A HYBRID MULTI-CRITERIA DECISION MAKING METHOD FOR RISK ASSESSMENT OF PUBLIC-PRIVATE PARTNERSHIP PROJECTS

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"To Shokoh"

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ABSTRACT

As governments embark on Public Private Partnership (PPP) projects to develop their infrastructure, effective risk assessment has become an important step to ensure success of these projects. However, there are many unsuccessful stories of PPP projects that have been reported all around the world. Thus, it is essential for both public and private sectors to apply efficient risk assessment approaches to allocate and manage risks more effectively. Literature review revealed a continuous endeavor for better PPP project risk modelling and assessment. Various techniques have been developed for use in the management of risks in construction. However, these techniques are limited to addressing risks relating to only cost, schedule, or technical performance individually or at best a combination of cost and schedule risks. Previous work so far is lacking a comprehensive model capable of handling impact of risks on all project objectives simultaneously; namely cost, time and quality. Thus, the main objective of this study is to develop a hybrid risk assessment method that capable of capturing impact of risks on the three project objectives comprehensively. To achieve this aim, this research explores the risk assessment approaches and proposes a hybrid alternative method based on the Fuzzy Analytic Network Process (FANP) and Multiple Objective Particle Swarm Optimization (MOPSO). The Fuzzy logic was used to convert linguistic principles into systematic quantitative-based analysis. Also, in order to consider the dependency and feedback between risks and criteria, ANP method is applied as a Multi-Criteria Decision Making (MCDM) method. Then, MOPSO, as a MCDM method, was used to assess the risks based on the project objectives. Objective functions have been developed to minimize the total time and cost of the project and maximize the quality. The research approach was a mixed-method approach and the field work included a series of questionnaires and interviews. It started with semi-structured interviews with PPP professionals. A mail survey was administered and more than 114 questionnaires were sent to construction and PPP professionals based in Malaysia. Out of 114, 88 valid responses have been received. An on-line survey was carried out as well in order to enrich the findings of the mail survey. The proposed hybrid approach was used to assess the collected data. A total of 30 significant risks were identified and evaluated. According to the results, it was found that "construction completion", "construction cost overrun" and "interest rate volatility" are the highest ranks associated with the Malaysian PPP projects risks. Finally, the viability of the proposed hybrid approach was investigated through conducting semi-structured interviews with PPP professionals from construction and administration sector. It is concluded that the proposed hybrid MCDM method for risk assessment is a viable alternative to the existing practice. This may help bridging the gap between theory and practice of risk assessment in construction projects. It also can be applied through the public and private sectors to improve risk assessment and management. The research findings recommend further exploration of the potential applications of hybrid MCDM methods in construction management domain.

ABSTRAK

Ketika kerajaan melaksanakan projek Perkongsian Awam-Swasta (PPP) untuk pembangunan infrastruktur, penilaian risiko yang efektif telah menjadi satu langkah penting bagi menjamin kejayaan projek-projek ini. Walau bagaimanapun, terdapat laporan di serata dunia mengenai projek PPP yang tidak berjaya. Oleh itu, adalah penting bagi kedua-dua sektor awam dan swasta untuk mengaplikasikan pendekatan penilaian risiko untuk mengagihkan dan menguruskan risiko dengan lebih berkesan. Kajian semula literatur mendedahkan satu usaha berterusan untuk memperbaiki pemodelan risiko dan penilaian projek PPP. Pelbagai teknik telah dibangunkan untuk kegunaan dalam pengurusan risiko untuk industri pembinaan. Walau bagaimanapun, teknik ini adalah terhad kepada menangani risiko yang berkaitan dengan kos, jadual, atau prestasi teknikal secara individu atau pada tahap terbaik hanyalah gabungan kos dan penjadualan risiko sahaja. Kajian sebelum ini menunjukkan kekurangan model yang menyeluruh yang mempertimbangkan pelbagai jenis kesan risiko kepada objektif projek yang berbeza secara serentak iaitu kos, masa dan kualiti. Objektif kajian ini adalah untuk membangunkan satu model hibrid penilaian risiko yang mampu menagani impak risiko pada semua objektif kejayaan projek. Bagi mencapai tujuan ini, kajian ini menerokai pendekatan penilaian risiko dan mencadangkan kaedah alternatif hibrid yang berasaskan Fuzzy Analytic Network Process (FANP) dan Multiple Objective Particle Swarm Optimization (MOPSO). Logik Fuzzy telah digunakan untuk menukar prinsip linguistik dalam analisis berdasarkan kuantitatif-sistematik. Malahan, untuk mempertimbangkan pergantungan dan maklumbalas antara risiko dan kriteria, kaedah ANP telah digunakan sebagai kaedah Multi-Criteria Decision Making (MCDM). Untuk langkah seterusnya, MOPSO, sebagai kaedah MCDM, telah digunakan untuk menilai risiko berdasarkan objektif projek iaitu masa, kos dan kualiti. Fungsi objektif telah dibangunkan untuk mengurangkan jumlah masa dan kos projek dan memaksimumkan kualiti. Pendekatan kajian yang digunakan adalah pendekatan kaedah-bercampur dan kerja lapangan terdiri dari siri soal selidik dan temu bual. Ia bermula dengan wawancara separa berstruktur dengan profesional PPP. Tinjauan mel dijalankan dan lebih daripada 114 soal selidik telah dihantar kepada profesional yang terlibat dalam industri pembinaan PPP yang berpangkalan di Malaysia. Dari 114 soal selidik, sebanyak 88 jawapan telah berjaya diterima. Dalam usaha untuk memperkayakan hasil kajian melalui sistem mel, kaji selidik dalam talian juga turut dijalankan. Pendekatan hibrid yang dicadangkan telah digunakan untuk menilai data yang dikumpul. Sebanyak 30 risiko yang penting telah dikenalpasti dan dinilai. Daripada keputusan, didapati bahawa "penyelesaian pembinaan", "kos pembinaan berlebihan" dan "turun-naik kadar faedah" adalah faktor dengan kedudukan yang paling tinggi yang dikaitkan dengan risiko projek-projek PPP di Malaysia. Akhir sekali, kesahihan model penilaian hibrid yang dicadangkan telah dinilai dengan mengadakan temubual berstruktur separa dengan anggota profesional PPP dari sektor pembinaan dan pentadbiran. Dirumuskan bahawa metodologi penilaian risiko hibrid MCDM yang dicadangkan boleh menjadi alternatif kepada amalan sedia ada. Ini boleh membantu merapatkan jurang antara teori dan amalan penilaian risiko dalam projek-projek pembinaan. Ia juga boleh dilaksanakan di sektor awam dan swasta untuk meningkatkan keberkesanan penilaian dan pengurusan risiko. Dapatan kajian mengesyorkan penerokaan lanjut keatas potensi aplikasi kaedah hibrid MCDM di dalam lapangan pengurusan pembinaan.

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AIRMIC	-	Association of Insurance and Risk Managers
AHP	-	Analytic Hierarchy Process
ANN	-	Artificial Neural Networks
ANP	-	Analytic Network Process
APM	-	Association for Project Management
BBN	-	Bayesian Belief Networks
BOO	-	Bootstrap
BSI	-	British Standards Institute
CBR	-	Case-Based Reasoning
DSS	-	Decision Support System
ERM	-	Enterprise Risk Management
FANP	-	Fuzzy Analytic Network Process
FMEA	-	Failure Modes and Effects Analysis
FTA	-	Fault Tree Analysis
FMADR	-	Fuzzy Multiple Attributes Direct Rating
FST	-	Fuzzy Set Theory
GA	-	Genetic Algorithm
GTOPSIS	-	Group Technique for Order Preference by Similarity to Ideal Solution
HRBS	-	Hierarchical Risk Breakdown Structure
ID	-	Influence Diagramming

IRM	-	Institute of Risk Management
LR	-	Literature review
MADM	-	Multi Attribute Decision Making
MCDM	-	Multi-Criteria Decision Making
MCS	-	Monte-Carlo Simulation
MODM	-	Multi Objective Decision Making
MOPSO	-	Multiple Objective Particle Swarm Optimization
MCDM	-	Multi-Criteria Decision Making
OGC	-	Office of Government Commerce
PERT	-	Program Evaluation and Review Techniques
PFI	-	Private Finance Initiative
P-I	-	Probability-Impact risk model
PPP	-	Public-Private Partnership
PPPs	-	Public-Private Partnership Projects
PSO	-	Particle Swarm Optimization
PT	-	Probability Theory
PMI	-	Project Management Institute
QU	-	Questionnaire
RAM	-	Risk Assessment Matrix
RM	-	Risk Management
SS	-	Sensitivity Analysis
SP	-	Stochastic Programming
SD	-	System Dynamics
SWOT	-	Strengths-Weaknesses-Opportunities-Threats Analysis
UT	-	Utility Theory
WBS	-	Work Breakdown Structure

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CHAPTER 1

INTRODUCTION

1.1   Introduction

Inadequate infrastructure is a constraint on growth worldwide, and particularly in developing countries. World demand of infrastructure is expected to rise and public owners are increasingly challenged by stakeholders to optimize the use of available funds to maximize the delivery of infrastructures (Koppinen and Lahdenperä, 2004). Infrastructure services are often inadequate to meet demand, resulting in congestion or service rationing. To cover this issue, one approach is the application of alternative delivery methods, like public-private partnership (PPP) that aids funding and increases synergy between public and private entities based on trust, allowing more capital availability for the development of infrastructure.

PPP is "a contractual agreement between a private and public sector" whereby the financial resources and the skills of each part are shared to satisfy the public requirement for public products or services or products (Ke *et al*., 2010a) and suitable allocation of risks, resources, and rewards (Chou *et al*., 2015). In Malaysia, Public-Private Partnership Unit (3PU) has been established to manage the said budgetary challenges. The concept of PPP is that the investment, risk, responsibility, and reward are shared between the public and private sector (Ismail and Rashid, 2007).

In this regard, Malaysia is identified as a leader in the Association of Southeast Asian Nations in drawing up mechanisms to encourage public–private

partnerships (PPPs) to attract finance infrastructure development (Valipour *et al*., 2014). In the last decade, Malaysia has experienced high economic growth. In the 10th Malaysian plan, government shall establish more PPP projects to promote the economic growth. Accordingly, the Malaysian government defined 52 new PPP projects worth RM63 billion for 2011–2015 (Valipour *et al*., 2014).

Despite the broad use and advantages of PPPs around the world, many PPP projects have failed to achieve the stated goal related to budget, deadlines, and quality (Thomas *et al*., 2003). The schedule delay and cost overrun in the PPP project were mainly caused by risks (Heravi and Hajihosseini, 2012; Ke *et al*., 2010b).

Like other projects, no PPP project is risk free. Even can be said, a long term period, heavy investments and the complexity of PPP projects generates enormous risks (Grimsey and Lewis, 2002; Zou *et al*., 2007). Most of the risks arise from these types of complexities in PPP projects (Heravi and Hajihosseini, 2012). For instances, political risk in two build operate transfer (BOT) projects in Thailand (Dey *et al*., 2002), delay risk in Euro Tunnel project (Ng and Loosemore, 2007), and the Sydney Railway project (Zhang, 2005a).

According to the World Bank, there are 381 unsuccessful PPP projects in the world. Malaysia's percentage of PPP project failures is the highest in East Asia with 22 failed projects. Types of risk are one of the reasons for unsuccessful PPP projects (Abednego and Ogunlana, 2006). Risk is associated with every project and each task and decision throughout the project life cycle (PLC) (BS-EN-62198, 2014). However, they are particularly evident in early stages of a project (Chapman and Ward, 1996).

Project risks are believed to be the key barriers against meeting project targets, such as cost, time, quality and scope, due to changes in a project they cause (Dey, 2001). Therefore, risk management is essential for construction projects especially projects that are based on PPP concept (Lam *et al*., 2007).

Risk management (RM) is an essential component of construction project management. It is a continuous process of risk identification, risk assessment, risk treatment and risk review and monitoring. Among these four major components, risk assessment is the most difficult one (Baloi and Price, 2003). However, it is frequently considered to be the most useful part of RM process (Smith *et al.*, 2009).

Construction risk analysis is a hot research topic; it has attracted so many researchers to contribute to it (Friedman, 1956; Gates, 1967; Spooner, 1974; Cooper *et al.*, 1985; Diekmann, 1992; Ward and Chapman, 2003; Dikmen *et al.*, 2007b; Mojtahedi *et al.*, 2010; Kuo and Lu, 2013; El-Sayegh and Mansour, 2015). This work is focused in researching this domain; where a genuine gap does exist in the literature of construction risk modelling and assessment.

Despite the criticism the Probability-Impact (P-I) risk model has received over years, it is still prevailing. In literature, a number of improvement proposals are present (Cooper *et al.*, 1985; Zhi, 1995; Tah and Carr, 2001; Hsueh *et al.*, 2007; Hashemi *et al.*, 2011; Taroun, 2014). Nonetheless, these attempts have provided limited improvements to modelling construction risk; they are not comprehensive enough to consider the characteristics of construction risk and its surrounding environment.

Risk analysis is mainly concerned with analyzing risk impact on project cost or project duration independently. It appears that analyzing risk impact on project quality is almost neglected (Taroun, 2014). Moreover, literature is lacking an assessment methodology that captures risk impact on the three project objectives; cost, duration and quality, simultaneously. Despite efforts to tackle this problem by many scholars (Franke, 1987; Willmer, 1991; Paek *et al.*, 1993; Williams, 1995; Dawood, 1998; Minato and Ashley, 1998; Mulholland and Christian, 1999; Stephen and Picken, 2000; Dey, 2001; Öztaş and Ökmen, 2005; Sanchez, 2005; Chan and Au, 2008; Kerzner, 2013), to the author's knowledge, no comprehensive risk assessment methodology with attention to the time, cost and quality has been developed yet. As a result, a special need rose to investigate this issue and trying to contribute to closing this gap by providing a usable method.

1.2   Statement of the Problem

Reviewing the studies of risk assessment, significant indicators show that it is important for public and private sectors to create a risk ranking method to assess significant risks. An accurate assessment of significant risks is important for participants as an input for risk response and allocation phase that ensure the success of risk management in PPP projects (Kumaraswamy and Zhang, 2008; Zavadskas *et al.*, 2010). However, the unavailability of comprehensive risk assessment method in PPP project makes the risk ranking practice infeasible. PPP projects are diverse and of complex relation and all risk factors are mutually independent and bear a complex and reciprocal influence on the other risk factors (Heravi and Hajihosseini, 2012; Ke *et al.*, 2010b). Lack of evaluation on communication and feedback between risks on project objectives is one of the reasons for weak risk assessment of PPP projects (Taroun, 2014). Each risk may be a source of other new risks, or increase the severity of other risks on project objectives. It is necessary to consider interdependencies among various risk events. Thus, to comprehend the potential effect of these risks, the risk evaluation should handle the combined impact of risk events, and clearly handle the actual interdependencies between all risks.

Previous studies have implied that there are two approaches for risk assessment, which are qualitative and quantitative approaches (Khazaeni *et al.*, 2012). Review of previous studies on risk assessment indicated that there is a lack of accurate methodology and comprehensive model for assessment of risk. In recent years, some researchers tried to propose appropriate risk assessment for PPP projects (Tah and Carr, 2001; Baloi and Price, 2003; Grimsey and Lewis, 2004; Bing *et al.*, 2005; Chapman, 2006; El-Sayegh, 2008; Shen and Xiao, 2009; Zavadskas *et al.*, 2010; Zegordi *et al.*, 2012), but most of the related studies have the following limitations and problems:

1. Despite the importance of risk management in PPP projects, there are few researches into risk identification and categorizing focusing on PPP projects in Malaysia.

2. There is a lack of studies that considered feedback and dependencies among risk assessment criteria (Probability and Impact) and type of risks. While consideration of this factors is critical for obtaining realistic results.

3. There are few studies on accurate and comprehensive risk assessment model for PPP projects, capable of capturing risk impact on different project objectives (Time, Cost and Quality).

The literature also agrees that there are specific risk factors in developing countries that are assumed as minimum or nonexistent in developed nations and they require closer attention (Kalayjian 2000). Lack of sufficient and proper attention to these unique risks in PPP projects has caused that, compare with developed countries, have more of these projects be reported as unsuccessful in developing countries. The combination of these limitations and problems is stimulating the interest to study more effective ways to assessment of construction and PPP project risks in these regions.

1.3   Research Questions

These questions are the starting point of this academic endeavor. They were revised after accomplishing a critical and extensive literature review and discussions with experts. The final questions of this research project are:

1. What are the significant risk in Malaysian PPP projects?
2. How can be Identify and categorize the significant risk in Malaysia?
3. What other parameters can be included in the Probability-Impact (P-I) risk model in order to better model risk and generate a more realistic risk assessment?
4. What are the effective methods to consideration of new parameters in order to assessing the risk with attention to the new features?
5. What are the effective tools to develop of quantitative risk assessment method in PPP projects with attention to the projects objectives?

1.4   Research Aim and Objectives

The overall aim of this research is to propose a hybrid risk assessment method that may solve the problem of the available tools and Multi Criteria Decision Making (MCDM) methods. This requires comprehending the existing theories and tools used for these purposes and evaluating them for deploying more suitable theories and proposing new analysis methodologies. Consequently, this approach may help to successful implementation of PPP projects through more accurate assessment of significant risks, in order to efficient risk allocation between public and private partners. To achieving the research aim, by addressing mentioned research questions, there are three research objectives for this study:

1. To identify and categorize significant risk factors in PPP projects.
2. To determine the weight of each risk based on the dependence, and feedback between criteria and risks in PPP projects.
3. To propose a hybrid risk assessment approach with attention to the interaction between risks and project objectives such as: cost, time and quality in PPP Projects.

1.5   Research Scope

Although risk management is not only critical success factor for PPP projects, but this research focuses on risk management covering identification and assessment of risk in this projects. In addition, this research aims to propose a new risk assessment approach which can be used by both parties: public sectors and private parties. Hence, data will be collected from both partners of PPP projects include construction Engineers, PPP experts, Consultants, Risk and Project Management professionals.

Due to limitations in time and resources, the geographical scope of the study was limited to the Malaysia. Diversity of the States within Malaysia provided a rich source of data and information to this research. While, the major limitation of this

study is the fact that PPP is a relatively new and unexplored mode of public procurement in the Malaysia, because similar to the other developing countries, only particular companies within the country are able to implement these projects. Therefore, the sample size was also limited to a select few companies that possessed the experience and knowledge of PPPs and active in implementation of PPP projects in consultation with the UKAS. The proposed risk assessment approach can be used to analyze any project regardless of its size or type. However, the importance of these proposals and the usefulness of them cannot be truly appreciated unless they are used in analyzing complex and strategic projects. Moreover, the proposals can be used beyond the boundaries of the PPP projects. However, in this project the focus will be on PPP projects.

1.6   Significance of the Study

Having identified a genuine gap in literature, the researcher aims to provide an original contribution to filling it in. This research project investigates the limitations of the existing risk models and assessment methodologies in an attempt to provide viable alternatives. The contribution is developed through investigation of dependence, feedback and interaction between risk and criteria. From these premises, the research will propose a new risk assessment methodology that enables assessing risk impact on different project objectives. The proposed risk assessment methodology, simultaneously, generate a more realistic and comprehensive outcome.

The model and the mechanism produced by this research is an unprecedented contribution to the original body of information and to PPP projects and the construction industry. Such an outcome would enable decision makers to make more informative decisions such as contingency estimation, mark-up estimation, bid price, selecting optimum procurement route, evaluating different proposals or projects. Furthermore, the results would certainly help to impact public policy improvement towards PPP and the way in which various sectors can carry out PPP contracts with due respect to their risk perceptions. A model will be developed to aid the decision making process when assessing project risk.

It is expected that the outcomes of this research would provide vital alternatives to the available ones in literature. The researcher is quite hopeful that this research will bring an original contribution to the literature of construction risk analysis and decision making. It is also hoped that it may help advance the practice of risk analysis and project evaluation.

1.7   Research Overview

Research methodology is the means by which a researcher can answer research questions. It includes the tools and techniques for data collection and analysis and justifies the rationale for choosing specific options to do so. The research was started by reviewing relevant literature in order to narrow down the research topic, draw boundaries around an existing gap in construction and PPP risk assessment and modelling literature and decide on a set of research questions. The aforementioned questions clearly define the existing literature gap and largely govern the future research direction. The next step was developing an alternative risk assessment methodology. Having done that, the author adopted the following research methodology to conduct this research project (Figure 1.1):

a) A critical review of the published literature was conducted. The review covered the theories and techniques of risk management, risk analysis and decision making. Such a comprehensive and critical review help to comprehend and evaluate the existing models, tools and techniques used for analysing risk and evaluating construction projects. Furthermore, the review covered the actual practice and investigated the limitations and shortcomings of the existing techniques which might prevent people from using them extensively.

b) In order to enrich the findings of the literature review, a pilot study was conducted in an active construction company in PPP projects. A focused group meeting was arranged with four managers in the company to discuss their practice of risk analysis. The meeting was crucial to having valuable insights about the actual practice of risk assessment in the Malaysian construction industry and PPP projects in general. It was a useful step to

focus the research direction and to revisit the initial research questions. The outcomes of the previous activities is a developed risk assessment model for PPP projects. A more sophisticated risk assessment methodology was proposed with attention to the project objectives. Simultaneously, a pilot survey form was sent to ten experts in PPP construction projects in Malaysia. The initial findings of these interviews and questionnaire survey were used to develop three type of questionnaires.

c) The research approach is a mixed-method approach and the field work included a series of questionnaires and interviews. The field work started with semi-structured interviews with PPP professionals. A mail survey was administered and more than 114 questionnaires were sent to construction and PPP professionals based in the Malaysia, 88 valid responses and 26 invalid ones were received. In order to enrich the findings of the mail survey, an on-line survey was administered.

d) Fuzzy Analytic Network Process (FANP) and Multiple Optimization Particle swarm optimization (MOPSO) methods were used to assess the data collected. For data analysis, methods employed in this research are statistical analysis, Microsoft Excel®, SPSS®, Super Decision software and MATLAB®.

e) Based on the theory and the published literature, the proposed methodology, used for developing risk assessment in PPP projects, validated theoretically. However, they required a practical validation which was more challenging. Practical validation was carried out using workshop in institute for risk and uncertainty and interview with experts. With a set of validation criteria, the method was presented. The feasibility of the method and the usability of it in construction industry and PPP projects were examined.

f) Finally, research findings were analysed, theoretical and practical implications were researched, conclusions were drawn, research limitations were acknowledged and further research questions were raised. A detailed account of the research methodology and tools and the rationale behind using them is provided in chapter 3.
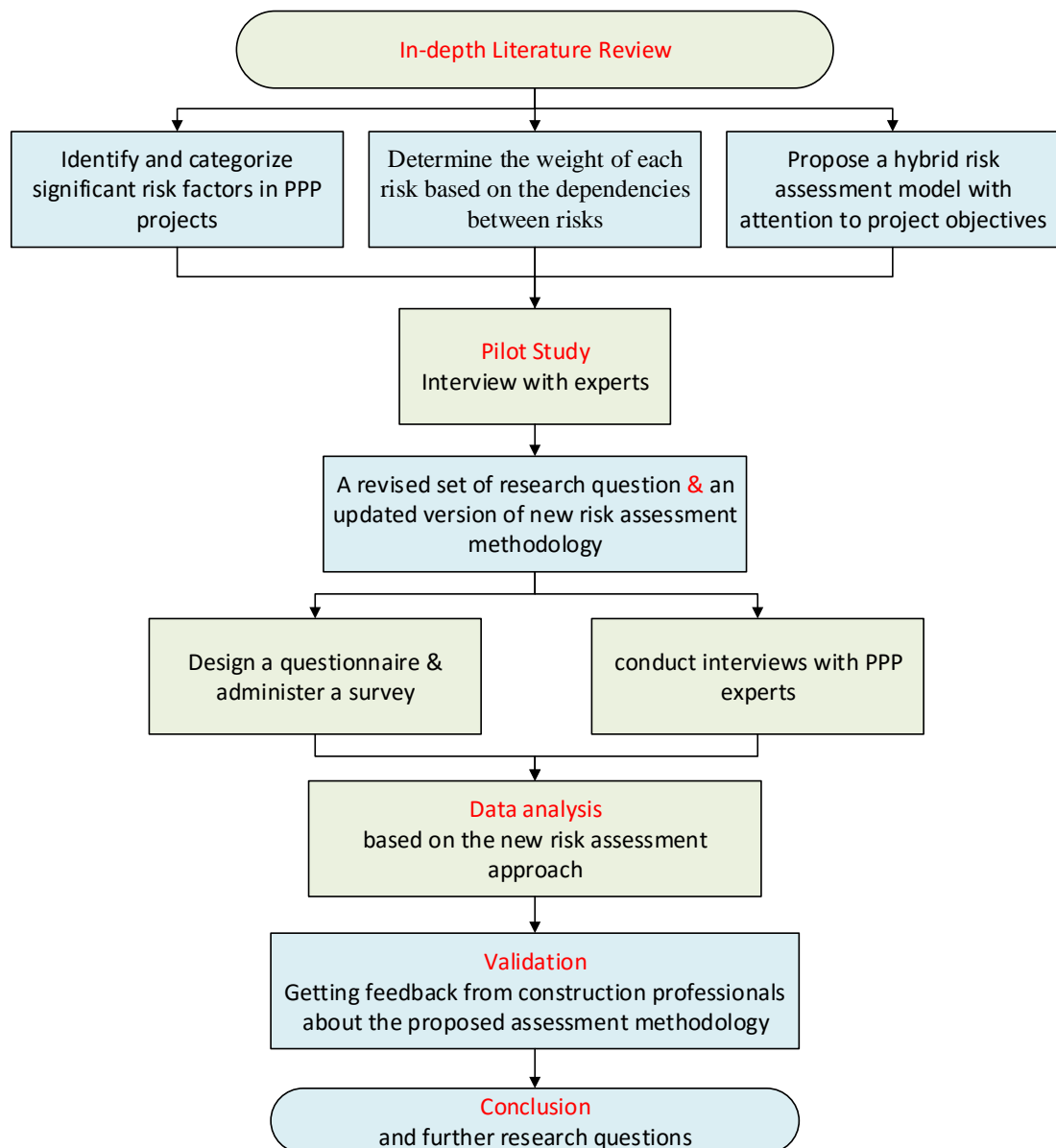
Figure 1.1 Research methodology overview

1.8   Thesis Structure

The structure of the thesis is presented in the following figure. In total, the thesis is composed of 6 chapters organized in four parts namely; introduction, literature review, field work and results and conclusions.
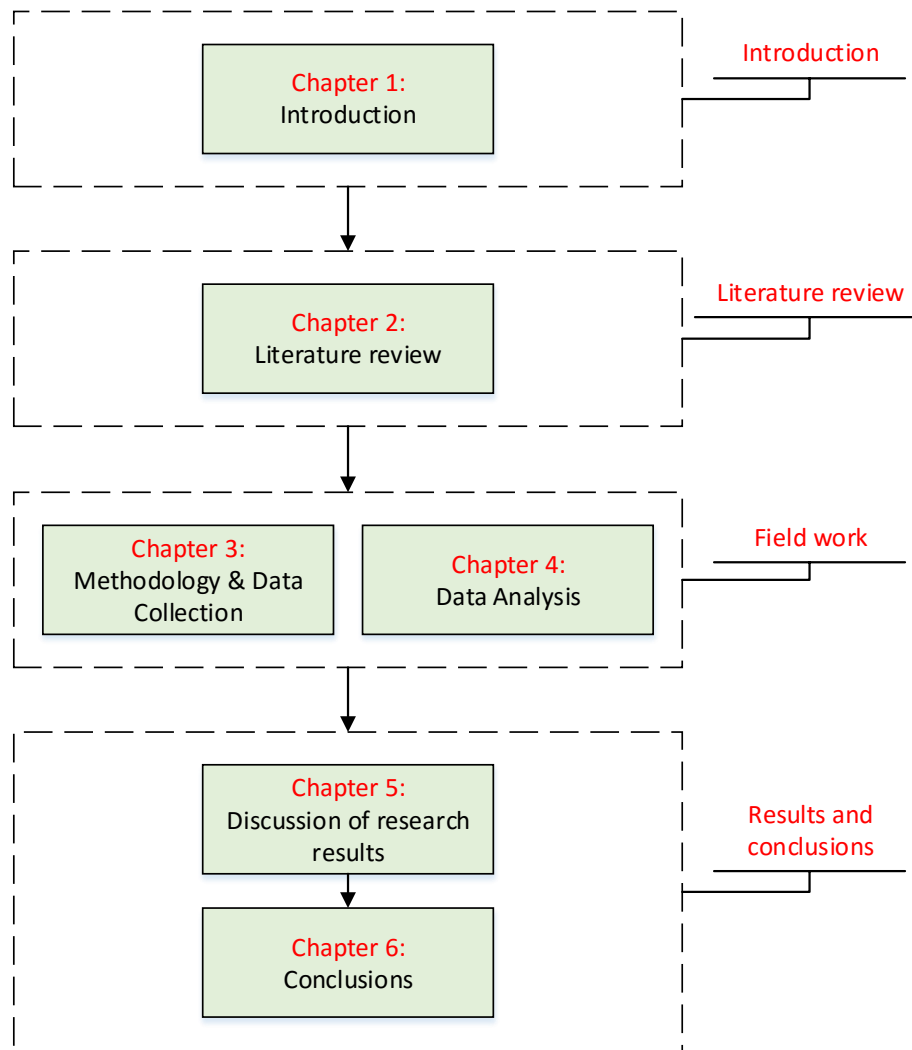
Figure 1.2 Thesis structure

The first part contains one chapter: Chapter one gives the introduction of the research study. It covers the research aim and objectives, scope and Research rationale. The research approach and the structure of the research report are also outlined. The second part is composed of one chapter which contains an extensive literature review covering the definition and implementation of PPP in developed and developing countries. Particular attention will be paid to the application of such procurement approaches in Malaysia. Chapter 2 also covers the literature of risk modelling and assessment. The review covers the models and assessment methodologies which have been devised and used over the last half a century. It ends with analyzing the findings of the review and revising research questions. This chapter is concerned with the limitations of the theories and tools used for aiding construction risk assessment.

Part three is formed of two chapters illustrating the field work and the obtained results from it. Chapter 3 discusses the proposed risk assessment model for construction and PPP projects and the theory behind the model. In addition, research methodology, philosophical orientation and research and data collection methods have been presented in this chapter. Chapter 4 presents a new risk model and a new risk assessment methodology in detail. This chapter also designated to present the collected data and analyze them. The analysis covers the data collected from the questionnaires and the interviews. It also presents the feedback of the participants in the validation cases and analyze them in an attempt to validate the new approach.

Part four is designated for discussing the obtained results and drawing conclusions. It is composed of two chapters. Chapter 5 discusses the research findings and investigates their validity and relationships to research questions and the literature. In addition, it critically evaluates the research process as a whole and examines the theoretical and practical implications of the research. Finally, chapter 6 summarises the whole thesis, presents the key findings and conclusions, highlights the research contribution, discusses the research limitations and outlines future research questions.

1.9   Summary

The objective of this chapter is to provide a critical, and constructive theoretical background on risks and PPP projects. The background of the study specifically presented an overview of the need for assessing the risk. In addition, this chapter is an introductory one that presents the research problem and outlines the research scope, objectives and questions. It also includes a brief presentation of the research methodology and demonstrates the structure of the thesis. Next chapter provides the reader with an introduction to risk and risk management, discusses the process of risk management, highlights its importance and discusses its practice.

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