify the stakeholders into different clusters, whereas the previous steps of this technique were manually conducted to evaluate the stakeholders' importance based on the selected attributes. Thus and based on (Babar et al. 2014a), (Bendjenna et al. 2012) attempts on automating some of the SQP process, the quantifying and prioritising process can be enhanced with an intelligent (implementing the rules of experts) and semi-automated solution (a new SQP technique). This minimizes the need for expert participation in terms of evaluating the stakeholders and reduces the chance for bias induced by the experts in conducting the SQP process (Babar et al. 2015b).

Although many efforts have been expended in developing SQP techniques, some limitations have been identified after their analysis, as presented in Table B.3, Appendix B. The limitations of the existing SQP techniques can be explained as follows.

Low implementation details refers to the capability of the technique to provide low process level details to quantify and prioritise the stakeholders. Most of the existing techniques do not support low-level details of implementation for the SQP process (Babar et al. 2014a, 2015b). The Razali and Anwar technique provides a conceptual framework for quantifying and prioritising the stakeholders with a high implementation level. The proposed steps for conducting the SQP process along with the attributes used for evaluating the stakeholders are given without in-depth implementation details. In addition, this technique failed to provide details of the measurement attribute criteria for each used attribute which can be used as standard guidelines in evaluating the stakeholder's importance based on the SQP attributes. The application of the AHP technique in performing the SQP process has been done by (Brito & Moreira 2003; Voola & Babu 2012; Voola & Vinaya Babu 2012) with a high level of abstraction. The pairwise comparison is implemented to quantify and prioritise the stakeholders in this technique. However, the detailed guidelines for estimating the stakeholder's influence are not described, which causes difficulty in decision-making when evaluating the stakeholders, such as how stakeholder S1 has three times more influence or two times less influence than stakeholder S2.

Similarly, the techniques of McManus and Babar et al.- Star Triangle also failed to illustrate low-level details for conducting SQP because both techniques provide high level categories of stakeholders without in-depth details for categorising the stakeholders as well as the stakeholder prioritisation of the same categories is not conducted. Ballejos & Montagna and Bendjenna et al.'s techniques do not support low process details for quantifying and prioritising the stakeholders owing to the inability to introduce clear and complete standard measurement criteria for the SQP attributes used in measuring the stakeholders' impact. Babar et al.-StakeMeter and Babar et al.-Bi-metric and FCM techniques could provide better process descriptions and guidelines on how to quantify and prioritise the stakeholders as compared to other techniques. However, the measurement criteria for each attribute used in measuring the priority value for each stakeholder of the two techniques are not provided. The inability to provide the in-depth process level details for SQP leads to the adoption of techniques that are difficult to implement in real project development (Babar et al. 2014a).

From the analysis results of this study, it was observed that most of the existing techniques perform the SQP process manually with lack of intelligence and automation level that make the techniques time-consuming (Babar et al. 2014a, 2015b). One of the most recent studies documented in (Babar et al. 2015b) performed performance evaluation for three existing techniques with respect to the time. These techniques are Babar et al.-StakeMeter, Babar et al.-Bi-metric and FCM, and Ballejos & Montagna. The study reported that the Babar et al.- StakeMeter technique has the lowest time-consuming performance compared to other techniques, wherein this technique performed the SQP process for 23, 32, and 21 stakeholders in approximately 7, 23, and 47 hours, respectively, followed by Babar et al.-Bi-metric and FCM that consumed 11, 31, and 65 hours for 15, 22, and 21 stakeholders, respectively. The Ballejos & Montagna technique has the highest time consumption with 28, 58, and 108 hours for 18, 43, and 53 stakeholders, respectively. The performance of Babar et al.-StakeMeter was found to be higher than the other two techniques owing to its ability to provide a clear and less complex manual process as compared to others. However, the response time of techniques still need to be improved by introducing an automated and intelligent system that will assist in minimising the computational complexity of the manual process, which is conducted to identify the priority value of the stakeholders and generate the prioritised list of the stakeholders.

Another limitation of the existing SQP techniques is linked with heavily relying on the involvement of highly specialized professionals such as business analysts and experts. From this research, it is observed that the execution of the SQP process is done by measuring the priority/impact value of stakeholders or/and classifying the stakeholders into different categories. The Razali and Anwar, Bendjenna et al., Babar et al.- Star Tranigle, and McManus techniques perform the SQP process by classifying the stakeholders into different categories of importance, where expert participation is highly desirable in order to initiate and conduct the categorisation process. The rest of the techniques (Babar et al.- Bi-metric, Ballejos & Montagna, AHP method, Lim et al., and Babar et al.-StakeMeter) also depend on the involvement of the experts to measure the stakeholders' importance degree by assigning a priority value for each stakeholder.

The experts perform the process of specifying the stakeholder priority value, or classifying them, conducted based on the used SQP attributes of the techniques without providing any description of the standard measurement criteria that can be used in evaluating the stakeholders with respect to each attribute used. This leads to these techniques being implemented without full involvements of the experts. Heavy reliance on highly professional human judgement sometimes is not preferred owing to human biases parameters and unavailability of experts, which consequently will impact the accuracy and reliability of the technique. Hence, there is a need to minimise the involvement of the experts using an intelligent and automated system that should be developed based on the experts' rules.

Evaluating the performance of the technique in real scenarios is an essential aspect in order to corroborate its findings. Most existing SQP techniques have not been implemented with large real-world projects, possibly owing to the ambiguity and complexity associated with the SQP process in terms of the time and efforts required to identify the priority value for each stakeholder and produce a prioritised list of stakeholders. Thus, there is a need to implement new algorithms that will enhance the SQP on the commercial side in the future. However, the process of quantifying and prioritising the stakeholders of the algorithms should be; provided in-depth level details and able to execute the SQP process with less cost effective in time; to be able to address the ambiguity and complexity issues. This will improve applicability of the SQP with large project practices in identifying the core stakeholders which assist the requirements engineers in eliciting and selecting the essential system requirements to be implemented.

2.5 Gap Analysis

The SLR-SQP and SLR-RP review embody the philosophy beyond the research of SQP and RP with providing comprehensive review and analysis of the SQP attributes, RP criteria and existing SQP and RP techniques. In this SLRs, 9 SQP techniques and 108 RP techniques were identified and critically analysed. The results of analysis show that each existing technique has been proposed with specific objectives and has some quality benefits and limitations. In summary, the findings revealed that key limitations still exist despite the presence of existing SQP and RP techniques, these key limitations serve as the motivation of the present research. These limitations can be summarised as follows:

i. Scalability issue in RP

As revealed from the analysis results of RP techniques in Table B.3 of Appendix B, scalability issue is reported as one of the main challenges in RP techniques, which makes them impracticable in the real industry side. Most RP techniques cannot be implemented well with a large set of requirements. Figure 2.11 presents the percentage of the existence of scalability issue in RP techniques.

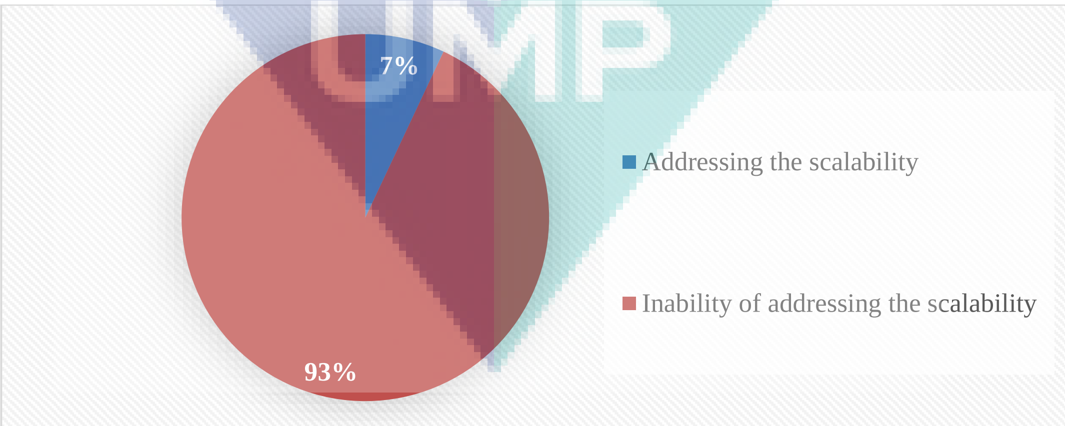

Figure 2.11 Percentage of the Existence of Scalability Issue in RP Techniques

The percentage of incapability of handling the scalability is 93% and 7% for the successful addressing scalability issue. The percentage was measured by calculating the number of the techniques that have been approved in addressing the scalability from identified RP techniques. Only seven of 108 existing techniques can scale well with a large set of requirements: minimal spanning tree (Karlsson et al. 1998), Hierarchical AHP (Karlsson et al. 1998), binary search tree (Karlsson et al. 1998), StakeRare (Lim & Finkelstein 2012), PHandler (Babar et al. 2015c), requirements triage (Duan et al. 2009), clustering-based technique for large-scale prioritisation (Achimugu et al. 2014a), SNIPR (McZara et al. 2015), an optimal solution analysis technique for RP (Veerappa 2012), ReproTizer (Achimugu et al. 2016) and RePizer (Khan et al. 2016)). However, these techniques suffer from other limitations, such as lack of automation of stakeholder quantification and prioritisation (SQP), incapability to handle requirement interdependencies, overreliance on the participation of human experts, time consumption, and unreliable and poor fault tolerance, as depicted Table A.2 in Appendix A.

ii. Shortage of addressing SQP in RP

SQP process plays a vital role as far as producing accurately and correctly prioritised lists of requirements is concerned (Benestad & Hannay 2012; Lim et al. 2010; Ling Lim et al. 2011; Razali & Anwar 2011). Specifically, the SQP process identifies the degree of impact of each stakeholder on RP on the basis of its perceived importance (Achimugu et al. 2014a, 2015; Ling Lim et al. 2011; Voola & Babu 2012). Table A.2 in Appendix A that most existing techniques do not adopt a well-defined SQP for prioritisation. Currently, requirement uncertainty prioritisation approach (RUPA) (Voola & Babu 2012), value-based intelligent RP (VIRP) (Ramzan et al. 2011), Evolve (Greer & Ruhe 2004) PHandler (Babar et al. 2015c) and StakeRare (Lim & Finkelstein 2012) are amongst pioneer techniques that consider SQP in their prioritisation process.

Table 2.1 presents the execution process used to performed SQP process in prioritisation processes of each technique. In RUPA VIRP and Evolve, the execution is based on manual adoption of the AHP-based method (Ramzan et al. 2011; Voola & Babu 2012) without providing details of the execution steps, and depend heavily on the involvement of the experts to conduct the process with (Ramzan et al. 2011; Voola & Babu 2012). Although, PHandler and StakeRare provide more clear implementation steps of conducting the SQP process than do RUPA (Voola & Babu 2012) and VIRP (Ramzan et al. 2011), they are depend heavily on the involvement of the experts to conduct the process and lack of providing measurement criteria for evaluating the stakeholders based on the SQP attributes. Also, In PHandler and StakeRare, the SQP is executed manually and time consumption.

Table 2.1 SQP Execution Process of the RP Techniques

Technique Name	Execution process
Evolve (Greer & Ruhe 2004)	Using AHP
Mathematical programming techniques (Li et al. 2010)	Based on (Li et al. 2010), the SA was performed, but the detail of how SQP was executed, had not been provided in prioritisation process of this technique
PHandler (Babar et al. 2015c)	Weighting the stakeholders is performed by experts manually, which it consumes time
Requirement uncertainty prioritisation Approach (RUPA) (Voola & Babu 2012)	Manually Weighting the participated stakeholders using AHP or by experts, project managers.
Value based intelligent requirement prioritisation (VIRP) (Ramzan et al. 2011)	The experts review each stakeholder profile and allot a score in the range of 1-10 for each stakeholder based on his significance and the overall impact that requirements posed by him may have on the success of the project.
StakeRare (Lim & Finkelstein 2012)	Weighting the stakeholders is performed manually on the basis of the stakeholders' recommendations and human expertise is exceedingly desirable in order to initiate and execute the technique

iii. Deficiency of the automation level and not being cost-effective with respect to time utilisation in RP and SQP.

Time is ordinarily critical in the industrial side, which makes it a crucial variable for the evaluation and implication of RP and SQP techniques (Achimugu et al. 2014d; Babar et al. 2014a, 2015b; Berander et al. 2006; Ma 2009; Ramzan et al. 2009).. From the analysis findings of the conducted SLRs (SLR-RP and SLR-SQP), it was notices that most of the existing techniques perform the SQP process and RP manually with lack of automation level and being time-consuming (Achimugu et al. 2014d; Babar et al. 2014a, 2015b).

Conducting the RP and SQP processes without employing the automation influences the efficiency of the technique with respect to it being more complex and not cost effective with time utilisation when quantifying and prioritising the stakeholders and prioritising the requirements (Achimugu et al. 2014d; Babar et al. 2014a, 2015b; Ma 2009). As the time consumption grows when of the number of requirements increases due to the complex manual process that will be required to execute the computational calculation to measure the relative impact of each stakeholder in RP and identify the relative priority value of each requirement (Achimugu et al. 2014d; Babar et al. 2014a, 2015b; Ma 2009). This manual computational complexity requires more effort in terms of time and increases the likelihood of human errors, indicating that the technique is impractical in a real scenario of being adopted in evaluating the participating stakeholders in RP and prioritising the requirements (Achimugu et al. 2014d; Babar et al. 2015b; Ma 2009). Thus, the performance of techniques still need to be improved by introducing an automated and intelligent system that will assist in minimising the computational complexity of the manual process. The fact of introducing the auditioned the predominant notion is that automation and intelligent process support of prioritisation will enhance the time effectiveness and scalability because some of the effort can be turned to the automation and intelligent process(Ma 2009).

iv. Lack of low-level implementation details of the SQP process, and absence of providing standard measurement criteria for stakeholder evaluation

As can be revealed from the conducted analysis of the existing SQP techniques in Table B.3 of Appendix B, the SQP existing techniques do not support low-level details of implementation for the SQP process (Babar et al. 2014a, 2015b). The proposed steps for executing the SQP process along with the attributes used for evaluating the stakeholders are presented without in-depth implementation details. Additionally, all of the existing SQP techniques fall short of presenting the measurement criteria for each attribute used in measuring the priority value for each stakeholder lead to induce the ambiguity in quantifying and prioritising stakeholders based on the SQP attributes and leads to the adoption of techniques that are difficult to implement in real project development (Babar et al. 2014a). The incapability of the technique in providing low-level details of implementation for the SQP process, along with the absences of attribute measurements criteria, induce low accuracy results since the ambiguity in the existing techniques can lead to a threat of executing the process in contrary to or beneath the standards expected in a specific profession Babar et al (Babar et al. 2014a, 2015b).

v. Overreliance on the participation of the professional expertise in conducting the RP and SQP

Even though, the usefulness of the RP and SQP techniques, a good human expertise is exceedingly desirable to be employed in order to initiate and execute the technique (such as assigning the priority value for each requirements, classifying the requirements and the evaluating the influence of participating stakeholders in the prioritisation). Heavily relying on the involvement of professional expertise is not preferred owing to human biases parameters and unavailability of experts that consequently can impact the accuracy of the technique (Aasem et al. 2010; Babar et al. 2015b, 2015c). (Babar et al. 2015b, 2015c). Possible biases can occur when experts evaluate the stakeholders with a given input of the impact value of each participating stakeholder in RP and specifying the priority value of the requirements or/and classifying the requirements. These biased inputs or evaluations can significantly impact the quality of the technique in terms of identifying the accurate priority values of the stakeholder, which will negatively impact the reliability of measuring impact values of the stakeholders RP process, identification of the accurate requirements priority values and specification quality of the most important requirements to be developed in order to secure a successful software system project (Achimugu et al. 2014d; Babar et al. 2015b, 2015c).

Concerning the issue of the unavailability of experts, Overreliance on the participation of the professional expertise is not preferred due to threats that are related to the validity of the technique in case there is a shortage of expertise in the SQP domain. In such a case, the execution of the technique (which requires good expertise in the stakeholder analysis) without the participation of good expertise can lead to difficulty in absorbing and interpreting the requirements needed in executing or initiating the technique, along with the issue of increasing the possibility of implementing the technique in a non-proper and professional way that will directly influence the quality of the result produced (Babar et al. 2015b, 2015c).

To address these key challenges, this research proposes a new semi-automated scalable RP technique called SRPTackle along with a new SQP technique namely, StakeQP. The StakeQP aims to perform SQP and produce a prioritised list of stakeholders automatically, removing the manual process with less time consumption as well as providing clear and low-level implementation details to be easily applied in academics and industries. Moreover, StakeQP includes the attribute measurement criteria which are proposed for use in evaluating each stakeholder's influence on the basis of SQP attributes to minimise the need for expert involvement during the SQP, thereby reducing the expert biases, as well as solving the issue of expert unavailability. Furthermore, the automation tool is developed and presented to automate the StakeQP process.

Whereas, the SRPTackle provides a semi-automated process on the basis of the combination of the constructed requirement priority value formulation function and the employing of classifying algorithm (K-means and K-means++) and binary search tree in order to minimise the need for the experts' involvement and make the SRPTackle efficient in term of time effectiveness and scale well to large set of requirements. Also, n automation implementation tool (SRPTackle-Tool) is developed along with providing clear implementation guidelines to automate the SRPTackle process and support straightforward implementation of the proposed technique in industrial and academic sectors for eliminating the manual process and minimising the time consumptions needed in conducting the prioritisation process.

2.6 Chapter Summary

This chapter provided a comprehensive investigation on the RP and SQP domains by conducting two SLR (SLR-RP, SLR-SQP respectively) to analyse and highlight the research gap precisely. The outcome of the SLR-SQP review demonstrated that the SQP process plays a key role in identifying the most critical requirements that lead towards the success of the developed system. SQP attributes were also reported along with the degree of importance of each reported attribute. Moreover, the existing techniques that focus on and discuss the quantification and prioritisation of stakeholders were identified and analysed with respect to their process description, usage attributes, types, and limitations. The identified existing techniques still face major limitations, such as the lack of low implementation details, lack of automation level, heavy reliance on the involvement of experts, time consumption, and absence of providing measurement criteria for each SQP attributes used in evaluating the stakeholders. Hence, these results present a strong reason to research the SQP domain further, and there is a need to develop a new technique that can provide solutions to the aforementioned limitations. In this research, a new semi-automated SQP technique (StakeQP) is proposed and presented in the chapter 4 to address the aforementioned SQP limitations

On the other hand, SLR-RP findings indicated that RP plays a vital role in ensuring the development of a quality system with defined constraints. The stakeholders involved in RP were reported, and new categories of the participating stakeholders were proposed. Additionally, 108 RP techniques were identified and analysed with respect to their benefits, prioritisation criteria, size of requirements, types in terms of automation level and their limitations. The analysis results revealed that limitations still exist in spite of the existence of current RP techniques. These limitations include time complexity, scalability, lack of automation level, lack of quantification and prioritisation for the participating stakeholders and need for substantial professional involvement. Therefore, in the chapter 5, a new semi-automated scalable RP technique (SRPTackle) is proposed with integration with new SQP technique (StakeQP) (that aims to perform the SQP for the participating the stakeholders in RP) to address the identified RP limitations. The next chapter (chapter 3) will provide a precise elaboration regarding the research methodology process, which presents the methodology used in conducting this research.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

In this research, a technique is proposed for scalable requirement prioritisation integrated with a new SQP technique. Thus, this research includes two dimensions, the main dimension centred on RP with focus on the SQP as sub dimension, which is needed to evaluate the participating stakeholders in the requirements prioritisation process. This chapter provides a comprehensive description of the methodology used in conducting this research. The chapter starts with providing a detailed explanation of the research methodology process in Section 3.2, followed by a chapter summary presented in Section 3.3.

3.2 Research Methodology Process

Figure 3.1 presents the research methodology process of this research, comprised of six stages which are planning, investigation, design and implementation, evaluation, and conclusion stages. Each stage has its own specified activities that are executed to deliver the output of the stage. The following subsections provide a detailed explanation for each listed stage of the research methodology process used.

3.2.1 Planning Stage

The planning stage of this research involved constructing the research objectives, scope, questions. The research scope was defined in order to specify the boundaries of this research, specifically on the domain of the requirements prioritisation along with stakeholder quantification and prioritisation. A full explanation of the output of this phase was provided in chapter 1.

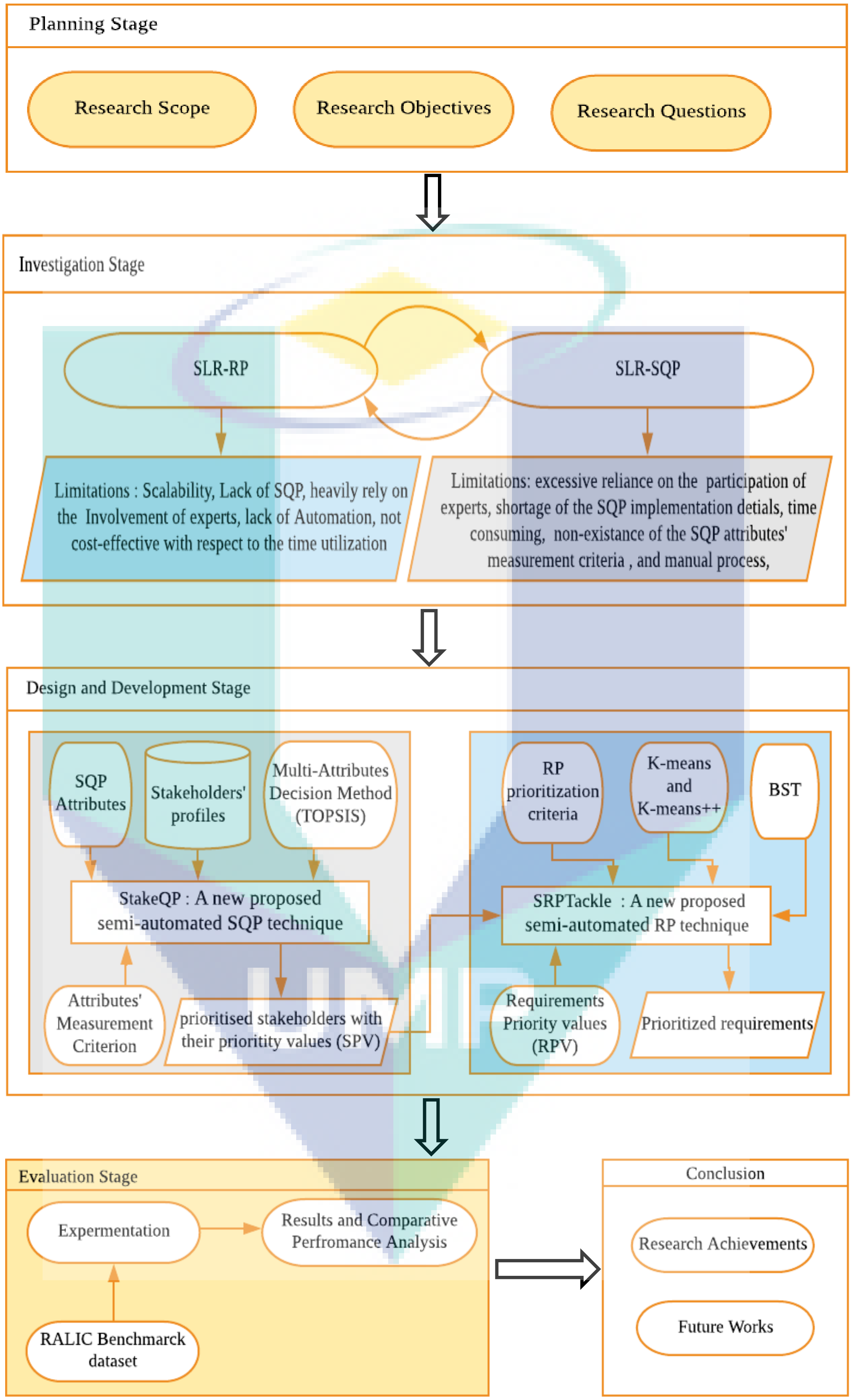

Figure 3.1 Research Methodology Process

3.2.2 Investigation Stage

Investigation stage aimed to provide critical exploration and analysis of the existing related works of the RP and SQP. The investigation phase was conducted by executing two systematic literature reviews: SLR-SQP and SLR-RP.

SLR-RP provides a comprehensive review on the requirements prioritisation domain via selecting and critically studying published studies by the current researcher that are relevant to the specified area. To achieve the aim, this research conducts a SLR on this topic. The output of the SLR-RP contributes to this research by scouting and discussing the RP domain in terms of providing available proof of the impacts and the importance of RP in system development process, presenting types of the stakeholders involved in prioritisation process, proposing categories of the identified RP stakeholder types, and identifying and analysing the existing RP techniques critically based on their prioritisation criteria, limitations, types with respect to the automation level, size of requirements to be prioritised with, and benefits.

The SLR-SQP specifically focuses on the SQP process in requirement prioritisation (RP) with respect to SQP importance in RP, SQP attributes, existing techniques, and limitations. The SLR-SQP explored the stakeholders' quantification and prioritisation domain in terms of providing available proof about the importance of SQP, identifying the attributes that are used to quantify and prioritise the stakeholders, and presenting and analysing current SQP techniques in terms of their implementation process description, types, and limitations.

The delivered outputs of this phase was the research gap, which indicate to the current limitations of RP and SQP. The SLR-RP reveals that the existing techniques still suffer serious limitations in terms of scalability, lack of SQP process, not cost effective in term of time utilization in prioritising the large set of requirements, lack of automation level, and the need of highly professional human intervention in term of the conducting the SQP process for evaluating the participating stakeholders and identifying the priority value of each requirement in RP process. On the other hand, the findings of the SLR-SQP reveal that the current SQP techniques face core challenges with respect to the lack of low-level implementation details, lack of automation, non-existence of measurement criteria for the attributes used to evaluate the stakeholders, time consumption, and heavy reliance on the involvement of experts. An in-depth explanation of these limitations was given in the chapter 2 of this research.

The SLR was selected as the research method to conduct the SLR-RP and SQP. The SLR method is aimed to evaluate all the existing studies that are relevant to the specific topic area in order to present a fair evaluation of a research topic by using a trustworthy, rigorous, and auditable methodology (Kitchenham & Charters 2007). The research methodology to conduct the SLR was based on the standard SLR guidelines proposed by Kitchenham et al. (Kitchenham & Charters 2007). Figure 3.2 shows the adopted research review protocol which consists of five phases: research questions; search process strategy; selection criteria including inclusion, exclusion, and quality assessment criterion; data collection along with data synthesis; and obtained result.

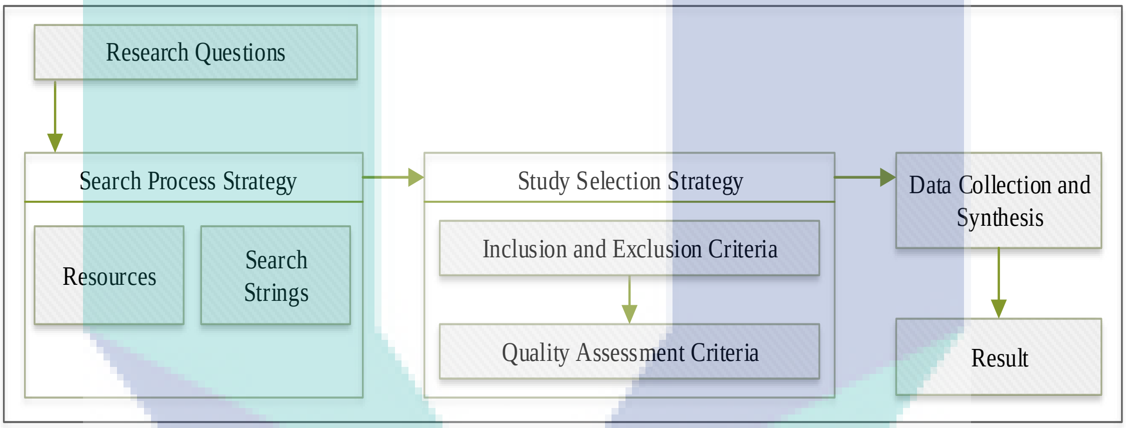

Figure 3.2 SLR-RP and SLR-SQP Review Protocol

The review protocol of each conducted SLR-RP and SLR-SQP is elaborated in section A.4 of Appendix A and section B.4 of Appendix B, respectively.

3.2.3 Development Stage

In this research, a new RP technique (SRPTackle) and a new SQP technique (StakeQP) are proposed in order to address the limitations that are revealed in the analysis phase and discussed in detail in chapter 2. SRPTackle aims to provide semi-automated process for prioritising large set of requirements based on the stakeholders' preferences. Whereas, the StakeQP technique is proposed with new attributes' measurement criteria for quantifying and prioritising the participating stakeholder in the RP process by identifying the stakeholder priority value (SPV) for each stakeholder, which will be used as input in the proposed SRPTackle. Therefore, it was essential to first design and develop the proposed SQP technique. In this phase, the design and development structure of the proposed SRPTackle and StakeQP techniques is presented. The following subsections present a detailed description of the design and development structure of the proposed StakeQP and SRPTackle techniques.

3.2.3.1 StakeQP technique

The SRPTackle structure design and development was constructed based on the basic features of SQP (that elaborated in Section 2.3 of chapter 2). Figure 3.3 presents the structure design and development of proposed StakeQP, which consists of the five components and the explanation of each component is as follows:

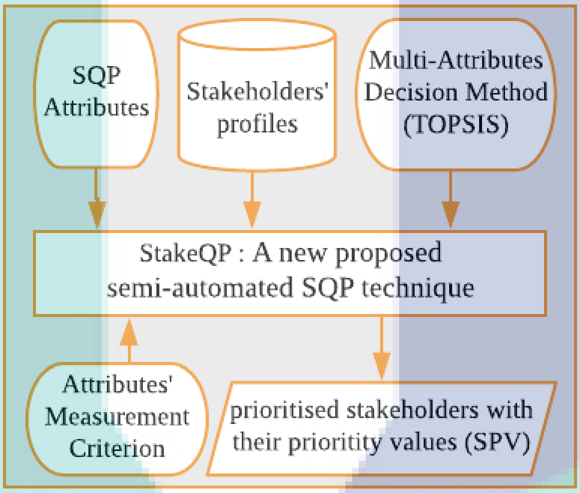

Figure 3.3 StakeQP Structure Design and Development

1. SQP attributes: the stakeholders are quantified and prioritised based on the different SQP attributes, thus SQP is considered as essential feature to be considered in SQP (Babar et al. 2015b). The existing attributes of the SQP were retrieved from the literature exploration. However, those attributes with the highest impact are to be given special consideration in SQP process, particularly in terms of identifying the requirements and successful system project development requires the utilization of the proposed technique in order to evaluate the stakeholder’s impacts. A detailed description of the StakeQP attributes is given in chapter 4.

2. Attributes’ Measurement Criterion: the measurement criteria are proposed for each considered SQP attribute. The considered SQP attributes along with their

proposed measurement criteria are utilized in order to compute the priority values for each participating stakeholder in the requirements prioritisation process.

3. Stakeholders' profiles: The stakeholder profile is another element to be considered in SQP. The stakeholders' profiles are derived from the documentation of the project in which its stakeholders must be quantified and prioritised by the StakeQP. The profile of each stakeholder should include the information details of each stakeholder with respect to the role responsibility, job scope, and experience, education background of each participated stakeholder. These stakeholders' profiles will be used as an input in calculating the priority value for each participated stakeholder using the predefined attributes and their proposed measurement criteria.

4. Application of the TOPSIS method: Multi attribute decision making (MADM) refers to the process of evaluating and ranking the number of alternatives on the basis of multiple defined attributes or criteria (Ishizaka & Nemery 2013; Mattiussi et al. 2014; Tzeng & Huang 2011; Zaidan et al. 2015). Several existing methods have been proposed to conduct the process of MADM (Mattiussi et al. 2014; Zaidan et al. 2015). One of these existing methods is TOPSIS (stands for Technique of Order Preference Similarity to the Ideal Solution) (Behzadian et al. 2012; Tzeng & Huang 2011; Velasquez & Hester 2013), which was initially introduced by Hwang and Yoon in 1981 (Tzeng & Huang 2011). It is a useful and practical technique that can be used in decision making for selecting and ranking a specified number of alternatives over listed criteria or attributes (Shih et al. 2007; Tzeng & Huang 2011). TOPSIS has the features of simplicity and speed, where the best alternatives can be revealed in a shorter time with a simple computation process compared with other techniques, such as AHP (Parkan & Wu 1997; Shih et al. 2007). Its output is simple and can be easily understood. Moreover, TOPSIS is executed with certain number of steps, which remain the same regardless of the alternative size and number of attributes (Shih et al. 2007; Velasquez & Hester 2013).

   With respect to the number of required inputs from the decision makers, TOPSIS does not require as many inputs as the other methods (Ishizaka & Nemery 2013; Olson 2004; Velasquez & Hester 2013). The only required input is related to the weight value for each defined attribute to initiate the process (Ishizaka &

Nemery 2013; Olson 2004; Velasquez & Hester 2013). However, the difficult issue of inputting and estimating the needed input of the attribute weights is controlled in this research, where the weight value of each StakeQP attribute is formulated based on stepwise procedure which will be elaborated in chapter 4. Therefore, TOPSIS is used to evaluate and rank the stakeholders (who are represented as alternatives) based on the defined proposed StakeQP attributes which are used as attributes. The alternatives will be indicated to the stakeholders which will be evaluated by the attributes which represent the StakeQP attributes. A detailed description of the process of the proposed StakeQP will be discussed in chapter 4.

3.2.3.2 SRPTackle Technique

Certain sub-components were designed and developed in order to come out with proposed (SRPTackle) in this research. The SRPTackle structure design and development was constructed based on the basic elements of conducting RP (that discussed in Section 2.2 of chapter 2). Figure 3.4 presents structure design and development of the proposed SRPTackle ,which consists of the following components:

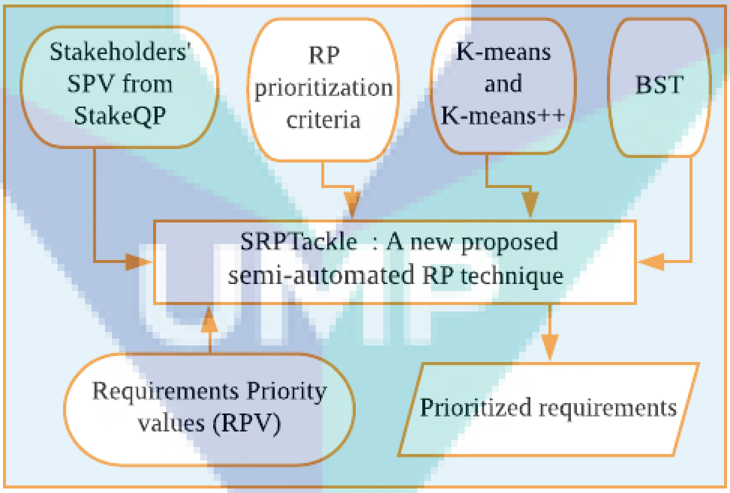

Figure 3.4 SRPTackle Structure Design and Development

1. Stakeholder priority value (SPV) of the participating stakeholders from the StakeQP: Stakeholders and evaluating their influences in RP process are considered one of the feature that should be consider in developing new RP. Therefore, the StakeQP technique performs the quantification and prioritisation for participated stakeholders in the prioritisation process by identifying the

priority value for the stakeholders (SPV). List of stakeholders SPV is the output of the StakeQP, which will be used as an input in this proposed SRPTackle to calculate the priority value for each system's requirement. Using the proposed StakeQP technique in quantifying and prioritising the participating stakeholders will reduce the need for heavy involvement of the expert and minimises the biasness that they pose.

2. RP prioritisation criteria: Specifying the prioritisation criteria is an essential element that should considered in designing new RP technique. In the proposed SRPTackle, the selection of the criteria used in prioritisation process of the proposed technique is derived from the literature exploration, where the analysis of the used RP prioritisation criteria with the current techniques was conducted in Section 2.4.2.3, chapter 2. It has been found that the importance and cost criteria are the most significant aspects in order prioritise the requirement. The importance criteria is used to prioritise requirements on the basis of their importance to functional beneficiary stakeholder (users and customers) needs in order to estimate their expected satisfaction (Karlsson & Ryan 1997; Lim 2010; Lim & Finkelstein 2012; Svensson et al. 2011). At the same time, prioritising the requirements based on the cost criteria is performed by technical stakeholders such as the development teams to specify the priority order of the requirements based on the required cost value for each requirement to be implemented (Karlsson & Ryan 1997; Sher et al. 2014a; Svensson et al. 2011). Therefore, the usage of these two criteria (importance and cost) will assist in guaranteeing the production of a balanced list of prioritised requirements on the basis of points of view of the all stakeholder types (functional beneficiary, technical and commercial stakeholders). Also, most of the current industrial companies aim to prioritise the requirements based on the importance prioritisation criteria to obtain the stakeholders' expectations and use cost aspect to prioritise based on required cost for implementing each requirement (Svensson et al. 2011).

3. Requirements priority values (RPV): One of the basic elements of conducting the RP is related the process, where requirements are prioritised by identifying the priority value of each requirement , classifying them and producing a ranked list of requirements (Achimugu et al. 2014d). In the proposed SRPTackle, the priority value for each requirement is calculated by considering the requirement's weight,

which is obtained from the involved stakeholder in RP process based on the selected prioritisation criteria (importance and cost) along with the obtained SPV of the stakeholder. The full details of the formula used to calculate the RPV is going to be discussed in chapter 6. The execution of calculating the RPV is performed automatically and the produced PRV of each requirements is then given as input to the K-means and K-mean ++ for classifying the requirements.

4. K-means and K-means++: There are two type of the data classification learning, supervised and unsupervised learning (Celebi et al. 2013). Supervised learning is related to the function that presents the structure of a labelled set of data (Celebi et al. 2013; Rokach & Maimon 2010). The labelled set of data is a group of data points that have been assigned to one or more class labels, which is used in training and teaching the machine to predict the correct grouping structure in the data based on the defined class labels (Mohammed & Chee Peng Lim 2015; Rokach & Maimon 2010). Unsupervised learning deals with unlabelled set of data, where data point is presented with no predefined class labels for the data sample (Celebi et al. 2013). Thus, the aim of unsupervised learning is to describe the structure of unlabelled data, which can be performed by unsupervised model such as clustering (Celebi et al. 2013; Rokach & Maimon 2010). Clustering is unsupervised learning classification with aim of classifying the unlabelled data points into several classifications with respect to information found in the data that describes the points and their relations such as suitable similarity measure(Celebi et al. 2013; Rokach & Maimon 2010).

One of the commonly used clustering algorithm is K-means (Arthur & Vassilvitskii 2007; Celebi et al. 2013). The K-means aims to cluster the data points into number of clusters and each cluster has its own centroids in which each point is grouped to the cluster with the nearest centroid (Rokach & Maimon 2010; Selim & Ismail 1984). K-means has salient properties of simplicity (simple and easy to be implemented in handling practical problems) (Celebi et al. 2013; Xu & Tian 2015; Xu & Wunsch 2005), computationally fast (speed) (Celebi et al. 2013; Xu & Tian 2015; Xu & Wunsch 2005) and efficiency in working with large datasets that contain numeric values (Arthur & Vassilvitskii 2007; Celebi et al. 2013; Huang 1998; Ordonez & Omiecinski 2004; Xu & Tian 2015)as compared other clustering methods such as K-medoids, PAM, CLARA and FCM. Thus, the

K-means is used in this research to cluster the requirements based on their obtained RPV, in which numeric values represent the priority value of each requirement.

The performance of the K-means with respect to speed (time utilization with number of iterations) and accuracy to find the optimal clustering can be affected by random initialization of the clusters' centroids, as improper centroid initialization can lead to drawbacks in terms of slower convergence (may require a high number of iterations to converge), empty clusters, and a higher probability of getting stuck in bad local minima which can present low accuracy result of clustering the data (Arthur & Vassilvitskii 2007; Celebi et al. 2013; Ordonez & Omiecinski 2004).

Hence, the K-means is considered to be sensitive to initial centroids selection and this can be handled with adapting proper initialization method for initializing the cluster centroids instead of random selection (Arthur & Vassilvitskii 2007; Celebi et al. 2013). K-means ++ algorithm is presented by (Arthur & Vassilvitskii 2007) as initialization method for centroids selection of the K-means. The K-means ++ added new value by improving the accuracy and the speed of the K-means algorithm as proven in (Arthur & Vassilvitskii 2007). Improvements are made by proposing new initialization method to initialize the cluster centroids in K-means. Nevertheless, the initialization method of K-means++ has been proven to address sensitivity to initial centroid selection issue and the performance of the K-means using K-means ++ initialization method substantially outperformed K-means with random centroids initialization in terms of producing more accurate clustering solution, and less time consumption of conducting the clustering process as fewer iterations are conducted to assist in achieving the local search converge (Arthur & Vassilvitskii 2007). Also, the process of K-means++ is fast and easy to implement in real practice (Arthur & Vassilvitskii 2007; Celebi et al. 2013). As a result, the K-mean++ is selected in the SRPTackle as initialization method for centroid selection of K-means algorithm. In this research, the number of clusters (K) is specified to be three based on the numerical assignment technique categorized as high, medium, low.

With large number of clusters (e.g. 100 clusters), the speed performance of the K-mean++ can be reduced due to the requirement of high number of iterations, which lead to some time utilization constraints in application of massive data practices (Arthur & Vassilvitskii 2007; Celebi et al. 2013). This may relate to the sequential nature of the K-mean++ by making an iteration over the data in order to initiate each centroid, where 99 iterations are required to find the centroids for the 100 cluster as the number of iterations is equal to(K-1) in K-means++ (Arthur & Vassilvitskii 2007; Celebi et al. 2013). However, with the specified number of clusters in the SRPTackle (three clusters), the K-mean ++ can perform the initialization for three cluster centroids without being time consuming as K-mean++ will need only two iterations to initialize three cluster centroids (as the first centroid is assigned uniformly at random from the data points and then two iterations to initialize the other two centroids(k-1)) (Arthur & Vassilvitskii 2007; Celebi et al. 2013). A detailed description of executing the clustering process with K-means algorithm along with K-means++ centroids initialization method in the proposed SRPTackle is explained in detail in chapter 5.

5. Binary Search Tree (BST): Several sorting methods are used to sort the requirements such as binary priority List , BST, bubble sort, and spanning tree matrix and AHP (Achimugu et al. 2014d; Bebensee et al. 2010; Beg et al. 2008; Karlsson et al. 1998). However, the BST has better effectiveness in dealing with large number of data to be sorted in ranked list with fewer comparisons, which leads to less time consumption as compared to another alternative methods such as bubble sort, spanning tree matrix, and AHP (Achimugu et al. 2014d; Ahl 2005; Khari & Kumar 2013; Lim & Finkelstein 2012). However, a drawback of using BST in requirements prioritisation is related to providing a simple ranking of requirements (without revealing to what extent each requirement is more essential than another) as no priority value is assigned to each requirement (Duan et al. 2009; Khari & Kumar 2013; Lim & Finkelstein 2012). In the proposed SRPTackle technique, the priority value of each requirement RPV is obtained from function of the formulation the RPV. Thus, the BST is selected in this research to generate the prioritised list of requirements in each cluster based on the obtained RPV of each requirement.

3.2.4 Evaluation Stage

The experimentation evaluation method was used to evaluate the proposed SRPTackle and StakeQP techniques with utilizing the RALIC benchmark dataset (Lim 2010; Lim et al. 2010). The RALIC dataset is a real industrial benchmark dataset for RALIC project that is considered as large-scale software project and stands for Replacement Access, Library and ID Card (Lim 2010; Lim et al. 2010). This software system project was initiated and developed as new access control system at University College London (UCL).

The development duration of RALIC project was two and a half years and was then implemented and used at UCL. The data collection of the RALIC project datasets were collected by Soo Ling Lim at the UCL. The documentation reports of selected RALIC project are provided in the RALIC dataset and the thesis of Soo Lim (Lim 2010; Lim et al. 2010).

To the best of our knowledge, the benchmark dataset of RALIC is the only available and complete dataset in RP and SQP domains that contain large set of requirements and stakeholders. Compared to other used datasets, the RALIC dataset includes detailed information of the large number of requirements and stakeholders of the RALIC project. The full details of the stakeholders' profiles and the requirement ratings from each participating stakeholder in the prioritisation process along with providing the ground truth that present the actual priority ranks of the RALIC stakeholders and the requirements, which can be used in evaluating the performance accuracy. Consequently, this dataset has been used in the evaluation of some of the existing RP and SQP techniques such as in (Achimugu et al. 2014a; Lim 2010; Lim et al. 2012, 2010; Lim & Finkelstein 2012; Ling Lim et al. 2011).

As a result, the RALIC benchmark dataset was selected to be used in order to evaluate the proposed SRPTackle and StakeQP techniques. The performance evaluation of the proposed techniques was conducted in order to assess the performance of the proposed techniques' accuracy and time consumption. Comparative performance analysis was also conducted to compare the performance of the proposed StakeQP and SRPTackle with existing techniques.

The stakeholders' agreements (satisfaction or perception) and comparison with the actual result are methods that can be used in measuring the technique's accuracy in the SQP and RP domains. Stakeholders agreements method is related to assessing the accuracy performance by evaluating the produced result from the point of view of stakeholders, where the percentage of stakeholders' agreements (or disagreements) on the produced result are revealed.

On the other hand, comparisons with actual result is conducted by comparing the produced result of the technique with actual result of the used projects' dataset. In this research, comparison with actual result is selected as the measurement method for assessing the accuracy performance of the proposed SRPTackle and StakeQP. The used RALIC dataset has the actual result of the RALIC project, known as ground truth of the prioritised requirements and the stakeholders, that has been built based on a rigorous and systematic process based on the stakeholder satisfaction or preferences.

Also, the selection of the comparison with actual result method will assist in a fair comparison with other existing techniques that used RALIC dataset in evaluating their performances with comparing their result with the actual data (the ground truth) of RALIC. The detailed structure of RALIC are as follows:

i. 410 raw textual description of requirements provided by stakeholders
ii. 1514 ratings from the same 76 stakeholders on 49 general requirements
iii. 3113 ratings from the same 76 stakeholders on 104 specific requirements
iv. 469 ratings from the same 79 stakeholders on 51 requirements
v. 1109 ratings from the same 79 stakeholders on 132 specific requirements
vi. 670 ratings from the same 77 stakeholders on 45 requirements
vii. 1219 ratings from the same 77 stakeholders on 83 specific requirements
viii. Details of Stakeholders' profiles
ix. Ground truth of the prioritised requirements and the stakeholders

The full details of the evaluation phase with using RALIC benchmark dataset in the proposed techniques are discussed previously in chapter 4 for StakeQP technique and chapter 5 for SRPTackle.

3.2.5 Conclusion Stage

In this phase, conclusion of this research was discussed by analysing the obtained results of this research in order to elaborate the achievements of this research in attaining the defined research objectives. Therefore, the achieved objectives of this research are illustrated in detail. Lastly, the future recommendations were specified and discussed in order to enhance the performance of StakeQP and SRPTackle.

3.3 Chapter Summary

This chapter illustrated the research methodology framework of this research. The used research methodology process is comprised of six stages which are planning, analysing, designing and implementation, evaluation, and results and conclusion. Each stage was explained in a thorough manner by discussing the sub activity of each stage which was required to be executed in order to accomplish the defined research objectives. The next chapter (chapter 4) presents the proposed StakeQP technique to solve the issue of lack of SQP in RP process and the limitations that are related to the current SQP techniques with respect to the shortage of low-level implementation details, non-existence of measurement criteria for the SQP attributes, lack of automation and intelligence level, time consumption, and heavy reliance on the involvement of experts in conducting the SQP process.

CHAPTER 4

STAKEQP: THE PROPOSED SEMI-AUTOMATED STAKEHOLDER QUANTIFICATION AND PRIORITISATION TECHNIQUE

4.1 Introduction

The findings of SLR-SQP in chapter 2 stated that the existing SQP techniques are facing certain issues with respect to lack of low process level details of SQP process, non-existence of standard measurement criteria for evaluating the stakeholders impact based on the SQP attributes, time consuming, lack of automation level, heavy reliance on the involvement the experts in performing SQP process, which promotes issues of natural human biases and availability of the experts (Babar et al. 2014a, 2014b, 2015b; Ballejos et al. 2007; Ballejos & Montagna 2011; Bendjenna et al. 2012).

Therefore, based on the reported limitations of the existing SQP techniques, the impulse of this research is stated to present proposes a new SQP technique (StakeQP) that can perform the SQP process with less time consumption and produce the prioritised list of stakeholders automatically to remove the manual process, reduce the need for the excessive reliance on human intervention, and provide low implementation details to be easily implemented in the academic and industrial sides. Another key contributing element of the proposed StakeQP is related to the inclusion of the new attribute measurement criteria (AMC). These measurement criteria are proposed to be used in evaluating each stakeholders impact based on the SQP attributes in order to minimize the need for the expertise' involvement during SQP process to reduce the expert biases along with solving the issue of the expert's availability. Furthermore, the automation tool is developed and presented to automate the StakeQP process. In order to assess the performance of the proposed StakeQP technique, the benchmark dataset of RALIC industrial project documented in (Lim 2010; Lim et al. 2010) is used to implement and evaluate the performance of the StakeQP and compare its performance result with other existing SQP techniques.

The rest of this chapter is structured into four main sections. Section 4.2 illustrates the proposed StakeQP technique in detail with respect to its proposed phases. Section 4.3 elaborates the developed automation tool along with implementation guidelines. Section 4.4 presents the evaluation of the proposed technique StakeQP. Section 4.5 enumerates the threat of the validity and Section 4.6 concludes this chapter.

4.2 Proposed StakeQP Technique

The process of the proposed StakeQP technique is shown in Figure 4.1. This technique aims to quantify and prioritise the stakeholders. The StakeQP process consists of three main phases, which are as follows:

i. Phase 1: Establishment phase:

a. Finalise the StakeQP attributes

b. Propose the AMC for each StakeQP attribute.

c. Formulate the StakeQP attributes weight values and attributes measurement criterion values.

ii. Phase 2: Stakeholders' profiles Collection.

iii. Phase 3: Formulate the stakeholder priority value (SPV) by calculating the stakeholder attribute value (SAV) and employing the TOPSIS method.

4.2.1 Establishment Phase:

The establishment phase is constructed initially in the StakeQP technique to present the low-level details of the StakeQP attributes along with their proposed AMC and to specify the weights of each StakeQP attribute with its AMC on the basis of the experts' inputs. These specified weight values of the attributes and the AMC are used to measure and assess the importance of the stakeholders for each StakeQP attribute. Then these attributes are used in specifying the final SPV while minimising the need for direct expert involvement in assigning the SPV to the stakeholder. Therefore, this phase is considered to be the basis for performing the full process of the proposed StakeQP technique. This phase consists of three sub-phases, and the explanation of these phases is illustrated precisely in following sub-sections.

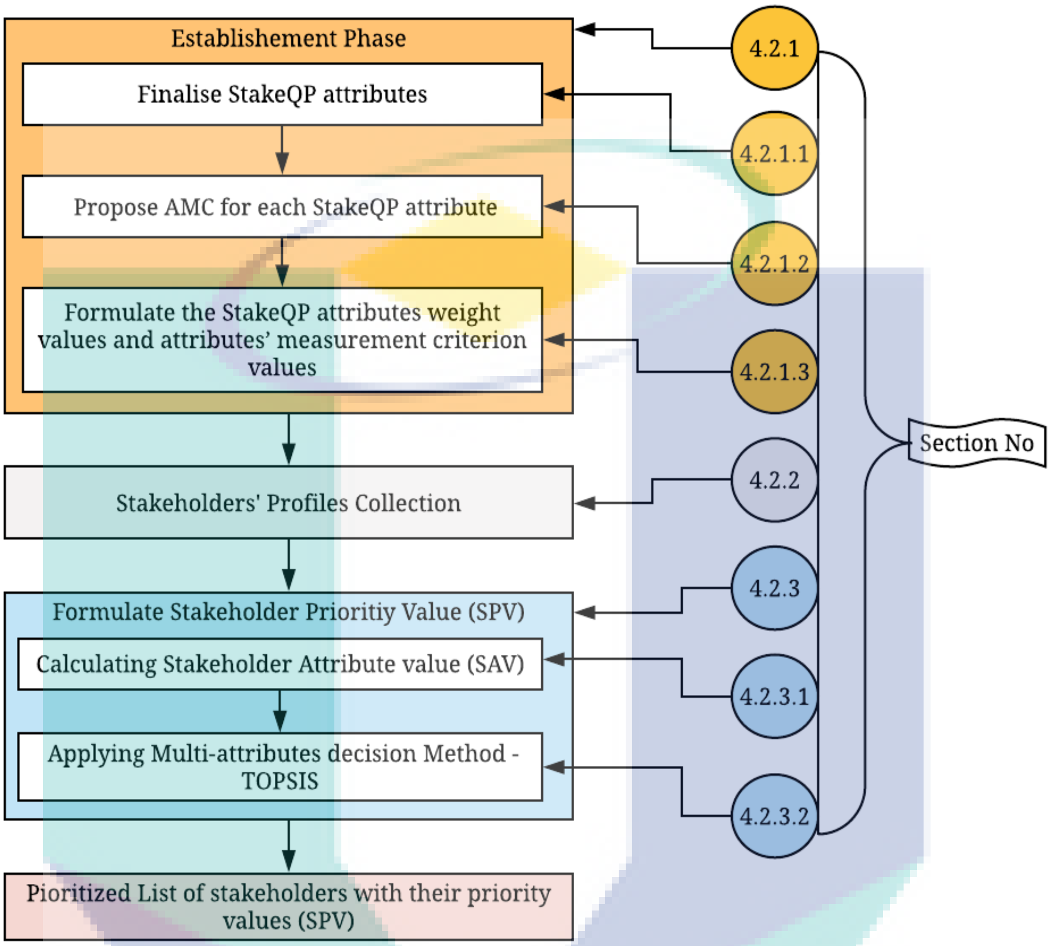

Figure 4.1 Process of StakeQP Technique

4.2.1.1 Finalising the StakeQP Attributes of Quantifying and Prioritising the Stakeholders

As discussed in chapter 2, Section 2.3, SQP attributes is one of the elements that should be specified in order to quantify and prioritise the stakeholders. Thus, the first step of the proposed technique is to finalise the attributes that will be used to perform the SQP in the StakeQP. Figure 4.2 presents the attributes selected for use in the SQP of the proposed technique

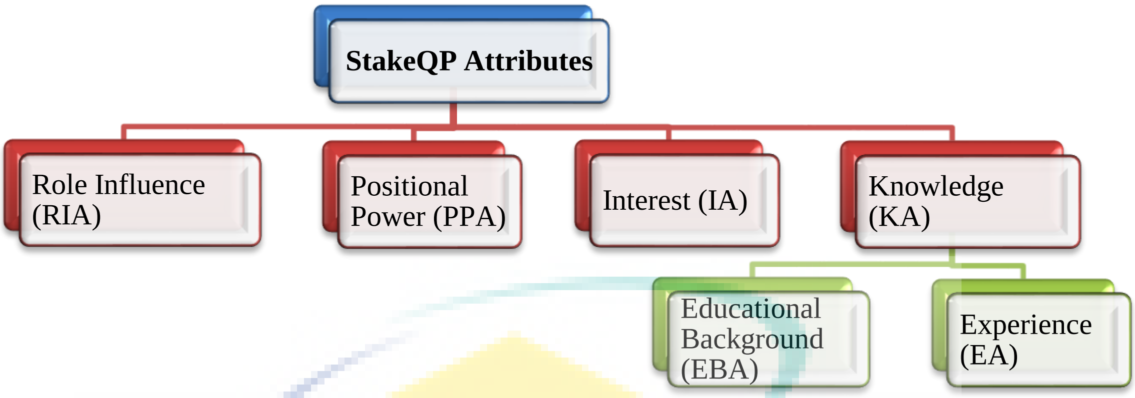

Figure 4.2 StakeQP Attributes

Four main attributes and two subdivided attributes are selected. These attributes include the role influence (RIA), the positional power attribute (PPA), interest (IA), and knowledge (KA), which is further subdivided into two attributes: experience (EA) and educational background (EBA). These attributes are referred to as StakeQP attributes in this study. Table 4.1 presents the definition of the StakeQP attributes. These attributes are retrieved from the literature review of SLR-SQP.

Table 4.1 Definitions of StakeQP Attributes

Attributes	**Description**	**Usage**
RIA	The influence of the stakeholder's role responsibility	To measure the degree of influence of the stakeholders' role
PPA	The level of the stakeholders' authority based on their positional power that can be imposed on the project's development or objectives	To measure the authority level of the stakeholders over a project
IA	The level of concern of the stakeholders towards achieving the defined goals of the system project	To measure the concern or willingness level of the stakeholders to allow the system project to satisfy its specified objectives or goals
KA	The knowledge level of the stakeholders about a related domain	To measure the influence level of stakeholders' knowledge based on their years of experience and educational background level
EA	Previous experience of the stakeholders in the related domain	To measure the stakeholders' influence in terms of their previous experience.
EBA	The level of stakeholders' educational background	To measure the influence level of the stakeholders' educational background.

The StakeQP attributes are considered to be the most important SQP attributes in the SQP domain as revealed in the findings of the SLR-SQP-Q2 (Section 2.4.2.2, chapter 2). This importance is due to the fact that the high impact of these attributes in the common practices of evaluating the stakeholders' salience with respect to their power, knowledge, experience, and role responsibility can be imposed on the project development and when measuring the stakeholders' interest towards the success of the project (Anwar & Razali 2015, 2016; Babar et al. 2013; Ballejos & Montagna 2011; Bendjenna et al. 2012; Lim et al. 2010; Razali & Anwar 2011).

4.2.1.2 Propose AMC

In this section, the measurement criteria of each listed StakeQP attribute are proposed and discussed in detail. The proposed measurement criteria are used to calculate the SAV for each StakeQP attribute, which assists in identifying the final SPV. The AMC is a measurement used to assess the stakeholders' influence on each attribute. The SAV refers to the value of the stakeholder for each StakeQP attribute. This value is measured on the basis of the proposed AMC. Hence, each listed StakeQP attribute will have different measurement criteria, as follows.

i. RIA measurement criteria (RIA-MC)

The important degree of influence of the stakeholders' role is related to the role responsibility (job scope) of the stakeholders in a project (Ballejos & Montagna 2011). Hence, the role responsibility and job scope are used to measure the degree of influence of the stakeholders' role. System stakeholders can have various roles on system development projects, such as suppliers, support staff and developers. These roles can be classified into different groups based on the stakeholder roles and concerns.

To capture all the roles of the system's stakeholders in the proposed technique, the standard group of stakeholder roles in the system development projects from the three standard resources : (IEEE-SA Standards Board 2000; ISO/IEC/IEEE 2011; Rozanski & Woods 2012) is adopted. Merging the roles of groups from the three standard resources is essential because it sufficiently covers the role of groups that can exist in system development projects. However, the role of experts and specialists are added to the list of the merged roles of groups to solve issues that cannot be solved by the participating stakeholders (Creplet et al. 2001). Table 4.2 presents the list of stakeholder role groups along with the description of each group used as a measurement criterion for the RIA.

Table 4.2 Detailed Description of the Measurement Criteria for RIA Attribute

Stakeholders' Role Group	**Description**
Acquirers	Oversee the system's procurement in the development process of system project; acquirers frequently represent the business sponsors, senior executives from the technology groups, marketing and sales. When the system project requires funding from the external investment, the investors can also act as acquirers.
Assessors	Oversee the conformance of the system to legal and standard regulation
Communicators	Describe the system to other stakeholders using training materials and documentation
Developers	Perform the system contraction and deployment from its specification (or lead the teams, which perform this construction and development process)
Maintainers	Handle the system evaluation once it is in use or ready to be used
Suppliers	Supply and/or construct the software, hardware or infrastructure, where the system will function
Support Staff	Related to staff who provides support to users of the product or system
System Administrators	Execute the system once deployed
Testers	Test the developed system to ensure that the system is convenient to be used
Users (Functional Beneficiary)	Specify the functionality of the system and ultimately make use of it
Consultant	Consultant acts more within mission, where standard solutions fit the forecasted project.
Expert	Intervenes mainly in unusual situations and operates a relatively new panel of knowledge

ii. PPA measurement criteria (PPA-MC)

The influence level of the stakeholders' degree of power can be measured on the basis of the authority level of the stakeholders in organisations. This authority level indicates the position power (management level) type of the stakeholders (DuBrin 2008; Laudon & Laudon 2017). Therefore, this attribute can be measured using the standard position levels of stakeholders in organisations (Austin & Hopkins 2004; Chatterjee 2009; DuBrin 2008; Laudon & Laudon 2017). These four levels include the top, middle, supervisory and worker levels. The first three levels (namely, top, middle and supervisory) are stated in (Austin & Hopkins 2004; Chatterjee 2009; Laudon & Laudon 2017) to the stakeholder who has the managerial position power. In (DuBrin 2008), the worker level was introduced as the fourth level to represent individual workers who do not hold any managerial position. Table 4.3 presents the explanation of the four levels.

Table 4.3 Detailed Description of the Measurement Criteria for PPA Attribute

Position Level	Description
Top Level	This level includes decisive people for directing and leading other people's efforts towards achieving success. It comprises chairman, vice president, president, board of directors, general manager, managing director, chief financial officer, chief operating officer and chief executive officer. The managers (people) of this group have the maximum level of authority.
Middle Level	This level comprises departmental heads, such as purchasing department head, sales department head, marketing manager, finance manager, plant superintendent and executive officer. People in this level are in charge of implementing the policies and plans structured by the top level. They also practice the roles of the top level for their associated department as they structure policies and plans for their department. They collect and organise the resources based on the defined policies and plans of the top level.
Supervisory Level	This level comprises superintendent, supervisors, sub-department executives, foreman and clerk. Managers of this level have limited authority; they work to execute the defined activities of the plan constructed by the previous two levels (top- and middle-position levels). They pass on the instruction to the workers and report to the middle level management. They are in charge of preserving discipline between the workers.
Worker Level	Those who do not hold any managerial position

iii. IA Measurement Criteria (IA-MC)

This attribute is deduced from the level of the stakeholders' concern with the project success (stakeholders' desire to achieve the project's goals or purpose). Three possible classes of stakeholders are defined in (Rabinowitz 2015; Sengupta 2017) on the basis of the stakeholders' interest in any project. The three classes are as follows.

1. Primary stakeholders: This includes beneficiaries who are directly affected by the project and stand to obtain money, services and skills.

2. Secondary stakeholders: This includes stakeholders who are in charge of obtaining the targets of the efforts or beneficiaries. Their jobs or lives might be affected by the results or by obtaining the goals of the project.

3. Key stakeholders: This includes stakeholders who oversee the law, legal and standard regulations and policy that may either conflict with or fulfil the goals of the project.

Four stakeholder interest levels are proposed on the basis of these defined classifications. A new level, namely, the sponsor and project manager level, is introduced to the defined primary stakeholder class in (Rabinowitz 2015; Sengupta 2017) because it has a higher interest level than the other stakeholder of the primary stakeholder class (Demir et al. 2015; Mendelow 1991; Support & Projects 2015). Therefore, the four stakeholders' interest levels are structured in this study as follows: a very high stakeholder interest level, a high stakeholder interest level, a medium stakeholder interest level and a low stakeholder interest level. The detailed description of these stakeholder interest levels are as follows.

1. Very high stakeholder interest level: This level includes only certain beneficiary stakeholders from the primary stakeholders' class. These stakeholders are the sponsors and project managers. They have higher levels of interest in the system project success because their main aim is to ensure that the project is successful in gaining revenue, which can be obtained when the project goals have been achieved (Demir et al. 2015; Mendelow 1991; Support & Projects 2015).

2. High stakeholder interest level: This level includes other beneficiaries of primary stakeholders who aim to obtain services, functions and skills. These stakeholders are users in the role of system development projects (Rozanski & Woods 2012). These users are considered functional beneficiaries who define and ultimately use the system's functionality.

3. Medium stakeholder interest level: This level includes the stakeholders of the system development project, excluding the project managers. These stakeholders can include communicators, developers, maintainers, suppliers, support staff and system administrators (Rozanski & Woods 2012).

4. Low stakeholder interest level: This level includes the key stakeholders who study, protect and prepare the policy and standard regulations that may conflict with or fulfil the projects' goals. These stakeholders are the assessors of the system development projects who oversee the conformance of the system to the legal and standard regulations (Rozanski & Woods 2012).

iv. KA Measurement Criteria (KA - MC)

The attribute of knowledge is used to measure the impact level of stakeholders' knowledge on the system development process via two-sub attributes, namely, EA and EBA. EA is used to measure the stakeholders' influence with respect to their prior experience. The influence of the stakeholders' years of experience can be measured using the categories introduced in (Worldwide 2017) as a consistent worldwide basis to distinguish the various job levels. The categories are as follows:

1. Category A: 0–1 year of experience
2. Category B: 1–3 years of experience
3. Category C: 3–5 years of experience
4. Category D: 5–8 years of experience
5. Category E: 8–10 years of experience
6. Category F: More than 10 years of experience

EBA is the second attribute used to assess the knowledge of stakeholders in terms of their educational level. This assessment is performed on the basis of the International Standard Classification of Education (ISCED 2011) (UNESCO 2012), which consists of nine levels (starting from level 0: early childhood education to level 8: doctoral or equivalent). However, only the last five levels of ISCED 2011 (level 5: short-cycle tertiary education, level 6: bachelor or equivalent, level 7: master or equivalent and level 8: doctoral or equivalent) are selected in evaluating the EBA of system stakeholders because levels zero to four are unrelated to this work. A full explanation on the five selected levels of the ISCED is presented in Table C.1 of Appendix C.

4.2.1.3 Formulating the StakeQP Attribute Weight Values and Attributes' Measurement Criterion Values

In the proposed technique, the stakeholders' selection is based on the StakeQP attributes. Hence, calculating the weight value of each proposed attribute and its proposed measurement criteria is essential to identifying the overall SAV. This phase is aimed at gaining the inputs from the industrial experts to formulate the attribute weight values (AWV) for each StakeQP attribute, as well as the measurement criteria value (MCV) for each AMC to measure the SAV. Obtaining the inputs of the values in this phase will assist in reducing the need for direct participation of the experts in SQP in assigning the SPV.

A survey with experts is conducted to obtain the importance values for each defined StakeQP attribute and the proposed measurement criteria. These values will be used in formulating the AWV of each defined StakeQP attribute and the MCV of each proposed measurement criteria for the specified StakeQP attributes, except for the measurement criteria for the EBA and IA. The standard sequence level number of the measurement criteria will be used as the importance values. The policy of expert judgement suggests that the number of experts to be targeted should be at least six in order to obtain quality and robust results (Almaliki et al. 2014; Cooke & Probst 2006). In this survey, the participants were comprised of 10 industrial experts. All participating experts have more than 10 years of relevant experience in the software development process and software project practices. Table 4.4 presents the years of experience and the latest job title of each included participating expert.

Table 4.4 Demographic Analysis of Participating Experts

Year of Experience	Latest Job Title
19 years	IS Executive Manager
14 years	Data and Infrastructure Business Owner
11 years	IT Solutions Operation Manager
12 years	Information Management Technical Consultant
26 years	Information Solutions and Project Manager
12 years	Senior System Engineer
11 years	Requirements Engineer
19 years	Senior System Analyst
18 years	Chief Technology Officer
13 years	Technical Project Manager

The survey is structured into two parts and follows the guidelines of the survey construction based on (Lin et al. 2015) . The first part is conducted to obtain the importance values of each specified StakeQP attribute. The second part is constructed to obtain the importance values of each proposed measurement criteria of the defined StakeQP attributes. The full details of the survey are given in Section C.1 of Appendix C. The hard copy of the survey is sent to two participants, and the soft copy via email is used to obtain the responses of another eight participants. Each participant is requested to rate the importance weight value using the seven importance levels of the Likert scale. The description and values of the Likert scale are structured based on (Lin et al. 2015; Vagias 2006). These used importance scale values along with description are illustrated in Table 4.5.

A detailed explanation of the steps for formulating the AWV and MCV of the proposed AMC are enumerated as follows.

Figure 4.3 shows the process of formulating the AWV of each specified attribute. The process begins by obtaining the importance values of each defined attribute from the conducted survey, where each participating expert assigns an importance value for the seven importance points of the Likert scale to each proposed attribute. Then Equation 1 is used to find the AWV of each proposed attribute by calculating the mean of the assigned values from the participating experts to each proposed attribute. The AWV values will be in the range of $1 \leq AWV \leq 7$.

Table 4.5 The Used Importance Level of Likert Scale

Importance Scale value	**Description**
1	Not at all important
2	Low importance
3	Slightly important
4	Neutral
5	Moderately important
6	Very important
7	Extremely important

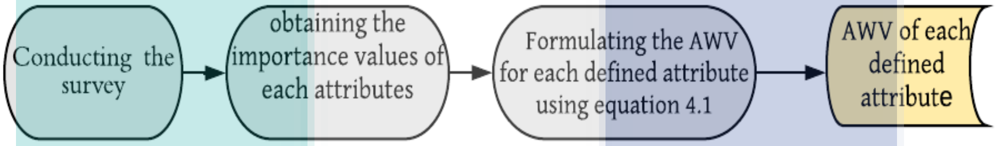

Figure 4.3 AWV Calculation Method

$$AWV_i = \frac{\left(\sum_{j=1}^{n} v_{i,j}\right)}{n} \qquad 4.1$$

where

AWV is a set of the weight values for the selected StakeQP attributes, $AWV = \{AWV_i \mid i = \text{RIA, PPA, IA, KA, EDA}\}$;

AWV_i is the importance value associated with the i^{th} attribute;

$V_{i,j}$ is the entered value of the i^{th} attribute provided by expert j, where $j = 1, \ldots, n$; and

n is the total number of participating experts.

The result of Equation 4.1 is presented in Table 4.6, which shows the AWV for each attribute that will be used to quantify and prioritise the stakeholder in the proposed technique. A higher attribute weight value indicates a greater influence on SQP. As shown in Table 4.6, the AWV of IA has the highest weight value (6.23) compared to the other attributes, thereby reflecting its considerable influence on the SQP. This attribute is followed by PPA with an AWV of 6.09, RIA with 6.02, and the subdivided attributes, EA and EBA of the KA, with 5.46 and 5.39, respectively.

Table 4.6 AWV of Each Proposed Attribute

Attribute		Attribute Weight Value (AWV)
RIA		6.02
PPA		6.09
IA		6.23
KA	EA	5.46
	EBA	5.39

Figure 4.4 presents the manner in which the MCV is formulated for each proposed AMC. In this study this method is called the MCV calculation method. This calculation process consists of three steps: obtaining the importance values of each measurement criteria, calculating the mean value of the obtained importance values of each measurement criterion and finding the MCV for each AMC.

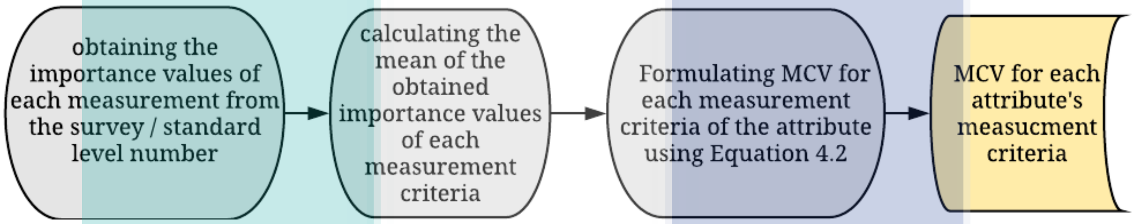

Figure 4.4 MCV Calculation Method

Obtaining the importance value of each measurement criterion is the first step in calculating the MCV of the proposed AMC. The importance value of each measurement criterion of PPA, RIA and KA in terms of EA is obtained by conducting the second part of the survey, in which the participating experts rate the importance value of each measurement criteria for each StakeQP attribute. The importance value is obtained on the basis of the same seven importance points of the Likert scale that are used in determining the AWV of each proposed attribute.

The standard level numbers of the selected ISCED 2011 levels are used as the importance values for the measurement criteria of KA in terms of EBA, whereas the importance values for the IA's measurement criteria are obtained on the basis of the proposed levels of interest. First, the importance values of each willingness level are obtained by ranking the number of each level. The very high interest level is given the highest ranking number of 4; 3 is given to the high interest level, 2 is assigned as the importance value of the middle interest level, and the low interest level is given the lowest ranking number of 1. Second, the mean value of the obtained importance values for each measurement criterion is calculated using Equation 4.2. The next step is to determine the

MCV of each AMC using Equation 4.3, where the obtained mean value of each attribute's AMC is divided by 7 (the maximum rating scale value) and then multiplied by the AWV of the attribute. This step is essential because it identifies the accurate MCV of the given attribute over the AWV.

$$M_{i,k} = \frac{\left(\sum_{j=1}^{n} P_{i,k,j}\right)}{n} \qquad 4.2$$

where

M is a set of the mean of the considered AMC, $M = \{M_i \mid i$ = RIA-MC, PPA-MC, IA-MC, KA-MC};

$M_{i,k}$ is a set of the importance values associated with the k^{th} measurement criteria of the i^{th} attribute;

$P_{i,k,j}$ represents the entered value associated with the k^{th} measurement criteria of the i^{th} attribute provided by expert *j*, where $j = 1, \ldots, n$; and

n is the total number of participating experts.

$$MCV_{i,k} = \left(\frac{M_{i,k}}{7}\right) * AWV_i \qquad 4.3$$

where

MCV is a set of measurement criterion values of each considered AMC;

$MCV_{i,k}$ is the measurement value of the i^{th} attribute for the k^{th} measurement criteria, where $K = 1, 2, 3, \ldots$, L. *K* represents the number of measurement criteria associated with the i^{th} attribute;

$M_{i,k}$ is the mean value of the k^{th} measurement criteria associated with the i^{th} attribute obtained from Equation 4.2; and

AWV_i is the importance value associated with the i^{th} attribute in Table 4.6.

Table 4.7 presents the results of formulating the measurement criterion value of the StakeQP attributes. The table shows each AMC associated with its obtained MCV. The MCV value refers to the influence value of each AMC that is associated with the stakeholder in calculating the SAV value for the stakeholders. Thus, a high MCV value represents a great influence of the AMC.

Table 4.7 MCV of Attributes Measurement Criteria

RIA-MC	Stakeholders' Role Groups	MCV
	Acquirers	5.24

	Assessors	5.24
	Communicators	4.70
	Developers	4.82
	Maintainers	4.88
	Suppliers	4.70
	Support Staff	4.76
	System Administrators	4.21
	Testers	4.64
	Users	5.36
	Consultant	4.45
	Expert	5.30
PPA-MC	**Position Level**	**MCV**
	Top level	5.48
	Middle level	5.72
	Supervisory Level	5.54
	Worker level	5.30
IA-MC	**Interest Level**	**MCV**
	Very high interest level	6.23
	High interest level	4.67
	Medium interest level	3.12
	Low interest level	1.56
KA in terms of EA -MC	**Standard Categories of Years of Experience**	**MCV**
	Category A: 0–1 year of experience	2.46
	Category B: 1–3 years of experience	3.11
	Category C: 3–5 years of experience	3.66
	Category D: 5–8 years of experience	4.15
	Category E: 8–10 years of experience	4.48
	Category F: More than 10 years of experience	4.64
KA in terms of EBA-MC	**Standard Educational Level**	**MCV**
	Short-cycle tertiary education	3.37
	Bachelor or equivalent	4.04
	Master or equivalent	4.72
	Doctoral or equivalent	5.39

The formulated AWV of each StakeQP attribute and the MCV of each AMC are considered to be constant values for this proposed StakeQP technique. The process of formulating the AWV and MCV will not be repeated during the execution of the StakeQP technique for quantifying and prioritising the stakeholders. Additionally, all of the process work of the establishment phase is only performed on the research scope of the proposed StakeQP technique, but not on the implementation scope of the StakeQP in conducting the SQP process. With the proposed AMC and the formulated AWV and MCV, the need for expert participation in evaluating the stakeholder (based on the proposed AMC of each defined StakeQP attribute) will be minimised. The detailed description of utilising the specified StakeQP attributes and their AMC, AWV and MCV in evaluating the stakeholders will be elaborated in the Section 4.2.3.

4.2.2 Stakeholder Profile Collection

Stakeholders' profiles are an essential input element in the SQP of StakeQP (Babar et al. 2015b; Lim et al. 2010). Thus, the profile of each system stakeholder must be collected. the profile of each stakeholder should be collected finalized attributes and their proposed AMC. Each profile should contain the details of each stakeholder in terms of the stakeholder's educational level, role, position, educational background and years of experience. The collected stakeholders' profiles are used as inputs for quantification and prioritisation. The stakeholders' profiles, the AWV of each proposed attribute, and the MCV of each AMC and stakeholders' profiles are used in the next step of calculating the SPV, which will be critically discussed in the next section (Section 4.2.3).

4.2.3 Formulating the SPV

This step is conducted to identify the SPV of each stakeholder. SPV presents the priority value of the stakeholders (representing the importance value of a stakeholder), which will be used to prioritise the stakeholders according to their identified SPV. The SPV of each stakeholder is formulated using two main processes: calculating the SAV for each proposed attribute and employing the multi-attribute decision method, namely, TOPSIS. The following sub-sections will provide a full explanation of the execution of these processes.

4.2.3.1 Calculating the SAV

SAV refers to the degree value of a given stakeholder for each proposed attribute. The SAV of each StakeQP attribute is calculated based on two input elements, namely, the MCV of each AMC and the stakeholders' profiles (formulating the MCV and collecting the stakeholders' profiles). The manner in which the SAV is calculated for each stakeholder on the basis of the specified StakeQP attributes with their specified measurement criteria is discussed as follows.

SAV of RIA: Role responsibility is used as a measurement criterion for RIA. Hence, the SAV of this attribute is identified on the basis of the MCV of the role responsibility of stakeholders (s) from the collected stakeholder profile, as shown in Equation 4.4.

$$SAV(RIA)_s = MCV\ (Stakeholder\ role\ responsibility\ type)_s \qquad 4.4$$

For instance, if type of the stakeholder role influence has been identified as acquirers based on the defined AMC for the RIA attribute, then SAV (RIA) of the stakeholder is measured with implementation of Equation 4.4. Hence, SAV (RIA) of the stakeholder will be the MCV of acquirers (which is 5.24 as shown in Table 4.7), which can be presented as $SAV(RIA)_s$ = MCV $(acquirers)_s$, then $SAV(RIA)_s$ = 5.24.

SAV of PPA: The standard position levels are used as measurement criteria for RIA. The SAV of PPA for each stakeholder is calculated on the basis of the MCV of the position level that is associated with each stakeholder (*s*) from his/her profile. Equation 4.5 is used to calculate the SAV of this attribute.

$$SAV(PPA)_s = MCV\ (Stakeholder\ position\ level)_s \qquad 4.5$$

SAV of IA: Three willingness levels are used as measurement criteria for IA. As a result, the SAV of IA is calculated on the basis of the MCV of each interest level that is associated with stakeholders (s), as shown in in Equation 4.6.

$$SAV(IA)_s = MCV\ (Stakeholder\ interest\ level)_s \qquad 4.6$$

SAV of the KA: This attribute has two subdivided attributes: EA and EBA. Therefore, the SAV of this attribute is identified on the basis of the SAV of these two attributes, as shown in Equation 4.7.

$$SAV(KA)_s = SAV(EA)_s + SAV(EBA)_s \qquad 4.7$$

The EA is measured using standard categories of years of experience. Thus, the MCVs of each standard category of the years of experience that are associated with a stakeholder from his/her profile are used to calculate SAV of EA for stakeholders. Equation 4.8 calculates the SAV of this attribute for each stakeholder.

$$SAV(EA)_s = MCV(stakeholder\ category\ of\ years\ of\ experience)_s \qquad 4.8$$

The MCV of the standard educational levels is used to find the SAV of EBA because the standard educational level is applied as measurement criteria for educational background. Hence, Equation 4.9 is used to find the SAV of the educational background of each stakeholder (s). The SAV of the educational background is the MCV associated with the educational background level of the stakeholder (s) retrieved from his profile.

$$SAV\,(EBA)_s = MCV\,(stakeholder\ educational\ level)_s \qquad 4.9$$

4.2.3.2 Applying Multi-attributes Decision Making (MADM) Method: TOPSIS

TOPSIS is used to evaluate and rank the stakeholders (represented as alternatives) on the basis of the defined proposed StakeQP attributes. The difficult issue of inputting and estimating the required input of the weights is controlled because the weight value of each StakeQP attribute is provided based on the identified AWV of each StakeQP attribute (in Table 4.6). The fundamental principle of TOPSIS is to determine the best alternative that is closest to the ideal solution and the farthest from the negative ideal solution (NIS) (Ishizaka & Nemery 2013; Tzeng & Huang 2011). The TOPSIS technique is performed using seven steps, which are explained in detail, as follows.

Step 1: Construct the Decision Matrix: Constructing the decision matrix D$[x_{ij}]_{mxn}$, which is comprised of m alternatives (stakeholders) linked with n attributes (defined SQP attributes) and filled up by the performance ratings of the alternatives of each attribute. Table 4.8 presents the constructed decision matrix D$[x_{ij}]_{mxn}$, the information of which is described as follows:

- *S* is a set of alternatives, $S = \{S_i \mid i = 1, \ldots, m\}$. This set of alternatives is the set of stakeholders who must be quantified and prioritised.
- *A* is a set of attributes, $A = \{A_j \mid j = 1, \ldots, n\}$. This set of attributes is the set of the specified StakeQP attributes, namely, RIA, IA, PPA, EA of KN and EBA of KN.
- *X* is the set of performance ratings of *S*, $X = \{x_{ij} \mid i = 1, \ldots, m; j = 1, \ldots, n\}$, where xij is the evaluation of stakeholder Si with respect to the specified StakeQP attribute Aj. The SAV of each stakeholder is the given value for xij, where each SAV presents the worth of stakeholders on each listed StakeQP attribute.
- *W* is a set of attribute weights, $W = \{w_j \mid j = 1, \ldots, n\}$ and is the set of specified StakeQP attribute weights. AWV is calculated on the basis of the importance value of each proposed attribute. Thus, the weight of each StakeQP attribute is

provided based on the value of AWV of each proposed attribute shown in Table 4.6. Therefore, the AWV of each proposed attribute is its weight value (1≤ AWV ≤ 7).

Table 4.8 Decision Matrix

Alternatives	Attributes (StakeQP attributes)				
	A_j	A_j	A_j	A_j	A_j
	w_j	w_j	w_j	w_j	w_j
S_i	x_{ij}	x_{ij}	x_{ij}	x_{ij}	x_{ij}
S_i	x_{ij}	x_{ij}	x_{ij}	x_{ij}	x_{ij}
S_i	x_{ij}	x_{ij}	x_{ij}	x_{ij}	x_{ij}
⋮	⋮	⋮	⋮	⋮	⋮
S_m	x_{mn}	x_{mn}	x_{mn}	x_{mn}	x_{mn}

Step 2: Construct the Normalised Decision Matrix: The decision matrix is then constructed by normalising the obtained decision matrix from Step 1. This step is performed to transform the various attribute dimensions into non-dimensional attributes to allow for a comparison across the specified StakeQP attributes. The decision matrix is normalised using Equation 4.10. Table 4.9 presents the constructed normalised decision matrix.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x_{ij}^2}} \, , i = 1, \dots, m.. and. \; j = 1, \dots, n \qquad 4.10$$

where

r_{ij} is the normalised score of a stakeholder; and

x_{ij} is the original score performance rating of the stakeholder in the previous decision matrix in Table 4.8.

Table 4.9 Normalized Decision Matrix

Alternatives	Attributes (StakeQP attributes)				
	A_j	A_j	A_j	A_j	A_j
	w_j	w_j	w_j	w_j	w_j
S_i	r_{ij}	r_{ij}	r_{ij}	r_{ij}	r_{ij}
S_i	r_{ij}	r_{ij}	r_{ij}	r_{ij}	r_{ij}
S_i	r_{ij}	r_{ij}	r_{ij}	r_{ij}	r_{ij}
⋮	⋮	⋮	⋮	⋮	⋮
S_m	r_{mn}	r_{mn}	r_{mn}	r_{mn}	r_{mn}

Step 3: Construct the Weighted Normalised Decision Matrix: The weighted normalised decision matrix is obtained by multiplying each r_{ij} normalised score with its

corresponding attribute weight, as shown in Equation 4.11. Table 4.10 presents the constructed weighted normalised decision matrix.

$$v_{ij} = r_{ij} * w_j \qquad 4.11$$

where

w_j is the weight of the specified StakeQP attribute;

v_{ij} is the obtained weighted normalised score of stakeholders; and

r_{ij} is the normalised score of stakeholders obtained from Step 2.

Table 4.10 Weighted Normalized Decision Matrix

Alternatives	**Attributes (StakeQP attributes)**				
	A_j	**A_j**	**A_j**	**A_j**	**A_j**
	w_j	w_j	w_j	w_j	w_j
S_i	v_{ij}	v_{ij}	v_{ij}	v_{ij}	v_{ij}
S_i	v_{ij}	v_{ij}	v_{ij}	v_{ij}	v_{ij}
S_i	v_{ij}	v_{ij}	v_{ij}	v_{ij}	v_{ij}
⋮	⋮	⋮	⋮	⋮	⋮
S_m	v_{mn}	v_{mn}	v_{mn}	v_{mn}	v_{mn}

Step 4: Identify the Positive Ideal Solution (PIS) and the Negative Ideal Solution NIS: The PIS is identified as a composite of the best weighted normalised scores exhibited by any stakeholder (in the weighted normalised decision matrix) for each StakeQP attribute, as shown in Equation 4.12. Meanwhile, a composite of the worst weighted normalised scores of any stakeholder for each attribute is identified as the NIS, as shown in Equation 4.13.

$$PIS = \{v_1^*, v_2^*, \ldots, v_n^*\}, where\ v^* = \{(max_i\ (v_{ij})\ if\ j \in J)\} \qquad 4.12$$

$$NIS = \{v_1', v_2', \ldots, v_n'\}, where\ v' = \{(min_i\ (v_{ij})\ if\ j \in J)\} \qquad 4.13$$

Step 5: Calculate the Separation Measure for Each Alternative (Stakeholder): This step is aimed at calculating the individual separation measures of each stakeholder from the PIS and NIS. The separation measures are calculated using the Euclidean distance. Equation 4.14, and 4.15 are executed to determine the separation measures of each stakeholder (alternative) from the PIS and NIS, respectively. S* and S′ are donated for the obtained separation value of each stakeholder from the PIS and NIS, respectively.

$$S_i^* = \left[\sum_{j=1}^{n} (v_{ij} - v_j^*)^2\right]^{1/2}, i = 1, \ldots, m \qquad 4.14$$

$$S_i' = \left[\sum_{j=1}^{n} (v_{ij} - v_j')^2\right]^{1/2} , i = 1, \ldots, m \qquad 4.15$$

where

S^* and S' represent the obtained separation values of each stakeholder from PIS and NIS, respectively.

Step 6: Find Ideal Stakeholders by Calculating the Relative Closeness Coefficient (RC_i) PIS: The relative closeness of each i^{th} stakeholder to the PIS is defined Equation 4.16.

$$RC_i = \frac{S_i'}{(S_i^* + S_i')} , 0 \leq RC_i \leq 1 \qquad 4.16$$

where

RC_i is the relative closeness value (SPV) of the i^{th} stakeholder to the IPS, which is between 0 and 1.

Step 7: Rank the Stakeholders: Finally, the set of stakeholders is ranked according to the descending order of their relative closeness RC_i (SPV_i). The highest SPV_i value indicates that more important stakeholders such as Si are to be considered in the system development process.

4.3 StakeQP Automation Implementation Tool (StakeQP-AIT)

The StakeQP-AIT is constructed with a .NET environment using HTML for the graphical user interface (GUI), a Microsoft SQL Server database for effective data management and execution and the C# programming language to execute the proposed StakeQP. The AWV of each StakeQP attribute and the MCV of each proposed AMC are stored in the constructed database. The proposed attributes and their measurement criteria, AWV and MCV, are identified and formulated in the establishment phase of this StakeQP technique. Figure 4.5 presents the phases of implementing the StakeQP technique using the StakeQP-AIT, which consists of two main components: the GUI and automation engine.

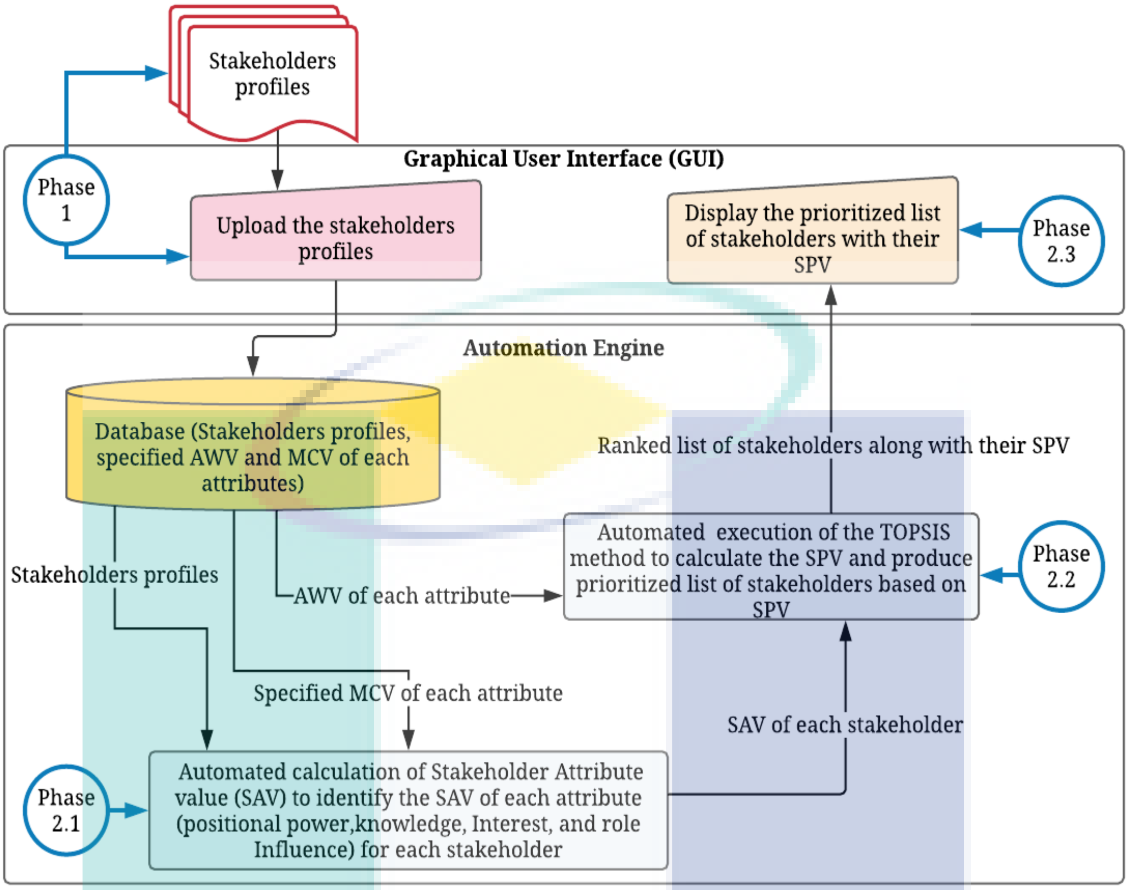

Figure 4.5 StakeQP-AIT Implementation Structure .

The two components include two phases, namely, the pre-requisite phase and the quantifying and prioritising phase. The pre-requisite input is essential for the other phases. Thus, it must be conducted prior to the implementation of other phases of the StakeQP-AIT. The quantifying and prioritising phase includes sub-steps and the presentation of the results. These phases are detailed as follows.

1. Phase 1: Pre-requisite Input. Collecting and storing the stakeholders' profiles. The stakeholder profiles must be collected on the basis of the proposed measurement criteria of each SQP attribute of this technique. Each stakeholder profile contains the details of each stakeholder, such as positional power, interest, years of experience, educational level and role influence. The identification process of these details is conducted based on the defined measurement criteria of each StakeQP attribute (Section 4.2.1.2). Then, these collected stakeholder profiles must be stored in the database by inputting or uploading via the developed GUI of the StakeQP-AIT tool. These stakeholder profiles are then used as an input to

quantify and prioritise the stakeholders in the next phase of the implementation guidelines.

2. Phase 2: Quantifying and Prioritising Processes. This phase includes the steps of quantifying and prioritising the stakeholders of the StakeQP. The StakeQP-AIT tool is used by calculating the SPV of each stakeholder and displaying the result using three automated steps, as follows.

   2.1 Automated Calculation of SAV. The SAV of each stakeholder is calculated using the automated tools of the technique. The stakeholder profiles and the specified MCV of each attribute are retrieved from the database and used as inputs to calculate the SAV of each stakeholder. The details of this calculation process have been described in Section 4.2.3.1.

   2.2 Automated Execution of TOPSIS. The obtained SAV of each stakeholder from the previous step and the AWV of each attribute are used as inputs for the TOPSIS algorithm, which is executed automatically via the developed automation tools to identify the SPV of each stakeholder. The prioritised list of stakeholders is produced on the basis of the identified SPV.

   2.3 Presentation of the Result. The prioritised list of stakeholders and their identified SPV are displayed on the GUI of the StakeQP-AIT. With these clear implementation steps of the semi-automated StakeQP-AIT, the implementer can perform SQP with minimal expert participation in order to initiate, absorb and implement the process. The implementer only needs to input the stakeholder profiles, such as their power position level, educational background, years of experience and their role in the system development project. Then the SPV is obtained through automated implementation based on the two sub-automated processes, namely, the automated calculation of SAV for each stakeholder and applying the automated TOPSIS method that will produce the final order list of the SAV for each system stakeholder.

With these clear implementation steps of the semi-automated StakeQP-AIT, the implementer can perform SQP with minimal expert participation in order to initiate, absorb and implement the process. The implementer only needs to input the stakeholder profiles, such as their power position level, educational background, years of experience and their role in the system development project. Then the SPV is obtained through automated implementation based on the two sub-automated processes, namely, the automated calculation of SAV for each stakeholder and applying the automated TOPSIS method that will produce the final order list of the SPV for each system stakeholder.

4.4 Evaluation

This section presents the evaluation of the proposed StakeQP performance. The StakeQP technique is proposed to quantify and prioritise the stakeholders with the capability of addressing the key issues of the SQP domain in terms of time consumption, lack of automation level and low-level implementation details, the need for expert participation in executing the SQP process and the absence of the measurement criteria for assessing the stakeholders' influence. Evaluating the StakeQP by implementing and testing its performance with an actual industrial project is essential to confirm its capability of solving the specified issues. The empirical experiment is selected as an evaluation method for the StakeQP technique, and the RALIC benchmark dataset is used to evaluate its performance. In addition, this section provides the details of the performance analysis of StakeQP and an elaboration of the threats to its validity.

4.4.1 Experimental Study

The benchmark dataset of the RALIC project is selected to evaluate the proposed StakeQP technique. Based on a thorough search of the relevant literature, the dataset of RALIC is the only available and complete dataset in the SQP domain. In comparison with other case studies, the RALIC dataset includes detailed information of the stakeholder profiles and the actual results for the priority ranks of the RALIC stakeholders. Thus, this dataset is used in evaluating the SQP techniques, such as in (Lim 2010; Lim et al. 2010). Hence, this project can be used in the evaluation, and the results can be compared with those of existing techniques. Moreover, RALIC is a large-scale software project used as replacement access, library and ID card project (Lim 2010; Lim et al. 2010). It was developed to improve the existing access control system by combining the photo ID card, access card and library card at University College London. A total of 85 relevant stakeholders from the RALIC documentation reports must be quantified and prioritised (Lim 2010; Lim et al. 2010).

Table 4.11 presents a sample of the RALIC stakeholders' profiles based on the defined measurement criteria of each StakeQP attribute. The documentation reports of the selected RALIC project are provided in the RALIC dataset and the thesis of Lim (Lim

2010; Lim et al. 2010). The experiment is conducted with 85 stakeholders of the RALIC benchmark dataset.

Table 4.11 Sample of the RALIC Stakeholder Profiles

Stakeholder ID	Stakeholder Role Group	Education Level	Category of Years of Experience	Stakeholder Positional Level	Stakeholder Interest Level
SID0234	Developers	6: Bachelor or Equivalent	C	Middle	Medium Interest
SID3010	Users	5: Short-cycle Tertiary Education	B	Worker	High Interest
SID7234	System administrators	6: Bachelor or Equivalent	C	Supervisory	Medium Interest

The experimental implementation of the proposed StakeQP technique is performed on the basis of the specified steps of StakeQP-AIT presented in Section 4.3. A desktop computer with 3.60 GHz, 16 GB RAM and the Microsoft Visual Studio 2010 full-package programme installed is used to run the experiment using the developed StakeQP-AIT tool. A detailed explanation of the experiment implementation steps is given in Appendix C, section C.2.Table 4.12 shows the experimental results and presents the list of the prioritised and quantified stakeholders, while the result of full list of stakeholders is given in Table C.2, Appendix C.

Table 4.12 Sample of the StakeQP Expermental Results

Rank	Stakeholder ID	SPV
1	SID3007	0.9142
2	SID9024	0.8987
3	SID3002	0.8564

The results show the list of stakeholders, including the stakeholder rank, stakeholder ID and the obtained SPV for each stakeholder. The SPV of each stakeholder is in the range of 0 to 1 ($0 \leq SPV \leq 1$) after normalising the steps of TOPSIS. However, the evaluation and the performance analysis will be discussed and highlighted in detail in the next section.

4.4.2 Performance Analysis and Result Evaluation

StakeQP is proposed in order to provide the prioritised list of stakeholders and solve certain issues of the existing SQP techniques. Thus, the evaluation performance of the StakeQP is based on these parameters. The accuracy of StakeQP is also measured for a comparison with existing techniques.

Time consumption is measured by the time consumed when executing the SQP process to produce the prioritised list of stakeholders on the basis of the generated SPV of stakeholders. The lack of an automation level is concerned with the capability of StakeQP to provide an automated SQP process, whereas the insufficient low-level implementation details are concerned with providing insufficient low-level implementation details for SQP. The need for highly professional human intervention is concerned with the capability of the StakeQP to generate results with minimal expert involvement.

In addition, nine existing techniques are selected for comparison with the performance of the proposed StakeQP based on the defined evaluation parameters. These existing techniques are derived from the conducted SLR-SQP in chapter 2, where they have been identified as available techniques that focused on the SQP process compared with other stakeholder analysis techniques. These techniques include the works of Razali and Anwar (Razali & Anwar 2011), Bendjenna et al. (Bendjenna et al. 2012), Babar et al. (Star Triangle (Babar et al. 2013), bi-metric (Babar et al. 2014a) and StakeMeter (Babar et al. 2015b)), the AHP method (Bendjenna et al. 2012; Brito & Moreira 2003; Voola & Babu 2012), Ballejos and Montagna (Ballejos & Montagna 2011), Lim et al.-StakeNet (Lim et al. 2010)), and McManus (McManus 2004).

The efficiency of StakeQP is measured with respect to the time consumed in SQP. The StakeQP took 6.25 s to produce the prioritised list of 85 stakeholders from the RALIC dataset with their SPV. This response time is better that the other existing techniques that take 23–58 h to quantify and prioritise 63 stakeholders (Babar et al. 2015b). Table 4.13 shows the comparative analysis of StakeQP with four SQP techniques based on the time consumption for the total number of stakeholders and the usage process type of the technique in terms of the automation level in conducting the SQP process. These four techniques are evaluated in terms of the time consumption and compared with other listed SQP techniques and one of these five techniques. Lim et al. introduced StakeNet (Lim et al. 2010) using the same dataset (RALIC) as the present study in the evaluation process.

The performance evaluation of the methods of Ballejos and Montagna and Babar et al. (bi-metric and StakeMeter) in terms of time consumption is reported based on the recent study of Babar et al. in (Babar et al. 2015b), where these three techniques are implemented with different numbers of stakeholders. The Babar et al.-StakeMeter took 7, 23 and 47 h to prioritise 23, 63 and 47 stakeholders, respectively, and the efficiency of this technique is higher than the other two techniques. The time consumption performance of the Lim et al.-StakeNet technique by Lim et al. is reported in (Lim et al. 2010). The Babar et al.-StakeMeter (Lim et al. 2010) technique took 17 h to quantify and prioritise 85 RALIC stakeholders. Evidently, the StakeQP consumes less time compared with the other existing techniques at 6.25 s for 85 stakeholders.

Table 4.13 Comparative Analysis of StakeQP with Existing Techniques based on Time Consumption

Technique	**Stakeholders**	**Time Consumption**	**Techniques' Process Types**
Ballejos and Montagna (Ballejos & Montagna 2011) (Babar et al. 2015b)	15 46 53	28 h 58 h 108 h	Manual
Babar et al. (bi-metric) (Babar et al. 2014a) (Babar et al. 2015b)	8 22 13	11 h 31 h 65 h	Manual
Babar et al. (StakeMeter) (Babar et al. 2015b)	13 32 21	7 h 23 h 47 h	Manual
Lim et al. (StakeNet) (Lim et al. 2010)	85	17 h	Manual
Proposed StakeQP	85	6.25 s	Semi-automated

Figure 4.6 shows the improvement percentage in terms of the time consumption of the proposed StakeQP with respect to each of the selected existing techniques. The improvement percentage is measured on the basis of the lowest time consumption by each technique in Table 11. The lowest time consumption of the techniques of Ballejos and Montagna, Babar et al. (bi-metric and StakeMeter) and Lim et al. (StakeNet) is 28, 11, 7 and 17 h for prioritising 15, 8, 13 and 85 stakeholders, respectively. The time consumption of StakeQP in prioritising 85 stakeholders is 6.25 s. Equation 4.17 is used to calculate the improvement percentage. It is a basic and well-known equation for finding the improvement percentage of the performance testing for a technique or firm (De Angelis & Grinstein 2011; Babar 2015; Babar et al. 2015c; Gong et al. 2011; Tice 2017).

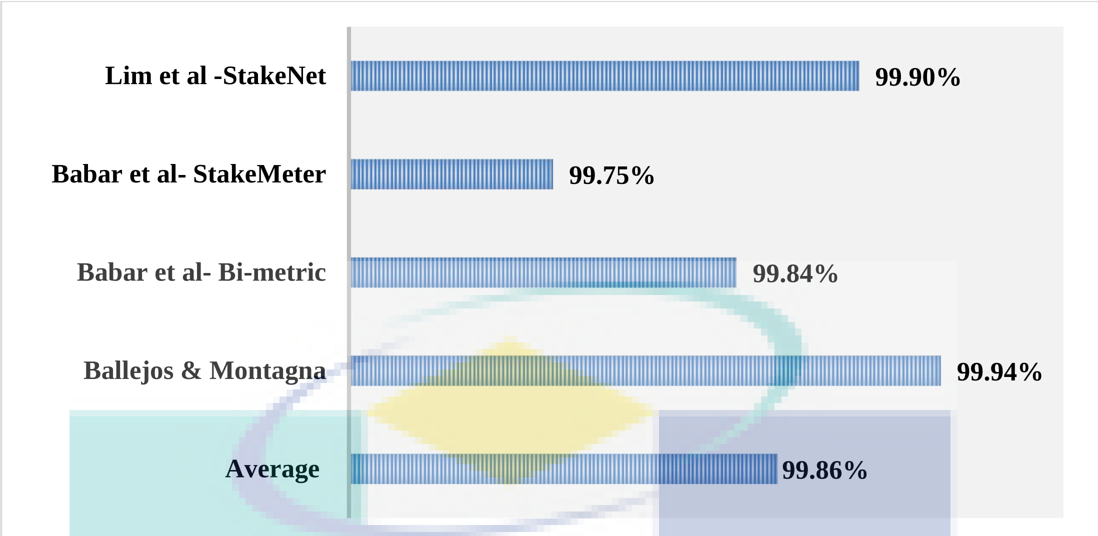

Figure 4.6 Performance Analysis of StakeQP with respect to Time Consumption

$$PIM_i = \frac{TS - TE_i}{TE_i} \times 100 \quad 4.17$$

where

PIM$_i$ is the percentage improvement of the StakeQP technique against the i[th] existing technique;

*TE*i is the lowest time consumption of the i[th] existing technique;

TS is the time consumption of the proposed StakeQP technique.

Figure 4.6 also shows that the time consumption efficiency of StakeQP is 99.94%, 99.84%, 99.75% and 99.90% better than that of Ballejos and Montagna, Babar et al. (bi-metric and StakeMeter) and Lim et al.-StakeNet, respectively. Moreover, the average performance of the StakeQP against all selected techniques indicates that its performance is better than the existing techniques in terms of the time consumption at a percentage of 99.86%, although the number of stakeholders prioritised in StakeQP (85 stakeholders) is larger than that in other existing techniques.

The StakeQP can automate SQP with less time consumption while producing the prioritised list of stakeholders with minimal expert participation by using clear implementation details with the proposed AMC, TOPSIS and the developed StakeQP-AIT tool. However, the selected existing techniques consume a large amount of time, given that these techniques executed their processes manually with expert involvement, thereby providing highly abstract information of the implementation details and not presenting any standard AMC for identifying the stakeholder priority

Moreover, the StakeQP technique proposed the AMC and the MCV of each proposed measurement criteria in its initial step. Thus, the proposed technique can solve the issue related to the absence of AMC in the existing techniques. Most of the existing techniques proposed only the attributes without providing their measurement criteria, depending on expert involvement. Hence, the stakeholders are evaluated by providing their weight value without defining the standard measurement criteria. The defined AMC and their identified MCV are combined to measure the SAV of each stakeholder, which is then used with the listed StakeQP attributes with their specified AWV, employing the TOPSIS algorithm to calculate the SPV and produce the ranked list of stakeholders. The StakeQP-AIT tool is used to solve the major issue of the existing techniques that require the involvement of professionals to quantify and prioritise the stakeholders. Thus, the result is generated in the experimental implementation by conducting all of the StakeQP steps automatically without expert participation.

Additionally, the accuracy of the StakeQP is measured by comparing the produced stakeholders' prioritised list against that of the ground truth, which is derived from the project documentation and given in (Lim 2010; Lim et al. 2010). Hence, accuracy is the intersection between the stakeholders' priority rank in the StakeQP list and their actual priority rank in the ground truth list (Lim 2010; Lim et al. 2010). The statistical measure of the Pearson correlation coefficient is used to find the degree of correlation (intersection) between the two lists. It is the best method of measuring the association between two variables because it is based on the covariance method (Evans 1996). The correlation coefficient value (r) ranges from +1 to −1, where +1, −1 and 0 indicate a perfect positive correlation, perfect negative correlation and no correlation, respectively. The interpretation of the correlation coefficient value is (r), where each range of the correlation coefficient with its associated degree of correlation is provided in Table 4.14 (Chowdhury et al. 2015; Evans 1996).

To calculate the correlation coefficient value (r) between the two lists, the Pearson correlation coefficient formula is used, as shown in in Equation 4.18. The obtained result is 0.8969 (89.69%), which is a positive correlation with a very strong positive degree of correlation (based on the interpretation of the correlation coefficients in (Chowdhury et al. 2015; Evans 1996)). Thus, the high X stakeholder rank in StakeQP indicates a high Y stakeholder rank in the ground truth, and vice versa.

Table 4.14 The Interpretation of Correlation Coefficients Value

Range of correlation Coefficients	Correlation Degree
0.80-1.00	Very strong positive
0.60-0.79	Strong positive
0.40-0.59	Moderate positive
0.20-0.39	Weak positive
0.00-0.19	Very weak positive
0.00 - (-0.19)	Very weak negative
(-0.20)-(-0.39)	Weak negative
(-0.40)-(-0.59)	Moderate negative
(-0.60)-(-0.79)	Strong negative
(-0.80)-(-1.00)	Very strong negative

$$r = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \overline{x})^2 \ \sum_{i=1}^{n} (y_i - \overline{y})^2}} \quad 4.18$$

where

r is the correlation coefficient value;

n is the number of samples, which are the stakeholders in each list (both lists consist of 85 stakeholders);

X_i is the rank of the i^{th} stakeholder in the StakeQP list; and

Y_i is the rank of the i^{th} stakeholder in the ground truth.

Figure 4.7 presents the percentage of the accuracy performance of the proposed StakeQP compared with the Lim et al.-StakeNet technique by Lim et al. (Lim et al. 2010). Lim et al.-StakeNet (Lim et al. 2010) is the only technique that has been evaluated in terms of accuracy, which is measured on the basis of the final ranking of each stakeholder using the same dataset (RALIC). Although the performance evaluation of the accuracy for the Ballejos and Montagna and Babar et al. (bi-metric and StakeMeter) techniques was conducted and reported by Babar et al. in (Babar et al. 2015b), these techniques are not selected for comparison because their reported accuracies were measured based on the selection of critical stakeholders rather than the stakeholder ranking values. Thus, they cannot be directly compared with the proposed StakeQP accuracy performance. Figure 4.7 evidently shows that the efficiency of StakeQP is higher than that of the Lim et al.-StakeNet. The accuracy result of StakeQP is 89.69%, whereas that of Lim et al.-StakeNet is 78.00%.

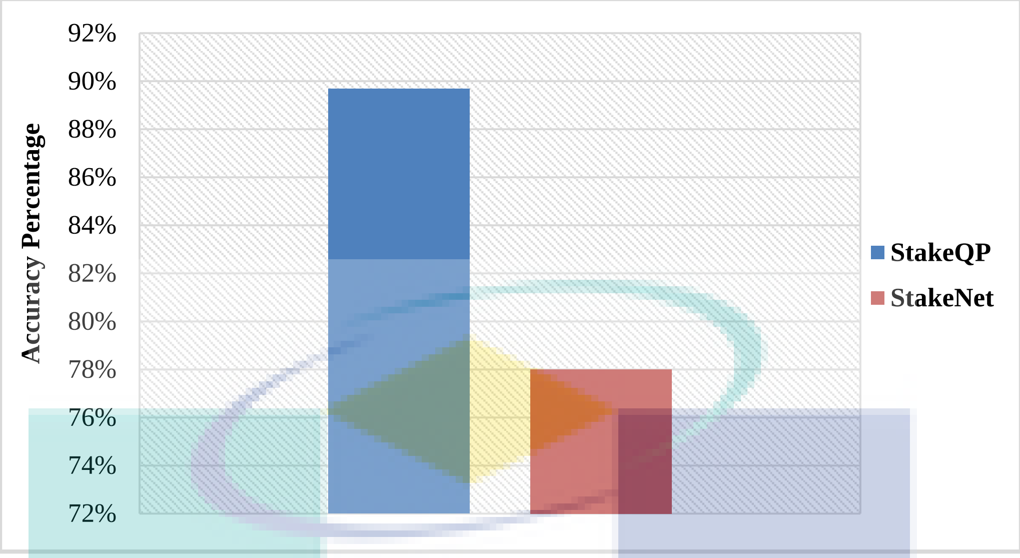

Figure 4.7 Accuracy Performance of StakeQP

Furthermore, Table 4.15 presents a comparative analysis of the proposed StakeQP technique with all existing techniques based on the other defined evaluation parameters as follows: low-level implementation details (guidelines), reduced expert involvement, automation tools for SQP and the existence of the AMC for measuring the priority degree of the stakeholders and the clearly defined stakeholder priorities by producing a ranked list of the stakeholders.

The results of the comparative analysis reveal that the proposed technique (StakeQP) can handle the key SQP issues, whereas most existing techniques cannot sufficiently provide support to various considered key parameters. Lim et al.-StakeNet and Babar et al.-StakeMeter are better techniques that can support fewer key parameters compared to other existing techniques because they focus on providing support to two key issues, namely, guidelines and defining the stakeholder priorities. However, these techniques overlook handling the key issues of automation tools, AMC, and heavily rely on expert participation given that these techniques perform their processes manually without providing the AMC of the attribute, thereby heavily relying on the participation of experts in conducting the SQP.

Moreover, the StakeQP-AIT was developed and used by practitioners of software in actual industries. The evaluation parameters of the performance analysis indicate that StakeQP is better than the existing techniques and can be beneficial in actual SQP practice.

Table 4.15 Comparative Analysis of StakeQP with Different Existing Techniques

Technique	AMC	Guide lines	Automat ion tools	Not require professional expertise's involvement	Defined stakeholders' priorities list
Razali and Anwar (Razali & Anwar 2011)	×	Partial	×	×	×
Bendjenna et al. (Bendjenna et al. 2012)	×	Partial	×	×	Partial
Babar et al.- Star Triangle (Babar et al. 2013)	×	Partial	×	×	Partial
AHP method (Bendjenna et al. 2012; Brito & Moreira 2003; Voola & Babu 2012; Voola & Vinaya Babu 2012)	×	Partial	×	×	Partial
Babar et al.- Bi-metric (Babar et al. 2014a)	×	Partial	×	×	✓
Ballejos & Montagna (Ballejos & Montagna 2011)	×	✓	×	×	Partial
Lim et al.-StakeNet (Lim et al. 2010)	×	✓	×	×	✓
Babar et al.-StakeMeter (Babar et al. 2015b)	×	✓	×	×	✓
McManus (McManus 2004)	×	Partial	×	×	×
Proposed StakeQP	✓	✓	✓	✓	✓

4.5 Threats to Validity

An empirical study can face various threats to validity (Wohlin et al. 2012). In the context of this study, we identify a few threats that may be associated with our experiment, and substantial efforts are undertaken to decrease such threats.

The selection of a benchmark dataset represents the first essential threat due to the lack of available benchmark datasets in the SQP domain (this can include detailed information of the stakeholders' profiles as essential inputs in the proposed StakeQP), given that SQP is the forthcoming research direction in stakeholder analysis. To address this threat, we select a benchmark dataset of an actual software project (RALIC), which is a well-known benchmark dataset in the domain of SQP and RP. RALIC is the only available and complete benchmark dataset in terms of providing detailed information on the stakeholder profiles for the proposed StakeQP. However, this dataset initially lacks details on the educational level and years of experience of the stakeholders. These missing details are necessary to cover the educational background and years of experience. The missing details are then obtained from the owner of the dataset by providing the range of the educational level and the years of experience of the stakeholders. Although the RALIC benchmark dataset is derived from the documentation of the RALIC software project, we cannot guarantee that this benchmark dataset represents the actual stakeholder details.

In addition, the performance comparison with other existing techniques poses a threat. Few techniques have been proposed for SQP as discussed in the previous chapter (Chapter 2 of SLR-SQP). However, not all techniques have been implemented and evaluated due to the ambiguity and complexity associated with the SQP and because of the unavailability of experts (Babar et al. 2015b).Thus, we cannot compare the proposed StakeQP technique with all available techniques. To eliminate this threat, we select recently published studies (Babar et al. 2015b; Lim et al. 2010) that present the most recent and the best results for the related SQP techniques and measure the defined evaluation parameters in this study.

The time consumption of each selected technique could form another source of threat. To compare the time consumption fairly, implementing and using all the techniques in the same environment is essential. However, this is difficult because the existing techniques are performed manually. To minimise this threat, we conduct a performance comparison of the time consumption of four existing techniques that can be implemented in actual scenarios with less time consumption (Babar et al. 2015b; Lim et al. 2010). These techniques (Babar et al.'s bi-metric and StakeMeter, Ballejos and Montagna's and Lim et al.'s StakeNet) perform their SQP processes manually, as reported in their published works. Thus, we cannot implement them with automated tools compared to the proposed StakeQP, which provides a semi-automated SQP process.

Another threat is related to the automation process issues. The automation process, although timesaving and with minimal to no human intervention, may elicit an issue of producing an unpredictable processing error or a low quality result where the implementer has not uploaded the stakeholder's profile based on the StakeQP attributes and their AMC. The reason is that the automated machine cannot execute a flexible variety of tasks, as it is restricted to execute the task based on what it has been programmed to do. Similarly, the StakeQP automation process is executed in the full process of evaluating the stakeholders based on the finalized attributes and their proposed AMC with an ability of completing the process if the stakeholder profile has been uploaded based on different attributes or measurements. To minimise this issue, we precisely explained the full process of the StakeQP attributes and the AMC in order to assist the implementer in specifying the profiles of the stakeholders based on the attributes and their AMC. Hence, we strongly recommended that the implementer carefully read the provided explanation. However, there is one threat here that is associated with the unknown costs that will be required to the keep the processes of the StakeQP-AIT updated because the cost disbursed in updating with a new procedure will demand high operational costs with respect to the research and development requirements to be performed.

4.6 Chapter Summary

Stakeholder selection plays a key role in eliciting and identifying the core requirements that need to be developed to satisfy the stakeholders' requirements. Thus, various techniques have been proposed for SQP. In this chapter, a new semi-automated SQP technique called StakeQP and a new AMC were proposed to address the limitations of the existing SQP, such as its excessive reliance on expert intervention, its time consumption caused by a lack of automation and unclear guidelines of the existing techniques, its ambiguity in terms of performing the SQP process and a lack of standard measurement criteria for the attributes used to identify the SPV.

The process of the proposed StakeQP technique was discussed in detail. The proposed StakeQP technique provides low-level implementation details of the SQP process using the TOPSIS method based on the StakeQP attributes and their measurement criteria, which are identified and proposed for SQP. To evaluate the performance of the StakeQP technique, an actual software project called RALIC was used by applying StakeQP, and a comparative analysis with other techniques was performed based on the defined evaluation criteria.

The findings demonstrate that StakeQP can generate more accurate results with less time utilisation and is more effective in handling the defined SQP limitations compared with the other alternative techniques. Chapter 5 elaborates in detail the proposed semi-automated scalable requirements prioritisation technique (SRPTackle) in order to address the identified limitations of requirements prioritisation that discussed in chapter 2 distinctly.

CHAPTER 5

SRPTACKLE: THE PROPOSED SEMI-AUTOMATED SCALABLE REQUIREMENTS PRIORITISATION TECHNIQUE

5.1 Introduction

This chapter provides comprehensive details of proposed technique to solve the limitations with requirement prioritisation techniques. As revealed and discussed in the SLR-RP, chapter 2, the existing RP techniques suffer from certain limitations. These limitations are related to the lack of quantification and prioritisation of the participating stakeholders, time consumption, the need for highly professional human intervention, and scalability.

Most of the existing techniques are relying on the heavy participation of the experts in order to execute the prioritisation process with respect to two main sub-processes: SQP process and assigning the priority values of requirements. This will lead to the issue of availability, and humans' natural bias induced by the experts. Furthermore, majority of the existing techniques performed the prioritisation process manually which will be costly in terms of time. Scalability is reported as another main issue in dealing with large set of requirements, since it will lead to the techniques to perform the prioritisation process with higher time-consumption and increase in the number of pairwise comparisons along with erroneous results that can be gained through the manually complex computation process. Thus, this chapter presents the proposed semi-automated scalable requirement prioritisation technique (SRPTackle) to address the above-mentioned limitations. The detailed description of the SRPTackle along with the constructed automation implementation tool of the SRPTackle are distinctly explained in the rest of this chapter.

Additionally. To affirm the capability of proposed technique in addressing the identified issues of the RP existing techniques, the empirical experiment is selected as an evaluation method. Benchmark dataset of large real project (RALIC) is used in assessing the performance of the proposed technique. The constructed automation implementation tools are utilized in implementing the proposed technique within the selected dataset. This chapter also provides the full details of the performance analysis of the SRPTackle and the threats to the validity in the conducted experiment.

5.2 The Proposed SRPTackle Technique

The process of the SRPTackle technique is illustrated in Figure 5.1. It consists of two major phases: pre and post prioritisation phases. The detailed description of each phase of the SRPTackle technique is given in the next sub sections.

5.2.1 Pre-prioritisation Phase

This aim of this phase is to obtain initial weighting value of the requirement from the stakeholders, which will be used as an input in the next phase (Post-prioritisation phase). The initial weighting values for the system requirement is conducted in this phase. In the SRPTackle technique, the participating stakeholders should assign initial weighting value for each requirement based on defined prioritisation criteria, importance and cost. Each functional beneficiary stakeholder (enduser and customer) should assign the weight value for each requirement based on the importance criteria (RIWV), which refers to the importance of requirement to the end-user to be implemented and delivered first. On the other hand, other all participating stakeholder types such as technical and commercial stakeholders (i.e. development team) assign the weight value to each requirement according to their cost of implementation (RCWV). The weightage values are taken with scale from 1 (less weighting value) to 5 (high weighting value). The RIWV and RCWV are considered as an output of the pre-prioritisation phase and served as input for conducting the second phase of the post prioritisation phase.

5.2.2 Post-prioritisation Phase

The aim of this phase is to perform the prioritisation process based on the initial weight values of the requirements. The full implementation of this phase is conducted with four steps: specifying the SPV value for each stakeholder, formulation of the RPV, classifying the requirements by employing the K-mean and K-means++ algorithms, and applying the BST algorithm. The following sub sections explain the details of performing each step in this phase as shown Figure 5.1.

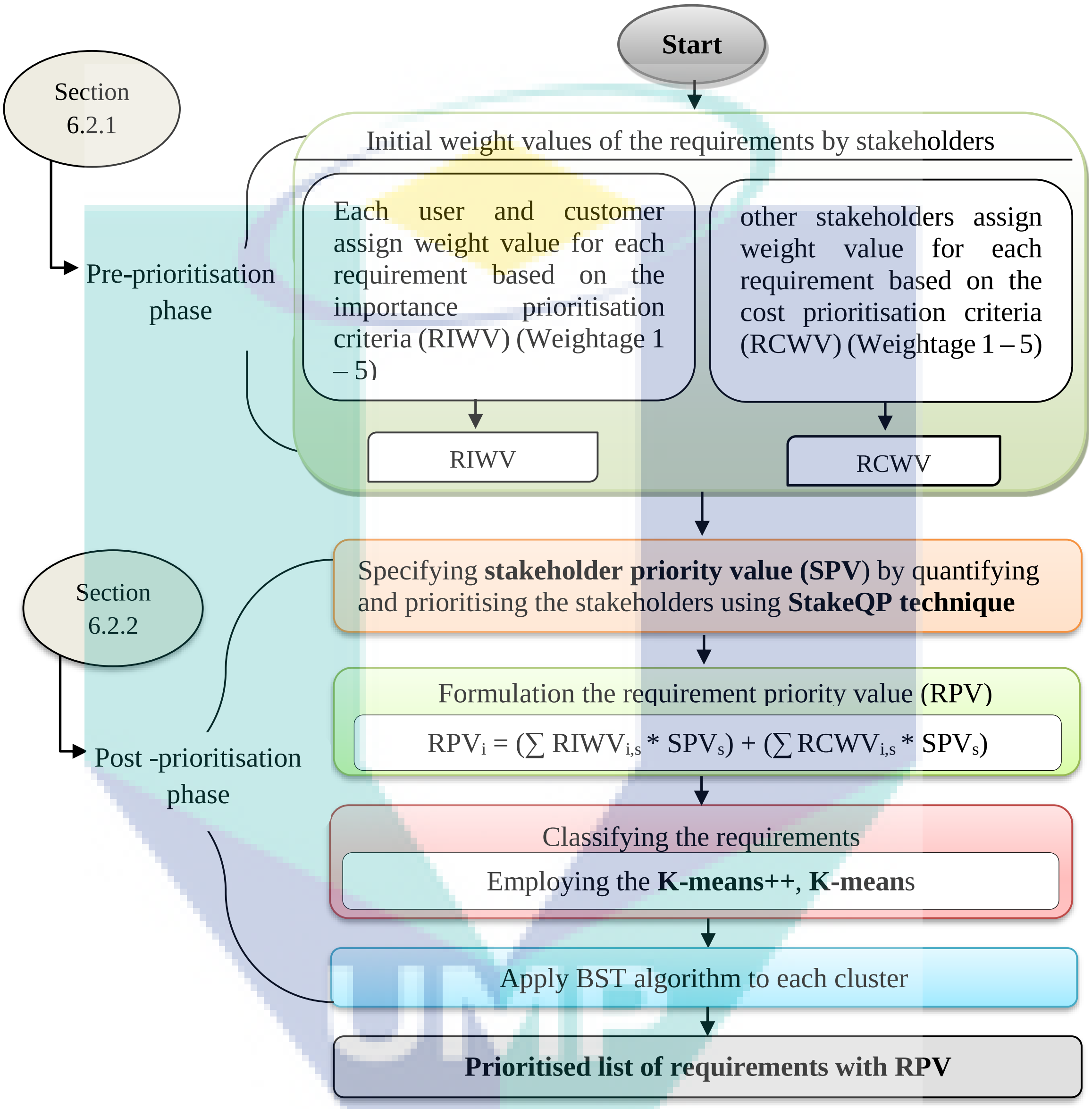

Figure 5.1 Process Structure of the Proposed SRPTackle Technique

5.2.2.1 Specifying the SPV of each Stakeholder by Quantifying and Prioritising the Stakeholders using StakeQP Technique

In this step, the StakeQP technique is executed in order to quantify and prioritise the stakeholders by identifying the SPV of each stakeholder as discussed in chapter 4. The identified SPV of the stakeholders are then used in specifying the RPV of each requirement as will be explained in the next step.

5.2.2.2 Formulation of the Requirement Priority Value (RPV)

Three inputs are used to identify the RPV, which are RIWV, RCWV and SPV, where RIRV, RCRV are obtained from the previous phase. Also, SPV is used as input since it refers to the priority value of the stakeholder who prioritised the requirements. (SPV) is identified from executing StakeQP technique. The calculation of RPV is based on the following Equation 5.1. The output of this step is RPV for each requirement which will be used as input for next step.

$$RPV_i = \left(\sum RIWV_{i,s} * SPV_s\right) + \left(\sum RCWV_{i,s} * SPV_s\right) \quad 5.1$$

Where,

RIWV: refers to the weight value of the i^{th} requirement that is given from the s^{th} stakeholder based on the importance criteria.

RCWV refers to the weight value of the i^{th} requirement that is given from the s^{th} stakeholder based on the cost criteria.

SPV: refers to priority value that associated with s^{th} stakeholder.

5.2.2.3 Classifying the Requirements

In the proposed SRPTackle, the K-means ++ along with K-means are employed to classify the requirements based on their identified RPV values. The number of clusters is specified to be three based on the numerical assignment (NA) technique, which suggested to group the requirements into three levels (low, middle, high) (Berander & Andrews 2005). However, in the proposed SRPTackle, the requirements are classified based on their obtained RPV values rather than asking the stakeholder to classify them as in NA technique. The classification of each requirement to each group (cluster) is performed based on the process of K mean algorithm. Figure 5.2 presents the pseudocode of the process of clustering the requirements into 3 clusters based on one demission which is RPV value of each requirement.

The implementation steps of the clustering process start with initialization of centroids for the three clusters: c1, c2, c3. The k-means centroids' initialization is critical to local optimal found owing to its impact on the accuracy and speed of k-means. To handle this issue, the K-means++ is used in this research to provide a careful initialization for the centroids instead of selecting them randomly. The random selection of the centroids can negatively affect the clustering speed and accuracy of the K-means++ clustering performance (Arthur & Vassilvitskii 2007).

Clustering Pseudo Code

Input : Number of cluster (K), set of Requirements' RPV (Y) = $\{y_1, y_2, y_r\}$
Output : Three clusters of requirements (low, medium, high)
Start
1 Choose the first cluster centroid (c_1) uniformly at random from Y
2 **Repeat**
3 For each y_r, compute the distance y to the nearest cluster centroid c_i using $E(y_r) = \sqrt{(c_i - y_r)^2}$
4 Choose the next cluster centroid c_i , selecting $c_i = y_r \in$ Y with probability $\frac{E(y_r)^2}{\sum_{y \in Y} E(y)^2}$
5 **Until** all the total of cluster centroids have been chosen
6 **Do**
7 For each y, compute the distance y_r to each defined cluster centroid c_i using $E_{ir} = \sqrt{(c_i - y_r)^2}$
8 Assign each y to the cluster with the closest centroid c_i.
9 Update each cluster centroids c_i by taking the average of the all assigned y_r in each cluster.
10 **While** (no longer changes in the cluster centroids) .
11 **End**

Figure 5.2 Clustering Pseudo Code

The initialization mechanism of the k-means++ is presented in line 1 to 5 of Figure 5.2. The first centroid (c1) is initialized randomly to any requirement RPV value (y_r) from Y as shown in line 1. The steps in line 2 to 5 are recursively executed to initialize the next centroids until all centroids of the defined clusters have been chosen. In line 3, the distance y_r to the nearest defined centroid ci is computed using Euclidean distance as shown in Equation 5.2, which is the most common owing to its computational simplicity because of its straight forward manner in computing the distance at each iteration (Arthur & Vassilvitskii 2007; Selim & Ismail 1984).

$$E(y_r) = \sqrt{(c_i - y_r)^2} \qquad 5.2$$

Where,

c_i is the centroid of i^th cluster

y_r is the RPV of the r^th requirement in the set Y

$E(y_r)$ is the distance y_r to the nearest cluster centroid c_i

The probability for each y_r to be the next centroid is calculated based on Equation 5.3 as in line 4. The y_r that has the high probability (farthest distance) from the defined centroids is selected to be next centroid. The core idea in K-means++ is to select the centroids one by one in a controlled fashion, where the set of initialized centroids bias the choice of the next centroid stochastically as K-means++ tries to select from far-away specified clusters' centroids.

$$P(y_r) = \frac{E(y_r)^2}{\sum_{y \in Y} E(y)^2} \qquad 5.3$$

Where,

y_r is the RPV of the r^th requirement in the set Y.

$E(y_r)$ is the distance of y_r to the nearest cluster centroid c_i.

$P(y_r)$ is the probability of selecting y_r to be the next centroid.

After obtaining the three initial clusters' centroids, K-means algorithm executes the process clustering as shown in line 6-10 of Figure 5.2. In line 7, the distance between y to each defined centroid c_i is computed using Euclidean distance in Equation 5.4. Based on the distance calculation, each y_r is grouped to the cluster with nearest centroid as shown in line 8. In line 9, each defined cluster centroid c_i is recalculated by taking the average of all its assigned y_r using Equation 5.5. The steps in line 7 to 9 are repeatedly executed until there will no further changes in the cluster centroids assignment, after which the final clustering is presented by clustering the requirement into three clusters with respect to their RPP value. With use of the K-means++ initialization mechanism for the centroids, K-means is able to produce an accurate requirements clustering result with fewer iterations compared, since the K-means++ has been approved to have the ability in enhancing the performance of the K-means in terms of accuracy and speed (Arthur & Vassilvitskii 2007).

$$E_{ir} = \sqrt{(c_i - y_r)^2} \qquad 5.4$$

where

c_i is the centroid of i^{th} cluster

E_{ir} is the distance y_r to the i^{th} cluster centroid

y_r is the RPV of the r^{th} requirement that belongs to i^{th} cluster centroid c_i

m_i is the number of the all assigned y_r in the i^{th} cluster centroid c_i

$$c_i = \frac{1}{m_i} \sum_{y_r \in c_i} y_r \qquad 5.5$$

Where

c_i is the centroid of i^{th} cluster.

y_r is the RPV of the r^{th} requirement that belongs to i^{th} cluster centroid c_i

m_i is the number of the all assigned y_r in the i^{th} cluster centroid c_i.

5.2.2.4 Applying the Binary Search Tree

The binary search tree (BST) algorithm is used as technique to prioritise requirement in (Khari & Kumar 2013). It has been proven that BST can work effectively with large set of data and is faster than other techniques such as AHP, but BST has inability of assigning priority value for each requirement (Ahl 2005; Khari & Kumar 2013; Lim & Finkelstein 2012). In the SRPTackle technique, the priority value of each requirement "RPV" is already obtained from previous steps of the SRPTackle technique. Thus, BST is used to rank the requirement in each cluster based on RPV of each requirement. BST will be executed first to the requirements in the high cluster category in order to produce a rank list of requirements to be implemented in high cluster, since the priority of the requirements in high cluster are more than the other two (middle and low clusters). This is followed by the middle cluster that contains requirements with higher priorities than those in the low cluster, which will be then sorted last. Figure 5.3 illustrates the pseudo code of the BST algorithm, which presents the application steps of the BST to produce a ranked list of requirements based on their RPV values.

The process is starting with step in line 1 of Figure 5.3 by selecting one requirement's RPV randomly as root node. Then, the steps from line 4 to 25 line is executed recursively to add each requirement's RPV. Each requirement's RPV is selected and compared to the root node. If the requirement's RPV is less important than the root node, compare it to the left subtree node value. If the requirement's RPV is less than root node value, compare it to the right subtree value, otherwise compare to the left subtree. If the node has no subtree, insert the requirement's RPV as the new leaf node. Otherwise, add the requirement's RPV to the right or left of the subtree; if it is less, then it is added to the left, otherwise it is added to the right. This process is repeated until all requirements' RPV have been compared and inserted in the BST.

```
    BST Algorithm Pseudo Code
    Input: Un-order presentation of the requirements RPV(x)
    Output: Descending  presentation of the requirements RPV
    Starts
1     Create the tree by selecting x randomly from the requirements' RPV list as root
      node value
2       Do
3         Take another x requirement's RPV
4           If  x is less than the root node value
5             Compare x with left subtree node value.
6                If the subtree is empty
7                   Create a leaf node with new requirement's RPV
8                Else
9                   If requirement's RPV is less than left subtree node value
10                        add the x to the left of the left subtree
11                  Else
12                        add the x to the right of the left subtree
13               End
14          Else if x is greater than or equals to the root node value
15            Compare x with right subtree value.
16               If the subtree is empty
17                  Create a leaf node with new requirement's RPV
18               Else
19                  If x is less than right subtree value
20                        add the x to the left of the right subtree
21                  Else
22                        add the x to right of the right subtree.
23               End
24          End
25      While (requirements RPV list != null )
26      If Tree != empty
27        Recursively print right subtree
28        Visit node
29        Recursively print left subtree
30      End
31    End
```

Figure 5.3 BST Pseudo Code

The steps in line 26 to line 30 show the process for sorting the requirement in a ranked list with descending mode, where the sorting process is executed by traversing through the entire BST with recursively printing the right subtree, followed by visiting the root and then recursively printing left subtree.

5.3 SRPTackle Automation Implementation Tool

Automation Implementation tool (SRPTackle-Tool) is developed in order to introduce the automation process of the prioritisation in the SRPTackle technique. The SRPTackle-Tool was constructed in C# programming language with .NET environment, HTML language for Graphical User Interface (GUI), and Microsoft SQL Server as database engine. Figure 5.4 shows the process of implementing the prioritisation process of SRPTackle technique using the SRPTackle-Tool, which is comprised of two main components: GUI, and automation engine. These two components contain two phases: input phase, and process and output phase. The details of these phases are presented as follows:

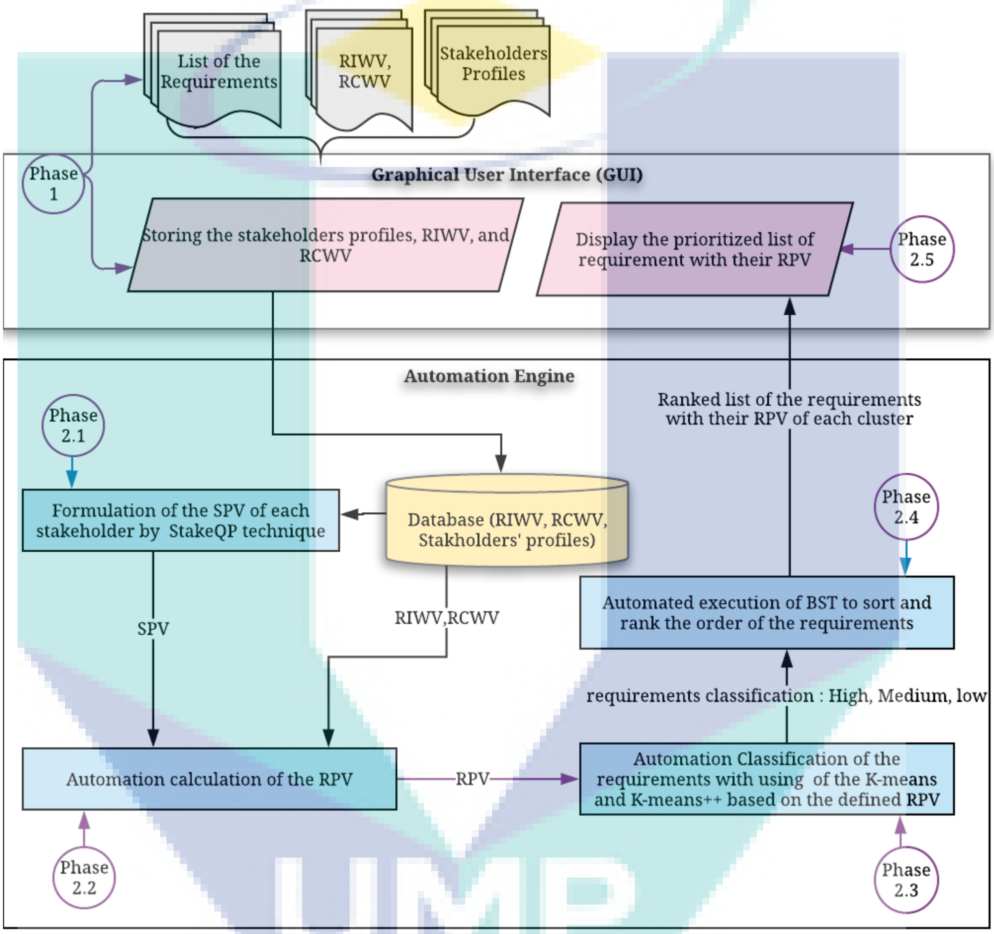

Figure 5.4 Implementation Structure of the SRPTackle-Tool

1. Phase 1, Input phase: in this step, the files (in excel format) of the list of the requirements, initial requirements weighting values, and the stakeholders' profiles files are uploaded into the GUI of the SRPTackle-Tool to be stored in the constructed database.

2. Phase 2, Process and output phase: Execution of the post-prioritisation phase of the SRPTackle technique: After uploading and storing the above-mentioned files, the SRPTackle-Tool is directly implementing the steps of the post-prioritisation phase and displaying the result within the following automated steps:

2.1 Automated formulation of the SPV of each stakeholder by executing the process of the StakeQP technique. The execution details of this step were provided in chapter4.

2.2 Automated calculation of the RPV for each requirement.

2.3 Automated classification of the requirements with K-mean and K-means++ to automatically classifies the requirements into three clusters (high, medium, low) based on the specified RPV. The details of executing this step is given in section 6.2.2 of this chapter.

2.4 Automated execution of BST to sort and rank the order of the requirements in each cluster and produce the prioritised list of requirements.

2.5 Presentation of the Result: Display the prioritised list of the requirements.

5.4 Experimentations

Large and medium requirement sets of the RALIC are used in order to validate the performance of the SRPTackle technique. List of 122 requirements are reported in the truth table of the RALIC requirements, which presents the actual result of the prioritised of the prioritised requirements (Lim 2010; Lim & Finkelstein 2012). These requirements are categorized into categories: general requirements and specific requirements, where each general requirement may have its own specific requirements. There are 49 general requirements and 73 specific requirements.

In this research, seven experiments are conducted using the RALIC requirements as shown in Table 5.1 with aim of evaluating the performance SRPTackle and comparing the SRPTackle' performance results with other alternative techniques. Each experiment is conducted within certain size set of requirements of the RALIC dataset. A precise description of the conducted experiment implementation steps is given in Appendix D, section D.1.

Experiment 1 is executed with medium set of requirements that contain 49 general requirements, while experiment 2, 3, 4, 5, 6, and 7 are conducted with large sets of requirements, consisting of requirements 50, 59, 65, 70, 73 and 122, respectively. These experiments are executed separately, where each experiment implements the proposed SRPTackle technique based on the defined steps of SRPTackle-Tool as presented in section 4.3. Figure 5.5 shows the sample of the experimentations result which present the partial list of the prioritised requirements, while full list of the prioritised requirements for the sample of the experimentations result is provided in the Appendix D.

Table 5.1 The Experiments Details

Experiment No	Size of requirements set	Number of requirements	RALIC requirements types
Experiment 1 (Exp.1)	Medium Set of requirements	49	General requirements
Experiment 2 (Exp.2)	Large Set of requirements	50	Specific requirements
Experiment 3 (Exp.3)	Large Set of requirements	65	Specific requirements
Experiment 4 (Exp.4)	Large Set of requirements	70	Specific requirements
Experiment 5 (Exp.5)	Large Set of requirements	73	Specific requirements
Experiment 6 (Exp.6)	Large Set of requirements	80	General requirements and their Specific requirements and
Experiment 7 (Exp.7)	Large Set of requirements	122	General requirements and their Specific requirements

The result presents the classification of the requirements into three clusters: high, medium, and low priority requirements and requirements of each cluster are prioritised. In each cluster, each requirement has its priority ranking (R) along with its obtained priority value (RPV). The results evaluation of the SRPTackle and the comparative performance with other alternative techniques are going to be discussed and highlighted precisely in the next section.

Final Result

Requirements prioritized list

High priority requirements' list			Middle priority requirements' list			Low priority requirements' list		
R	ID	RPV	R	ID	RPV	R	ID	RPV
1)	a.3	170.59	17)	b.2	72.98	21)	g.1	15
2)	a.1	152.07	18)	g.4	32.73	22)	e.2	13.81
3)	c.5	148.15	19)	b.1	27.48	23)	j.2	13.43
4)	c.1	142.41	20)	b.3	26.73	24)	e.1	12.94

Figure 5.5 Sample of Experimentation Result of the Partial List of the Prioritised Requirements.

5.4.1 SRPTackle Performance Analysis and Result Evaluation

The main objective of the proposed SRPTackle technique is to produce prioritised listed of requirements with ability of addressing the issue of scalability, lack of SQP process, heavy reliance of the expert participation in conducting the RP process, lack of automation level and time consumption. Therefore, the evaluation performance of the SRPTackle technique is conducted based on the mentioned issues. Also, the accuracy performance of the SRPTackle is measured in order to verify the ability of the techniques in solving the mentioned issues with acceptable accuracy rate compared to other existing techniques.

Lack of SQP process: addressing the lack of SQP process issue is related to the ability of the technique to analyse and reveal the impact value of each participated stakeholder on the prioritisation process of the requirements which assist in obtaining an accurate prioritised list of requirements. The SQP process is considered and executed in the SRPTackle technique through using the new proposed StakeQP technique**.** The StakeQP performed the SQP process for the participating stakeholders in the SRPTackle technique with less time consumption, reducing the need for expert participation in conducting the SQP process along with proposing measurement criteria for the attributes used to evaluate the stakeholders in RP process, and ability to produce more good result in identifying the impact value of each stakeholder compared to other SQP technique as explained in section 4.4, chapter 4.

A heavy reliance of the experts' participation and lack of automation: handling these two issues have to do with ability of the SRPTackle to automate and reduce the need for the expert involvement in conducting the prioritisation process. Executing the process of the SRPTackle technique using its developed automation SRPTackle-tool assists to conduct the prioritisation automatically with eliminating the manual process. Quantification and prioritisation of the participating stakeholders with using StakeQP assists to reduce the need for the experts' participation in measuring the impact value of the participating for each participating stakeholder on RP process. Also, formulation of the requirement priority value led to identify the RPV of each requirement without being heavily dependent on the experts in identifying the requirements' RPV. On the other hand, classifying the requirements and producing prioritised list of the requirements based on their identified RPV through implementation of the clustering algorithm (K-means and

K-means++), along with the BST led the SRPTackle technique to function without being heavily reliant on the expert intervention in assigning the RPV for each requirement and prioritising them.

Prioritisation Accuracy: The SRPTackle prioritisation accuracy is measured by comparing the ranked prioritised list of requirements produced by the SRPTackle with the ground truth list of the requirements. The accuracy of the requirement prioritisation is the similarity degree between the produced prioritised list of requirements (ranked list of the general requirement and specific requirements each) by the SRPTackle and the prioritisation in the list of ground truth.

The ground truth list presents the actual prioritised list of the RALIC requirements (ranked list of the general requirement and specific requirements) that is derived from RALIC project documentation in (Lim 2010). To find the similarity degree, the statistical measure of the Pearson correlation coefficient (r) is selected, which is known as the best method of measuring the association between two or more variables (Evans 1996). Also, it has been used by existing RP techniques for the same purpose of finding the accuracy of their prioritised result such as in (Asif et al. 2017) (Lim & Finkelstein 2012). The value of correlation coefficients (p) is ranged between +1 to -1, where +1 refers to a perfect positive correlation, -1 indicates a perfect negative correlation, and a 0 refers to no correlation. Equation 5.6 is used to calculate the correlation coefficients value (p) between the lists.

$$P = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \ \sum_{i=1}^{n}(y_i - \overline{y})^2}} \qquad 5.6$$

Where,

P is the Pearson correlation coefficient value.

n is the number of samples which are the requirements in each list (both lists consist of the same number of requirements)

x_i is the rank for requirement *i* in the list of SRPTackle.

y_i is the rank for requirement *i* in the ground truth.

Table 5.2 presents the accuracy result of the proposed technique in each conducted experiment, where it is noted that accuracy of the proposed SRPTackle is ranged between 0.93 to 0.94. These values reflect the very strong positive correlation degree (based on the interpretation of correlation coefficients in Table 4.14, chapter 4) which means high X requirements rank in the SRPTackle go with high Y requirement rank in the ground truth and vice versa.

Table 5.2 Accuracy Results of the SRPTackle

	Exp.1	Exp.2	Exp.3	Exp.4	Exp.5	Exp.6	Exp.7
Accuracy	0.9465 (94.65%)	0.9399 (93.99%)	0.9381 (93.81%)	0.9300 (93.0%)	0.9371 (93.71%)	0.9392 (93.92%)	0.9449 (94.49%)

Moreover, Figure 5.6 presents the comparison of accuracy results of the SRPTackle with three alternative techniques (StakeRare, Lim et al. GA, and Saffron). These models are considered to be the relevant works to the proposed SRPTackle as they were evaluated using the same size of requirement of the RALIC dataset and accuracy measurement method (to find the accuracy result) used in assessing the performance of SRPTackle. Also, these techniques performed the SQP process during prioritising the requirements in the same way as the SRPTackle does.

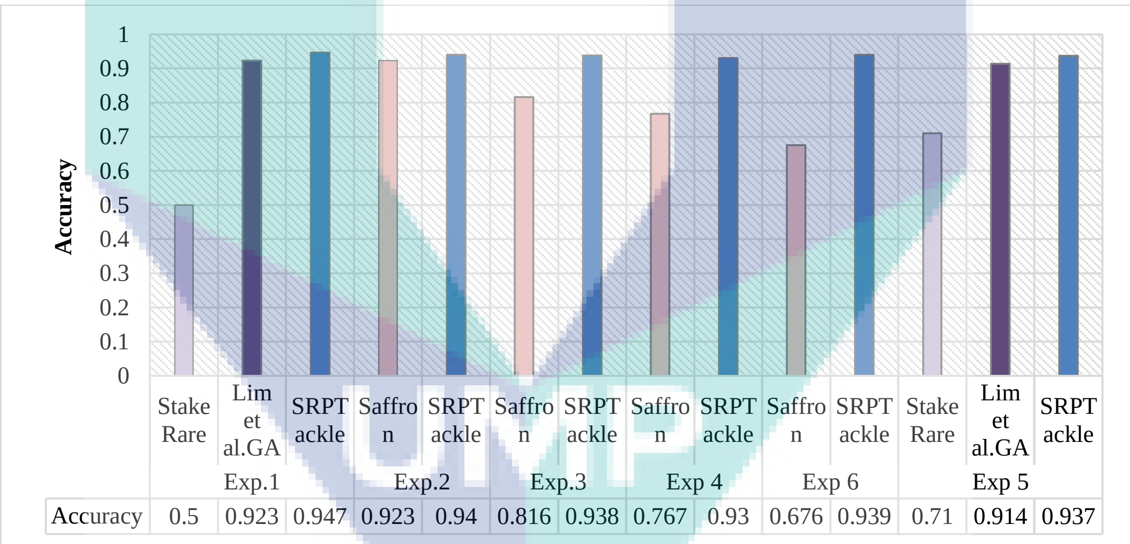

Figure 5.6 Accuracy Performance Analysis

In exp.1 and exp.5, the accuracy performance of the SRPTackle is compared with the techniques of the StakeRare, Lim et al.GA, since the accuracy performance of these two techniques were evaluated with same number of RALIC requirements (all 49), general requirements, and all (78) specific requirements in the conducted exp.1 and 2 of the evaluating SRPTackle. The accuracy performance result of the StakeRare was reported in (Lim & Finkelstein 2012), whereas the study of (Lim et al. 2012) reported the performance accuracy of the Lim et al. GA by conducting number of experiments with different initialization values for genetic algorithm (GA) used in the prioritisation process. However, the best reported accuracy result of the Lim et al.GA were selected to be compared with the proposed SRPTackle. As can be observed from accuracy result in Exp.1 and 5 of Figure 5.6, the proposed SRPTackle has better accuracy performance than other two existing techniques, where the accuracy result of the SRPTackle is 0.9465 and 0.9371, while the Lim et al. StakeRare is 0.5 and 0.71, and Lim et al. GA is 0.9228 and 0.9135 for Exp.1 and Exp. 5, respectively.

On the other hand, the accuracy performance of the proposed SRPTackle is also compared with Saffron technique, in which its accuracy performance was evaluated in (Asif et al. 2017) with same number of requirements in Exp. 2, Exp. 3, Exp. 4 and Exp. 6 of evaluating the SRPTackle. It is obvious that the efficiency of the StakeQP is higher than the existing technique, where the accuracy result of the SRPTackle is 0.9399, 0.9381, 0.93, and 0.9392, while the Saffron is 0.9231, 0.8156 0.7669, and 0.7669 for Exp.2, Exp.3, Exp.4 and Exp. 6, respectively.

Time consumption: Time consumption is referred to as the time consumed by the SRPTackle in prioritising the requirements to produce a ranked list of requirements. While conducting the six experiments, the time consumed by the SRPTackle was measured. Table 5.3 presents the time-consumption of the SRPTackle for producing the result in each conducted experiment. The SRPTackle has consumed 5.02, 5.02,5.41, 5.46, 5.48 and 5.99 seconds for producing the final prioritised list of requirements for Exp.1, Exp.2, Exp.3, Exp.4, Exp.5 and Exp.6, respectively. This is a good response time in producing a prioritised list for medium and large and set of requirements compared to the other existing techniques such as AHP technique that consumed 25 to 40 minutes for prioritising medium set of requirements (Khari & Kumar 2013; Shao et al. 2017).

Table 5.3 SRPTackle Time Consumption Results

	Exp.1	**Exp.2**	**Exp.3**	**Exp.4**	**Exp.5**	**Exp.6**	**Exp.7**
Time consumption (seconds)	5.02	5.02	5.41	5.46	5.48	5.52	5.99

Figure 5.7 presents the comparative time consumption performance of the SRPTackle with two techniques (Lim et al.GA (Lim et al. 2012) and Optimal Solutions Analysis(OSA) (Veerappa 2012)) that perform the RP process with less time consumption considering to other existing technique. The time consumption of these

techniques has been evaluated with same number of requirements (all requirements and specific requirements) of the RALIC dataset used in the conducted Exp 1, Exp.5, and Exp.5 of evaluating the SRPTackle. Additionally, the Lim et al. GA and OSA techniques have same features as the SRPTackle in terms of performing the requirements prioritisation process with supported automation tool and considering SQP process as well. However, the StakeRare and Saffron are not included as their time consumption performance were not evaluated and reported. As can be noticed from Figure 5.7, the performance of the SRPTackle is more effective than other two techniques in terms of consuming less time for prioritising the medium and large set of requirements.

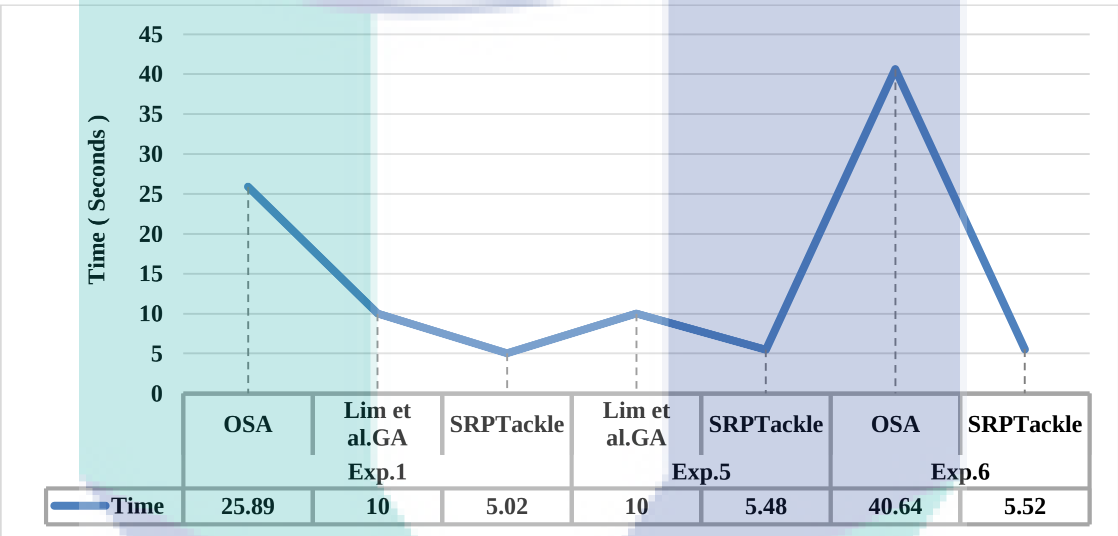

Figure 5.7 Time Consumption Performance Analysis

Furthermore, Table D.1 in Appendix D presents the comparative analysis of the SRPTackle technique with other existing techniques in different studies based on the elements of time consumption, scalability, SQP process existence, size of requirements set, number of requirements, and type of technology/ automation tool used or developed in executing the experiment for implementing the technique. These existing techniques are included to be compared with the SRPTackle, since the prioritisation process of these techniques are the most commonly used in the prioritisation process (Achimugu et al. 2014d; Babar et al. 2015c). Also, the performance of techniques is evaluated with size types of requirement set (small, medium, and large of requirement set). From Table D.1 in Appendix D, it is evident the efficiency of the SRPTackle technique is better than each existing technique based on the time consumption of producing the prioritisation with executing SQP process, even if the implementation of some of these techniques was executed with supported automation tool except the NA technique (as reported in the NASN2 study).

The SRPTackle was able to prioritise the requirements automatically with less time consumption as shown in the evaluation performance results. This can be related to the semi-automated process that was adopted in conducting the RP process with use of the developed automation tool (SRPTackle-Tool) with eliminating the manual process. Additionally, the ability of the StakeQP in performing the SQP process for the participated stakeholders with less time consumption assists to reduce the time consumption of quantifying and prioritising the stakeholders in the prioritisation process of the SRPTackle. Also, utilization of the speed feature of the clustering algorithms used along with BST in categorizing and prioritising the requirements assist in minimizing the time that is needed in producing a ranked list of the requirements compared to other techniques such as AHP, pairwise comparison, and CBRank that perform pairwise comparisons and/or relied on the expert to perform the process, which will consume a lot of time.

Scalability: scalability is referred to as the inability of the technique to prioritise large set of requirements. Factors such as number of comparisons (Achimugu et al. 2014d; Avesani et al. 2005; Berander et al. 2006; Ma 2009; Tonella et al. 2010), time consumption (Kukreja et al. 2012), and the lack of the automation and intelligent level (Achimugu et al. 2014d; Ma 2009) play a key role in raising the scalability issue in most of the existing techniques. For instance, in techniques of bubble sort, AHP, and pairwise comparison techniques, the prioritisation process is conducted by evaluating the relative priorities between pairs of requirements (Achimugu et al. 2014d; Berander & Andrews 2005; Karlsson et al. 1998). The number of comparisons increases dramatically as the number of requirements grows, which makes the prioritisation process highly complex and tiring. This will undoubtedly induce the scalability of the prioritisation process (Achimugu et al. 2014d; Avesani et al. 2005; Berander et al. 2006; Ma 2009; Tonella et al. 2010).

Additionally, the manual process with heavy reliance on the experts that are required in order to perform the process and the computational calculation to identify the relative priority value of each requirement can be more complex and time consuming (Achimugu et al. 2014d; Ma 2009). Hence, having to deal with hundreds or thousands requirements of renders this technique unmanageable (Achimugu et al. 2014d; Ma 2009). In addition, when conducting the RP process, the scalable RP technique should work with large set of requirements without being time consuming (Kukreja et al. 2012). In the SRPTackle, the hybridization of function of RPV formulation, K-means++ and K-means, BST, and the developed automation tools addresses the scalability to a good extent as shown in the results which present the ability of this technique to efficiently handle the large set of requirement with less time consumption and better accuracy result compared to other existing techniques that can scale up.

The RPV formulation is used to calculate the priority value of each requirement with performing based on the input requirement weights given by the stakeholders without performing any pairwise comparisons in formulating the RPV that disrupt the effectiveness in dealing with large of requirement. This is because as number of the requirement increase, issues of complexity in terms of implementing the prioritisation and time consumption are increased. Moreover, employing BST and clustering algorithm (K-means++ and K-means) in the SRPTackle is not only for reducing the expert biases with minimizing the experts' participation in generating the ranked list of requirements, but also the main achievement is enabling the SRPTackle to work with large set of requirements. The K-means provides the ability to cluster the large number of requirements of the RALIC dataset accurately into three specified clusters based on the specified RPV of each requirement as shown in the experimentation results with the used initialization method of K-means++.

In addition, the BST is used in this research for sorting the requirements in each cluster. The effectiveness of the BST to deal large number of requirements to be sorted in prioritised list with fewer comparisons as compared to the AHP and Bubble Sort techniques make the SRPTackle more effective in terms of dealing with large set of requirements. With the RALIC dataset use of 122 requirements in the experiment, the complexity for total number of comparisons for BST is (O(log n) in the best case, where the constructed BST is balanced, and O(n Log n) with unbalanced BST (where n is the number of the requirements) (Beg et al. 2008; Karlsson et al. 1998; Kaur & Bawa 2013; Ma 2009) . Total comparisons with using AHP or Bubble Sort is equal to (n * (n-1) / 2), which is hard to be practically implemented and consumes plenty of time (Babar et al. 2015c; Karlsson et al. 1998).

Table D.1 in Appendix D shows the techniques of PHandler, CBRank, StakeRare, OSA, Lim et al. GA, and Saffron have been applied successfully to the large set of requirements. The PHandler technique has succeeded in dealing with large numbers of requirements. The back-propagation neural network along with process of analytical hierarchical enabled the technique to prioritise up to 500 hundred requirements, which is the highest number of prioritised requirements among all other existing techniques as shown in its evaluation performance in (Babar et al. 2015c). The accuracy and time consumption of prioritisation performance have not been measured. On the other hand, the SRPTackle has salient properties compared to the PHandler with respect to the ability of accurately prioritising the requirement with reducing the need of the involvement of the experts and executing the prioritisation process automatically with less time consumption, since the essential need of the experts' participation to conduct the prioritisation process and lack of the automation level are reported as limitations of Handler (Babar et al. 2015c).

In the CBRank technique, the stakeholders' preferences with employing methods of machine learning are used to prioritise the large scale of requirements. The performance analysis of this technique presented its ability of prioritising 100 requirements efficiently as compared to the AHP technique, while expert intervention is vitally needed to conduct the prioritisation. Although this technique is one of the useful techniques in addressing the scalability issue with accuracy percentage of 80%, the SRPTackle can be considered as an alternative technique as it has achieved higher accuracy percentage in prioritising the large set of requirements with 93.0% as minimum accuracy result and 94.65% as maximum accuracy result. Also, CBRank prioritisation process consumes more time than the SRPTackle (as shown in Table D.1 in Appendix D).

The StakeRare technique addressed the scalability issue by utilizing the collaborative filtering and social network in prioritising the requirements. The evaluation of this technique was executed based on accuracy aspect on the dataset of the RALIC requirements and presented its ability to prioritise large set of requirements with a good accuracy result. However, the accuracy performance of the SRPTackle is better than the StakeRare as presented in Figure 5.6 of the accuracy performance. Also, the execution of this technique is manually performed with heavy reliance of the experts' participation.

Other techniques that have been applied to the large set of the RALIC dataset include OSA, Lim et al. GA, Saffron. Even though these techniques are found to be less time consuming and more accurate in producing prioritisation result compared to other techniques, the SRPTackle is able to generate more accurate results with less cost effective in terms of time (as shown in Figure 5.6 and Figure 5.7) . Also, the StakeQP is more effective in addressing the issues of the need for substantial professional involvement in implementing RP process than these techniques, since these techniques are heavy dependence on the participation in performing the SQP process along with specifying the RPV for each requirement and prioritising them.

5.5 Threats to Validity

Experimental based researches are often subjected to some threats to validity (Wohlin et al. 2012). In this research, considerable efforts are undertaken to minimize and eliminate these threats; however, few of these threats are beyond the control. The first threat is the comparison with existing RP techniques. Within RP, there could be various techniques to be compared with as shown in the SLR-RP. However, performance comparison with all of these techniques has not been conducted owing to different reasons such as unavailability of the source code of these techniques for public use. However, to eliminate this threat, the performance of the proposed SRPTackle technique has been compared with those compared techniques (selected techniques) that are considered to be the most relevant works to the proposed SRPTackle technique, since these selected techniques were evaluated using RALIC dataset with the same size of requirements of the and the same accuracy measurement method as the present study in the evaluation process of the proposed SRPTackle. Also, those selected techniques have executed their own SQP processes during prioritising the requirements as same as the SRPTackle does. On the basis of the thorough search of the relevant literature, those selected techniques and benchmarks for comparison are the best results published so far with using the same RALIC benchmark dataset.

Another significant threat is concerning to the time consumption of prioritising the requirements for each technique, which is highly subjective to the running environment. Thus, the implementation of all the techniques is compulsory to be conducted in the same prioritisation environment. To minimize this threat, the time consumption performance of the SRPTackle has been compared with the tools of three techniques that has been evaluated with using RALIC dataset with the same number of requirements as the present study in the evaluation process. The comparison could present an indication for the prioritisation time; however, there is one threat here, which is related to the implementation language differences of the techniques' tools. Nonetheless, the performance of techniques' tools can be impacted with low specifications of the machine (i.e., desktop or laptop, and etc..) used to run these tools, but the execution of the tools of those compared techniques was carried out on machine with specifications that defined by the authors to be as minimum specification to execute the tools efficiently.

5.6 Chapter Summary

A new scalable semi-automated RP technique (SRPTackle) was proposed with integration with the proposed StakeQP in this chapter to address the defined limitations of the RP techniques. A precise commentary on the process of the proposed StakeQP technique along with its implementation structure of its developed automation tool were presented. The proposed SRPTackle provides a semi-automated process to prioritise the large set of requirements and perform the SQP process for the participating stakeholders with removing the manual process and minimizing the need for the expert intervention in assigning the priority values of requirements and conducting the SQP process.

The proposed SRPTackle is based on the combination of the StakeQP technique, RPV formulation function, classifying algorithm (K-means and K-means++), and BST. The StakeQP used to perform to quantify and prioritise the stakeholder impact by identifying the SPV values for each participating stakeholders in the RP process. The RPV formulation function utilized to specify the RPV value of each requirement based on the defined SPV of each stakeholder and the assigned initial weight value of the requirement that is obtained from the participating stakeholders. To classify the requirements into three defined levels (high, medium, low), the K-means and K-means++ were employed to classify the requirements based on their specified RPV. Lastly, the BST algorithm were then utilized to sort the requirements and produce the prioritised list of requirements.

Additionally, seven experiments have been conducted to assess the performance of the proposed SRPTackle with large set of requirements of the RALIC benchmark dataset. The findings demonstrate that SRPTackle can handle large set of requirements with ability of producing more accurate results with less time cost effective and more effective in addressing the defined RP limitations compared to other existing RP techniques. The upcoming chapter (chapter 6) articulates the conclusion and the future work of this research.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Introduction

In this chapter, a synopsis of this research is given by briefly reviewing each of the previous five chapters of this thesis along with an elaboration of how the defined research objectives were achieved within this research. Followed by a section that elaborates the contributions of this research, and finally the suggestions for future work is discussed in another section.

6.2 Thesis Synopsis

Chapter 1 provided a clear introduction of this research. This chapter started with presenting an introduction about the domain of this research by explaining the RP along with SQP and highlighting the significance of SQP and RP process in the software development process. Also, the problem background, problem statement has been elaborated distinctly by demonstrating and justifying the need for a new RP technique along with a new SQP technique that can address the currents limitations of the SQP and RP by having the ability to prioritise large scale requirements and along with quantifying and prioritising the participated stakeholder with minimizing the need for the expert participation, less time consumption and producing more accurate result compared to the alternative techniques. The objectives, questions, and scope of this research were then elaborated distinctly in this chapter.

To achieve the first objective, chapter 2 introduced as comprehensive analysis of research gap of this work by conducting two systematic literature reviews (SLR-RP and SLR-SQP). The SLR-SQP provided a comprehensive review of the SQP domain by selecting and studying critically published works that are related to the specified domain.

The aim of the SLR- SQP has been achieved by exploring the SQP domain in terms of providing available proof about the importance of SQP in RP, identifying the attributes that are used to quantify and prioritise the stakeholders, and presenting and analysing current SQP techniques in terms of their implementation process description, types, and limitations. In addition, the detailed discussion of the overall limitation of SQP was presented, which assist to open new opportunities to utilise and enhance the domain with proposing new SQP technique.

On the other hand, the SL-RP concentrated on providing a detailed discussion of the impact of the RP in system development process, reporting the stakeholder types that are involved in RP and also categorizing the identified RP stakeholder types into three main categories (functional beneficiary, commercial and technical stakeholders). Also, 108 RP techniques were discussed and analysed based on predefined parameters: benefits, prioritisation criteria, types, suitable set of requirements to be prioritised with, and limitations. Furthermore, the overall limitation of RP was identified and discussed precisely, which assist to have clear view of the need for a new RP technique to be proposed in order to address the identified limitations.

Chapter 3 presented the research methodology process that describes the research methodology used in conducting this research to achieve the defined objectives of this research.

To achieve the first objective of this research, in chapter 4, a new semi-automated stakeholder quantification and prioritisation technique (StakeQP) was proposed based on AMC to address the defined SQP limitations. In this chapter, new attributes measurement criteria were proposed and formulated to be used in evaluating the stakeholders based on the finalized StakeQP attributes. A detailed explanation of the process structure and the automation implementation has been described precisely. Additionally, part of the defined third research objective that is related to the evaluation of the proposed StakeQP performance with respect the accuracy and time consumption was achieved by conducting experimentation and comparative analysis against the existing SQP techniques. The StakeQP performance has been competitive in producing more accurate result of quantifying and prioritising the stakeholder with being less time cost consuming and more effective in addressing the specified SQP limitations compared to other alternative techniques.

The second research objective along with other part of third research objective (that is associated to the assessment of the SRPTackle performance in terms of the accuracy and time consumption) have been achieved in chapter 5 by proposing the new SRPTackle technique with integration with the proposed StakeQP technique process to address the defined RP limitations. The SRPTackle provides semi-automated process to prioritise large set of requirements with of execution of the SQP process based on the adoption of the proposed StakeQP to execute SQP process for the participating stakeholders along with formulation of the RPV of each requirements and application of the K-means, K-means++, and BST algorithms to classify the requirements and produce the prioritised list of requirements. In addition, seven sets of experiments have been conducted to evaluate the performance of the proposed SRPTackle with respect to the time consumption and accuracy. The experimentation results reveal the SRPTackle has ability to prioritise large set of requirements with capability of being more efficient in terms of addressing the identified RP limitations, producing more accurate results and being more effective with respect to time consumption when compared to the existing RP techniques.

Placing the chunks together, this research has obtained its defined objectives by proposing, implementing and evaluating StakeQP and SRPTackle techniques. Table 6.1 presents the research objectives achievements associated with thesis chapters that included the achievement of the objective.

Table 6.1 Research Objectives Achievements

No	Research Objective	Achievement
1.	To study the RP and SQP in terms of SQP attributes, RP criteria and techniques with their limitations	Chapter 2
2.	To propose a new SQP technique (StakeQP) based on new attributes' measurement criteria.	Chapter 4
3.	To propose a new semi-automated scalable RP technique (SRPTackle) with integration with the new StakeQP technique	Chapter 5
4.	To evaluate the proposed StakeQP and SRPTackle techniques with respect to the accuracy and time effectiveness.	Evaluation of StakeQP in Chapter 4 and the SRPTackle in Chapter 5.

6.3 Research Contribution

This section deals with the contributions of this research to the requirements engineering and stakeholder analysis domains. Figure 6.1 presents the research contributions. The core contributions of this research can be related to the conducted SLR reviews and development of the StakeQP and SRPTackle techniques along with their automation tools. Additionally, proposed attribute measurement criteria, formulation of the MCV and AWV for the SQP process are another contribution of this research. The detailed explanation of each of these contribution is presented as follows:

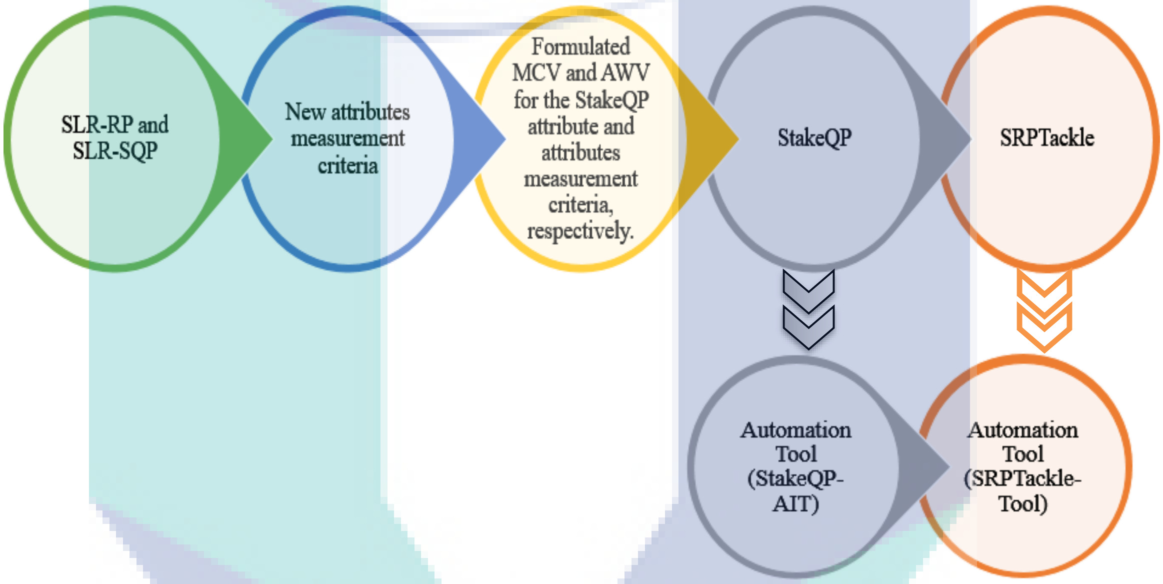

Figure 6.1 Research Contributions

i. SLR RP and SLR-SQP

Having conducted SLR-RP and SLR-SQP, the RP and SQP has been extensively discussed in stakeholder analysis and requirements engineering domains.

Based on the current observations, there are no other review research studies on the topic of SQP. This includes both SLRs and systematic mapping reviews. However, generally, there are researches on the topic of stakeholder analysis, but none of them focus on the area of SQP. Another reason as to why SQP is an important topic to be researched is the forthcoming research trend in the analysis of stakeholders of a system, thus making SQP an essential topic that requires thorough experimentation. Other than that, the literature study plays an essential role in providing a clear view with less time consumption for researchers and practitioners about certain research themes such as SQP.

The Findings of the SLR-SQP demonstrated that SQP is a crucial process in requirement prioritisation (RP). Seventeen SQP attributes were revealed along with their description, usage impact, and degree of importance. Furthermore, nine techniques that focus on quantification and prioritisation of the stakeholders were identified and critically analysed in terms of their description, SQP process involved, SQP attributes used, types, and limitations. The SLR-SQP contributions can be expressed as follows:

1. Detailed and specific overview impact of the SQP process in RP

2. Detailed analysis of SQP attributes along with their definition, usage impacts, and degree of importance

3. Detailed investigation of existing SQP techniques in terms of their description, SQP process involved, SQP attributes used, types, and limitations

4. Detailed overview of limitations or challenges of SQP techniques

On the other hand, several review studies have been conducted in order to identify and investigate the RP techniques strengths and weaknesses. Some of these reviews include researches by Khan (Khan 2006), Kaur and Bawa (Kaur & Bawa 2013), Pergher and Rossi (Pergher & Rossi 2013), Pitangueira et al. (Pitangueira et al. 2015) and Achimugu et al. (Achimugu et al. 2014d). Such reviews have managed to bring out the performance of the existing RP techniques. However, observing this field with a closer lens reveals that there are in fact two main limitations. There are two facets in which there is still a need for focus and study in regards to RP.

The first facet is that the current reviews are not focused enough when it comes to analysing the various characteristics of decision makers, the prioritisation criteria they use, RP activity in the software development context and significance of RP in the software development process. The second facet is that ever since the last published review, there have been several new RP techniques that have introduced new material. These new techniques create a necessity for a new study to be conducted. The most recent review was performed by Achimugu et al. (Achimugu et al. 2014d), in which a total of 49 techniques were analysed. However, in this research another evaluation criterion was added which increases the number of techniques to 108. The number of techniques includes both the new techniques introduced, and also the techniques that are covered based on the new evaluation criteria. Hence, the contribution of the SLR-RP can be summarised as follows:

1. Detailed and specific overview of the significance of the RP process in software development.

2. Detailed investigation of the usage prioritisation criteria in the RP process.

3. Analysis of the participating stakeholders in RP.

4. Proposed new categories of the participating stakeholders

5. Empirical evidence of other uncovered and recent RP techniques and their limitations.

6. Proposed new categories of the existing RP techniques

7. Detailed analysis and benefits, usage size of the requirements set to be prioritised and type of each RP technique.

8. Detailed analysis of usage contexts of RP techniques and selected studies.

Therefore, The SLR-RP and SLR-SQP are comprehensive source for practitioners and researchers who are working in the field of SQP and RP and their findings are useful for researchers and practitioners in improving the current state of the art and state of practices.

ii. Proposing AMC

As revealed from the literature, the existing SQP techniques fall short of providing measurement criteria for each attribute used for measuring the stakeholder impacts. Thus, new measurement criteria are proposed for each attribute used in quantifying and prioritising the stakeholders in this research. The description and implementation of these proposed AMC were also provided. Based on the findings of conducted literature, the proposed AMC is one of the first measurement criteria for assessing the stakeholder impact according to the SQP attributes in the SQP domain.

iii. Formulating AWV and MCV for each StakeQP attribute and proposed AMC, respectively.

Another contribution of this research is related to the formulation of AWV for each finalized StakeQP attribute and the MCV for each AMC. The aim of formulating the AWV and MCV was to identify the weight value of each StakeQP attribute along with its proposed AMC in order to be used in specifying the overall SAV of the stakeholder, which refers to the worth degree value of given stakeholder for each StakeQP attribute.

In this research, the SAV formulation function is also constructed to measure worth degree value of given stakeholder for each StakeQP attribute as explained in chapter 4, section 4.2.4.1. The formulation process was performed based on the conducted survey of industrial experts and defined the AWV and MCV calculation methods. The core purpose of the survey was to obtain the importance values of the attributes and their proposed AMC, which were then used in formulating the MCV and AWV based on the steps of the defined AWV and MCV calculation methods. The formulated AWV and MCV are added as new value to the SQP domain, which provide assistance in assessing the SAV of each stakeholder according to the attributes. In this research, the SAV formulation function is also constructed to measure worth degree value of given stakeholder for each StakeQP attribute as explained in chapter 4, Section 4.2.4.1.

iv. Proposing StakeQP technique

As observed from the conducted SLR-SQP, the shortage of low implementation details, nonexistence of AMC, time consumption, heavy reliance on the involvement of highly professional human and manual process are the current limitations of the existing SQP techniques, which affects their accuracy results. Thus, the StakeQP technique is proposed with ability of addressing the identified SQP challenges in this research. The proposed StakeQP introduces new low implementation details of executing the SQP automatically based on the finalized StakeQP attributes, the proposed AMC, the formulated AWV and MCV, the constructed SAV formulation function and the adoption of the TOPSIS method.

Furthermore, the StakeQP reduces the need for the experts' participation and minimizing the extent of expert bias along with time consumption in conducting the SQP by quantifying and prioritising the stakeholders based on the proposed AMC for the StakeQP attributes used to evaluate the stakeholders. The formulated AWV and MCV are used to calculate the SAV of the stakeholders by execution of the SAV formulation function. Then, the TOPSIS method are applied to calculate the SPV of each stakeholder and generated prioritised list of stakeholders based on their identified priority values. Also, the StakeQP provides a new semi-automated process to reduce the cost effectiveness of time utilization along with providing low level details of quantifying and prioritising the stakeholders. The findings of the conducted evaluation demonstrate that StakeQP is capable to produce more accurate results with less time consumption and more effective in addressing the defined key limitations compared to other alternative techniques.

With respect to the managerial side, StakeQP has a various number of contributions. As revealed from the literature, the existing SQP techniques fall short of providing the AMC for each attribute used for measuring the stakeholder impacts. Thus, new AMC are proposed in this research for each attribute used in quantifying and prioritising the stakeholders. The description and implementation of these proposed AMC are also provided. The proposed AMC is one of the first measurement criteria that can be used by the project manager to assess the stakeholder impact according to the SQP attributes in the SQP domain. Another contribution of the StakeQP to the SQP managerial side is related to the formulation of AWV for each finalized StakeQP attribute and the MCV for each proposed AMC. With the usage of the formulated AWV and MCV along with the automation process of the StakeQP in identifying the SPV of each stakeholder, the project manager can assess the stakeholders' impacts by measuring the degree value of a given stakeholder for each StakeQP attribute and prioritising them without being heavily reliant on expert involvement. As a result, StakeQP can also assist the projects managers in achieving the cost-savings benefits by saving the cost resources of the project that are usually located for hiring the experts to participate in conducting the SQP process.

Additionally, with the automation, fast speed and low implementation details features of StakeQP, the project managers can perform SQP in a proper and efficient way in the industrial and academic sectors without requiring considerable amount of effort (such as a tedious manual process, the necessity of the experts' participation, possible human errors in the manual process, time and effort workloads). Furthermore, the ability of StakeQP in producing better accuracy results than alternative techniques in identifying the core stakeholders with their SPV value can enable the project managers to reveal stakeholders with high levels of impact on the project outcomes and give high priority to these stakeholders at the outset of the project development process. This will consequently lead the project managers to establishing an effective planning strategy for maximising the benefits of the organisations based on the most influential stakeholders, which induce winning support from most of the specified stakeholders, bringing more potential resources during the project development and increasing the possibility of producing a successful project.

v. Proposing SRPTackle technique

RP is considered as a key role in producing a successful system by selecting the most important requirements to be developed and released. Various techniques have been introduced to perform the RP process and produce list of prioritised requirements. In this research, a critical analysis on the existing RP techniques has been conducted in the SLR-RP. although the presence of existing RP techniques and their usefulness in conducting the prioritisation process, the analysis result revealed that certain limitations still exist, which are the scalability, lack of automation, time complexity, lack of quantification and prioritisation for the participating stakeholders and need for substantial professional involvement. Thus, SRPTackle technique with integration with the proposed StakeQP is proposed and implemented to address the listed limitations.

The proposed SRPTackle provides a semi-automated process to prioritise the large set of requirements with reducing the need for the expert participation in specifying the RPV of each requirement and conducting the SQP process. The prioritisation process of the proposed SRPTackle is based on the proposed StakeQP, constructed RPV formulation function, the adoption of the K-means and K-means++, and BST.

The proposed StakeQP is integrated into the SRPTackle for the purpose of quantifying and prioritising the participating stakeholder process which lead to address the issues of lack of SQP process and minimize the experts' participation in conducting the SQP process during the prioritisation process of the requirements. The RPV formulation function is constructed to calculate the RPV of each requirement instead of depending on the involvement of experts in specifying the RPV. The RPV formulation function measures the RPV based on the defined stakeholders' SPV (obtained from the

StakeQP) and the initial weights value (considered as input from the involved stakeholders). The K-means is applied to classify the requirements into three defined clusters based on the identified RPV of the requirements and the K-means++ is adopted as an initialization method for K-means in order to enhance the accuracy and time performance of the K-means in clustering the requirements. Finally, the BST is employed to sort the requirements and generate the prioritised list of the requirements. The experimental results show the SRPTackle are capable to prioritise large set or requirements with ability of producing more accurate results with less time consumption and more efficient in handling the specified limitations when compared with the existing RP techniques.

On the basis of the evaluations performance conducted, The SRPTackle can introduce certain number of contributions to the managerial side in the development process of software system projects. The SRPTackle is one of the first technique that conducts the RP process without being exceedingly reliant on the human expertise participation. With clear implementation details with the constructed RPV formulation function; and the classification algorithm using K-means and K-means++; and BST for classifying and prioritising the requirements, the project manager can produce a prioritised list of requirements with minimal expert participation. Thereby, the SRPTackle can enable the project manager in minimising the cost expenses of the project development business that typically located for contracting the expert to initiate and execute the RP process.

Additionally, with the capability of the SRPTackle in generating more accurate prioritisation results comparing to alternative techniques in producing prioritised list of requirements with their classification levels and RPV values for large scale projects, the project manager can reveal the requirements with high level of importance to be implemented at the early stage of the project development process. This will consequently assist the project manager in optimizing the limited resources usage effectively during the development process, and constructing an effective plan of financial implications of the requirements and staged deliveries, allowing for the expansion of projects with excellent outputs and increasing the likelihood of securing a successful system project.

Furthermore, with the time effectiveness, ability to scale well with large number of requirements, automation and clear implementation guidelines features of the

SRPTackle, the project manage can perform the RP process for the projects with large-scale requirements in a professional and proper manner without necessitating extensive amount of effort (i.e. time workloads, tiring tedious manual process, the need for the involvement of the professional expertise, computational complexity, likelihood of human errors).

vi. Automation Tools support (StakeQP-AIT SRPTackle Tool)

In this research, two automation tools, StakeQP-AIT and SRPTackle, were developed to support the implementation of the StakeQP and SRPTackle techniques, respectively. As can be noticed from the literature (SLR-SQP and SLR-RP), all the existing SQP techniques and most of the RP techniques are executing the process manually with heavy dependence on the expert intervention. The developed StakeQP-AIT and SRPTackle are considered as one of the first automation tools in SQP and RP domain, respectively. With support of these automation tools, the work load is successfully minimized in conducting the process of the proposed techniques by eliminating the manual process and reducing the expert interventions along with bias induced by the experts, which make the proposed techniques to be efficient with respect to the time utilization and accuracy.

Utilising these techniques and its automation tools, the organisation can obtain a direction towards the core requirements and stakeholders along with assisting decision makers in shaping up the project direction and anticipating reactions from the stakeholders concerning the development of the project. Eventually, with the existence of such developed tools, the software system project will have a lower possibility of failure due to the participation of the inadequate stakeholder, a shortage of the expertise, an omission of the core requirements, biased prioritisation results and a time constraint.

6.4 Future Work

Through the conducted experimentations and comprehensive literature exploration of this research, several future trends can be suggested to extend and further the work in the proposed StakeQP and SRPTackle techniques. These future trends can be briefly summarised as follows:

i. Improve the SRPTackle performance with respect to catering the requirements independencies

Handling requirement interdependencies is another important consideration in RP. The proposed SRPTackle assumes that all the requirements are independent and place the concerns of these interdependencies as future work. Also, as revealed from the conducted SLR-RP, most existing RP techniques lack addressing requirement interdependencies.

Not until recently has the need to cater to requirement dependencies during an RP process emerged. This need has been addressed by techniques of the multi-aspect-based RP (Sher et al. 2014a), multi-decision-maker RP via multi-objective optimisation (Kifetew et al. 2017), SNIPR (McZara et al. 2015), value-based RP (Kukreja et al. 2013), mathematical programming (Li et al. 2010), Drank (Shao et al. 2017) ,RP under non-additive-value conditions (Sureka 2014), social network analysis for RP (Fitsilis et al. 2010) and interactive RP (Tonella et al. 2013a).

Although these techniques provided such good solutions of handling the requirements interdependencies during the prioritisation process as compared to other techniques, these four techniques have limitations in terms of manual process and the need of the experts' participation. Also, more work is needed to assess the effectiveness of these techniques in terms of evaluating and verifying the capability of their process in addressing the requirements interdependencies. Thus, the SRPTackle technique is recommended to handle the dependencies among the requirements automatically with reducing the experts' involvement especially with the large set of requirements.

ii. Improve the StakeQP performance with respect to addressing the stakeholder classifications

future research can be conducted in improving the StakeQP performance with respect to catering the stakeholder classifications and is considered to be an important aspect in the process of the stakeholder analysis (Lehtinen et al. 2018; Zedan & Miller 2018). The final output of the StakeQP process is a ranked list of stakeholders based on the defined SPV values without classifying the ranked stakeholders in different categories, such as the "most important stakeholders", "medially important stakeholders'' and ''less important stakeholders". Hence, the next phase is to enhance the robustness of the StakeQP in terms of classifying the stakeholders. This improvement can be achieved by employing the classification algorithms of supervised or unsupervised learning, which will make StakeQP be an intelligent support decision solution in quantifying and prioritising the stakeholders with the ability of categorising these stakeholders on the basis of their defined SPV values.

iii. Extend the Implication of the proposed StakeQP and SRPTackle with different project datasets

In this research, the proposed StakeQP and SRPTackle have been applied to a large real software project (RALIC benchmark dataset). However, with limited resources and other constraints in accessing other benchmark datasets that can be used in the RP and SQP domains, the proposed technique could not be applied with other projects datasets. Thus, it is suggested to call for further research to extend the implication of the proposed StakeQP with different project datasets. Additionally, so far the StakeQP is implicated in performing the SQP with 85 stakeholders. However, the StakeQP technique is suggested for implementation with larger projects that contain hundreds or thousands of stakeholders.

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APPENDIX A
SLR-RP

Tabel A.1 Summary of the Related Studies Compared to this Review (SLR-RP)

Study Reference	Study Focus	Similar Findings Compared to this SLR	Uncovered Findings Added into this SLR
Khan (Khan 2006)	• Highlighted detailed overview of eight RP techniques from eight selected studies.	• Overview of RP. • Empirical evidence for the eight compared RP techniques.	• Detailed and specific overview of the significance of the RP process in software development. • Detailed investigation of the usage prioritisation criteria in RP process. • Empirical evidence for other RP techniques. • Participating stakeholders in RP process. • Detailed analysis of the limitations and benefits, dataset to be prioritised and type of each RP technique. • Detailed analysis of the usage contexts of RP techniques and selected studies
Kaur and Bawa (Kaur & Bawa 2013)	• Conducted performance overview of seven common RP techniques with respect to their measurement scale, time consumption, granularity, complexity and fault tolerance.	• Empirical evidence of the seven selected RP techniques.	• Overall overview of RP. • Detailed and specific overview of the significance of the RP process in software development. • Detailed investigation of the usage prioritisation criteria in the RP process. • Empirical evidence of other RP techniques. • Participating stakeholders in the RP process. • Detailed analysis of the limitations and benefits, dataset to be prioritised and type of each RP technique. • Detailed analysis of the usage contexts of RP techniques and selected studies.

Table A.1 (continued)

Study Reference	Study Focus	Similar Findings Compared to this SLR	Uncovered Findings Added into this SLR
Pergher and Rossi (Pergher & Rossi 2013)	• Investigated RP areas that had been explored by existing studies and clarified the state of the art in the conducted empirical research in RP.	• Overall overview of RP.	• Detailed and specific overview of the significance of the RP process in software development. • Detailed investigation of the usage prioritisation criteria in RP. • Empirical evidence for other RP techniques. • Participating stakeholders in RP. • Detailed analysis of the limitations and benefits, dataset to be prioritised and type of each RP technique. • Detailed analysis of usage contexts of RP techniques and selected studies.
Pitangueira et al. (Pitangueira et al. 2015)	• Analysed the SBSE approaches that had been introduced by the researcher to solve issues of software RP.	• Overall overview of RP.	• Detailed and specific overview of the significance of RP in software development. • Detailed investigation of the usage prioritisation criteria in RP. • Empirical evidence of other RP techniques. • Analysis of the participating stakeholders in RP. • Detailed analysis of the limitations and benefits, size of the prioritised requirements set and type of each RP technique. • Detailed analysis of usage contexts of RP techniques and selected studies.
Achimugu et al. (Achimugu et al. 2014d)	• Analysed steps involved in the prioritisation process. • Analysed 49 RP techniques in terms of limitations, description and measurement scale.	• Overall overview of RP. • Detailed overview of the 49 RP techniques' limitations.	• Detailed and specific overview of the significance of the RP process in software development. • Detailed investigation of the usage prioritisation criteria in the RP process. • Analysis of the participating stakeholders in RP. • Empirical evidence of other uncovered and recent RP techniques and their limitations. • Detailed analysis of and benefits, usage size of the requirements set to be prioritised and type of each RP technique. • Detailed analysis of usage contexts of RP techniques and selected studies.

Tabel A.2 Analysis of the RP Techniques in term of Prioritisation Criteria, Size Set of Requirements, Limitations and Benefits

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
1	A Conceptual Model And Process For Client-Driven Agile RP (Racheva et al. 2010a)	Business value, risk and effort estimation	NS			*	It requires the involvement of experts to conduct the prioritisation process.	NS
2	Adaptive Fuzzy Decision Matrix Model for RP (Achimugu et al. 2014e)	Reusability, flexibility, performance and maintainability	Small	*		*	It is heavily reliant on expert participation to initiate and conduct prioritisation.	It can consider more than one prioritisation criteria.
3	Adaptive Fuzzy Hierarchical Cumulative Voting (Jawale et al. 2017)	NS	Small		*	*	NS	NS
4	AHP (Avesani et al. 2005; Berander & Andrews 2005; Huang et al. 2013; Karlsson 1996; Karlsson et al. 1998; Karlsson & Ryan 1997; Racheva et al. 2010b)	Importance, cost and penalty	Small	*	*	*	It is complex and has a large number of requirements. Its speed is slow.	It produces accurate results and is suitable for use with small sets of requirements.
5	AHP_GORE_PSR (Sadiq et al. n.d.)	NS	Small	*		*	It needs to be tested with a real project dataset to allow for performance evaluation.	NS

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
6	Analytical Model for Requirements Selection Quality Evaluation (Regnell et al. 2003)	Importance	Medium				The analytical model used is limited by approximations required by the technique, which affects the prioritisation performance efficiency in terms of accuracy.	NS
7	ANN Fuzzy AHP Model (Singh et al. 2018)	NS	NS			*	It heavily relies on the involvement of experts to initiate the prioritisation process It does not consider the dependencies among the requirements	NS
8	Approach for RP based on Tensor Decomposition (Misaghian & Motameni 2018)	Importance, business values, cost and risk	Small	*		*	It is not catering the dependencies among the requirements It has not been implemented and evaluated with large set of requirements	It is less time consumption than AHP method
9	A priori technique (Anand & Dinakaran 2017)	Value	Small				The technique has been only applied to a small set of requirements manually.	It introduces a parallelised and implementable method in addressing the stakeholder conflicts in the RP process.
10	A Preference Weights Model For Prioritising Software Requirements (Achimugu et al. 2014b)	Importance	Small			*	The proposed technique needs to be tested with a large set of requirements. It needs to reduce the disagreement rate amongst final rank weights.	It is a fast and fully automated technique.

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
11	A Web-based Multi-criteria Decision-making Tool For Software RP (Achimugu et al. 2014c)	Importance	Small	*		*	Rank reversals are present. It needs to test the developed tools with a large set of stakeholders and requirements to validate its effectiveness and performance.	NS
12	Architecture Trade-off Analysis Method (Clements et al. 2002; Thakurta 2013)	Quality goals and dependency	NS		*	*	It requires detailed technical knowledge to execute the technique. It does not address requirement interdependencies.	Scenario generation based on requirements is suitable for dynamic and static properties.
13	Attributed Goal-oriented Requirements Analysis Method (Kaiya et al. 2002)	Correctness, unambiguity, completeness, inconsistency, modifiability and traceability	NS			*	It is heavily reliant on the involvement of expert analysts in execution.	NS
14	Benefit and Cost Prediction (Daneva & Herrmann 2008)	Importance	NS			*	It does not provide priority value for each requirement and does not handle the dependencies amongst the requirements.	It can handle the costs and benefits of the requirements.
15	Binary Priority List (Achimugu et al. 2014d; Bebensee et al. 2010)	Benefit	Small	*		*	It considers only one type of stakeholder (product manager) and only one aspect (benefit).	It can be used as a sorting algorithm for requirements.

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
16	Binary Search Tree (Ahl 2005; Babar 2011; Beg et al. 2009; Khari & Kumar 2013)	NS	Large			*	It provides a simple ranking without assigning priority values to requirements.	Its implementation is simple. It is usable for large numbers of requirements.
17	Binary Tree (Aasem et al. 2010; Beg et al. 2009)	Importance	Small	*		*	It is complex and does not scale well. It is not implemented and tested in a collaborative environment.	It can be used as a sorting algorithm for other RP techniques.
18	Bubble Sort (Achimugu et al. 2014d; Babar et al. 2015c; Karlsson et al. 1998)	NS	Small	*	*	*	It provides a simple ranking and does not assign priority values to requirements.	It can be used as a sorting algorithm for other techniques.
19	Case Based Ranking (Achimugu et al. 2014d; Perini et al. 2013)	Importance	Small, Medium	*		*	It cannot support coordination in negotiations amongst stakeholders.	It uses machine learning to reduce the amount of information required from the stakeholders.
20	Clustering-based Technique For Large Scale Prioritisation (Achimugu et al. 2014a)	Importance	Large			*	It requires the expert to implement the prioritisation process. It needs to be tested with additional projects for its results to be generalised.	It can handle a large set of requirements.

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
21	Cognitive Driven RP (Carod & Cechich 2010)	Importance	Small	*		*	It does not address the dependencies amongst the requirements.	It improves stakeholders' negotiation by reducing misunderstandings.
22	Conceptual Model of Agile RP (Racheva et al. 2008)	Importance and business value	NS				NS	NS
23	Correlation-based Priority Assessment Framework (Liu et al. 2006)	Business estimation, management and quality	Small	*		*	It does not consider the negative correlations amongst requirements in the priority assessment. It needs to be tested with a large set of requirements to evaluate its results.	It is helpful in understanding the relationships amongst requirements from multiple perspectives.
24	Cost–benefit Analysis Method (Thakurta 2013)	Cost, benefit and schedule	NS			*	Well-defined steps of quantifying benefits and costs are absent.	It provides business measures for particular system changes.
25	Cost- value Approach (Achimugu et al. 2014d; Karlsson & Ryan 1997)	Importance and cost	Small	*	*	*	Involvement of professional business analysts (experienced software engineers) is required to execute the prioritisation process. Complexity increases with large/medium sets of requirements. It ignores requirement interdependencies.	It is a clear and usable method. It can integrate judgments of cost and value of requirements that are considered for implementation.

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
26	Cumulative Voting (CV) (A, Persis Voola 2013; Berander & Andrews 2005; Chatzipetrou et al. 2010; Karlsson et al. 2006; Thakurta 2013; Wiegers & Beatty 2013)	Importance	Small	*		*	It does not permit the evaluation of the relative priority difference amongst the requirements.	It is fast and simple.
27	Dot Voting (Racheva et al. 2008, 2010a)	Importance	NS			*	It ignores requirement interdependencies.	NS
28	DRank (Shao et al. 2017)	Dependency and importance (stakeholders preferences)	NS				It requires professional intervention to perform the prioritisation process.	It considers business dependencies amongst the requirements. It provides an easy-to-use method of selecting the prioritisation criteria.
29	Eclipse Process Framework (Racheva et al. 2010a)	Easy to use	NS				NS	NS

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
30	Evolve (Achimugu et al. 2014d; Farhan M Khan 2009; Greer & Ruhe 2004)	Risk, benefit resources, business value and effort	Small	*	*		It is computationally complex.	The evaluation and the identification of benefits are associated with different release plans.
31	Exploiting User Feedback in Tool-supported Multi-criteria RP (Morales-Ramirez et al. 2017)	Value	NS			*	It needs to be validated in real scenarios for performance assessment. The decision makers are a prominent source of information for prioritising the requirements, which can affect the prioritisation process with biases induced by the decision makers.	It can consider the feedback of different stakeholders, such as the users and decision makers, in the prioritisation process.
32	Fuzzy AHP (Achimugu et al. 2014d; Bajaj & Arora 2013; Lima et al. 2011)	Software goals	Small	*		*	It needs to be tested with large projects and does not handle the dependencies amongst requirements.	NS
33	Fuzzy-based MoSCoW (Ahmad et al. 2017)	Importance	Small			*	It cannot prioritise the requirements with participation of more than one stakeholder and handle the requirement dependencies in the prioritisation process. The technique needs to be validated with large numbers of requirements for the performance to be generalised.	NS

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
34	Fuzzy Hierarchical CV (Easmin et al. 2014) (Sharif et al. 2014)	Importance	Medium			*	It has a high-risk decision.	NS
35	Fuzzy Technique to RP (Lima et al. 2011)	Importance and software goals	Small	*		*	It has only been applied to a small set of requirements It needs to be applied in real scenarios.	NS
36	Fuzzy Multi-criteria Decision-making Approach for software RP (Achimugu et al. 2015)	Importance	Small	*		*	It needs to be implemented and tested with additional projects, especially those with large sets of requirements, for performance validation.	NS
37	Goal Oriented Approach for Software Requirements Elicitation and Prioritisation (Chandra et al. 2017)	Cost and effort	Small	*			NS	NS
38	Graph-oriented Requirement Selection (Mougouei & Powers 2017)	Cost and value	Small	*		*	NS	It considers the value-related dependencies in the selection process of the requirements
39	Handling uncertainty in agile RP and scheduling (Logue & McDaid 2008)	Business Value	Small	*		*	It needs to be validated with large scale of requirements and lack of handling the dependencies amongst the requirements.	NS

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
40	Hierarchical CV (HCV) (Berander & Svahnberg 2009; Patrik & Jonsson 2006)	Importance	Medium			*	It does not cater the requirements interdependencies.	Scalability and resulting priorities are improved with HCV compared with those of CV.
41	Hierarchical AHP (Achimugu et al. 2014d; Karlsson et al. 1998; Vestola 2010)	Importance	Medium /large		*	*	It is hard to be applied. It produces many judgment errors because it cannot address consistency, as in the case of AHP. It is unreliable and has poor fault tolerance.	It reduces the number of comparisons in the AHP technique.
42	Hybridized technique for RP (Achimugu & Selamat 2015)	Importance	Small	*			It has been applied to small-scale requirements only.	NS
43	Integrated Prioritisation Approach (Dabbagh & Lee 2014)	Importance	Small	*		*	It needs to be adopted in a controlled experiment in a real scenario setting to explore the technique performance and compare the experiment findings with those of other studies.	It can prioritise functional and non-functional requirements and consumes less time than does AHP.
44	Interactive RP (Tonella et al. 2013a)	Importance and dependency	Medium			*	It needs to be tested in a complex industrial situation.	NS
45	Kano Model (Racheva et al. 2008, 2010a)	Importance	NS			*	NS	NS

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
46	Lanchester Theory (Fehlmann 2008)	Customer satisfaction with technical excellence	Small	*		*	It does not set relative values for the linguistic terms, which can assist the relative weight calculation across all the requirements. It needs to be implemented with a large set of requirements for performance validation.	NS
47	Market Driven RP model (Iqbal et al. 2010)	Importance	Small	*		*	It does not address the requirement interdependencies in the RP process, and its efficiency must be evaluated with real and large industrial projects.	NS
48	Mathematical Programming Technique (Li et al. 2010), (Li et al. 2010)	Dependency in terms of influence and cost	NS				NS	It considers requirement interdependencies and SQP.
49	MoSCoW (Kukreja et al. 2012; Ma 2009; Wiegers & Beatty 2013)	Importance	NS			*	It does not assign priority values to requirements and ignores the requirement interdependencies.	NS
50	Minimal Spanning Tree (Achimugu et al. 2014d; Karlsson et al. 1998; Khan 2006)	NS	Medium /large		*	*	It is sensitive to judgment error as all redundancy is eliminated. It is unreliable and has poor fault tolerance.	It eliminates the redundancy of the pairwise comparison of AHP. It is suitable for large sets of requirements if reliability and fault tolerance are not important.

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations: Scalability	Limitations: Time Consumption	Limitations: Lack of SQP	Limitations: Other limitations	Benefits
51	Multi-aspects Based RP Technique (Sher et al. 2014a)	Business and technical aspects	Small	*		*	It is heavily dependent on the involvement of experts to execute the RP process. Its performance must be evaluated with a large set of requirements.	NS
52	Multi-criteria Preference Analysis Requirements Negotiation (MPARN) for RP (Avesani et al. 2005; In et al. 2002)	NS	Small	*		*	It does not detect inconsistencies amongst ranking values.	NS
53	Multi-objective Next Release Problem for RP (Tonella et al. 2013a; Zhang et al. 2007)	Value and cost	Large	*		*	It does not produce an ordered list of requirements as final result and instead groups requirements for the planning of subsequent releases. It also does not handle requirement interdependencies.	NS
54	Multi-objective ant colony optimisation for requirements selection (del Sagrado et al. 2015)	Importance, cost and dependency	Large			*	The performance efficiency of the techniques must be evaluated to reveal its efficiency in terms of accuracy, complexity and time consumption.	It can address requirement dependencies.
55	Multi-decision-Maker RP Via Multi-objective Optimisation (Kifetew et al. 2017)	NS	NS			*	The prioritisation process heavily relies on the participation of decision makers, and technique performance has not been evaluated.	It handles requirement dependencies.

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations: Scalability	Limitations: Time Consumption	Limitations: Lack of SQP	Limitations: Other limitations	Benefits
56	Multi-voting System for RP (Racheva et al. 2008, 2010a)	Importance	Small	*		*	It cannot be executed for more than 20 requirements.	NS
57	New approach for RP (Alawneh 2018).	Value and cost	Small	*		*	It has been tested with small set of requirements and lack of evaluating the importance of the participating stakeholders	NS
58	New Strategy for Prioritising Functional Requirements (Condori-Fernandez et al. 2018)	Dependency	Small	*		*	It does not evaluate the impact of the participating stakeholder in the prioritising the requirements	NS
59	Numerical Assignment (NA) (Achimugu et al. 2014d; Babar et al. 2015c; Berander & Andrews 2005; Hatton 2008; Karlsson 1996)	Importance and time	Small			*	It cannot provide a definition of a ranking list. It does not provide priority values for requirements and standard descriptions of specified categories to stakeholders.	It is easy to use. It is relatively straightforward.
60	Optimal Solutions Analysis technique for RP (Veerappa 2012)	Cost and value	Large				It cannot handle requirement interdependencies and heavily relies on the involvement of experts, which may induce human bias.	It considers SQP and can work with large sets of requirements.

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
61	Pair-wise Comparison (Berander 2004; Karlsson 1996; Karlsson et al. 2007; Thakurta 2013)	Importance	Small	*	*	*	It is complicated and produces unreliable results.	It can work with various comparison criteria that are based on the decision makers.
62	Partial Order Assimilation Approach for RP (Easmin et al. 2014)	Decision making	Medium			*	It cannot combine stakeholders' feedback when two or more important ranking functions are present. It cannot handle requirement dependencies.	NS
63	Performance Enhancement in RP by Using Least-squares-based Random Genetic Algorithm (Ahuja et al. 2018)	Cost	Small			*	It has been applied to the small set of requirements. It lacks of addressing the dependencies among the requirements during the prioritisation process	It can performs the prioritisation process with less time consumption than AHP technique
64	PHandler (Babar et al. 2015c)	Importance	Large				It requires the involvement of professional business analysts and experts to perform the RP process and needs AHP to be performed and merged with requirement values. It does not consider requirement interdependencies.	It can work with a large set of requirements. It considers SQP in its prioritisation.
65	Ping Pong Balls (Racheva et al. 2008, 2010a)	Importance	Small	*		*	NS	NS

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
66	Planguage (Perini et al. 2013)	Stakeholders' goal	Small	*	*	*	It uses basic ranking and does not provide relative differences amongst ranks.	NS
67	Planning Game (Achimugu et al. 2014d; Ahl 2005; Babar et al. 2015c; Berander 2004; Karlsson et al. 2007; Yousuf et al. 2016)	Importance	Small	*		*	It does not identify the priority value of each requirement.	It is suitable for innovative development models, such as extreme program, because of its flexible behaviour.
68	Planning Game Combined With AHP (A, Persis Voola 2013; Karlsson et al. 2007; Thakurta 2013)	Importance	Small	*		*	The RP process is highly reliant on experts' involvement.	NS
69	PRFGORE (Sadiq & Jain 2014)	Performance, security and reliability	Small			*	It lacks tools to support the participating decision makers in conducting the prioritisation process. It does not address requirement interdependencies. The effectiveness of the proposed technique has not been empirically evaluated with real industrial projects.	NS

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
70	Prioritisation Analysis For RP (García-Soler et al. 2018)	Importance	Medium			*	It does not address the requirements interdependencies	It provides iterative procedure that can be used to identify, select and prioritise requirements of the user.
71	Priority Groups (Achimugu et al. 2015; Lehtola et al. 2004)	Importance	NS	*	*		It is not easy to use, is unreliable and has poor fault tolerance.	NS
72	Prioritising Requirements in Agile Development (Al-Ta'ani & Razali 2016b)	Cost, risk and schedule	NS				It has not been implemented and evaluated in empirical experiments with real projects.	It can handle the factors concerning the effectivity of the RP process.
73	Quality Functional Deployment QFD (Li et al. 2012; Sadiq & Shahid 2009; Taylor & Wasserman 1993)	Technical importance	Small	*		*	NS	NS
74	Quantitative WinWin (Ruhe et al. 2002, 2003)	Importance, effort, business value and time	Small				The prioritisation is based on the availability of a precise model for the effort estimation and willingness of the participating stakeholders in eliciting their preferences. Its scalability needs to be assessed with large sets of requirements.	It can provide quantitative analysis for good decisions in selecting the core requirements.

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
75	Ranking (Berander & Andrews 2005; Forouzani et al. 2012; Karlsson 1996)	Importance	Small	*		*	It cannot align many stakeholders' preferences and does not handle requirement dependencies.	It is convenient technique with participating only single stakeholder
76	Ranking Based on Product Definition (Racheva et al. 2008, 2010a)	Product criteria: business and technology	NS	*		*	The execution of the RP process is heavily reliant on the involvement of professional analysts.	NS
77	RIZE (Rahim et al. 2017)	Business value, cost, risk and volatility	Small	*		*	An empirical evaluation is needed to assess the efficiency of the technique.	It is easy to understand and use.
78	Relative Weighting (Racheva et al. 2010a)	Importance	NS			*	It is heavily reliant on the involvement of experts to perform RP.	NS
79	ReDCCahp (Ibriwesh et al. 2018)	Cost and value	Medium	*		*	It does not cater the requirements interdependencies in the prioritisation process	It is more effective than AHP in prioritising medium set of requirements with less complexity
80	RePizer (Khan et al. 2016)	Cost	Large			*	It requires participating experts to execute the prioritisation and does not consider requirement dependencies.	NS
81	ReproTizer(Achimugu et al. 2016)	Importance	Medium /Large			*	It does not address requirement interdependencies.	It automates the RP process

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
82	Requirement Triage (Duan et al. 2009)	Business goal	Large			*	It does not recall results and is prone to error and the RP execution heavily depends on experts' participation	NS
83	RUPA (Voola & Babu 2012)	Importance	Small	*	*		It lacks automation and intelligent terms. It relies on the involvement of professional business analysts to perform RP, and it has computational complexity.	It provides a priority value for each requirement. It considers SQP.
84	Round The Group Prioritisation (Racheva et al. 2008, 2010a; Svahnberg & Karasira 2009)	Importance	Small	*		*	It is heavily reliant on the participation of professional analysts in RP.	NS
85	RP Solution Model (Soumya Krishnan 2018)	Cost, dependency and benefit	NS			*	It provides only the conceptual procedure for performing the RP process without implication it with the real scenarios	NS
86	RP under Non-additive Value Conditions (Sureka 2014)	Dependency, value and cost	NS	*		*	It has not been validated with real industrial projects.	It considers the dependencies amongst the requirements during prioritisation.
87	RP_WOA (Alzaqebah et al. 2018)	Cost and value	Medium			*	There is a need to validate the accuracy performance of the technique It lacks of considering the requirements independencies	Ability to prioritise the requirements with efficient time consumption performance

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
88	SAFFRON : A Semi-automated Framework for Software RP (Asif et al. 2017)	Importance	Medium, Large			*	The RP execution heavily depends on experts' participation and does not address requirement interactions.	It updates the prioritisation lists whenever new requirements are elicited.
89	Simple Multi-criteria Rating Technique By Swing for RP (Avesani et al. 2004, 2005)	NS	NS	*	*	*	It does not detect inconsistencies amongst ranking values.	NS
90	SNS Technique (Seyff et al. 2015)	NS	Small	*		*	It is not specifically concerned about presenting the set of prioritised requirements and does not consider requirement dependencies.	It enables an asynchronous communication amongst distributed end users to reveal their needs.
91	SNIPR (McZara et al. 2015)	Importance and dependency	Large			*	It heavily needs professional intervention to implement the prioritisation process.	It handles requirement interdependencies.
92	Social Network Analysis Technique for RP (Fitsilis et al. 2010)	Importance	Small	*	*	*	A practical evaluation of the technique's performance has not been implemented to investigate its efficiency.	It considers requirement dependencies in the prioritisation process.
93	Software Architecture Analysis Method for RP (Thakurta 2013)	Quality attributes	NS			*	It does not provide a quality metric. It does not provide low implementation details.	It specifies areas with high potential complexity.

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
94	Software Engineering Risk: Understanding and Management for RP (Clements et al. 2002; Gaur et al. 2010; Greer et al. 1999; Thakurta 2013)	Cost, risk and benefit	Small	*		*	It does not address requirement interdependencies and aspects of the customers. It requires the involvement of professional analysts to perform the RP process.	It considers the three major aspects to the organisation. It can be used to prioritise system changes.
95	Software RP Using Fuzzy Multi-attribute Decision Making (Ejnioui et al. 2012)	NS	NS			*	The performance of this technique has not been evaluated with industrial projects.	NS
96	Software RP based on non-functional requirements (Garg & Singhal 2017)	Importance	Small	*		*	It does not consider SQP and requirement interdependencies during the prioritisation process.	NS
97	StakeRare (Lim & Finkelstein 2012)	Importance	Large				It heavily relies on the involvement of experts to execute the RP process, and the quality of the requirements depends on the stakeholders' response and does not consider requirement interdependencies.	It considers the SQP process. It can work well with a large set of requirements.
98	Technique for Ordering from Similarity to Ideal Solution to Prioritise the Requirements(Achimugu et al. 2014d; Kukreja 2013)	Business goals and ease of realisation	NS			*	It cannot update ranks whenever new requirements are extracted. It cannot hierarchically organise requirements.	NS

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
99	Theme Screening (Racheva et al. 2010a)	Importance	NS			*	NS	NS
100	Tool-supported Collaborative RP Process (Busetta et al. 2017)	Budget and effort	Small			*	It does not consider requirement interdependencies. Additional empirical evaluation must be conducted to verify and generalise the technique's effectiveness, especially in prioritising a large set of requirements.	NS
101	Top Ten (Berander & Andrews 2005; Forouzani et al. 2012; Karlsson 1996)	Importance	Small	*		*	It is ambiguous in identifying the priority values of requirements.	It works well with a small set of requirements.
102	Value-Based RP (Achimugu et al. 2014d; Kukreja et al. 2013)	Goals of the project, business value	NS		*	*	It requires the participation of project managers and expers in performing prioritisation. It cannot hierarchically organise requirements and exhibits poor prerequisite handling.	It handles requirement interdependencies.
103	VIRP (Ramzan et al. 2011)	Feasibility, modifiability, urgency, traceability, testability, completeness, consistency, understandability and non-redundancy	Medium				It It does not categorise the ordered requirements, i.e. classification as most essential, medially essential and less essential.It heavily depends on the participation of experts to perform prioritisation and manually executes SQP.	t considers the SQP process.

Table A.2 (continued)

No	Technique	Prioritisation Criteria	Size of Requirements sets	Limitations				Benefits
				Scalability	Time Consumption	Lack of SQP	Other limitations	
104	Value-oriented Prioritisation VOP (Azar et al. 2007)	Cost, risk, penalty and business values	Small	*	*	*	It does not address the dependencies amongst the requirements during prioritisation.	It considers the business value in prioritising requirements.
105	Weighted Criteria Analysis (Racheva et al. 2008, 2010a)	Importance	NS		*	*	It ignores requirement interdependencies.	NS
106	Wiegers' Matrix technique (Benestad & Hannay 2012; Thakurta 2013; Wiegers & Beatty 2013)	Customer benefit, penalty, cost and risk	NS			*	It heavily relies on the involvement of professional analysts or experts in performing RP. It does not handle requirement interdependencies.	It can integrate various assessment criteria to evaluate requirements.
107	WGW (Hudaib et al. 2018)	Importance	Medium	*		*	It heavily depends on the involvement of experts to perform prioritisation and it is manually executed. It lacks of considering the dependencies among the requirement during prioritisation process.	NS
108	WinWin (Gruenbacher 2000)	NS	NS			*	The final consensus, especially when biased stakeholders are participating, is hard to obtain.	NS

NS : Not Specified

Tabel A.3 The Stakeholders Who Involved in Requirements Prioritisation

Stakeholders who involve in RP	Reference
Software architects and experts, product manager, customers	(Thakurta 2013)
Analysts, customers	(Kaiya et al. 2002)
Customers and experts	(Daneva & Herrmann 2008)
Product managers	(Bebensee et al. 2010)
Users	(Racheva et al. 2008)
Managers, software developers and customers	(Liu et al. 2006)
Software engineers, requirements engineers, customers and users	(Karlsson & Ryan 1997)
Group of customers and decision makers (project managers)	(Berander & Andrews 2005; Chatzipetrou et al. 2010)
Development teams	(Racheva et al. 2010a)
Marketing teams and developers	(Fehlmann 2008)
Developers	(Li et al. 2010)
Product managers and customers	(Karlsson et al. 1998)
Technical and business experts	(Sher et al. 2014a)
Software architectures and analysts	(Tonella et al. 2013a)
Experts (professional business analysts), requirements engineers and customers	(Babar et al. 2015c)
Experts, (programmers) and customers	(Ahl 2005; Karlsson et al. 2007)
Customers and design teams	(Taylor & Wasserman 1993)
Requirement specialists and groups of customers	(Forouzani et al. 2012)(Karlsson 1996)
Users, business analysts, customers and experts	(Racheva et al. 2008, 2010a)
Project managers, requirements engineers and customers	(Voola & Babu 2012; Voola & Vinaya Babu 2012)
Business analysts and experts	(Gaur et al. 2010; Thakurta 2013)
Architects	(Achimugu et al. 2015)
Customers and project managers and experts	(Kukreja et al. 2013)
Company executives, company vice presidents, project manager and marketing managers	(Azar et al. 2007)
Project managers, key customer representatives, development representatives	(Benestad & Hannay 2012)
Analysts	(Gruenbacher 2000)
Requirements engineers, marketing managers, professional team leaders, experienced end users	(Shao et al. 2017) (Iqbal et al. 2010)
System development teams, experts and customers	(Lim & Finkelstein 2012; Ramzan et al. 2011)

A.4 SLR-RP Review Protocol

The following sub-sections explain the defined activities of the designed review protocol in Figure 3.2, chapter 3 , that were conducted to obtain the results of the SLR-RP.

i. Research Questions

The aim of this study was to study, analyse and summarise the RP domain in terms of its significance in the system development process, existing RP techniques, stakeholders involved in the prioritisation process, RP challenges or limitations and future sets for further research. To achieve this aim, the four research questions were defined as shown in section 2.4.1, chapter 2.

ii. Search Process Strategy

The search process strategy aims to search for primary studies that are relevant to the specified research topics (Kitchenham & Charters 2007). In this work, the search process is carefully executed to identify all the relevant existing studies. The search process is conducted using two activities: search term and resources to be researched. To comprehensively search for related studies, the search strategy began with an online search of digital libraries. In this review, the relevant studies are extracted from the same digital libraries and scientific databases, as presented in Table A.4. These digital libraries were selected because they are considered as relevant libraries for SLRs in software engineering (Zhang & Babar 2010). In addition, they can provide at least one online search engine with options for conducting an advanced search by keywords and results filtering via publication year and type or by domain area. The search process is compiled from various types of publications, such as published conference proceedings, journal papers, chapters in books, and workshops.

Table A.4 List of Resources

Resource Name	Resource Link
SpringerLink	(http://www.springerlink.com).
Wiley InterScience	(http://www3.interscience.wiley.com).
ACM Digital Library	(http://portal.acm.org).
Compendex	(http://www.engineeringvillage.com).
IEEE Xplore	(http://www.ieee.org/web/publications/xplore/).
ScienceDirect	(http://www.sciencedirect.com/).
Elsevier	(http://www.elsevier.com).
ISI Web of knowledge	(http://www.isiknowledge.com).
Google scholar	(https://scholar.google.com)

Ensuring the formulation of accurate search strings is an essential process when performing an online search in electronic databases (Kitchenham & Charters 2007) in order to ensure the quality of the elicited studies. In this review, search terms were formulated on the basis of the defined research questions along with a stepwise procedure, which are as follows (Kitchenham & Charters 2007)s:

1. Identifying the main terms on the basis of the respective research questions

2. Finding the alternative synonyms and spelling of the main terms

3. Verifying the search terms of relevant studies and

4. Using the Boolean OR/AND operators to combine the search terms.

A list of search strings was identified to search for relevant studies. The output search strings that were used in this study are as follows:

1. Requirements prioritisation (OR / AND) selection.

2. Requirement Prioritisation in OR for Software Release Planning OR Release Planning.

3. Significance (OR / AND) Importance (OR / AND) impacts of requirements prioritisation.

4. Requirements prioritisation techniques OR methods OR frameworks, OR approaches.

5. Requirements prioritisation AND stakeholders.

6. Stakeholders' roles (OR / AND) types of the requirements prioritisation.

7. Stakeholders in the requirements prioritisation.

8. Limitations OR challenges OR issues of requirement prioritisation techniques.

9. Context (OR / AND) domain (OR / AND) principle of requirements prioritisation OR RP activity within software development context (OR / AND) domain (OR / AND) principle.

10. Benefits OR advantages of requirement prioritisation techniques OR methods OR frameworks, OR approaches.

11. Size of requirements OR size set of requirements in requirements prioritisation OR techniques OR methods OR frameworks, OR approaches.

12. Criteria OR aspects OR attributes of requirement prioritisation techniques OR methods OR frameworks, OR approaches.

All search strings were combined with Boolean operators (AND, OR) to extend the searching of studies and to increase the relevance of the search process. the search strings have been implemented to the titles, abstracts and keywords of the papers in the identified electronic databases and then retrieved papers that include one of the identified search strings.

iii. Study Selection Strategy

In the initial stage of the search process, 878 prospective studies were collected from the online digital libraries. To produce accurate and precise answers for the specified research questions, critically evaluate and scrutinise were needed to each collected work. Thus, the study selection process was designed to conduct scrutiny. Figure A.1 presents the process of the study selection strategy used, which consists of two main phases: inclusion and exclusion criteria and QAC. The inclusion and exclusion criteria were formulated on the basis of the specified research questions.

Complementing Figure A.1, Table A.5 presents the formulated inclusion and exclusion criteria of this review. The titles, abstracts and content of each collected study were concisely studied. Thus, studies that cannot provide potential answers to the listed research questions were excluded. Published studies that are written in English were included and excluded those published in other languages.

Furthermore, for each study that has various versions, the recent and most complete one was included, and the other copies of the same study were excluded. Grey studies (works in progress, unpublished or non-peer-reviewed publications, such as studies published on websites or those that do not have such bibliographic details as publication date or type) were also excluded. Thus, 201 relevant studies were selected after the implementation of the defined inclusion and exclusion criteria. QAC were used to identify the most relevant search studies to the research domain. Several QAC checklists were formulated based on the guidelines of Kitchenham et al.(Kitchenham et al. 2007; Kitchenham & Charters 2007) with respect to the defined aim of this study. Table A.6 presents the formulated quality checklist used to evaluate the quality of the 201 studies.

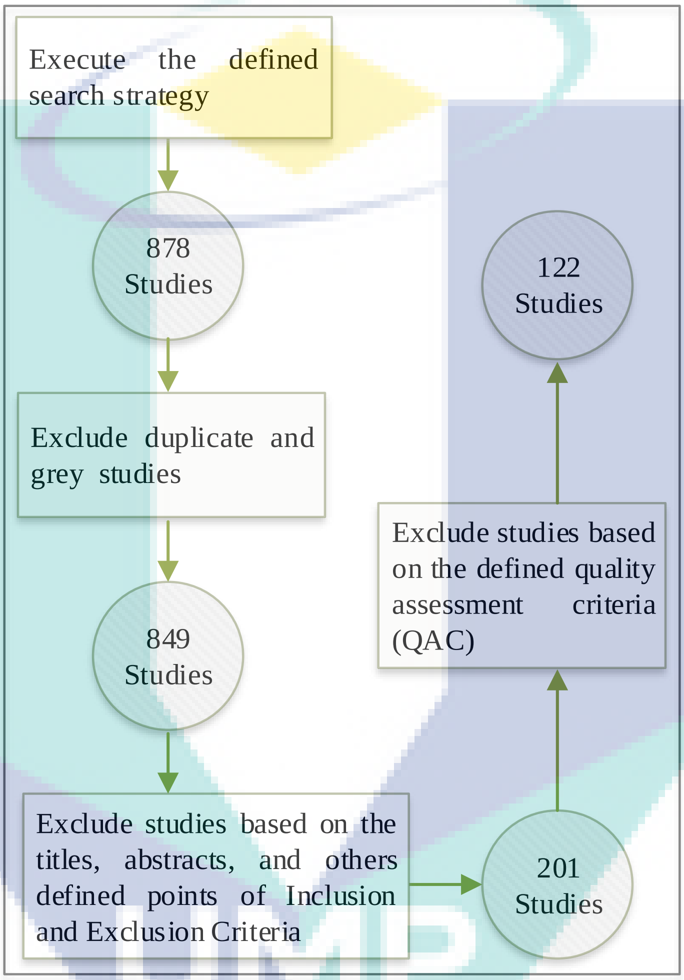

Figure A.1 SLR-RP Study Selection Process

Table A.5 SLR-RP Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
• All studies published in English. • Studies that can provide potential answers to research questions on the basis of content, keywords, titles and abstracts of the studies. • Empirical studies and experience reports based on experts.	• Studies that are not written and published in English. • Duplicate studies. We included the most recent and complete versions and excluded other copies of the same study. • Studies that are irrelevant to the research questions. • Grey studies.

The defined QAC checklist comprises six questions. The answer to each question can be 'Yes', 'moderately' or 'No', which were assigned point scores of 2, 1 and 0, respectively. QAC was applied by a precise study of the titles, abstracts and content of each study, assignment of a quality score to every study and then calculation of the overall quality scores by the summation of all answer scores to the defined checklist questions.

Table A.6 SLR-RP Quality Assessment Criteria

ID	Question	Answers' Point Scores
QA1	Is the aim of the study adequately elaborated?	Yes = 2/ moderately = 1/ no = 0
QA2	Is the context of research expounded well?	Yes = 2/ moderately = 1/ no = 0
QA3	Does the study concentrate on the related domain of RQs?	Yes = 2/ moderately = 1/ no = 0
QA4	Is the proposed technique/solution obviously elaborated?	Yes = 2/ moderately = 1/ no = 0
QA5	Is the assessment of introduced technique executed on adequate project data sets or case studies ?	Yes = 2/ moderately = 1/ no = 0
QA6	Is the result of the study obviously clarified?	Yes = 2/ moderately = 1/ no = 0

Result comparisons and discussions were conducted by the authors to address contradictions and thus achieve a consensus. To ensure dependability of the findings, studies that obtained quality scores of less than 6 (which are less than half of the full quality score of 12) were excluded. Thus, 122 works were selected as primary studies of this review. Table A.7 presents the selected studies with their corresponding reference numbers and final quality scores.

Tabel A.7 SLR-RP Quality Scores' Result of the Selected Studies.

Reference	QA1	QA2	QA3	QA4	QA5	QA6	Overall Score/12
(Lim & Finkelstein 2012)	2	2	2	2	2	2	12
(Babar et al. 2015c)	2	2	2	2	1	2	11
(Berander & Andrews 2005)	2	2	2	1	0	1	8
(Farhan M Khan 2009)	1	1	2	1	0	1	6
(Port et al. 2008)	1	2	1	1	1	1	7
(Forouzani et al. 2012)	2	1	2	1	1	1	8
(Li et al. 2012)	2	2	2	2	2	1	11
(Achimugu et al. 2014a)	2	2	2	2	1	2	11
(Racheva et al. 2010b)	2	2	2	1	0	2	9
(Karlsson et al. 2006)	2	1	1	1	1	1	7
(Ling Lim et al. 2011)	2	2	2	2	2	1	11
(Lehtola et al. 2004)	2	2	2	1	0	2	9
(Ramzan et al. 2011)	2	1	2	2	2	1	10
(Achimugu et al. 2014b)	2	2	2	2	1	2	11
(Karlsson et al. 1998)	2	2	2	2	1	2	11

Table A.7 (continued)

Reference	QA1	QA2	QA3	QA4	QA5	QA6	Overall Score/12
(Shao et al. 2017)	2	2	2	2	1	2	11
(Karlsson & Ryan 1997)	2	2	1	2	1	2	10
(Babar 2011)	2	2	2	1	0	1	8
(Achimugu et al. 2015)	2	2	2	1	1	1	9
(Achimugu et al. 2014d)	2	2	2	2	0	2	10
(Khan 2006)	2	1	2	1	1	2	9
(Şen & Baraçli 2010)	2	2	2	2	1	1	10
(Logue & McDaid 2008)	2	1	2	1	1	1	8
(Garg & Singhal 2017)	2	1	1	1	0	1	6
(Procte & Businge 2013)	2	1	1	1	0	1	6
(Hujainah et al. 2016)	2	2	1	1	0	1	7
(Lim et al. 2010)	2	2	1	2	2	1	10
(Achimugu et al. 2014c)	2	2	2	1	1	2	10
(Iqbal 2012)	2	1	2	2	1	2	10
(Ma 2009)	2	2	1	1	1	2	9
(Perini et al. 2013)	2	2	2	2	1	1	10
(Duan et al. 2009)	2	2	2	2	1	1	10
(Voola & Babu 2012)	2	2	2	2	1	1	10
(Greer et al. 1999)	2	1	2	2	1	1	9
(Benestad & Hannay 2012)	2	2	1	1	2	2	10
(Li et al. 2010)	2	2	2	1	1	1	9
(Greer & Ruhe 2004)	2	2	2	2	1	1	10
(Aasem et al. 2010)	2	1	1	1	0	1	6
(Yousuf et al. 2016)	2	1	2	1	0	1	7
(Bendjenna et al. 2012)	2	2	1	0	0	1	6
(Avesani et al. 2004)	2	2	1	1	1	1	8
(Sher et al. 2014a)	2	2	2	2	1	1	10
(Kukreja et al. 2013)	2	1	1	1	0	1	6
(Tonella et al. 2013a)	2	2	2	2	2	1	11
(Thakurta 2013)	2	2	1	2	1	2	10
(Kaiya et al. 2002)	1	2	1	1	1	1	7
(Daneva & Herrmann 2008)	2	1	2	1	0	1	7
(Bebensee et al. 2010)	2	2	1	2	1	1	9
(Racheva et al. 2008)	1	2	2	1	0	1	7
(Liu et al. 2006)	2	2	1	2	1	2	10
(Chatzipetrou et al. 2010)	1	1	1	1	1	1	6
(Racheva et al. 2010a)	1	1	2	1	0	1	6
(Fehlmann 2008)	2	1	1	1	0	1	6
(Ahl 2005)	2	2	2	1	0	2	9
(Karlsson et al. 2007)	2	2	2	1	1	2	10
(Taylor & Wasserman 1993)	2	2	2	1	1	1	9
(Karlsson 1996)	2	2	1	1	1	2	9
(Voola & Vinaya Babu 2012)	2	1	2	2	1	1	9
(Gaur et al. 2010)	2	1	1	1	1	0	6
(Azar et al. 2007)	2	1	2	1	0	0	6
(Gruenbacher 2000)	1	1	2	1	1	1	7
(In et al. 2002)	2	1	1	2	2	1	9
(Berander 2004)	2	2	1	1	1	2	9
(Avesani et al. 2005)	2	2	2	1	2	2	11

Table A.7 (continued)

Reference	QA1	QA2	QA3	QA4	QA5	QA6	Overall Score/12
(Patrik & Jonsson 2006)	2	2	2	2	1	1	10
(Hatton 2008)	2	1	2	1	1	1	8
(Beg et al. 2009)	2	1	2	1	1	1	8
(Berander & Svahnberg 2009)	2	2	1	2	2	2	11
(Sadiq & Shahid 2009)	2	1	1	1	1	1	7
(Svahnberg & Karasira 2009)	2	1	1	1	1	1	7
(Carod & Cechich 2010)	2	2	1	2	1	2	10
(Lima et al. 2011)	2	2	2	2	1	1	10
(Kukreja et al. 2012)	1	1	1	1	1	1	6
(Khari & Kumar 2013)	2	1	2	1	1	1	8
(Bajaj & Arora 2013)	1	2	2	1	1	1	8
(A, Persis Voola 2013)	2	1	2	1	0	1	7
(Kukreja 2013)	2	1	1	1	0	1	6
(Huang et al. 2013)	2	2	2	2	1	1	10
(Wiegers & Beatty 2013)	2	1	2	1	0	1	7
(Easmin et al. 2014)	2	1	1	1	1	1	7
(Sadiq et al. n.d.)	2	1	2	1	1	1	8

iv. Data Collection and Synthesis

In this study, the data collection and referencing process was executed with use of the software Mendeley. Furthermore, data were collected on the basis of the defined research questions. Each selected study was carefully analysed to obtain any relevant data that can help in addressing the questions. Then, in the data synthesis step, proofs were collected from the data gathered from the selected studies to answer the stated research questions (Kitchenham & Charters 2007). In this systematic review, the data were synthesised qualitatively and quantitatively. Data related to the significance of the RP process were analysed critically to answer SLR-RP-Q1 by presenting the impact of the RP process on ensuring the success of the system development process.

To answer SLR-RP-Q2, techniques of RP are highlighted and visualised using a descriptive diagram, in which the collected existing techniques from the selected studies are categorised according to execution type (manual, semi-automated and fully automated) used in prioritisation. Prioritisation criteria, benefits, size of requirements and limitations of each existing RP technique are reported. Each RP technique was critically analysed, and the results are presented in a tabular form as shown in Table A.2. The stakeholders involved in the prioritisation process are reported in tabular form as shown in Table A.3, and the categorisation of the identified stakeholders is displayed in descriptive diagram to provide answers to SLR-RP-Q3 as shown in Figure 2.6 in chapter

2 . To answer SLR-RP-Q4, the RP contexts of the listed techniques in SLR-RP-Q2 and the selected studies were identified; furthermore, the usage frequency of each identified context in the RP techniques is reported and visualised as a bar chart as shown in Figure 2.7 in chapter 2. The categorisation of the selected studies based on their publication years and focus with respect to their contexts is illustrated as a scatter diagram as shown in Figure 2.8 in chapter 2.

A.4.1 Overview of the SLR Selected Studies

The results and discussion of this SLR and an overview of the included studies are illustrated in this section. A total of 121 works were finally considered as primary studies for this review. These primary studies consisted of 48 conference papers, 48 journal papers, 11 book chapters, 6 published theses, 5 workshop papers and 2 papers for IEEE bulletins and symposia. illustrates the percentage for each publication channel of the selected primary studies. The Figure A.2 shows that the conference and journal publication type have the highest percentage of 40%. The type of book chapters publication amounts to 9%. Published theses comprise 5%, followed by 4%, for the published workshops and 2% for symposia and IEEE bulletins.

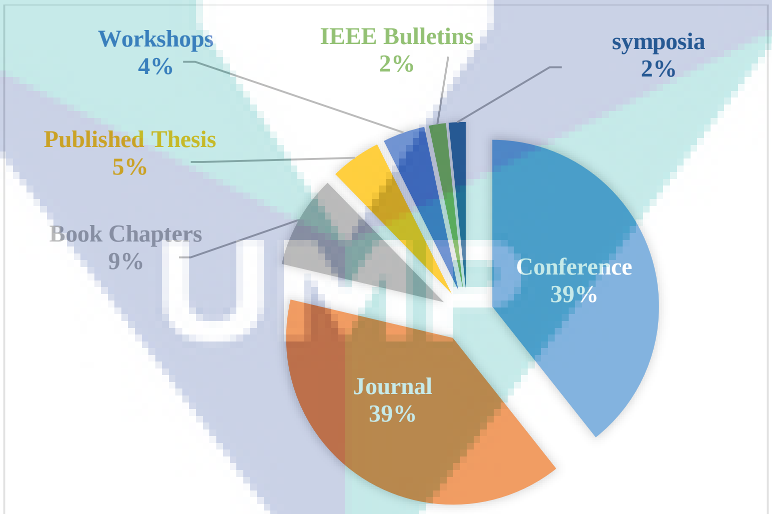

Figure A.2 SLR-RP Percentage of the Selected Studies' Publication Channels

A.4.2 SLR-RP Threats to Validity

Systematic review researches are often subjected to four different types of threats to validity (i.e., conclusion, internal, construct and external validity).

As the name suggests, threats to conclusion validity involves the potential issues that affect the conclusion as the result of the improper treatment of the variables of interest against the outcome. One potential threat to the conclusion validity relates to the bias in the selection of relevant studies and data synthesis. To mitigate this threat, a precise study selection strategy was designed on the basis of (Kitchenham & Charters 2007), which includes the inclusion and exclusion criteria and extensive QAC. This strategy was applied precisely to validate the appropriateness of each included study. Also, the data were critically extracted and then qualitatively and quantitatively synthesised to obtain data from the selected primary studies. Additionally, a set of particular QAC was applied to prevent imprecise inclusion. However, it still cannot guarantee that the defined inclusion and exclusion criteria, QAC and data synthesis are sufficient to repress the threats of bias in selecting the relevant studies and data synthesis of this review.

Threats to internal validity relates to the issues that concerns with the relationship of the variables of interest and the outcome. In the current study, the performance of a particular RP can be dependent on the scale of project undertaken. Some RP techniques are applied only to small projects by choice (i.e., sometimes owing to the limited available case studies at the time). As a result, their true performance for large projects might not be fairly evaluated. To mitigate this issue, multiple sources of publications of the same work have considered (such as from relevant journals, book chapters and conferences) whenever possible

Construct validity threats concern on the relationship between the application and theory. One threat to the construct validity comes from the exclusion of the potential relevant studies. To repress this threat, a rigorous search strategy was defined and used reduce the threat to completeness of retrieval and to include all the studies relevant to the RP domain. Consequently, website articles, studies in progress, research published in non-peer-reviewed publications, collectively called grey studies, were excluded. These excluded studies may provide answers to any of the research questions. As such, potential relevant studies might have been missed.

Finally, threats to external validity involve the issues that limit the ability to generalize the SLR findings outside the study scope. As mentioned in the defined study selection strategy, the non-English studies and grey studies were excluded. The threats here establish in whether the final selected studies of this review are able to constitute all types of review studies in field of the RP. It can be considered that the constructed review protocol assisted us to select a typical set of studies that can include the domain knowledge of the former researches and provide a comprehensive source of data and information for practitioners and researchers who are working in the field of RP. However, the results in this SLR are more concern on the RP domain from the academic perspectives than the industrial environments. Additionally, to be specific, there might be grey issues related to next release problem that have not been considered (e.g. versioning of artefacts and configuration managements) as they do not impact requirements prioritisation directly.

APPENDIX B
SLR-SQP

Table B.1 Summary of Related Studies Findings

Study References	Study Focus	Similar Findings Compared to this SLR	Uncovered Findings Added into this SLR
Pacheco and Garcia (Pacheco & Garcia 2012)	• Stakeholder identification methods in requirements elicitation	• Overview of the importance of stakeholder analysis in requirements elicitation	• Detailed and specific overview impact of the SQP process in RP • SQP attributes along with their definition, usage impacts, and degree of importance • SQP techniques • Evaluation of existing SQP techniques • Limitations or challenges of SQP techniques
Babar et al. (Babar et al. 2014b)	• Stakeholders management (quantification) in value-based software development sector	• Quantification attributes and usage context • Overview of the importance of stakeholder quantification • Omissions in stakeholder quantification process	• Detailed overview of the impact of the SQP process • Detailed analysis of SQP attributes in terms of their definition, usage impacts, and degree of importance • SQP techniques • Detailed evaluation of existing SQP techniques in terms of used SQP process and attributes • Detailed overview of limitations or challenges of SQP techniques
Mok et al. (Mok et al. 2015)	• Stakeholder management studies in mega contraction projects (MCP)	• Overview of the importance of stakeholder analysis in project development	• Detailed and specific overview impact of the SQP process in RP • SQP attributes along with their definition, usage impacts, and degree of importance • SQP techniques • Evaluation of existing SQP techniques • Limitations or challenges of SQP techniques

Table B.2 SQP Attributes

No	Attribute Name	Citations	Attribute Description	Attribute Usage Impact
1.	Power or Influence	(Babar et al. 2013; Ballejos & Montagna 2011; Bendjenna et al. 2012; Brito & Moreira 2003; Lim et al. 2010; Voola & Vinaya Babu 2012)	Indicated as the influence/power that the stakeholder can impose on project development or its objectives. The power can be incentive, utilitarian, or coercive.	Used to measure the level of the stakeholder authority over the project.
2.	Interest	(Babar et al. 2013, 2014a, 2015b; Ballejos & Montagna 2011; Razali & Anwar 2011)	Refers to concern of the stakeholder towards achieving the defined goals of the system project. Hence, it represents the relation between the stakeholders' needs and the specified goals/purposes of the system.	Used to measure willingness level of stakeholder in making the developed system meet its defined goals.
3.	Urgency	(Bendjenna et al. 2012)	Refers to the degree to which stakeholder requirements call for immediate attention.	Used to measure how the criticality and time-sensitivity the claims/requirements are from the stakeholder.
4.	Role Responsibility (Job Scope)	(Babar et al. 2013, 2015b; Ballejos & Montagna 2011; Razali & Anwar 2011)	Refers to the influence of role responsibility that the stakeholder has.	Can be used to measure the influence degree of the stakeholder's role.
5.	Personality	(Babar et al. 2015b)	Refers to the stakeholder personality with respect to his/her cooperation, inspiration, performance, and visionary, knowledge sharing.	Helps in observing the personality of a stakeholder to measure the influence of his/her personality in the workplace
6.	Experience	(Babar et al. 2013, 2014a, 2015b; Razali & Anwar 2011)	Refers to the past experience years of the stakeholders in the related domain.	Can be used to measure the stakeholder impact in term of his/her prior experience.
7.	Knowledge	(Babar et al. 2013, 2014a, 2015b; Razali & Anwar 2011)	Refers to the knowledge level of the stakeholder about a related domain in terms of technical and business knowledge.	Can be used to measure the stakeholder importance degree with respect to the business domain knowledge and software project knowledge.

Table B.2 (continued)

No	Attribute Name	Citations	Attribute Description	Attribute Usage Impact
8.	Legitimacy	(Babar et al. 2015b; Bendjenna et al. 2012)	Refers to 'a generalised perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed systems of norms, values, beliefs, and definition'.	Used to measure the stakeholder legitimate needs in the project.
9.	Training	(Babar et al. 2014a, 2015b)	Refers to the stakeholder's qualifications in terms of being trained properly or not.	Used to measure the existence of domain training of the stakeholder.
10.	Skills	(Babar et al. 2014a, 2015b)	Refers to stakeholder's professional abilities (collaboration, communication, domain experience, and knowledge) concerning the related domain.	Used to measure the influence degree of the stakeholders in terms of his/her professional abilities.
11.	Managerial Abilities	(Babar et al. 2014a)	Refers to management ability /level of the stakeholder to assist the organisation in achieving its goals.	Assists in measuring the importance degree of stakeholder's managerial abilities in his/her respective professional domain.
12.	Objectivity	(Babar et al. 2014a)	Refers to the ability of the stakeholders in elaborating the defined needs of the systems.	Can be used to measure the degree of the stakeholder's ability to describe properly the intended meanings of the needs.
13.	Risk	(Babar et al. 2015b)	Refers to the risk that the stakeholder can impose.	Used to measure the risk level that is imposed by the stakeholder.
14.	Self esteem	(Babar et al. 2014a, 2015b)	Refers to 'the stakeholder is holding the status as per his or her required skills.	Used to measure the skill of stakeholders in terms of self-esteem.
15.	Education background	(Babar et al. 2014a; Razali & Anwar 2011)	Refers to current level of stakeholders' educational background.	Used to assess influence degree for educational background of the stakeholder.

Table B.2 (continued)

No	Attribute Name	Citations	Attribute Description	Attribute Usage Impact
16.	Environment	(Babar et al. 2015b)	Refers to the stakeholder professional ethics in the work environment with respect to his/her ability to endure the memory stress (cognitive load), perform the task creatively, and share his/her experience and knowledge with other staff.	Used to measure the environmental ethics of the stakeholder in the workplace.
17.	Instability	(Babar et al. 2015b)	Refers to the stakeholder instability factor that indicates the ability of the stakeholder to face new changes and bear the extra work load.	Assist in measuring the natural instability of the stakeholder in terms of their ability to face new challenges and additional workload.

Table B.3 Analysis of Stakeholders' Quantification and Prioritisation Techniques

ID	Technique Name	Involved SQP Process	Used Attributes	Limitations	Type
1	Razali & Anwar (Razali & Anwar 2011)	• Stakeholder identification using scope, goal, domain of project. • Filtering the identified stakeholders based on business domain knowledge and interest, their educational background, experience, job scopes, and interpersonal skills (communication, negotiation, collaboration) • Prioritising the stakeholders	Interest, knowledge, experience, role, educational background, and job scopes	• Do not provide low- level descriptions of how to prioritise stakeholders. • Need to be tested more to confirm its accuracy and feasibility	Manual
2	Bendjenna et al. (Bendjenna et al. 2012)	• Classifying the stakeholders based on the Mitchell's model based on three attributes: power urgency, and legitimacy • Next, use fuzzy Choquet integral as an aggregation operator and generalise the weight arithmetic means	Power, urgency, and legitimacy	• Needs to be tested with large-scale problem to assess its effectiveness. • Requires involvement of high-level professional expert to input the weight for the stakeholder. • Results of the techniques are not widely accepted. • Lack of low implementation details of how the experts assign the priority value for the stakeholder.	Manual
3	Babar et al.- Star Triangle (Babar et al. 2013)	• Categorising the stakeholders into groups based on role responsibility • Then the experts prioritise the specified groups based on business process knowledge, and experience	Role, power, business process knowledge, experience, training,	• Heavy reliance on the involvement of experts in prioritising the stakeholders • Lack of low implementation details of how the experts assign the priority value for the stakeholder	Manual
4	AHP method (Bendjenna et al. 2012)	• Using series pairwise comparison • Next, synthesising the result	Influence	• Do not provide low-level descriptions of how to estimate the priority value of each stakeholder	Manual

Table B.3 (continued)

ID	Technique Name	Involved SQP Process	Used Attributes	Limitations	Type
5	Babar et al.-Bi-metric (Babar et al. 2014a)	• The industry expert assigns a value to each attribute for each participating stakeholder • Next, the fuzzy c-mean is used for clustering in order to define the threshold for the stakeholder	Skill (domain knowledge, managerial abilities, domain training, and self-esteem).Interest: (domain scope knowledge, business knowledge, and objectivity)	• Requires involvement of industry expert • Lack of low implementation details of how the experts estimate the priority value of each stakeholder • Needs more testing with large problem to assess its effectiveness • Not fully automated	Manual
6	Ballejos & Montagna (Ballejos & Montagna 2011)	• Quantify and prioritise stakeholders using quantitative calculation based on their role influence, power, and interest regarding the system	Interest, power, and role influence	• Performs the SQP process manually. • Only concerned with the influence and power attributes. • Time consuming and lack of producing a final ordered list of stakeholders.	Manual
7	Lim et al. (Lim et al. 2010)	• Determine the scope of project • Based on the scope of project, identify an initial set of stakeholder roles • For each role, find the stakeholders • For each stakeholder, obtain their stake and recommendations • Draw a social network with the stakeholders as nodes and their recommendations as directed edges • Prioritise stakeholders by applying social network measures to the network	Role, influence /power	• Requires good expertise in stakeholder analysis domain to conduct the SQP process • Executes the SQP process manually	Manual

Table B.3 (continued)

ID	Technique Name	Involved SQP Process	Used Attributes	Limitations	Type
8	Babar et al.-StakeMeter (Babar et al. 2015b)	• Identify the stakeholders' responsibility • Divide the stakeholders into groups based on their responsibilities • Calculate the stakeholder value based on the factors identified by the experts • Inclusion and exclusion criteria are defined by the requirements engineer based on stakeholder value	Interest, risk, hierarchy, skill, communication, legitimacy, knowledge, personality, environment, and instability	• Requires good expertise in stakeholder analysis domain • Needs more testing with large problem to assess its applicability • Lack of low implementation details of how experts estimate the priority value of each stakeholder and how the inclusion and exclusion criterion is defined by the requirements engineer • Not fully automated	Manual
9	McManus (McManus 2004)	• Prioritises the stakeholders by categorising them into three categories: Primary Stakeholders, Secondary stakeholders, and External Stakeholders	Power, interest, and influence	• Lack of low implementation details of how the prioritising process of stakeholders is conducted • Provides only sample ranking categories of stakeholders without assigning priority value for each stakeholder	Manual

B.4 SLR-SQP Review Protocol

The detailed explanation of execution the defined activities of the designed review protocol of the SLR-SQP in Figure 3.2, chapter 3 is given in the following subsections.

i. SLR-SQP Research Questions

Five research questions were formulated as a guideline for the SLR-SQP. These formulated research questions are as shown in section 2.4.2, chapter 2.

ii. Search Process Strategy

The search process is executed using the same process that discussed in the section of the search process of the SLR-RP (section A.4, ii). The list of search strings formulated and used in the searching for the related works is as follows:

1. Stakeholder analysis
2. Stakeholder prioritisation
3. Stakeholder quantification
4. SQP attributes
5. Importance of SQP
6. SQP techniques/methods/activities
7. Limitations (AND/OR) challenges, (AND/OR) types, (AND/OR) benefits of SQP.

The studies that related to this review were extracted from the electronic database resources that presented in Table A.4, Appendix A.

iii. Study Selection Criteria

Study selection strategy is performed to determine whether or not the compiled studies in the initial stage of the search process have to be included (Kitchenham & Charters 2007). In this review, the study selection strategy is implemented by considering two sub-criteria: inclusion and exclusion criteria, and quality assessment criteria.

1. Inclusion and Exclusion Criteria

Two hundred and ten probable studies were collected during the initial search process. Thus, scrutiny was essential to identify the most relevant studies to the SQP domain. As a result, inclusion and exclusion criteria were designed based on the specified research question. First, the title and abstract of each collected study were carefully examined; next, the studies that were not related to SQP and not able to address any of the formulated research questions were excluded.

In the case of multiple versions of the same study, the most complete and recent version of the study was included, and other multiple copies were excluded. The studies included in this study were published between 1999 and 2018. In addition, all research studies written in languages other than English were excluded from the list of relevant studies, including those that were published in English-based journals. Details of the defined key points of inclusion and exclusion criteria for this SLR are given in Table B.4.

Table B.4 SLR-SQP Inclusion and Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
• Research works that are written in English. • Research works that focus on stakeholder quantification and/or prioritisation domain. • All research works focusing on stakeholder quantification (or, and) prioritisation techniques based on the keywords and title of the papers. • Empirical research paper, an experience report based on experts. • Relevant papers that include the potential answers to research questions by carefully examining the abstract of collected papers.	• All research studies that are not written in English. • Duplicate papers: excluding multiple copies of the same study and including only the most complete and recent. • All papers that do not relate to the specified research questions. • Papers that are only concerned with the stakeholder identification issue without further details on how to quantify and/or prioritise the stakeholder. • All papers considered to be grey papers which do not have bibliographic details such as publication type/date.

2. Quality Assessment Criteria

The quality assessment criteria (QAC), considered one of the most essential stages in the study selection strategy (Kitchenham & Charters 2007), is executed to assess the quality of selected studies. The assessment of the selected studies is performed based on QAC quality questions (Kitchenham & Charters 2007), which were formulated based on the specified research questions that are related to the SQP research domain. Table B.5 presents the generated quality questions used in this study. Each QAC question has only three answers: yes, partially, and no. If a study received 'yes' as an answer, then a quality point of 1 is assigned to it, a quality point of 0.5 is assigned to a study that received 'partially' as an answer, and a quality point of 0 is awarded to a study that received 'no' as the answer.

The QAC was applied with the participation of all authors of this work by precisely studying the title, abstracts, and contents of each study. First, each author assigned a quality point to each defined question. The results of the quality scores for each selected study that had been reviewed by the authors were collected. The comparisons and discussion among the authors were then conducted to address the contradictions with the purpose of obtaining a consensus in specifying the final quality score for each question and obtaining the overall quality scores of the study by summing all the quality points of the defined questions.

Table B.5 SLR-SQP Quality Assessment Criteria

ID	Question(Q)	Answer Score Points
Q1	Is the objective/aim of the research sufficiently illustrated?	Yes = 1/ partially= 0.5/no = 0
Q2	Does the study focus on the SQP domain?	Yes = 1/partially = 0.5/no =0
Q3	Does the study illustrate the SQP attributes?	Yes = 1/partially = 0.5/no =0
Q4	Is the proposed technique/solution clearly explained?	Yes = 1/partially = 0.5/no =0
Q5	Is the evaluation of the proposed technique performed on adequate project data sets or case studies?	Yes = 1/partially = 0.5/no =0
Q6	Does the research contribute to the domain in terms of academic or industry sector?	Yes = 1/partially = 0.5/no =0
Q7	Is the result of the research clearly stated?	Yes = 1/partially = 0.5/no =0

However, to ensure the reliability of the review's findings, only the relevant studies that received a score greater than 3.5 are included, which is half of the full-score (7). As result, 31 out of 210 research studies are selected as primary studies to the research domain. The result of the quality score for each selected study is presented in Table B.6.

Figure B.1 illustrates the document retrieval process of SLR-SQP and consists of four stages. At the first stage, 210 probable research studies have been collected. In the second stage, the collected research studies were scrutinised by employing the inclusion and exclusion criteria key points based on screening the title and abstract of each collected research study to exclude irrelevant and duplicated studies, which resulted in 85 studies remaining.

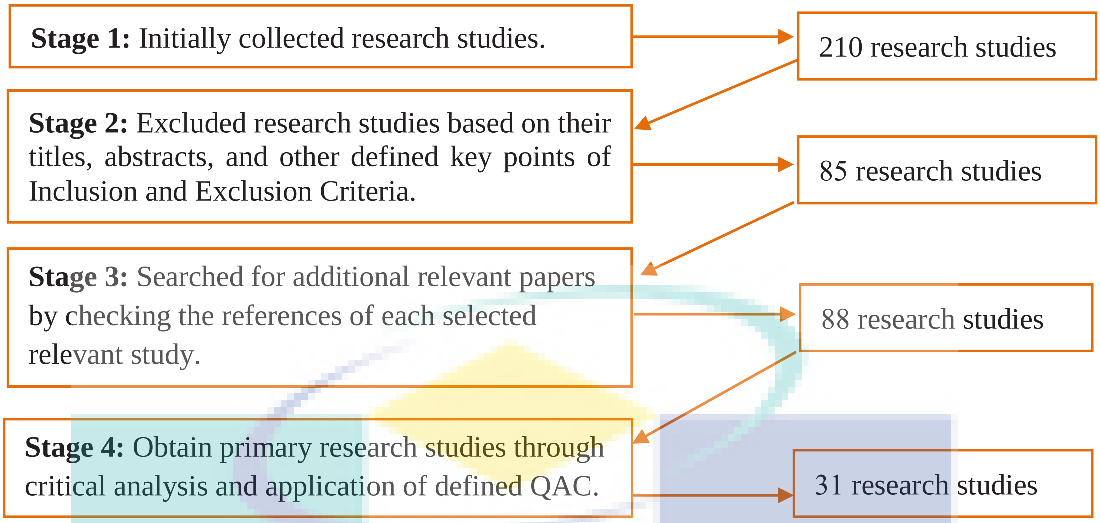

Figure B.1 SLR-SQP Stages of Document Retrieval Process

Table B.6 SLR-RP Quality Scores' Result of the Selected Studies.

References for Selected Studies	Q1	Q2	Q3	Q4	Q5	Q6	Q7	SCORE/7
(Razali & Anwar 2011)	1	1	1	0.5	0	1	1	5.5
(Lim & Finkelstein 2012)	1	0.5	0.5	0.5	0.5	1	1	5
(Preiss & Wegmann 2001)	1	1	0.5	0.5	0.5	0.5	0	4
(Power 2010)	1	0.5	0.5	0.5	0	1	0.5	4
(Lim et al. 2010)	1	1	1	0.5	0.5	1	1	6
(Bendjenna et al. 2012)	1	1	1	1	0.5	1	1	6.5
(Babar et al. 2014a)	1	1	1	1	0.5	1	1	6.5
(Babar et al. 2015b)	1	1	1	0.5	1	1	1	6.5
(Babar et al. 2015c)	1	0.5	0.5	0.5	0.5	1	1	5
(Ling Lim et al. 2011)	1	0.5	0.5	0.5	0.5	1	1	5
(Berander 2004)	1	0.5	0.5	0	0	1	1	4
(Benestad & Hannay 2012)	1	0.5	0.5	0	0	1	1	4
(Ballejos & Montagna 2011)	1	1	1	1	0.5	1	1	6.5
(Babar et al. 2014b)	1	0.5	0.5	0.5	0	1	1	4.5
(Babar et al. 2015a)	1	0.5	0.5	0.5	0.5	1	1	5
(Babar et al. 2013)	1	1	1	0.5	0.5	1	1	6
(Damian 2007)	0.5	1	0.5	0	0	1	1	4
(Dearden, P., S. Jones 2003)	1	1	1	0.5	0	1	1	5.5
(Jepsen & Eskerod 2009)	1	0.5	0.5	0.5	0	1	1	4.5
(Lim et al. 2012)	1	1	1	0.5	0.5	1	1	6
(Lindblom & Ohlsson 2011)	1	0.5	0.5	0	0	0.5	1	3.5
(McManus 2004)	1	0.5	1	0.5	0	1	0.5	4.5
(Parent & Deephouse 2007)	1	1	1	0.5	0.5	1	0.5	5.5
(Rawlins 2006)	1	0.5	1	0.5	0	1	1	5
(de Vivero & Alba 2007)	0.5	1	0.5	0.5	0.5	1	1	5
(Seale 2003)	0.5	1	0.5	0.5	0	1	1	4.5
(Varvasovszky 2000)	1	0.5	0.5	0.5	0	1	1	4.5
(Mayers 2005)	0.5	0.5	0.5	0.5	0	1	1	4
(Voola & Vinaya Babu 2012)	1	0.5	0.5	0.5	0	1	1	4.5
(Brito & Moreira 2003)	1	0.5	0.5	0	0	1	1	4
(Voola & Babu 2012)	1	0.5	0.5	0.5	0.5	1	1	5

Subsequently, additional relevant papers were searched by checking the references of each study in the third stage. This step was essential to ensure all relevant studies have been collected, even those studies that might be missed in the initial stage of the search process. As a result, only three relevant papers were identified, making the total number of the remaining studies to be 88; these studies were then carefully analysed by applying the defined QAC in the fourth stage. Consequently, 31 relevant studies were finally selected as primary studies to address the stated research questions of this SLR.

iv. Data Collection

In this SLR, the data collection process is performed with the support of Endnote software tool. Data were collected based on the perspective questions of this work. Each collected study is carefully analysed to obtain suitable information that can be used to answer the defined research question. The research studies that highlight and cover the importance or the impact of SQP in system development are collected and carefully studied to answer SLR-SQP-Q1. To answer SLR-SQP-Q2, the researchers collected research studies that concern aspects, attributes, and criteria that are used to quantify and prioritise the stakeholders in various software system domains. In addition, SLR-SQP-Q3 and SLR-SQP-Q4 target research studies that propose, discuss, and evaluate existing SQP techniques in order to identify the involved SQP process, types, benefits, and limitations of each existing SQP technique.

v. Data Synthesis

The objective of this exercise is to extract proof from the selected research studies to address the research questions enumerated (Kitchenham & Charters 2007). In this SLR, the extracted data comprised qualitative data, such as the importance of performing the SQP process along with the existing limitations of existing SQP techniques, and quantitative data, such as the accuracy of existing SQP techniques and the number of attributes used by the techniques to prioritise and quantify the stakeholders.

In addition, data that are relevant to the importance of SQP in RP were analysed to provide an answer to SLR-SQP-Q1 by detailing the impact of performing the SQP in the RP. In SLR-SQP-Q2, SQP attributes were identified from the selected research studies. The visualisation tool, which is pareto chart, was used to display the significance degree of each identified attribute based on its frequency usage in the collected relevant studies as shown in Figure 2.9,chapter 2.

Meanwhile, the answers to SLR-SQP-Q3 reported the existing techniques that were focused on quantifying and prioritising the stakeholders, and the outcome was also conceived in the form of bar charts as shown in Figure 2.10 , chapter 2. The answers to SLR-SQP-Q4 were reported by identifying the involved SQP process, types, and limitations of each existing SQP technique from the selected research studies. A tabular form was used to present the outcome of SLR-SQP-Q4 as shown in Table B.3.

B.4.1 Overview of SLR-SQP Selected Primary Research Studies

This section provides an overview of the SLR-SQP selected primary research studies. Finally 31 ,research papers were selected as the primary studies to be within the scope of this review, which comprises the following: 12 research papers published in journals; 8 research papers presented in conferences; 5 research papers mentioned in chapters of books; 2 research papers, each published in theses and IEEE bulletins; and 1 research paper extracted from a symposium.

The percentages of the selected research studies shown in Figure B.2 are as follows: journal papers (41 %), book chapters (24 %), conference papers (17 %), theses and IEEE bulletins (7 % of each type), and symposium (6 %). Meanwhile, Figure B.3 shows the publication years of the selected research studies for conducting this SLR; most SQP studies were published in the years from 2009 to 2013. In the line graph of Figure B.3, there is no edge corresponding to the years 2003 and 2005 because the same number of studies (two) were published in 2003 and 2004, respectively, while, one study was published in 2005 and 2006, respectively.

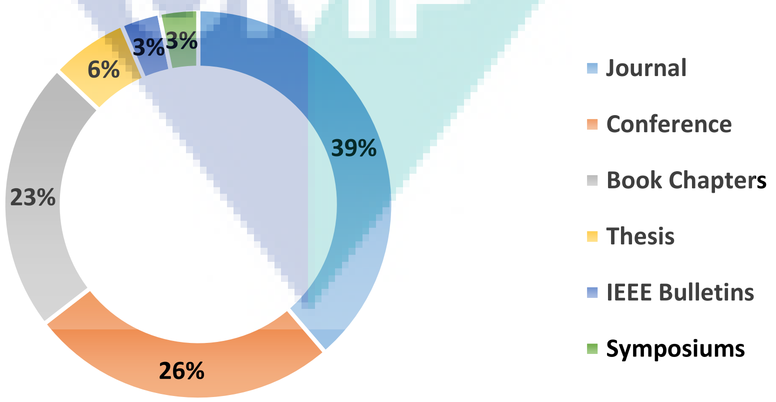

Figure B.2 SLR-SQP Percentage of Selected Research Studies

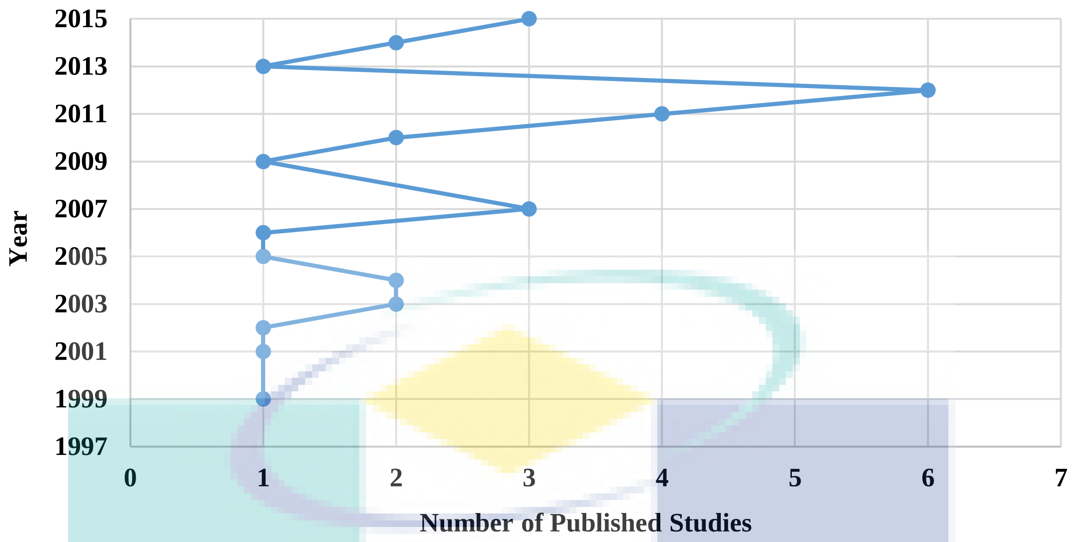

Figure B.3 SLR-SQP Publication Years of Selected Research Studies

B.4.2 SLR-SQP Threats to Validity

The three major threats to any systematic review are completeness, publication bias, and data synthesis. For the completeness threat, the defined protocol has been used with rigorous review search strategy to establish this review on the SQP domain. Thirty-one research studies were finally detected and selected to address the stated research questions of this review. However, there is no guarantee that all relevant studies are captured in this review, in view of recent increased concern about the SQP domain during the period from 2007 to 2015. In addition, relevant materials written in languages other than English were not included, which leads to the possibility of omitting important or relevant studies.

With regards to threats in data synthesis, the QAC to conduct the process of data synthesis in this study were defined. The QAC were applied to identify the studies that can provide sufficient answers to the research question. However, there was no guarantee that this defined QAC could adequately satisfy this mission. Another weakness is with respect to publication bias, which is counted as a threat in this review. Publication bias refers to the issue that positive consequences are more likely to be published than negative ones (Kitchenham & Charters 2007). However, to repress this threat, the included studies were subjected to comprehensive study selection criteria. In addition, an extensive quality assessment was applied to the included studies to ensure the completeness of the search and validate the appropriateness of each included study. Thus, grey studies (studies that are in progress, technical reports, and unpublished or non-peer reviewed publications) that include the answers to the identified research questions are excluded in this review. This is one of the limitations of this review as potential answers might have been missed because of the exclusion of grey studies.

APPENDIX C
STAKEQP

Table C.1 Detailed Description of the Measurement Criteria of Education Background Atrribute.

ISCED 2011 Level no	Description
5:Short-cycle tertiary education	"Short first tertiary programmes that are typically practically-based, occupationally-specific and prepare for labour market entry. These programmes may also provide a pathway to other tertiary programmes."
6:Bachelor or equivalent	"Programmes designed to provide intermediate academic and/or professional knowledge, skills and competencies leading to a first tertiary degree or equivalent qualification."
7:Masteror equivalent	"Programmes designed to provide advanced academic and/or professional knowledge, skills and competencies leading to a second tertiary degree or equivalent qualification."
8 : Doctoral or equivalent	"Programmes designed primarily to lead to an advanced research qualification, usually concluding with the submission and defence of a substantive dissertation of publishable quality based on original research"

C.1 Stakeholder Quantification and Prioritisation Survey

Dear Honourable Expert,

Salam Alikum W.B.

I am Fadhl, a doctoral student at the Faculty of Computer Systems and Software Engineering, Universiti Malaysia Pahang. In fulfilment of the degree, I am currently working on one part of my dissertation, which is related to the domain of stakeholder quantification and prioritisation on requirement elicitation and prioritisation. You have been selected to participate in my research, since I strongly believe that you could give valuable input to my research. The survey will take approximately 15-20 minutes of your time. Please rest assured that all responses will be treated with the highest confidentiality, and they will be reported as aggregates in my report. I hope that you will give your utmost consideration to participate, and for that, I am indeed very grateful. If you need to know more about my research work, please do not hesitate to contact me. I am extremely delighted to share it with you.

Demographic Information: **Please fill up your information below**

- **Name**

  ____

- **Contact Email**

  ____

- **Years of Experience.**

  ____

- **Latest Job Title**

  ____

Section A: Stakeholder Quantification and Prioritisation Attributes (SQP)

Stakeholders who are involved in requirements elicitation and prioritisation, and a system development can be quantified and prioritised by certain attributes. Please rate the level of the importance of the following attributes that can be used in quantifying and prioritising the stakeholders:

Attributes		**Attribute Description**	**Attribute Usage Impact**	**Scale**						
				Not at all important	**Low importance**	**Slightly important**	**Neutral**	**Moderately important**	**Very important**	**Extremely important**
Role Influence Attribute		The influence of the stakeholder's role responsibility	To measure the influence degree of the stakeholders' role	1	2	3	4	5	6	7
Power Positional Attribute		The level of the stakeholders' authority based on their positional power that can be imposed on project development or its objectives	To measure the authority level of the stakeholders over a project	1	2	3	4	5	6	7
Interest Attribute		The level of concern of the stakeholders towards achieving the defined goals of the system project	To measure the concern or willingness level of stakeholders to allow the system project to satisfy its specified objectives or goals	1	2	3	4	5	6	7
Knowledge in term of :	Experience	Previous experience of the stakeholders in the related domain	To measure the stakeholders' influence in terms of their previous experience	1	2	3	4	5	6	7
	Educational Background	The level of stakeholders' educational background	To measure the influence level of the stakeholders' educational background	1	2	3	4	5	6	7

Section B: Measurement Criterion of the Stakeholder Quantification and Prioritisation Attributes

This section provides the measurement criterion for SQP attributes (role influence attribute, power positional, interest, experience attributes), which can be used as standard guidelines in evaluating the stakeholder's influence based on the SQP attributes. Please rate the level of the importance of the following attributes' measurement criterion.

B.1 Role Influence Attribute Measurement Criteria

The important influence degree of stakeholders' role is related to the role responsibility (job scope) of stakeholders in a project. Hence, the role responsibility and job scope are used to measure the influence degree of stakeholders' role. System stakeholders can have various roles on system development projects, such as suppliers, support staff and developers. Kindly rate the level of the importance of the following stakeholders' role group :

Stakeholders' Role Group	Description	Scale						
		Not at all important	Low importance	Slightly important	Neutral	Moderately important	Very important	Extremely important
Acquirers	Oversee the system's procurement in the development process of system project; acquirers frequently represent the business sponsors, senior executives from the technology groups, marketing and sales. When the system project requires funding from the external investment, the investors can also act as acquirers.	1	2	3	4	5	6	7
Assessors	Oversee the conformance of the system to legal and standard regulation	1	2	3	4	5	6	7
Communicators	Describe the system to other stakeholders using training materials and documentation	1	2	3	4	5	6	7

Stakeholders' Role Group	Description	Scale						
		Not at all important	Low importance	Slightly important	Neutral	Moderately important	Very important	Extremely important
Developers	Perform the system contraction and deployment from its specification (or lead the teams, which perform this construction and development process)	1	2	3	4	5	6	7
Maintainers	Handle the system evaluation once it is in use or ready to be used	1	2	3	4	5	6	7
Suppliers	Supply and/or construct the software, hardware or infrastructure, where the system will function	1	2	3	4	5	6	7
Support Staff	Related to staff who provides support to users of the product or system	1	2	3	4	5	6	7
System Administrators	Execute the system once deployed	1	2	3	4	5	6	7
Testers	Test the developed system to ensure that the system is convenient to be used	1	2	3	4	5	6	7
Users (Functional Beneficiary)	Specify the functionality of the system and ultimately make use of it	1	2	3	4	5	6	7
Consultant	Consultant acts more within mission, where standard solutions fit the forecasted project.	1	2	3	4	5	6	7
Expert	Intervenes mainly in unusual situations and operates a relatively new panel of knowledge	1	2	3	4	5	6	7

B.2 Power Position Attribute Measurement Criteria

The influence level of stakeholders’ power degree can be measured on the basis of the authority level of stakeholders in organisations. This authority level indicates the position power (management level) type of stakeholders. Therefore, this attribute can be measured using standard position levels of stakeholders in organisations. Kindly rate the level of the importance of the following position levels of the stakeholders :

Position Level	Description	Scale						
		Not at all important	Low importance	Slightly important	Neutral	Moderately important	Very important	Extremely important
Top Level	This level includes decisive people for directing and leading other people's efforts towards achieving success. It comprises chairman, vice president, president, board of directors, general manager, managing director, chief financial officer, chief operating officer and chief executive officer. The managers (people) of this group have the maximum level of authority.	1	2	3	4	5	6	7
Middle Level	This level comprises departmental heads, such as purchasing department head, sales department head, marketing manager, finance manager, plant superintendent and executive officer. People in this level are in charge of implementing the policies and plans structured by the top level. They also practice the roles of the top level for their associated department as they structure policies and plans for their department. They collect and organise the resources based on the defined policies and plans of the top level.	1	2	3	4	5	6	7
Supervisory Level	This level comprises superintendent, supervisors, sub-department executives, foreman and clerk. Managers of this level have limited authority; they work to execute the defined activities of the plan constructed by the previous two levels (top- and middle-position levels). They pass on the instruction to the workers and report to the middle level management. They are in charge of preserving discipline between the workers.	1	2	3	4	5	6	7
Worker Level	Those who do not hold any managerial position	1	2	3	4	5	6	7

B.3 Experience Attribute Measurement Criteria

The influence of the stakeholders' years of experience can be measured using the years of experience categories which are considered as a consistent worldwide basis to distinguish the various job levels of the stakeholders. Kindly rate the level of the importance of the following years of experience categories

Years of experience Category	**Scale**						
	Not at all important	**Low importance**	**Slightly important**	**Neutral**	**Moderately important**	**Very important**	**Extremely important**
Category A: 0–1 year of experience	1	2	3	4	5	6	7
Category B: 1–3 years of experience	1	2	3	4	5	6	7
Category D: 5–8 years of experience	1	2	3	4	5	6	7
Category E: 8–10 years of experience	1	2	3	4	5	6	7
Category F: More than 10 years of experience	1	2	3	4	5	6	7

C. 2 Details of Experiment Implementation and Result

The details of experiment implementation's steps are enumerated as follows:

1. Phase 1, Pre- requisite Step: Collecting and Storing the Stakeholders Profiles of RALIC Project Dataset

The process of collecting the stakeholders' profiles of RALIC dataset was performed by Soo Ling Lim at UCL in term of gathering the requirements along with all stakeholders. The stakeholders' profiles of this project used in evaluating proposed SQP technique (StakeNet technique) in (Lim 2010; Lim et al. 2010). However, to implement this dataset in this research, it was firstly essential to study and check the stakeholders' details in term of detecting duplication, and containing all the required details of each stakeholder with respect to the attributes of StakeQP. This is because, in this research, each stakeholder profile has to contain the details of stakeholder's role, position, education level, years of experience. Thus, the process of checking the availability of these details in each stakeholder profile was extremely essential to fulfil the StakeQP pre-requisite step that aims to contain complete stakeholders' profiles that contain all the required details.

However, it found that the stakeholder profiles of RALIC dataset contain the details of name, role, position and department for each stakeholder of RALIC project. These given details are used by researchers along with the owner of the dataset in matching these details to corresponding role influence group measurement criteria, positional power level measurement criteria, and interest level measurement criteria of StakeQP for each stakeholder. Whereas stakeholders' details with respect to the years of experience and education level were not provided in the dataset. Hence, the owner of RALIC dataset was also contacted by the authors of this research to provide that missing details. The missing details were then finalized with owner of the dataset by providing the expected range of education level and years of experience for each RALIC stakeholder.

Then, the collected information details of each stakeholder can be stored to the developed database via the GUI of the technique's automated tool. The home page of the automation tools of StakeQP is shown in Figure C.1. The process of storing each collected stakeholder profiles can be performed by two ways (uploading file, designed SQP form) as shown in Figure C.1. The first way is by saving the collected information details from the previous steps in excel file format and then upload it as shown in Figure C.2. On another hand, Figure C.3 present the second way of storing the collected stakeholders profile. It is executed by using the designed SQP form that should be filled with the details of each stakeholder that are collected.

In conducting experiments, the process of storing each collected stakeholder profiles of RALIC is performed with uploading file way, where all the details of the collected stakeholders' profiles are saved in excel file format. Figure C.4 presents the message of successful storing of the RALIC stakeholder profiles with options of managing the stored profile of each stakeholder. Figure C.5 present the managing the stored profile of each stakeholder webpage, where the details of each stakeholder's profile are displayed with options of editing and deleting the stored profile, and adding new stakeholder's profile.

2. Phase, Quantifying and Prioritising Process

Based on the defined implementation guidelines, this step includes three steps (two steps for formulating the SPV of each attribute and one step is for producing the result). These three steps are executed automatically after clicking the "Find result" button in Figure C.

Step:2.1, and Step 2.3 (2.1 Automated Calculation of SAV and Automated Execution of the TOPSIS algorithm):

The two steps are automated calculation of SAV (step 2.1), and automated execution of the TOPSIS method (step 2.2). These two steps are executed automatically after clicking the "Find result" button in Figure C.4. The SAV is calculating for each stakeholder based on the stored MCV of each attribute's measurement criteria and the details of each stakeholder's profile of RALIC. Whereas, The SAV of each stakeholder and AWV of each attribute are used to find the SPV of each stakeholder and the final ranked list of stakeholders by executing the TOPSIS method.

Step 2.3: Presentation of the Result

The automated tools presented the result that contain the prioritised list of the RALIC stakeholders that consist of the 85 stakeholders as shown in Table C.2. The result presents the stakeholder rank, ID, and the obtained SPV for each stakeholders of the RALIC with obtained SPV of each stakeholders. The SPV of each stakeholder is between the range of 0 to 1 ($0 \leq SPV \leq 1$) as it has normalized in the steps of TOPSIS.

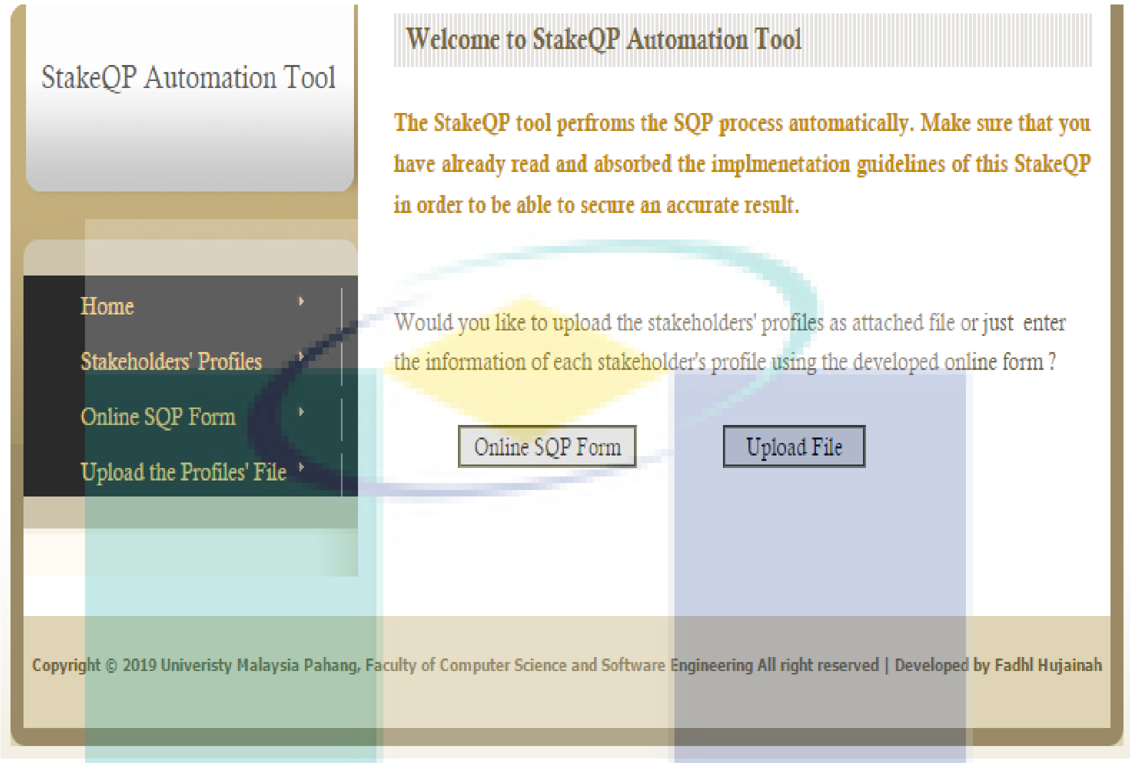

Figure C.1: Home Page of StakeQP Automation Tool.

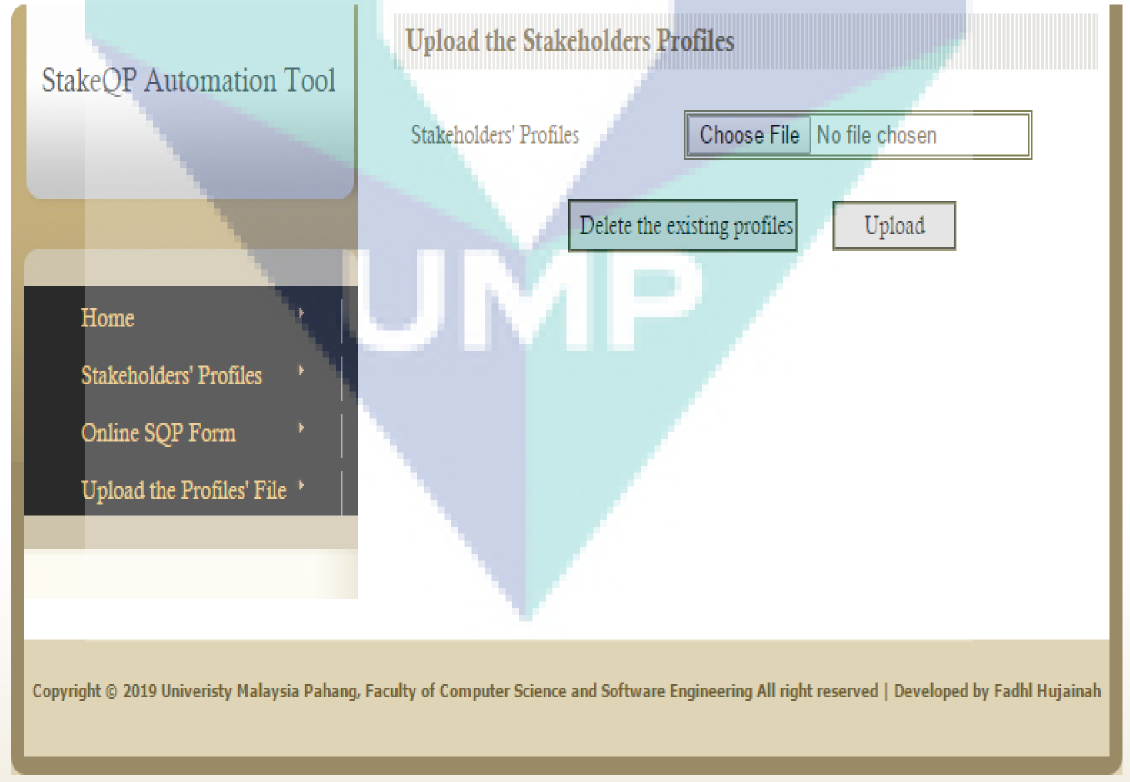

Figure C.2: Uploading the File of Stakeholders Profiles

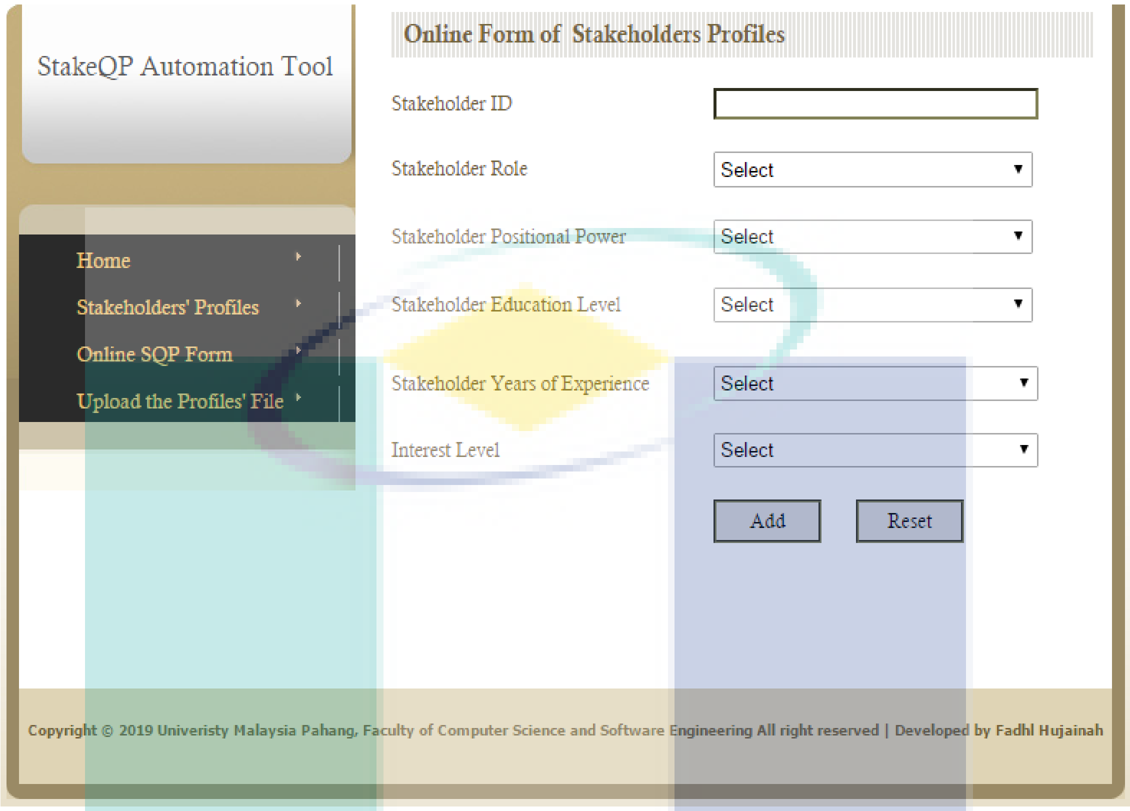

Figure C.3: Online SQP Form

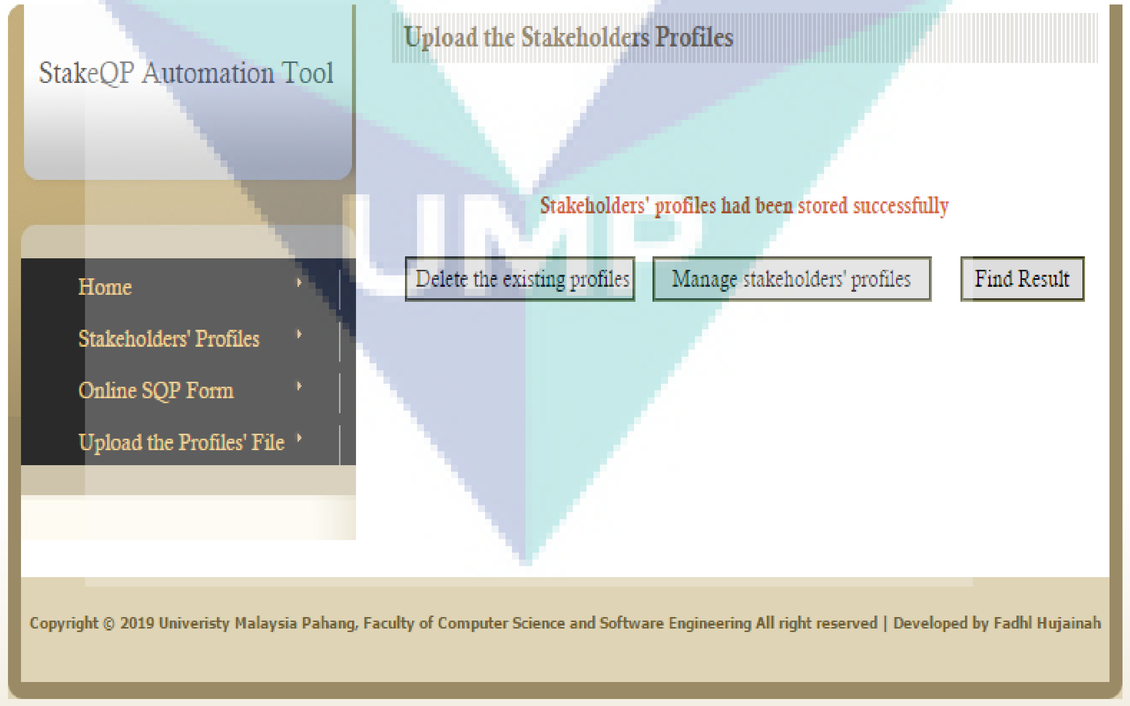

Figure C.4: SQP Storing Stakeholders' Profiles

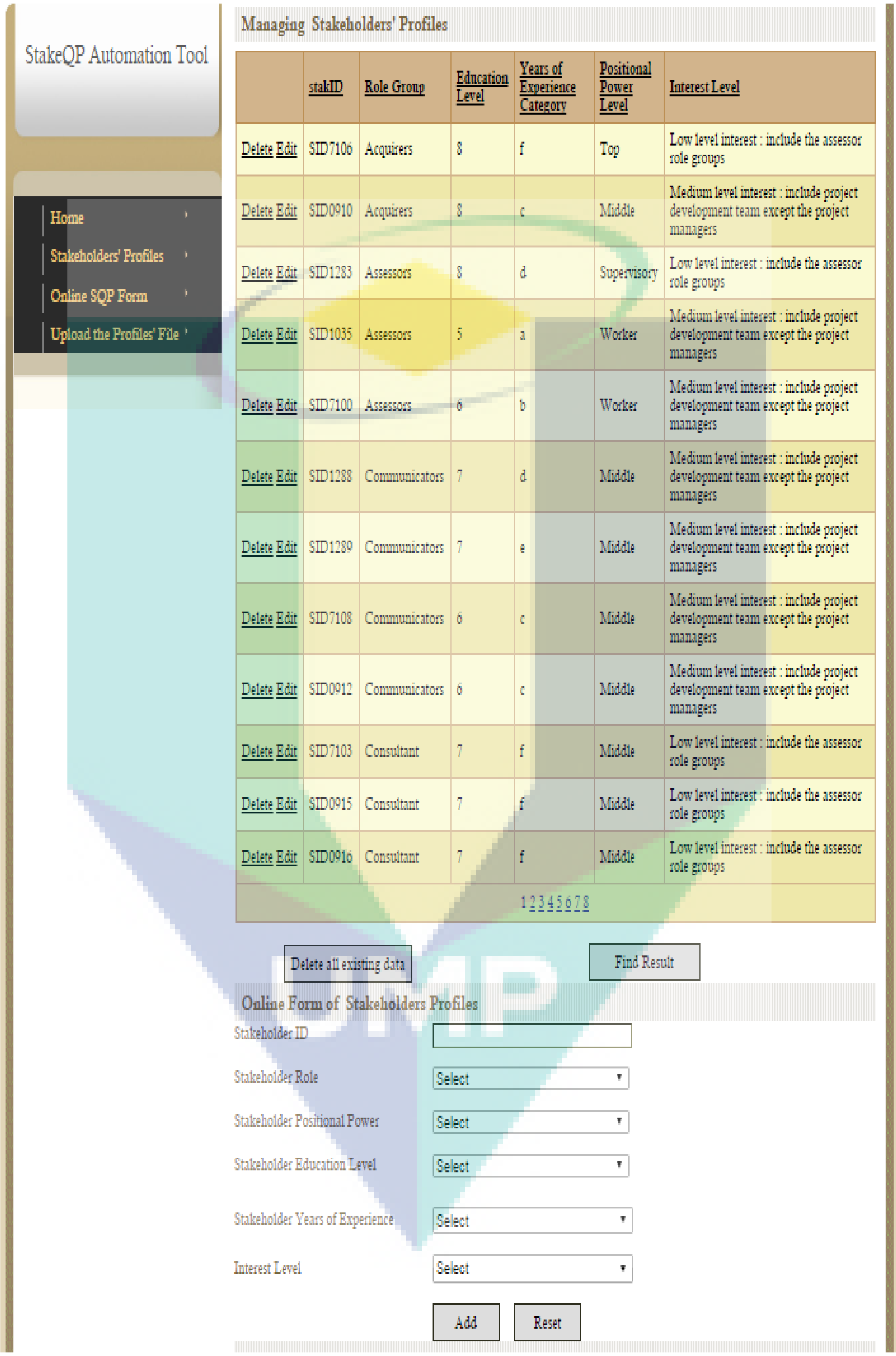

Figure C.5. Managing the Stored Stakeholders' Profiles.

Table C.2 StakeQP Expermentaion Results of the RALIC Stakeholders Quantification and Priroitisation

Rank	Stakeholder ID	SPV
1	SID3007	0.9142
2	SID9024	0.8987
3	SID3002	0.8564
4	SID0904	0.822
5	SID9022	0.8091
6	SID0908	0.8064
7	SID7109	0.8012
8	SID9030	0.772
9	SID0902	0.7593
10	SID3005	0.7413
11	SID9027	0.7394
12	SID9023	0.7169
12	SID3010	0.7169
14	SID0900	0.7042
14	SID0931	0.7042
14	SID0936	0.7042
17	SID9029	0.6583
18	SID0911	0.655
18	SID3009	0.655
20	SID1289	0.6499
21	SID1286	0.6491
21	SID0901	0.6491
21	SID1034	0.6491
24	SID0937	0.6403
25	SID0910	0.6366
26	SID0905	0.624
27	SID1288	0.6128
28	SID3006	0.6103
29	SID1036	0.6032
30	SID0909	0.5923
31	SID0938	0.5872
31	SID9028	0.5872
31	SID9021	0.5872
34	SID9234	0.5819
34	SID1037	0.5819
36	SID0907	0.5688
37	SID5234	0.556
38	SID0234	0.5552
39	SID1285	0.5504
40	SID8234	0.5481
41	SID1282	0.5244
42	SID7106	0.5219
43	SID7105	0.5188
44	SID3234	0.5141
44	SID0920	0.5141
44	SID1287	0.5141
44	SID1032	0.5141
48	SID4234	0.5133
49	SID1033	0.5077
49	SID9020	0.5077

Table C.2 (continued)

Rank	**Stakeholder ID**	**SPV**
51	SID1039	0.5006
52	SID0919	0.5001
53	SID7107	0.4945
54	SID7108	0.4889
54	SID0912	0.4889
56	SID0903	0.4858
57	SID7104	0.4826
58	SID0918	0.4789
59	SID1283	0.4711
60	SID6234	0.4693
61	SID3001	0.4662
62	SID3008	0.4637
63	SID1234	0.4581
64	SID0917	0.4526
64	SID0906	0.4526
66	SID0915	0.4405
66	SID0916	0.4405
66	SID7103	0.4405
69	SID0913	0.4382
70	SID7234	0.4277
71	SID1281	0.4127
72	SID1038	0.4075
73	SID0914	0.4019
73	SID3003	0.4019
73	SID7102	0.4019
76	SID7100	0.4009
77	SID3004	0.3963
78	SID1031	0.3907
79	SID9026	0.3848
80	SID3090	0.3288
81	SID9025	0.3232
82	SID2234	0.3229
83	SID1280	0.3099
84	SID1035	0.2601
85	SID7101	0.2554

APPENDIX D
SRPTACKLE

D.1 Details of Experiments Implementation and Results

The detailed explanation of implementing the experiments is illustrated as follows:

1. **Input step**

In each experiment, the files of requirements list, requirement weighting values, and stakeholder profiles are obtained from the RALIC dataset that were provided in (Lim 2010; Lim & Finkelstein 2012). The requirements list file contains the details of Id. and title for all requirements that need to be prioritised. The file of requirement weighting values contains the weighting values of each requirement. These values were obtained from the documentation of the RALIC dataset in (Lim 2010; Lim & Finkelstein 2012) by taking the weighting values for each requirement that was given by 76 stakeholders of the RALIC project. The profiles of the 76 participating stakeholders were obtained from the RALIC documentation as discussed in chapter 4, section 4.2.2. The process of storing these files into the database of the web developed tool is performed by uploading them to GUI of the web developed tool as shown in Figure D.1.

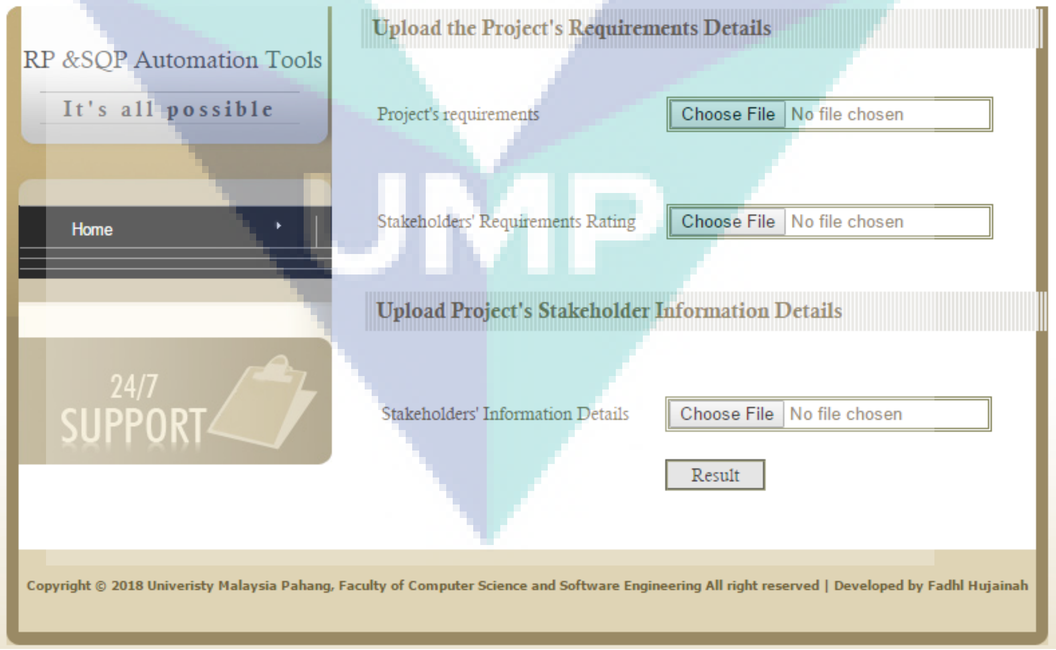

Figure D.1 Input Step in The Automation Tool of the SRPTackle Technique

2. **Process and output: Execution of the post-prioritisation phase of the SRPTackle technique**

After uploading the required files of the input phase in each experiment, the five steps of the post post-prioritisation phase are then executed automatically by clicking on the “find result” button in Figure D.1. Then result of the experiment is produced. Figure D.2 present the produced prioritised list of requirement of the SRPTackle. As shown in Figure D.2, the requirements are classified into three clusters: high, medium, and low priority requirements list. In each cluster, each requirement has its priority ranking (R) along with its obtained priority value (RPV).

Final Result

Requirements prioritized list

High priority requirements' list			Middle priority requirements' list			Low priority requirements' list		
R	ID	RPV	R	ID	RPV	R	ID	RPV
1)	a.3	170.59	18)	g.4	32.73	32)	b.6	8.1
2)	a.1	152.07	19)	b.1	27.48	33)	h.4	8.07
3)	c.5	148.15	20)	b.3	26.73	34)	f.1	7.24
4)	c.1	142.41	21)	g.1	15	35)	j.5	3.64
5)	c.3	142.29	22)	e.2	13.81	36)	j.1	3.6
6)	a.2	141.66	23)	e.1	13.52	37)	j.3	3.55
7)	c.2	141.61	24)	b.7	13.43	38)	f.6	3.2
8)	d.1	140.43	25)	g.5	11.92	39)	e.3	2.72
9)	c.4	138.51	26)	f.4	11.82	40)	j.2	2.5
10)	d.2	137.26	27)	h.2	11.2	41)	j.7	2.35
11)	d.6	137.21	28)	b.5	10.22	42)	j.9	1.16
12)	d.5	136.66	29)	f.2	10.12	43)	j.8	1.16
13)	d.4	134.65	30)	f.5	9.54	44)	j.4	1.16
14)	g.3	111.8	31)	j.6	9.41	45)	j.13	1.16
15)	g.2	107.35				46)	j.12	1.16
16)	b.4	98.56				47)	j.11	1.16
17)	b.2	75.92				48)	j.10	1.16
						49)	i.1	0.58

Figure D.2 SRPTackle Sample of Experimentation Result of Full Prioritised List of Requirements.

Table D.2 Existing Techniques' Comparative Analysis

No	Technique	Study id	Reference	Scalable	SQP	Reduced the need of the expert	Size of Requirement set	Number of Requirements	Time consumption	Type of Technology/ tool used in conducting experiment
1	AHP	AHP- SA1	(Karlsson & Ryan 1996)	No	No	No	Small,	11	35 minutes	No tools
		AHP- SA2	(Karlsson1 et al. 2004)				Small	8, 16,	14.2 minutes, 26.7 minutes,	No tools
		AHP- SA3	(Ahl 2005)				Small	13.	10.5 minutes.	Computer automation tool
		AHP- SA4	(Khari & Kumar 2013)				Medium	30	43 minutes	No tools
2	Pairwise comparison (PC)	PC-SP1	(Karlsson 1996),	No	No	No	Small,	14	38 minutes	No tools
		PC-SP2	(Karlsson et al. 2007)				Small	8, 16,	14.2 minutes, 26.7 minutes,	No tools
3	Tool support Pairwise comparison (TSPC)	TSPC -ST1	(Karlsson et al. 2007)	No	No	No	Small	16	9.4 minutes	Computer automation tools
4	Numeral Assignment (NA)	NA-SN1	(Karlsson 1996)	No	No	No	Small	14	83 minutes	No tools
		NA-SN2	(Khari & Kumar 2013)				Medium	30	50 minutes	No tools
5	Cumulative voting 0r 100 $ Test (CA)	CA-SC1	(Ahl 2005);	No	No	No	Small;	13	3.5 minutes	Computer automation tool
		CA –SC2	,(Khari & Kumar 2013)				Medium	30	30 minutes	No tools

Table D.2 (continued)

No	Technique	Study id	Reference	Scalable	SQP	Reduced the need of the expert	Size of Requirement set	Number of Requirements	Time consumption	Type of Technology/ tool used
6	Planning Game (PG)	PG -SG1	(Ahl 2005) ,	No	No	No	Small	13;	1.75 minutes	Computer automation tools
		PG -SG2	(Karlsson et al. 2007),				Small	8, 16	8.1 minutes, 12.0 minutes	No tools
		PG -SG3	(Khari & Kumar 2013)				Medium	30	25 minutes	No tools
7	Value Oriented Prioritisation (VOP)	VOP-SV1	(Khari & Kumar 2013)	No	No	No	Medium	30	20 min	Fuzzy logic tool
8	PG with AHP (PGcAHP)	PGcAHP-SPA1	(Ahl 2005)	No	No	No	Small	13	5.5 min	Computer automation tool
9	PHandler	PHandler - SH1	(Babar et al. 2015c)	Yes	Yes	No	Large	100, 200, 300, 500	NR	Manual - Neural Networks tool
10	StakeRare	StakeRare - SS1	(Lim & Finkelstein 2012)	Yes	Yes	No	Medium , Large	43, 80	NR	Manual
11	Evolve	Evolve - SE1	(Shao et al. 2017)	No	Yes	No	Medium	35	6.12 minutes	Semi-automated
12	Case Base Rank(CBRank)	CBRank - SR1	(Perini et al. 2013)	Yes	No	No	Medium, large	25, 50, 100	NR	Semi-automated
		CBRank - SR2	(Shao et al. 2017)				Medium, large); medium	35	9.58 minutes	

Table D.2 (continued)

No	Technique	Study id	Reference	Scalable	SQP	Reduced the need of the expert	Size of Requirement set	Number of Requirements	Time consumption	Type of Technology/ tool used
13	DRank	DRank - SD1	(Shao et al. 2017)	No			Medium	35	7.22 minutes	Semi-automated
14	Interactive GA-Based Prioritisation (IGABP)	IGABP - SI1	(Tonella et al. 2013b)	No		No	Medium	26, 23, 21, 49	NR	Genetic algorithm tool
15	Optimal Solutions Analysis(OSA)	OSA-SO1	(Veerappa 2012)	Yes	No	No	Medium, Large	49, 73	25.89 minutes, 40.64 minutes	Semi-automated
16	Lim et al.GA ,	Lim et al.GA ,	(Lim et al. 2012)	Yes	No	No	Medium, Large	49, 73	10 seconds, 10 seconds	Semi-automated
17	Saffron	Asif et al. Saffron	(Asif et al. 2017)	Yes	Yes	No	Medium, Large	50, 65	NR	Semi-automated
18	SRPTackle	-	-	Yes	Yes	Yes	Medium, Large	49, 50, 65, 70, 73, 80 122	5.02, 5.02, 5.41, 5.46, 5.48, 5.52, 5.99 seconds	Semi-automated

NR : Not Reported

APPENDIX E
ACHIEVEMENTS

E.1 Publications: 14 published papers (9 ISI (3 Q1 and 1 ISI Q3) and 5 Scopus)

Selected Publications:

Hujainah, F., Bakar, R.B.A. & Abdulgabber, M.A. 2019. StakeQP: A semi-automated stakeholder quantification and prioritisation technique for requirement selection in software system projects. *Decision Support Systems* 121: 94–108. **(ISI Q1, Journal Impact Factor: 3.847). Status: Published**.

Hujainah, F., Bakar, R.B.A., Abdulgabber, M.A. & Zamli, K.Z. 2018b. Software requirements prioritisation: A systematic literature review on significance, stakeholders, techniques and challenges. *IEEE Access* 6: 71497–71523. (**ISI Q1, Journal Impact Factor: 4.098). Status: published.**

Hujainah, F., Abu Bakar, R.B., Al-haimi, B. & Abdulgabber, M.A. 2018a. Stakeholder quantification and prioritisation research: A systematic literature review. *Information and Software Technology* 102: 85–99. **(ISI Q1, Journal Impact Factor = 2.921) Status: Published.**

Hujainah, F., Bakar, R.B.A. & Abdulgabber, M.A. 2019. Investigation of requirements interdependencies in existing techniques of requirements prioritization. *Tehnicki vjesnik* 26(4): 1186–1190. **(ISI Q3, Journal Impact Factor = 0.644) Status: Published.**

Hujainah, F., Bakar, R.B.A., Al-Haimi, B. & Abdulgabber, M.A. 2018c. Investigation of Stakeholder Analysis in Requirement Prioritization Techniques. *Advanced Science Letters* 24(10): 7227–7231. **(ISI Web of Science) Status: Published.**

Hujainah, F., Abu Bakar, R.B., Al-Haimi, B. & Nasser, A.B. 2016. Analyzing requirement prioritization techniques based on the used aspects. *Research Journal of Applied Sciences* 11(6): 327–332. **(Scopus Q4) Status: Published.**

Hujainah, F. & Abu Bakar, R.B. SRPTackle: A Semi-automated Requirements Prioritization Technique for Scalable Requirements of Software System Projects. *Advances in Engineering Software* **(ISI Q1, Impact Factor = 4.194) Status: Under review.**

E.2 ISI Q1 Papers

i. First ISI Q1 Paper:

Decision Support Systems 121 (2019) 94–108

Contents lists available at ScienceDirect

Decision Support Systems

journal homepage: www.elsevier.com/locate/dss

StakeQP: A semi-automated stakeholder quantification and prioritisation technique for requirement selection in software system projects

Fadhl Hujainah[a,*], Rohani Binti Abu Bakar[b], Mansoor Abdullateef Abdulgabber[c]

[a] Software Engineering Research Group, Faculty of Computer Systems and Software Engineering, Universiti Malaysia Pahang, Kuantan 26300, Malaysia
[b] Soft Computing and Intelligent System Research Group, Faculty of Computer Systems and Software Engineering, Universiti Malaysia Pahang, Kuantan 26300, Malaysia
[c] Faculty of Computer and Cyber Science, Software Engineering, University Prince Mugrin, Al-Madinah 41499, Saudi Arabia

ARTICLE INFO

Keywords:
Stakeholder analysis
Stakeholder prioritisation
Stakeholder quantification
Multi-attribute decision-making
TOPSIS
Software system project

ABSTRACT

Stakeholder quantification and prioritisation (SQP) is performed on the basis of the stakeholder's influence. The involvement of adequate stakeholders plays a crucial role in identifying and selecting the most essential requirements to produce a successful system. However, the current SQP techniques still face serious limitations, such as having insufficient low-level implementation details, being time-consuming, lacking an automation level, heavily relying on professional expertise and having no attribute measurement criteria (AMC) for stakeholder evaluation. These key issues serve as the motivation of the present study. Hence, this study is aimed at proposing a new semi-automated technique called StakeQP to address the reported key limitations. StakeQP introduces new low-level implementation details to perform SQP automatically on the basis of the newly proposed AMC using the multi-attribute decision-making method, namely, the technique of order preference similarity to the ideal solution (TOPSIS), to achieve an efficient StakeQP. The effectiveness of StakeQP is evaluated using a benchmark dataset of the actual software project. The findings show that StakeQP can produce more accurate results with less time consumption and is more effective in addressing the defined key limitations compared with other alternative techniques.

1. Introduction

Requirement engineering is a crucial phase in system development, which involves eliciting, documenting and maintaining system requirements [1–3]. This process is conducted on the basis of stakeholder preferences [1,4]. Hence, selecting appropriate key stakeholders is essential to identifying and capturing the complete requirements that are relevant to the system, resulting in a good-quality system [5–7]. As reported in [8,9], the system project success rates were 29%, 27%, 32%, 28% and 29% from 2011 to 2015. This outcome indicates that many projects failed to produce a successful system. The participation of stakeholders, who lack power, knowledge, interest and influence, resulting in a low-quality system, is a major cause of failure in many system projects [4,5,10–12].

System development projects are usually performed with limited time, cost, materials and staff. Consequently, it is difficult to implement and develop all stakeholder requirements with these limited resources [3,13]. Thus, identifying and prioritising requirements are essential to capturing the core requirements based on the stakeholders' preferences. Selecting the most essential and complete requirements can only be achieved with the involvement of appropriate and core stakeholders [4,5,14,15]. However, stakeholders have different influences on the success of system development projects [10,11,16]. These differences can be influenced by their knowledge, interest, power and role on the system projects [5,10,16,17]. Furthermore, the number of different types of participating stakeholders can be immense, with each one construing their requirements differently. This difference will create complications in deciding which stakeholders have more influence on the project than others [4,11,18]. Thus, the stakeholder quantification and prioritisation (SQP) process is conducted to identify the influence (priority) value of each stakeholder (SPV) and prioritises them on the basis of the identified influence values [6,11,18], where the stakeholders are quantified and prioritised on the basis of certain attributes, such as power, influence and role [5,6].

Additionally, detecting the stakeholders' influences and prioritising their importance accordingly can assist the project manager in providing a clear view about the expectations, roles and needs of the stakeholders who have a potential influence on a certain activity of the project development process, which assists managers in factoring in the planning project in order to win support from the most influential

* Corresponding author.
E-mail address: fadelhogina@gmail.com (F. Hujainah).

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ii. Second ISI Q1 Paper:

IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

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Digital Object Identifier 10.1109/ACCESS.2018.2881755

Software Requirements Prioritisation: A Systematic Literature Review on Significance, Stakeholders, Techniques and Challenges

FADHL HUJAINAH[1], ROHANI BINTI ABU BAKAR[1], MANSOOR ABDULLATEEF ABDULGABBER[2], AND KAMAL Z. ZAMLI[1], (Member, IEEE)
[1]Faculty of Computer Systems and Software Engineering, Universiti Malaysia Pahang, Kuantan 26300, Malaysia
[2]Faculty of Computer and Cyber Science, Software Engineering, University Prince Mugrin, Al-Madinah 41499, Saudi Arabia

Corresponding author: Fadhl Hujainah (fadelhogina@gmail.com)

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ABSTRACT As one of the gatekeepers of quality software systems, requirements' prioritization (RP) is often used to select the most important requirements as perceived by system stakeholders. To date, many RP techniques that adopt various approaches have been proposed in the literature. To identify the strengths, opportunities, and limitations of these existing approaches, this paper studied and analyzed the RP field in terms of its significance in the software development process based on the standard review guidelines by Kitchenham. By a rigorous study selection strategy, 122 relevant studies were selected to address the defined research questions. Findings indicated that RP plays a vital role in ensuring the development of a quality system with defined constraints. The stakeholders involved in RP were reported, and new categories of the participating stakeholders were proposed. Additionally, 108 RP techniques were identified and analyzed with respect to their benefits, prioritization criteria, size of requirements, types in terms of automation level, and their limitations; 84 prioritization criteria were disclosed with their frequency usages in prioritizing the requirements. The study revealed that the existing techniques suffer from serious limitations in terms of scalability, the lack of quantification, and the prioritization of the participating stakeholders, time consumption, requirement interdependences, and the need for highly professional human intervention. These findings are useful for researchers and practitioners in improving the current state of the art and state of practices.

INDEX TERMS Requirements prioritization, stakeholders, techniques, challenges, systematic literature review, requirements prioritization criteria.

I. INTRODUCTION

Requirement engineering (RE) is one of the most essential phases in software development. RE is mainly concerned with the process of eliciting, documenting and maintaining stakeholders' requirements [1], [2]. Often, meeting and securing stakeholders' core requirements is one of the main reasons for producing a good-quality software system [3]–[5].

One important aspect of RE is requirements prioritization (RP). As the name suggests, RP relates to the process of identifying the most essential requirements for the implementation of a successful system [5], [6]. RP is an iterative process [7] that involves critical and complex decision-making activities that facilitate the development of a high-quality system within defined constraints [5], [8]. Specifically, RP ensures the correct ordering of requirements' implementation as perceived by stakeholders [9]–[13] (i.e. by rearranging the requirements according to importance using various prioritization criteria, such as importance, cost, penalty and risk [6], [10], [14], [15]). Here, the stakeholders' involvements often lead to an accurate prioritization result.

iii. Third ISI Q1 Paper:

Information and Software Technology 102 (2018) 85–99

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Information and Software Technology

journal homepage: www.elsevier.com/locate/infsof

Stakeholder quantification and prioritisation research: A systematic literature review

Fadhl Hujainah[a,*], Rohani Binti Abu Bakar[a], Basheer Al-haimi[b], Mansoor Abdullateef Abdulgabber[a]

[a] Faculty of Computer Systems and Software Engineering, Universiti Malaysia Pahang, Kuantan, Pahang, Malaysia
[b] Faculty of Industrial Management, Universiti Malaysia Pahang, Kuantan, Pahang, Malaysia

ARTICLE INFO

Keywords:
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Stakeholders prioritisation
Systematic review

ABSTRACT

Context: Stakeholder quantification and prioritisation (SQP) is executed to quantify and prioritise stakeholders of the system based on their impacts. Selecting and involving the appropriate stakeholders are considered one of the major factors for producing a successful system.
Objective: The objectives of this paper is to provide precise investigation regarding the SQP domain with respect to its impact on prioritising requirements, identifying SQP attributes, critically investigating the existing techniques, and presenting the challenges and recommended future works.
Method: The systematic literature review (SLR) guidelines proposed by Kitchenham are adopted to guide the review process. The identified related studies underwent a rigorous study selection process. Thus, 31 out of 210 identified studies were selected as primary studies to address adequately the formulated research questions.
Results: Findings demonstrate that SQP is a crucial process in requirement prioritisation (RP) because of its ability to identify stakeholders' impact on the systems requirements that lead to the production of a correctly prioritised list of requirements. Seventeen SQP attributes are revealed along with their description, usage impact, and degree of importance. Furthermore, nine techniques that focus on quantification and prioritisation of the stakeholders are identified and critically analysed in terms of their description, SQP process involved, SQP attributes used, types, and limitations. The findings reveal that these techniques face some challenges with respect to the lack of low-level implementation details, lack of automation and intelligence level, and heavy reliance on the involvement of experts.
Conclusion: SQP has been extensively discussed in stakeholder analysis and requirement prioritisation domains. Based on the findings, a new intelligent solution is suggested to minimise the need for expert participation in conducting the SQP process along with proposing measurement criteria for the attributes used to evaluate the stakeholders. The deficiency of research works regarding the selection of SQP techniques is also observed.

1. Introduction

Software engineering (SE) is a domain that aims to produce good quality software by concentrating on the phases of developing a system [1,2]. The aim of the phases is to plan, analyse, design, develop, and test the developed system [1,3]; thus, SE is more than just the programming side of the system development lifecycle [4]. Each of these system development phases is associated with critical activities that should be accurately executed to unerringly accomplish the phase [5]. Requirements engineering is considered to be one of the critical principles in the phases of system development because it deals with the process of identifying, documenting, and maintaining requirements of the system [3,6]. The process of managing the requirements is performed based on the needs of the stakeholders [7–10].

The term 'stakeholder' is defined as any person or organisational group with interest in or ability to affect the system or its environment [11–15]. The stakeholders play a key role in producing an accurate requirements list that must be implemented; selecting and involving the appropriate stakeholders is considered one of the major processes for improving the quality of a system [16–20]. This will lead to increased opportunities in obtaining a successful system [16,19,21,22]. Many projects have failed to produce successful systems, and one of the reasons is the involvement of stakeholders in the project development who lack interest, lack knowledge, and have a low impact on the success of the project development [16,23–26]. According to reports in [23,27], Fig. 1 summarises the percentage of successful system development

* Corresponding author.
E-mail address: fadelhogina@gmail.com (F. Hujainah).

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E.2 List of Awards

i. Excellent Publication Award Recipient, FSKKP, 2018

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

Excellent Publication Award

Hereby certifies that

FADHL MOHAMMED OMAR HUJAINAH

As an excellent publication award recipient

In recognition on the outstanding numbers of published papers in 2018

on

28th December 2018

at

FSKKP Gala Dinner

Dean
FACULTY OF COMPUTER SYSTEMS & SOFTWARE ENGINEERING
UNIVERSITI MALAYSIA PAHANG

ii. Excellent Awards (Journal Publication), UMP, 2018:

iii. Outstanding Postgraduate Student Award (Q1 Success Story), FSKKP, 2019

FSKKP SUCCESS STORY

PROFILE

Name	:	***Fadhl Mohammed Omar Hujainah (PhD)***
Current Sem.	:	*Semester 8 /2019*
Status	:	*Submitted for VIVA VOCE*
Thesis Title	:	*A Semi-Automated Requirements Prioritisation Technique for Scalable Requirements with Stakeholder Quantification and Prioritisation*
Supervisor	:	*Assoc. Prof. Dr. Rohani Abu Bakar*
Co-Supervisor	:	*Dr. Mansoor Abdullateef Abdulgabber*
Publications	:	*14 research articles* *9 ISI (3 Q1) & 5 Scopus*

What motivates you in writing?

The writing process begins with passion and love. Writing is something that I love to do and is part of my lifestyle. Beside this personal motivation, the strongest motivation is the encouragement and full support from my supervisor and co-supervisor. Their wonderful guidance and insights drive me to write. Plus, they work hand in hand with me, and their words of motivations keep my passion for writing alive. Additionally, the passion and keen interest of the faculty, Dean and TDR in giving full support for securing quality of publication and providing a good research environment play a key role in motivating me to struggle and work hard to write and get published in well reputed journals.

How do you manage your time between research, writing and other commitments?

I always schedule my activities, tasks and works by creating a daily or weekly effective schedule, allowing for a contingency time for unexpected tasks. In my schedule, I set the high priority tasks first, including breaks, and consider a day or half day off every weekend as part of the schedule. I work hard to stick to the schedule created and fiercely protect my time from any distractions to keep me on track to accomplish the defined goals. Establishing a good balance between research, writing and personal life requires a lot of effort, but it can be achieved by being committed to an effective schedule.

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iv. **Gold Medal** at International Competition and Exhibition of Creation, Innovation, Technology and Research Exposition (CITREX 2019), Pahang, Malaysia – February 2019:


Universiti Malaysia PAHANG

CITREX | CREATION, INNOVATION, TECHNOLOGY & RESEARCH EXPOSITION (CITREX)

Certificate of Award

GOLD MEDAL

This Certificate of Award is presented to

Associate Professor Dr.Rohani Binti Abu Bakar,Dr. Zalili Binti Musa,Azma Binti Abdullah,Fadhl Mohammed Omar Hujainah

For the invention entitled

StakeQP: Automated Tool for Stakeholders Quantification and Prioritization in Software Systems Development

CREATION, INNOVATION, TECHNOLOGY & RESEARCH EXPOSITION 2019

12th – 13th February 2019, Universiti Malaysia Pahang

PROFESSOR TS DR. KAMAL ZUHAIRI ZAMLI

DEPUTY VICE CHANCELLOR (RESEARCH & INNOVATION)

UNIVERSITI MALAYSIA PAHANG

v. **Silver Medal** at 30th International Invention, Innovation & Technology Exhibition (ITEX'19), Malaysia, Malaysia – May 2019:


ITEX
INTERNATIONAL INVENTION, INNOVATION & TECHNOLOGY EXHIBITION, MALAYSIA

Certificate of Award

This is to certify that

PM DR. ROHANI, FADHL MOHAMED OMAR HUJAINAH,
DR. ZALILI BINTI MUSA, PUAN AZMA BINTI ABDULLAH
UNIVERSITI MALAYSIA PAHANG

MALAYSIA

has been awarded the

ITEX 2019 SILVER MEDAL

for the invention

AN AUTOMATED TOOL FOR STAKEHOLDER QUANTIFICATION AND PRIORITIZATION FOR SOFTWARE SYSTEM PROJECTS

at the

30TH INTERNATIONAL INVENTION, INNOVATION & TECHNOLOGY EXHIBITION 2019

KUALA LUMPUR, MALAYSIA
2 – 4 MAY 2019

MALAYSIAN INVENTION AND DESIGN SOCIETY
MINDS

Academician Emeritus Professor
Tan Sri Datuk Dr Augustine Ong Soon Hock
President
Malaysian Invention and Design Society

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MINISTRY OF ENERGY, SCIENCE, TECHNOLOGY, ENVIRONMENT & CLIMATE CHANGE MALAYSIA
MINISTRY OF EDUCATION MALAYSIA
IFIA INTERNATIONAL FEDERATION OF INVENTORS' ASSOCIATIONS
MyIPO

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MATRADE
Malaysia External Trade Development Corporation

UMP

vi. First Place Winner of 3 Minutes Competition, FSKKP, 2017:

Universiti Malaysia PAHANG

Engineering • Technology • Creativity

This is to certify that

FADHL MOHAMMED OMAR HUJAINAH

PCS15001

was

Selected as FIRST prize winner for

UMP 3 MINUTES THESIS COMPETITION 2017

March 08, 2017

FACULTY OF COMPUTER SYSTEMS & SOFTWARE ENGINEERING

ASSOCCIATE PROFESSOR DR. MAZLINA ABDUL MAJID

Deputy Dean (Research & Graduate Studies)