# QUANTITATIVE RISK ALLOCATION APPROACH IN PUBLIC-PRIVATE PARTNERSHIP PROJECTS

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To my beloved family especially my wife

“Soudabeh Sabetian”

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# ABSTRACT

Risk allocation is an important factor in risk management to ensure successful achievement of the implementation of Public-Private Partnership projects (PPP). Several PPP projects have failed to meet budget, deadlines, and quality inspection. There are 327 unsuccessful PPP projects around the world and Malaysia is the second highest in East Asia with 22 failed projects. Inappropriate risk allocation has led to adversarial relationships between contracting participants and has consequently increased project cost, time and poor quality. Thus, it is very important for the public and private sector to choose a fair risk allocation in order to make strategic decisions. The aim of this study was to develop an optimal quantitative approach to enhance the equitable risk allocation in PPP projects. This study presents a Fuzzy Analytic Network Process model for equitable risk allocation which converts linguistic principles and solves the problem of independence and feedback between criteria and barriers using Analytic Network Process (ANP) method. Objective functions are then developed to minimize the total time, the cost of the project and maximize the quality while satisfying risk threshold constraints. The combinatorial nature of the risk allocation problem describes a multi-objective situation that can be simulated as a knapsack problem (KP). The formulation of the KP is described and solved by applying genetic algorithm. A total of 42 risks was identified and evaluated. The finding of this study shows "construction completion delay" was the most important risk with the highest rank. Finally, of 42 significant risks, 16 was allocated to the public sector, 11 were allocated to the private sector and 15 were shared between public and private sector as the best package of shared risks. The results of this investigation can be implemented by the government to enhance risk allocation process which may encourage the participation of the private sector through better risk allocation. As a conclusion, a new method has been developed regarding equitable quantitative risk allocation. It helps the project owners as well as contractors and subcontractors to better manage risk, cost and time savings and at the same time improve the overall quality of PPP projects.

# ABSTRAK

Peruntukan risiko adalah faktor penting dalam pengurusan risiko bagi memastikan pencapaian yang berjaya dalam pelaksanaan projek Perkongsian Awam-Swasta. Beberapa projek PPP telah gagal untuk mencapai belanjawan yang ditetapkan, had waktu penyiapan dan kualiti pemeriksaan. Terdapat sejumlah 327 projek PPP yang tidak berjaya di seluruh dunia dan Malaysia adalah yang kedua tertinggi di timur asia dengan jumlah 22 projek yang menemui kegagalan. Pengagihan risiko yang tidak berpatutan boleh menjuruskan kepada pertikaian dalam hubungan di antara pihak yang terlibat dan secara tidak langsung akan meningkatkan kos dan masa projek serta menurunkan kualiti projek berkenaan. Oleh yang demikian, adalah amat penting bagi sektor awam dan swasta untuk memilih corak pengagihan risiko yang sesuai dalam membuat keputusan yang strategik. Matlamat kajian ini adalah untuk membangunkan kaedah pendekatan kuantitatif yang optimum bagi menambahbaik pengagihan risiko secara saksama dalam projek PPP. Kajian ini menghasilkan model Proses Rangkaian Analitik Kabur untuk mengagihkan risiko dengan saksama di mana ia mengubah prinsip linguistik dan menyelesaikan masalah kebergantungan serta tindak balas di antara kriteria dan halangan menggunakan kaedah ANP. Kemudian, fungsi objektif dibangunkan bagi meminimumkan jumlah masa dan kos projek serta memaksimumkan kualiti bagi memenuhi kekangan penentuan titik permulaan risiko. Sifat kombinatorik daripada masalah pengagihan risiko menunjukkan situasi multi-objektif boleh disimulasikan sebagai masalah buntil (KP). Formulasi KP diterangkan dan diselesaikan dengan menggunakan kaedah algoritma genetik. Sebanyak 42 risiko telah dikenalpasti dan dinilai. Dapatan kajian ini menunjukkan bahawa "kelewatan penyiapan pembinaan" adalah risiko yang paling penting dan berada dalam peringkat tertinggi. Akhir sekali, dalam sejumlah 42 risiko yang berkaitan, 16 risiko telah diagihkan kepada sektor awam, 11 kepada sektor swasta manakala 15 lagi dikongsi bersama antara sektor awam dan swasta serta pakej perkongsian risiko terbaik dipilih. Hasil daripada kajian ini boleh digunapakai oleh pihak kerajaan bagi menambahbaik proses pengagihan risiko yang berpotensi dalam menggalakkan penyertaan sektor swasta melalui pengagihan risiko yang telah ditambah baik. Kesimpulannya, kaedah baru berkaitan pengagihan risiko secara kuantitatif yang saksama telah dibangunkan. Ini dapat membantu empunya projek serta kontraktor dan sub-kontraktor bagi menguruskan risiko dengan lebih baik, menjimatkan masa dan kos, serta pada masa yang sama meningkatkan kualiti keseluruhan bagi projek PPP.

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## LIST OF ABBREVIATION AND SYMBOLS

| | | |
|---|---|---|
| * | - | asterisk mark (significant value) |
| AHP | - | Analytic Hierarchy Process |
| ANP | - | Analytical Network Process |
| BAI | - | Balance Allocation Index |
| BBB | - | Battle–Belmuden–Brain writing |
| BLT | - | Build-Lease-Transfer |
| BOO | - | Build-Operate-Own regression |
| BOOT | - | Build-Operate-Own-Transfer |
| BOT | - | Build-Operate-Transfer |
| BROT | - | Build-Rehabilitate-Operate-Transfer |
| BTO | - | Build-Transfer-Order |
| CIDB | - | Construction Industry Development Board |
| CNB | - | Collective Note Book |
| CR | - | Consistency Ratio |
| DBFO | - | Design-Build-Finance-Operate |
| DOSH | - | Department of Occupational Safety and Health |
| ELECTER | - | Elimination and Choice Expressing Reality |
| EPU | - | Economic Planning Unit |
| EU | - | European Union guidelines |
| FAHP | - | Fuzzy Analytic Hierarchy Process |
| FANP | - | Fuzzy Analytic Network Process |
| FLINMAP | - | Fuzzy Linear Programming Technique for Multidimensional Analysis of Preference |
| FMADM | - | Fuzzy Multi Attribute Decision Making |
| FMEA | - | Failure-Mode and Effect Analysis |

| | | |
|---|---|---|
| FTOPSIS | - | Fuzzy Technique for Order of Preference by Similarity to Ideal Solution |
| GA | - | Genetic Algorithm |
| GMP | - | Guaranteed Maximum Price |
| GOM | - | Government of Malaysia |
| KLIA | - | Kuala- lumpur International Airport |
| KP | - | Knapsack Problem |
| MADM | - | Multi Attribute Decision Making |
| MATLAB | - | Matrix Laboratory |
| MCDA | - | Multi Criteria Decision Attribute |
| MCDM | - | Multi Criteria Decision Making |
| NGT | - | Nominal Group Technique |
| NP | - | Non-deterministic Polynomial |
| PFI | - | Private Finance Initiative |
| PMI | - | Project Management Institute |
| PPI | - | Private Participation in Infrastructure |
| PPP | - | Public Private Partnership |
| RBS | - | Risk Breakdown Structure |
| REHDA | - | Housing Developers Association Malaysia |
| SMART | - | Simple-Multi-Attribute Rating Technique |
| SPSS | - | Software Package used for Statistical Analysis |
| SPV | - | Special Purpose Vehicle |
| TCC | - | Contracts and Target Cost contract |
| TOPSIS | - | Technique for Order of Preference by Similarity to Ideal Soiution |
| U.K | - | United Kingdom |
| U.S | - | United State |
| UAE | - | United Arab Emirates |
| UKAS | - | Unit Kerjasama Awam Swasta |
| VFM | - | Value for Money |
| WBS | - | Work Breakdown Structure |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Overview

In recent years, governments the world over have seen a significant increase in cooperation between private and public sector as a way to finance the development and operation of infrastructure projects (Heravi and Hajihosseini, 2011). Public-Private Partnership (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 (Canadian Council for PPP, 2013). PPP is handled in such a way that the incentive, responsibility, investment, and risks are shared between the private and public sector (Ke *et al*., 2013). Introduction of Public-Private Partnership (PPP) procurement approach is seen as a solution to eliminate the possibilities of contributing more damages to the financial health of an economy as well as increasing the level of skills needed. Over the past several decades, governments have turned increasingly to PPP as a way of financing, maintaining infrastructure and providing public services in the face of budgetary challenges (CDT, 2006). 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 (Khairuddin, 2010). 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 (Leong, 2010). 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 2011–2020 (Leong, 2010).

Although PPPs have many benefits, the system have some drawbacks related to complexities in planning, arrangement in relation to documentation, the dynamic nature of documentation, capital budget and taxation, control, monitoring, performance, politics and policies (Grimsey and Lewis, 2002). Most of the risks arise from these types of complexities in PPP projects (Heravi and Hajihosseini, 2011). For instances, political risk in two build operate transfer (BOT) projects in Thailand (Dey *et al*., 2002), delay risk in Euro Tunnel project, Betuwe Railway in Netherlands (Ng and Loosemore, 2007), and the Sydney Railway project (Zhang, 2005).

Therefore, risk management is essential for construction projects especially projects that are based on PPP concept (Lam *et al*., 2007). Risk management process is a specific approach to project management (ISO, 2009). This process includes four main parts in PPP project including; risk identification, risk assessment, responding to reduce risk, and proper allocation of contingencies (Shen *et al*., 2006). Risk identification is the process of identifying the significant risks that could affect the project. Assessment of risk is the process of evaluating risks by assessing their probability of occurrence and their impacts on the project. Risk response is the whole process of creating a management technique including risk allocation and management plan for the risk (Lam *et al*., 2007). Based on Malaysia's PPP Guideline (2009), one of the essential features for risk management is optimal risk sharing, whereby risk is allocated to the party who is the best able to manage that risk. Accordingly, risk allocation is the most significant part in the risk management process for PPP projects. Risk management can guide project stakeholders to reduce the likelihood and consequences of adverse events and maximize the probability and consequences of positive events in project decision (Ng and Loosemore, 2007).

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). For example, the Betuwe Railway and the parker Schop Den Bosch in Netherlands (Ng and Loosemore, 2007), Railway project in Sydney (Zhang, 2005) Iranian toll road Chalus-Tehran, Kerman power plant in Iran (Heravi and Hajihosseini, 2011), the Horgos-Pozega Highway in Serbia and the Zagreb Wastewater Treatment Plant in Croatia (Boardman and Vining, 2012). The schedule delay and cost overrun in the PPP project were mainly caused by risks (Heravi and Hajihosseini, 2011). Project risk may be specified as an uncertain event or condition which, if it happens, has a positive or negative effect on the project purpose, such as cost, time, quality and scope (PMI, 2008). In reality, risks in PPP projects, or generally in construction projects, cannot be eliminated but they should be managed and shared between parties through agreement clauses (Andi, 2006). The contract could be the primary way for allocation of risk to the construction project between parties through clauses and contract conditions (Motiar Rahman and Kumaraswamy, 2005).

## 1.2 Background of Problem

Several PPP projects have failed to achieve budget, deadlines, and quality; most of these projects have been exposed to high risks (Thomas *et al*., 2003). According to the World Bank, there are 327 unsuccessful PPP projects in the world. It is observed that Latin America and East Asia Pacific see the highest failure rate in terms of number of projects canceled, at 135 and 86 projects respectively. Malaysia's percentage of PPP project failures is the second highest in East Asia with 22 failed projects. The number of PPP projects that have failed in Sub-Saharan Africa, South Asian, Europe and Central Asia were 50, 13 and 36 respectively (World Bank, 2013). Types of risk are one of the reasons for unsuccessful PPP projects (Abednego and Ogunlana, 2006).

Risks must be properly identified, understood and evaluated by all parties. A review of the implementation of PPP projects revealed that these projects involve risks due to the large investment, a long contractual concession period, and complicated technology (Heravi and Hajihosseini, 2011). Delmon (2000) stated that the impact of risks in completing a PPP project is significant because these risks can be described as uncertain events that have negative effect on project objectives. A proper risk management strategy is essential for controlling and reducing the risks. In this regard, risk allocation is a major component of PPP risk management. Additionally, balancing risk construction projects remains evasive as shown by a high divergence level among the participants who took part in the study of risk allocation (Wibowo and Mohamed, 2010).

In general, the purpose of the actual private sector is profitability while the aim of the public sector is efficiency in meeting public sector targets. These different aims have therefore resulted in disagreement in allocation preferences among public and private sector thus leading to an extended PPP contract settlement process or PPPs that are potentially problematic. The allocation of risks should be carried out optimally otherwise the actual value for money target will probably be threatened. It is a fact that proper risk allocation exercise between private and public sectors is a critical key in achieving value for money (VFM) in PPP projects. Imperfect risk allocation comprises one of the main causes of the failure of private sector participation (Marques and Berg, 2010) or for its success if it is carried out adequately (Murphy, 2008).

Improper risk allocation has negative impacts on the success of a PPP project in terms of time, cost, and quality (Ke *et al.*, 2013). A recent survey by the Construction Industry Institute (CII) concludes that inappropriate allocation of risk results in at least a 3%contingency in bids (CII, 2006). Another study by Zaghloul and Hartman (2003) reported that using disclaimer clauses to allocate risks adds a premium of between 8% and 20% to construction project bids, depending on whether business conditions were favorable, fair or high. Accordingly, unbalanced risk allocation may cause increased costs for both parties in the contract (Jin and Zhang, 2011). Improper allocation of risks is common in the construction industry leading to

adversarial interaction contract, disputes and claims (Kumaraswamy, 1997). In addition, the cost of inappropriate allocation of risk could be seen in the reaction from contractors; for instance adding a high contingency (premium) to the bid cost or the delivery of poor quality work (Khazaeni *et al*., 2012b; Lam *et al*., 2007).

Zaghloul and Hartman (2003) revealed that allocation of risk occurs in any situation where some participants are responsible for the delivery of the project. Risk allocation and risk detection are different between partners in projects. Nevertheless, risk allocation may significantly affect the behavior of the project participants and therefore, project cost and performance. Moreover, there is no agreement on an optimal risk allocation between participants in the construction industry. Thus, it is vital for the project stakeholders to evaluate and allocate risks properly through the whole project life cycle.

## 1.3 Research Problem

Reviewing the studies of risk assessment, significant indicators show that it is important for public and private sector 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. However, the unavailability of comprehensive risk assessment method in PPP project makes the risk ranking practice unfeasible. PPP project 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. Lack of evaluation on communication and feedback between risks on project objectives is one of the reasons for weak risk assessment of PPP projects. 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 allocation which are qualitative and quantitative approaches (Khazaeni *et al*., 2012a). Review of previous studies on risk allocation indicated there is a lack of quantitative and comprehensive models for selecting the optimal allocation of risk. In recent years, some researchers tried to propose appropriate risk allocation patterns for construction projects, but most of the related studies have the following limitations and problems:

i. There is a lack of risk allocation model in previous research based on risk allocation barriers and criteria.
ii. Lack of evaluation on independency and feedback between risk allocation criteria and barriers on project objectives is one of the reasons for weak risk allocation model of PPP projects. In the proposed models from previous researches, practical limitations of the allocation procedure (such as limited capability of the private sector in accepting the project risks) have not been considered.
iii. Moreover, the relationship of risk allocation with the project goals was not clearly identified. Project risk allocations to each factor may have consequences in the form of expense, time or range, such that it is impossible to make decisions without considering those factors. Therefore, choosing the appropriate risk allocation requires a multi-purpose decision making model that can choose the best percentage of shared risks.
iv. Finally little is known about risk assessment and risk allocation in Malaysian PPP projects.

## 1.4 Research Aim and Objectives

Based on the thorough review of the related issues and problems, the aim of this study is to provide key PPP project participants, specifically public and private sectors, with a realistic decision-making tool that will provide an alternative to the current practice of typically allocating risks by aversion. Consequently, this instrument may reduce dispute, cost overrun, tension and delays resulting in better

project implementation. This study attempts to develop a quantitative risk allocation approach through a professional perspective with the intention of exposing methods that will improve the efficient and effective optimal risk allocation of PPP project. The objectives are outlined as follows:

1. To identify and evaluate the significant risks in Malaysian PPP projects.

2. To identify and evaluate the barriers of risk allocation in Malaysian PPP projects.

3. To identify and evaluate risk allocation criteria in Malaysian PPP projects.

4. To develop shared risk allocation method with attention to dependency, feedback and interaction between risk allocation criteria and barriers in PPP projects.

5. To develop quantitative risk allocation approach to determine percentage of shared risks between public and private sector in Public Private Partnership projects.

## 1.5 Hypothesis

The problems are directly related to the current practice of risk assessment and risk allocation in PPP projects which negatively influence the performance of the construction project. These problems along with the adversarial relationship between project parties (lead by disputes, claims, tension, and litigation) caused by the current practice of risk assessment and risk allocation will be hypothesized. The first theory being tested in this study is that there is significant difference in the risk perceptions on the assessment of risk and risk allocation between private and public sector in PPP projects. The second theory being tested in this study is that there is no

significant difference in the risk perceptions on the assessment of risk and risk allocation between private and public sector in PPP projects.

## 1.6 Research Scope

Although there are many factors that may influence the success of PPP project, this research focuses on risk management covering identification, assessment and allocation of risk between public and private sector. Since it is impractical to carry out a universal survey, this study is focusing on Malaysia as a geographical area. Therefore, this research was limited to commercial construction firms and PPP project. Diversity of the States with in Malaysia provided a rich source of data and information to this research. This study was carried out by using questionnaire survey and interviews. Thus, to reduce errors and increase the accuracy of the model, qualitative judgments of experts has been converted into quantitative information using fuzzy logic and ANP approach. Although this study has the above mentioned limitations, the author strongly believes that this finding may be useful to the PPP projects in other areas of the world due to the similarities of PPP and construction practice and business environment.

## 1.7 Significance of the Study

It is vital for the private and public sectors to completely understand the various risks related to PPPs through the whole life cycle of infrastructure projects, the significance of risks and the best way to allocate them to ensure long-term achievement of partnerships. The identification, classification, evaluation, and investigation of problems of this particular current practice of allocation of risk and also the identification, classification, evaluation of criteria and barriers to optimal risk allocation in the PPP project can represent an authentic contribution to the body of knowledge and to the PPP projects. The contribution is developed through investigation of dependence, feedback and interaction between criteria and barriers to

optimal risk allocation associated with the current practice of risk allocation. 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. The findings of this study may help public and private sector (stakeholders) in preparing a highly effective useful risk allocation framework to be used in bidding and submitting documents, therefore savings time in arbitration and contract transaction. This study should help project stakeholders in terms of better risk management, time saving, reduced overall cost and enhancement of the general quality of PPP project. The model provides an innovative and helpful instrument to the PPP industry experts and providers through introducing a realistic mechanism regarding developing a better decision support model for optimal risk allocation. 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.

## 1.8 Brief Methodology of Study

The research was conducted through both qualitative and quantitative approaches. The research consisted of four main stages. The first stage focused on the identification of research objectives, design of research methodology and gaining background knowledge on the topic. This stage started with a comprehensive review of reported literature on risk management and PPP in Malaysia and overseas in order to capture the lessons learned from other countries and to identify the knowledge gap pertaining to the research problems. These activities had been accomplished through conducting a comprehensive literature review, such as journals, articles, books, internet sources, newspapers and holding informal discussions with experts and researchers. The second stage focused on the data collection. Literature review is really a research method in which the collections associated with resources are to be combined and significantly analysed to ensure that the obtained reviews complement the proposed research scope. The majority of the contents in the literature review are generally supported by several resources to compliment the validity statements. This stage was carried out through the collection of case study data, interviews with

experts in PPP projects and distributing the questionnaire survey to the public and private sector.

The third stage was the actual data interpretation and analysis phase. An initial research is performed to identify typical contents that are proper and appropriate to be involved into the questionnaire survey structure. In this stage, questionnaires that were successfully obtained from the chosen respondents were analysed. A series of questionnaire survey were also carried out to obtain the Fuzzy ANP Risk Assessment Model, shared risk allocation model and to determine the percentage of each shared risk for PPP projects in Malaysia which was developed using Analytic Network Process and Fuzzy method and Genetic Algorithm respectively. For data analysis, methods employed in this research are statistical analysis, Excel, SPSS, Super Decision software and MATLAB. The final stage offered the conclusions and recommendations. These were accomplished by deriving findings from the analysed data, derivation recommendations for the study scope and also advising recommendations for future study. Figure 1.1 shows the research methodology flow chart as used for this study.

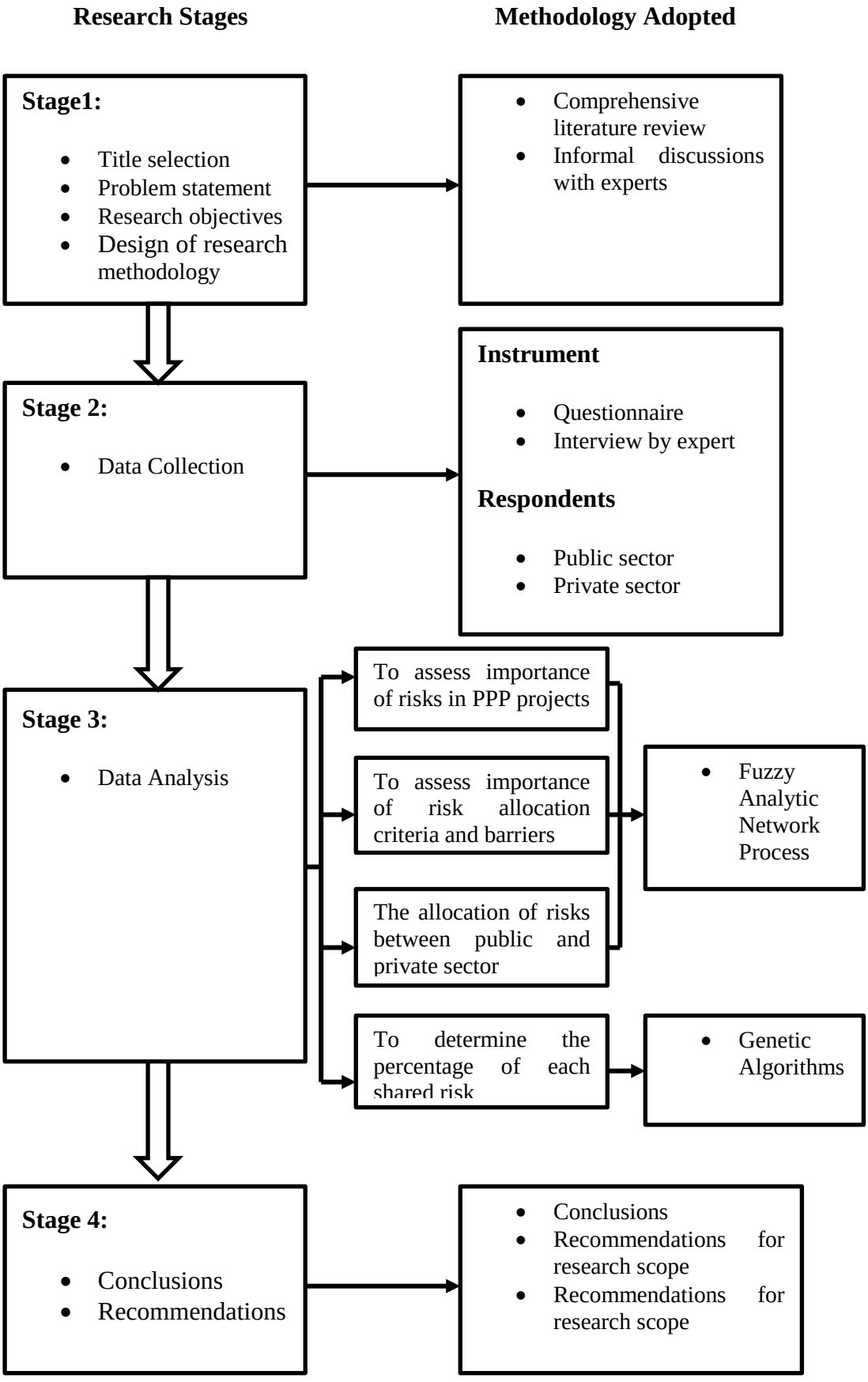


**Figure 1.1** Flow chart of Research Methodology

## 1.9 Structure of Thesis

This thesis is divided into seven chapters.The structure of this research report is as follows:

i. Chapter 1 gives the introduction of the research study. It covers the background, research aim and objectives, scope and significance of the research. The research approach and the structure of the research report are also outlined.

ii. Chapter 2 contains an extensive literature review covering the pertinent literature about the definition and implementation of PPP in developed and developing countries. It aims to inform the readers about the application of PPP in different parts of the world. Particular attention will be paid to the application of such procurement approaches in Malaysia. Essential published literature on risk management, particularly on risk assessment and risk allocation, is reviewed in this chapter.

iii. Chapter 3 illustrates the overall research methodology for the study. Different methods of data collection through a questionnaire survey as well as structured interviews will be explained in detail. The chapter explains the research design, process and data analysis techniques used.

iv. Chapter 4 presents the development of a Fuzzy ANP risk assessment model using Analytic Network Process and fuzzy synthetic evaluation method and identified significant risk allocation criteria and barriers using ANP method. The potential applications of the model are discussed. The validation of the model in the form of several structured face-to-face interviews with experts having direct hands-on experience with PPP projects in Malaysia is also documented in this chapter.

v. Chapter 5 presents the development of a shared risk allocation model using Analytic Network Process and fuzzy synthetic evaluation method and developed quantitative method to determine the percentage of shared risk using Knapsack problem and Genetic Algorithm. The potential applications of the model are discussed.

vi. Chapter 6 discuss the findings from chapter four and chapter five in line with the literature review (chapter two). This chapter will also confirm the presence of any links between the findings of this study and the literature.

vii. Chapter 7 includes the conclusions, discusses the contributions of the research, and identifies the limitations of the study. Core directions for future studies are also recommended in this chapter.

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