THE “WATER-SPECIFIC PPP RISK MODEL”

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ABSTRACT

Risk assessment is one of the key success factors of public-private partnerships (PPP) water projects. Factors such as utility condition problems, unsustainable increase in water supply requirements, socio-technical issues and changes in government policies can cause such capital-intensive projects to overrun planned budget and schedule allocations. Where the project is a commercial asset, delayed completion time and cost overruns usually have significant impact on the profitability of the project as well as the estimated returns on investment over the operational phase of the project. Understanding the specific risks involved in PPP water projects can be very crucial in designing containment measures to deal with their likely impact on the projects. Through the combination of review of literature and questionnaires, different risk elements in PPP water projects were first identified. The identified elements were then rated and prioritized using the Analytical Network Process (ANP) to demonstrate the complex interactions among those risks and to establish the most salient Value-for-Money (VFM) variables on PPP water projects. The outcome of this research is an innovative ANP-based model known as the "Water-Specific PPP Risk Model" that offers a platform to incorporate tangible and intangible risk variables into a risk assessment process in water infrastructure projects.

DEDICATION

To

My Father and Mother, so that you are proud

My Wife and Kids, with love

Myself, so that you know, you can always do it!

ACKNOWLEDGEMENTS

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HERIOT WATT UNIVERSITY

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Table of Contents

List of Tables

List of Figures

CHAPTER 1: INTRODUCTION

1.1 Outliers

(1)

Canadian hockey is a meritocracy. Thousands of Canadian boys begin to play the sport at the "novice" level, before they were even in kindergarten. From that point on, there are leagues for every age class, and at each of those levels, the players are sifted and sorted and evaluated, with the most talented separated and groomed for the next level. By the time players reach their mid-teens, the very best of the best have been channelled into an elite league known as Major Junior A, which is the top of the pyramid. And if your Major Junior team plays for the Memorial Cup, that means you are at the very top of the top of the pyramid.

In the mid-1980s, a Canadian psychologist named Roger Barnsley was watching a game in the Major A hockey league with his family when his wife made an observation that an incredible number of the players were born in January, February, and March. Barnsley was astonished when he went home that night and looked up the birth dates of as many professional hockey players as he could find as he saw the same pattern his wife noted. More players were born in January than in any other month, and by an overwhelming margin. The second most frequent birth month? February. The third? March. Barnsley looked at the composition of the National Hockey League. Same story. The more he looked, the more he came to believe that this is a fact for Canadian hockey.

The explanation for this is quite simple, it has nothing to do with astrology, nor is there something magical about the first three months of the year. It is simply that in Canada the eligibility cut-off for age-class hockey is January 1st. A boy who turns ten on January 2nd, then could be playing alongside someone who doesn't turn ten until the end of the year, and – at that age – a twelve month gap in age represents an enormous difference in physical maturity. When coaches are making the selection, they are tending to pick the bigger and more coordinated players who have had the benefit of extra months of maturity. A selected player will get better coaching, and his team mates are better, and he plays more games and practices two or three times than he would have otherwise. In the beginning, this advantage is not so much but at the age of thirteen of fourteen, with the benefit of better coaching and all the extra practice under his belt, he really is better, so he's the one more likely to make it to the Major Junior A League, and from there into the big leagues. - Malcolm Galdwell in his book "Outliers".

(2)

In 1985, Maco authorities (China) signed a concession contract with a private company. The quantity and quality of water greatly improved. Ten years later the city's gross domestic product had tripled. Maco today has one of the highest living standards anywhere in Asia. Even though the improvement in water distribution is not the main reason for the economic miracle, it is unlikely that such impressive development would have been possible without it. - Fredrik Segerfeldt in his book "Water for Sale".

(3)

By the end of 1993, the government of Peru had spent $3.4 billion on nine public sector large-scale water projects. Although several of the projects had been completed decades earlier, they had achieved only 6.6 percent of anticipated outcome in terms of creating new land for farming, and not one single kilowatt-hour of electricity had been generated. The cost of irrigated farmland created came to between $10,000 and $56,000 per hectare, whereas normal irrigable land in the same region costs $3,000. It would be not just a pity but quite outrageous if millions of people were to starve, fall ill, and die through water shortages brought about by the strident propaganda of vested interests and powerfully ideological movements with quite different ends in view. – Karen Bakker in her book "Privatizing Water".

(4)

"The (World) Bank once had a quite different approach to public works: it was an enthusiastic financier of monumental projects, and would typically lend the money to build large dams. Many of the dams were spectacular failures, delivering few, if any, benefits (except to politicians and construction firms) while displacing millions of people and leaving behind environmental destruction and public debts. The Bank is now getting out of the dam business and into water privatization" – William Finnegan of the New Yorker.

(5)

According to proponents, private sector participation in the urban water supply sector displayed an impressive increase, both in terms of numbers of projects and investment. However, this data is disputed, and the World Bank has been accused of providing greatly overestimated statistics in private sector participation. In any case, the observation is not universally true, as the level of private sector activity was spatially variable. Concession contracts were rare in regions where overall investment was lowest. The lowest income regions and countries tend to be disproportionately under-funded compared to middle-income countries. – Karen Bakker in her book "Privatizing Water".

The above noted examples confirm that the determination of a single "answer" for any single "question" is nearly impossible. Different views leads to different answers for the same question, and without a common base of comparison, any answers could only end-up being considered as outliers.

1.2 Research Background

The water sector has many characteristics that makes it challenging for private sector involvement. This includes a large fixed cost in its capital investment that has no alternative use (irreversible). Such high fixed cost of water systems lead to economics of scale that contribute to conditions of natural monopoly. Also, given the sensitivity of the water sector to public, the governments are typically heavily involved in regulating water services, which increases the regulatory and political risks to private companies undertaking this type of investment.

In the early 1990s, market-driven approaches for water resources management started to gain acceptance. Privatization and decentralization have become the main reform policies of the major international organizations (World Bank, International Monetary Fund, Organization for Economic Cooperation and Development). Water became recognized as an economic good, i.e., a commodity that should be priced at its cost of provision

(including environmental externalities) and its true value to society (Ouyahia, 2006). The number of people served to some extent by the private sector was 5% of the world's population in 1999, increased to 10% in 2006, and 11% in 2008, and reached by 2012 approximately 14% of the world's population, with around 960 million people being served (Pinsent Masons Water Yearbook 2012-2013). The water PPP market includes well-established markets like: United Kingdom, United States, France, Italy, Spain and Germany. Emerging markets includes mainly China, beside Brazil, India and Russia.
However, the attraction of water infrastructure to investment is considered to be low when compared to other types of infrastructure. As of 2005, privatization in water infrastructure attracted only 5% of the investment commitments in developing countries (Izaguirre and Hunt, 2005).

The heated debate on the usefulness of private participation in the water sector is far from being settled. The proponents and opponents typically support their claims with figures that should strengthen each party's arguments. A critical review of the most common assumptions/allegations made by each party is discussed in this thesis. In general, the proponents of water privatization have always linked the poor political condition in some countries to the deficiency in water supply management especially in third world countries. This is a very general assumption that ignores the fact that the same political bodies will be responsible in engaging private sector parties in new water PPP projects. On the other side, the opponents have put most of their efforts opposing the concept of water privatization disregarding the currently known operation and management deficiencies under the public scheme.

The literature review showed a severe drop in investment in water PPP between 2008 and 2009 with a minor rebound rate. Also, the cancellation rate of water PPP projects is about 26% compared to 4% in electricity, 3% in telecom, and 13% in Natural Gas. This has added to a heated debate between proponents and opponents of private participation in water infrastructure.

Studying the risk assessment of Water-specific PPP remains very limited, where the risk identification is generally based on using generic lists of risks. For risk evaluation, the research work is generally adopts simple to fairly complex techniques that is not being utilized in industry practice.

1.3 Problem Statement

The heated debate over private participation remains far from being settled. Both proponents and opponents of water privatization support their claims with figures that should strengthen each party's argument. However, in the lack of a common base of comparative analysis, each party's arguments are not indicative and could only be considered as outliers.

The case was clearly summarized by Karen Bakker (2010):

> *"Most of the debate has been centered on the relative merits of the public and private sector in managing large-scale reticulated water-supply networks. Unbiased research is rare; an examination of comparative performance is often influenced by ideological commitments. It is thus somewhat predictable that proponents and opponents of water privatization rarely agree on research strategies."*

Further to the above, the research on water infrastructure remains short of addressing the severe drop in the number of water PPP projects since 2008, where only a minor rebound in amount of investment occurred since then.

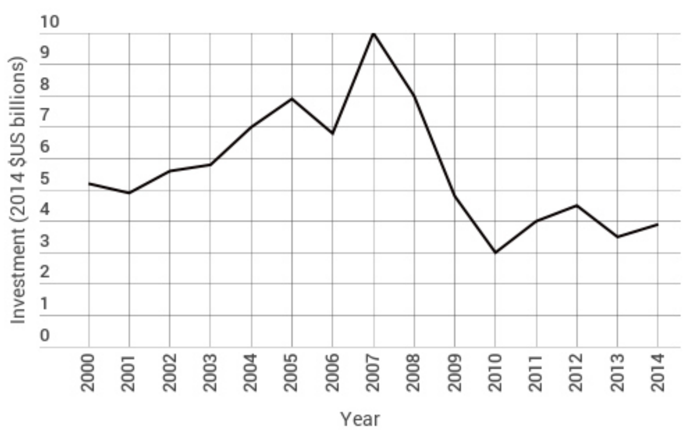


Figure 1.1: Private Participation in Water Infrastructure between 2000 and 2015
Source: World Bank Group (2015b).

This is in addition to the high percentage of cancelled/distressed projects in the water sector in comparison to other infrastructure sectors, with a percentage of approximately 26% of the total investment made in this sector by 2015, compared to 4% in electricity, 2% in telecom, and 13% in Natural Gas. The statistics of cancelled/distressed of various infrastructure sectors is presented in Figure 1.2, where the gap between the water sector and other sectors can be clearly observed.

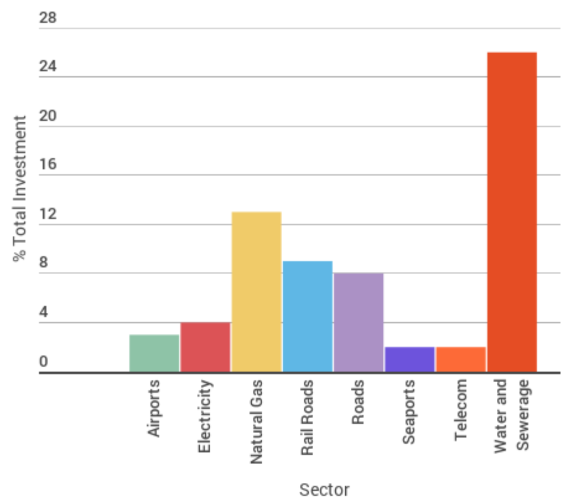


Figure 1.2: Percentage of Cancelled/Distressed Projects between 1990 and 2015.
Source: World Bank (2015a).

1.4 Research Hypotheses

Private sector involvement in water infrastructure is still a controversial issue, with a relatively weak record in the Water sector in comparison to other infrastructure sectors. In practice, the Government's decision to proceed with Public-Private Partnerships is dependent on proving the value for this procurement model over the traditional procurement mechanism, through a process known as "Value-for-Money analysis". As such, it is foreseen that adopting an improved risk assessment model dor new Water PPP projects would allow for a better evaluation of potential Water PPP projects.

1.5 Research Aim and Objectives

The study aims to develop a new risk assessment model for Water PPP projects that specifically addresses the risks associated with Water PPP projects, and through an analytical model, it would allow for comprehensive and proactive risk management of Water PPP Projects. The model, which is utilizing the Analytical Network Process (ANP) methodology, will be useful to governmental agencies for the assessment of risks effectively, efficiently and equitably, which will allow for a more reliable "Value-for-Money" analysis, which deals with the evaluation of new PPP projects.

To achieve the research aim, the following objectives were developed:

Objective One: *To identify and describe the significant risks associated with water PPP Projects with respect to cost and analyze the main reasons for projects' cancelation.*

Objective Two: *To analyze the interactions among the water-specific risks*

Objective Three: *To assess the severity of the identified Water-Specific risks*

Objective Four: *To develop a new model for the assessment of water-specific PPP risks*

1.6 Research Design

As shown in Figure 1.3, the research started by conducting a comprehensive literature review (Stage 1) on Water Public-Private Partnerships (task A: Chapter 2), and Risk in Water Public-Private Partnerships (task B: Chapter 3). At the end of stage 1, the research gap was identified.

In stage 2 (Chapter 4: Research Methodology), the research gap (i.e. problem) was defined, the research questions were formulated, and the research objectives were formed, and the research design was completed (task C).

In stage 3, the research objectives were tackled. This includes the identification of the Water-Specific PPP Risks (task D: Chapter 5), and a questionnaire survey was issued to assess the severity of the identified risks (task E: Chapter 5).

In stage 4, an improved risk analysis methodology was proposed (task F: Chapter 6), and based on the outcome of the questionnaire survey; the identified water-Specific PPP risks were prioritized (task G: Chapter 6).

In stage 5, the “Water-Specific PPP Risk Model” was developed (task H: Chapter 6) and the validation of the proposed model was undertaken (task I: Chapter 6). Finally, the conclusion and recommendations of the research was made, along with the recommendations for future research (task J: Chapter 7).

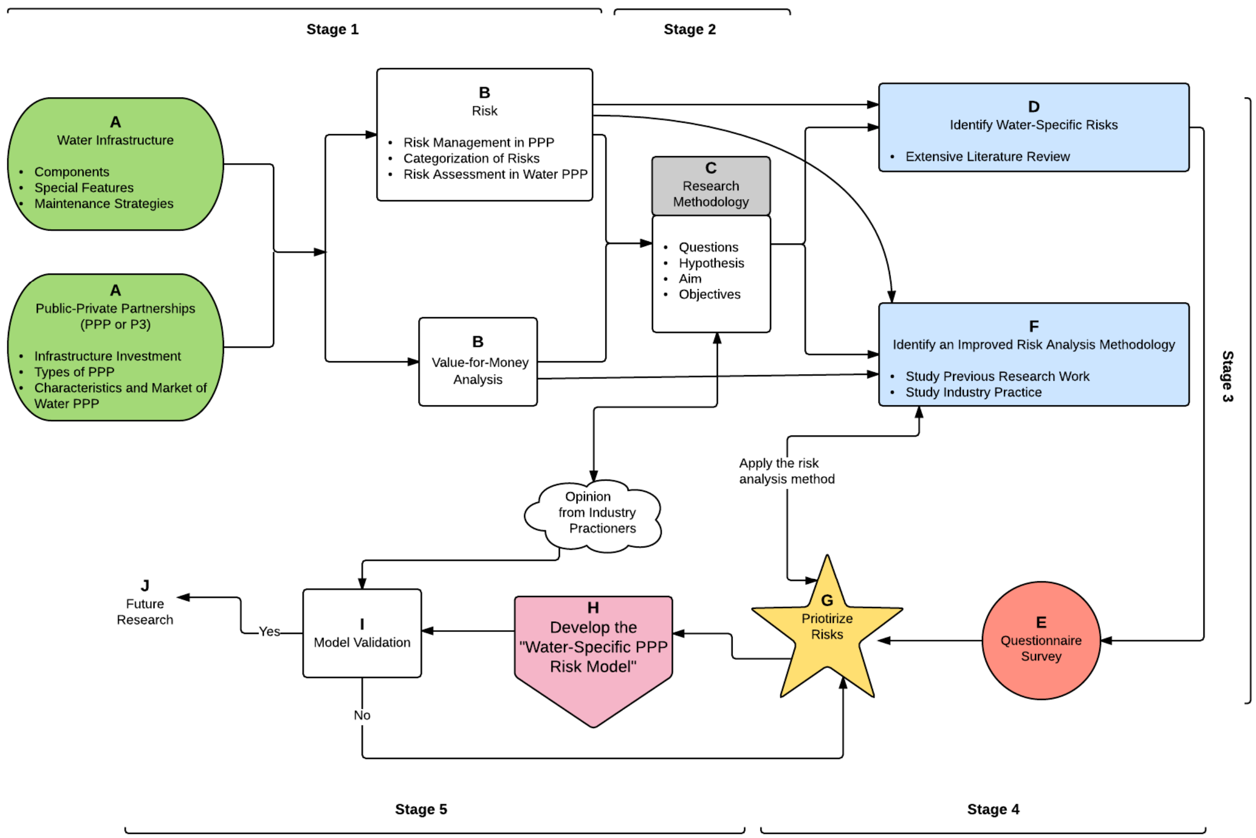


Figure 1.3: Research Plan

1.7 Thesis Structure

The thesis comprises five stages that are represented in 7 chapters. A brief introduction of each chapter is given under this section in order to outline the logical progression of the thesis.

Chapter 1 introduces the topic and provides a brief overview of the thesis including a background to the subject, the research problem, aim and objectives, and the research design.

Chapters 2 and 3 form the literature review.

- Chapter 2 introduces the special features of water infrastructure, the background of Water Public-Private Partnerships and its various forms along with some market statistics, and concludes with a critical review of literature.

- Chapter 3 presents the principles of risk management in Public-Private Partnerships, along with a review of research and industry practice with respect to water infrastructure. The chapter concludes with a critical review of literature.

Chapter 4 outlines the research methodology adopted for the research. It involves the systematic approach procedures upon which the research is based, the data is collected and interpreted, and the findings are evaluated.

Chapter 5 presents the identified water-specific PPP risks along with an assessment of the main failure cases in the water PPP sector. The chapter introduces the setup and conclusion of the questionnaire survey, undertaken to assess the severity of the identified risks.

Chapter 6 presents the development of the substantive Analytic Network Process (ANP) model for the prioritization of the identified risks. The chapter provides the calculation of the "Risk Priority Index, (RPI)" as a project ranking method for identified risks. The chapter introduces the developed "Water-Specific PPP Risk Model" along with the validation results.

Chapter 7 The chapter provides a review of the original research objectives and the extent at which they were achieved, where the main conclusions are to be presented and the limitations of the research to be acknowledged, with recommendations for further research.

1.8 Research Limitations

- This study particularly concentrated on the drinking water component, which may include raw water collection, transportation, and treatment or could be limited to water distribution to the consumers (private houses, industrial, commercial, or institution establishments). The risk profile would vary depending on the project scope. Such differentiation was not feasible in this research but could be considered as a future research prospective.

- The risks elements considered in this research are those directly relevant to the Water PPP planning and subsequent operation and maintenance. Other potential common PPP risks covering the social, construction, political aspects of the project should also be considered for a successful PPP, however are considered beyond the scope of this research. Such demarcation should be reflected on the developed Water-Specific PPP Risk Model.

- As with all survey based research there are bound to be limitations, which need to be acknowledged. Readers are therefore reminded of the potential effect of sampling, unsystematic (i.e. random) and measurement errors and their likely impact on the data collected, analysis undertaken and the conclusions drawn. The demographic profile of the respondents suggests that they have reasonable involvement and direct professional experience, which should accord some reasonable credibility to the quality of responses received.

  It is also important to acknowledge the relatively small sample size used for the study. However, this should not nullify the conclusions drawn, given that the relevant variation statistics showed a reasonable deviation.

- Furthermore, the researcher still lacked some real data to demonstrate the validity of the risk model developed by the proposed approach. Due to confidentiality reasons, it was not possible for public sector officials and contractors to disclose real data. It is therefore recommended, for future research, to test the model using real data.

CHAPTER 2: WATER PUBLIC-PRIVATE PARTNERSHIPS

2.1 Introduction

This chapter initiates the literature review of this research by presenting the specific features of the water sector and defining the term "Public-Private Partnerships (PPP or P3)" and its various forms. This chapter also provides the background of PPP in the water sector with an overview of the water PPP market worldwide.

The chapter concludes with a critical review of literature addressing the debate on the suitability of PPP for the water sector along with an analysis of the main water PPP market statistics.

2.2 The Special Features of Water Infrastructure

The water sector has many characteristics that makes it challenging for private sector involvement, as noted under this section.

- *Capital Investment*

The fixed cost associated with water infrastructure components like water distribution systems and storage / treatment plants is considered high when compared to other types of infrastructure. Besides, the water sector assets are mostly with no alternative use (i.e. irreversible). According to Armstrong *et al.* (1994), fixed costs of water infrastructure in England and Wales represent 80 percent of total cost. Another feature of water infrastructure is that 70-80 percent of the water infrastructure assets are underground (Infrastructure Canada, 2004) where uncertainty about the condition of assets (like underground pipelines) may discourage potential investors (Rees, 1998) or be a source of a potential claim after the contract is awarded (Penelope and Cowen, 1997).

- *Natural Monopoly*

Unlike other infrastructure sectors, the high fixed costs of water systems lead to economics of scale that contribute to conditions of natural monopoly (Ouyahia, 2006)

With the exception of construction, transportation, treatment and distribution of water are all normally spatial monopolies.

- *Health and Safety Regulations*

Given the sensitivity of the water sector to public, the governments are typically heavily involved in regulating water services, which increases the regulatory and political risks on private companies undertaking this type of investment.

2.3 Water Public-Private Partnerships

Hardcastle *et al*. (2003) defines Public-Private Partnerships (abbreviated as PPP or P3) as: *"Any contractual arrangement between a public sector agency and a for-profit private sector concern, whereby resources and risks are shared for the purpose of delivery of a public service or development of public infrastructure".* The forms of PPP would differ in the magnitude to which they move ownership, finance, and accountability out of the public sector into private hands. A list of the main forms of PPP is presented in Table 2.1.

In the early 1990s, market-driven approaches for water resources management started to gain acceptance. Privatization and decentralization have become the main reform policies of the major international organizations (World Bank, International Monetary Fund, Organization for Economic Cooperation and Development). PPP has been introduced as the most common scheme of project development.

In 1992, 500 participants including experts representing 100 countries and 80 international, inter-governmental and non-governmental organizations attended the International Conference on Water and the Environment (ICWE) in Dublin, Ireland. At its closing session, the conference adopted the Dublin Statement.

	SERVICE CONTRACTS	MANAGEMENT CONTRACTS	LEASE CONTRACTS	CONCESSIONS	BOT
Scope	Multiple contracts for a variety of support services such as meter reading, billing, etc.	Management of entire operation or a major component	Responsibility for management, operations, and specific renewals	Responsibility for all operations and for financing and execution of specific investments	Investment in and operation of a specific major component, such as a treatment plant
Asset Ownership	Public	Public	Public	Public/Private	Public/Private
Duration	1–3 years	2–5 years	10–15 years	25–30 years	Varies
O&M Responsibility	Public	Private	Private	Private	Private
Capital Investment	Public	Public	Public	Private	Private
Commercial Risk	Public	Public	Shared	Private	Private
Overall Level of Risk Assumed by Private Sector	Minimal	Minimal/moderate	Moderate	High	High
Compensation Terms	Unit prices	Fixed fee, preferably with performance incentives	Portion of tariff revenues	All or part of tariff revenues	Mostly fixed, part variable related to production parameters
Competition	Intense and ongoing	One time only; contracts not usually renewed	Initial contract only; subsequent contracts usually negotiated	Initial contract only; subsequent contracts usually negotiated	One time only; often negotiated without direct competition
Special Features	Useful as part of strategy for improving efficiency of public company; Promotes local private sector development	Interim solution during preparation for more intense private participation	Improves operational and commercial efficiency; Develops local staff	Improves operational and commercial efficiency; Mobilizes investment finance; Develops local staff	Mobilizes investment finance; Develops local staff
Problems and Challenges	Requires ability to administer multiple contracts and strong enforcement of contract laws	Management may not have adequate control over key elements, such as budgetary resources, staff policy, etc.	Potential conflicts between public body which is responsible for investments and the private operator	How to compensate investments and ensure good maintenance during last 5–10 years of contract	Does not necessarily improve efficiency of ongoing operations; May require guarantees

BOT = build–operate–transfer, O&M = operation and maintenance.
Source: Heather Skilling and Kathleen Booth. 2007.

Table 2.1: Types of Public-Private Partnership Contracts
Adopted from Public-Private Partnership Handbook, Asian Development Bank, 2008

The Dublin Statement adopted four guiding principles to provide the framework for future actions (Ouyahia, 2006):

- Principle No.1: Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
- Principle No.2: Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.
- Principle No.3: Women play a central part in the provision, management and safeguarding of water.
- **Principle No. 4: Water has an economic value in all its competing uses and should be recognized as an economic good.**

The "Dublin principles" were reiterated during the United Nations Conference on Environment and Development in Rio, 1992, where market-driven approaches for water resources management gained further acceptance. Water was recognized as an economic good, i.e., a commodity that should be priced at its cost of provision (including environmental externalities) and its true value to society (Ouyahia, 2006). Since that time, the heated debate over the success of this approach never stopped.

For developing countries, the United Nations in its year 2000 Millennium Declaration, set eight goals for development, called the Millennium Development Goals (MDGs). These goals set an ambitious agenda for improving the human condition by 2015. In support of these goals, the Millennium Project was launched to recommend the best strategies for achieving the MDGs.

Even in developed countries, the appropriate roles of the public and private sectors were also questioned. The current system dominated by public provision was perceived as inefficient and the private sector was introduced as a way of bringing innovative approaches, efficient management and cutting the cost of public subsidies or redirecting them to the poor. This radical change in public policy has occurred worldwide and for all infrastructure sectors (Ouyahia, 2006). Decentralization policies and decline in government subsidies are occurring at a time when infrastructure needs to be renewed, whereas for developing countries and transitional economies the main challenge is investment in new infrastructure.

- *Water PPP Market in the World*

The number of people served to some extent by the private sector was 5% of the world's population in 1999, increased to 10% in 2006, and 11% in 2008, and reached by 2012 approximately 14% of the world's population, with around 960 million people being served (Pinsent Masons Water Yearbook 2012-2013).

- *Water PPP in Well-established Markets*

There are six markets with an extensive private sector presence: United States, where a survey conducted in 1995 by the United States Environmental Protection Agency (EPA) found that 28,500 privately owned water systems served approximately 14 percent of the U.S. population (Brubaker, 2003). France where the private sector share was estimated at approximately 79% in 2005, Italy where 11% of the market was served by the private sector and semi-private companies in 1987; Spain where the private sector share was estimated at approximately 46% in 2005; Germany with approximately 8% of the market through long term, and England & Wales (Pinsent Masons Water Yearbook 2012-2013).

- *Water PPP in Emerging Markets*

China has been seen as a large market of interest and it is considered as the single most important driver. Brazil, India, and Russia have been the main drivers of the market in recent years, and the pace of growth in China appears to be accelerating. Over the past decade, they have accounted for 70% of the global market, chiefly driven by China's need to modernize its infrastructure (Pinsent Masons Water Yearbook 2012-2013).

- *Water PPP in the United Kingdom*

Water privatization started in 1989 by the government of Margaret Thatcher, which privatized the ten previously public regional water and sewerage companies in England and Wales through the sale of assets. At the same time the economic regulatory agency OFWAT was created. The Environment Agency was set responsible for environmental regulations, and the Drinking Water Inspectorate for regulating drinking water quality in the United Kingdom.

However, the attraction of water infrastructure to investment is considered to be low when compared to other types of infrastructure. As of 2005, privatization in water infrastructure attracted only 5% of the investment commitments in developing countries (Izaguirre and Hunt, 2005).

Below are some further statistics of private sector participation in water projects (World Bank 2016):

- Number of countries with private participation 64
- Projects reaching financial closure 906
- Total investment ($ Billion) 85
- Region with largest investment: Latin America and the Caribbean 49%

  (Note: While China is considered as the largest market, the "East Asia and Pacific" comes second with respect to investment by region for private sector participation in the water sector)

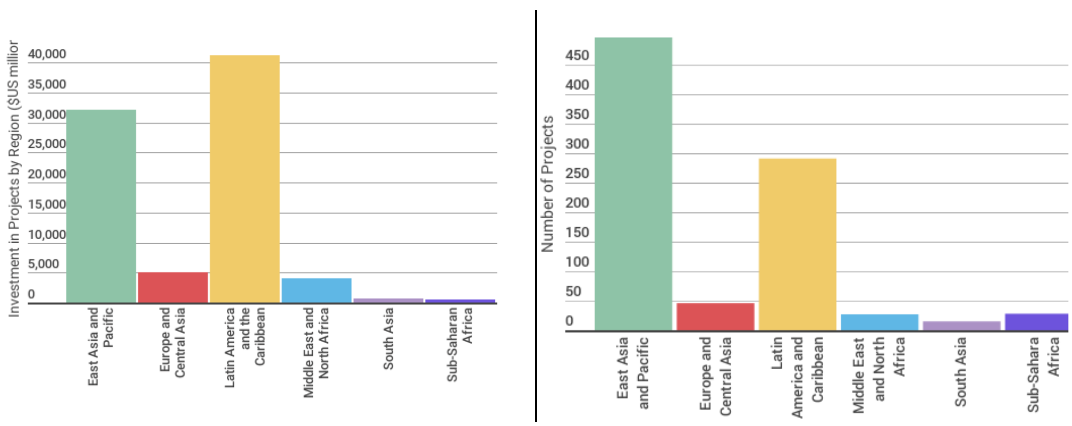


Figure 2.1: Private Participation in the Water Sector, between 1990 and 2015.
Source: World Bank (2015a).

- By 2012, almost 60 percent of projects were treatment plants, while the remaining 40 percent were for utilities (World Bank, 2013).
- Local operators were noted of increasingly being key sponsors of private water projects in developing countries as foreign private sponsors continue to reduce their participation. Out of the new 35 projects in 2009, 26 projects were entirely

implemented by local private consortia. The share of water projects with at least one foreign sponsor dropped from 48% in 2007 to 26% in 2009 (World Bank, 2015b).

- Type of PPP with largest share in investment: Concession 62%

Refer to Figure 2.2 for statistics of types of PPP implemented in the water sector:

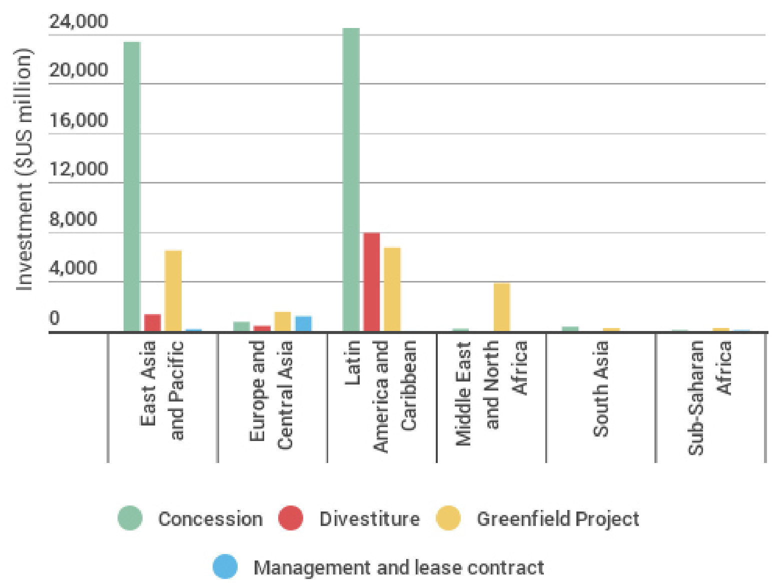


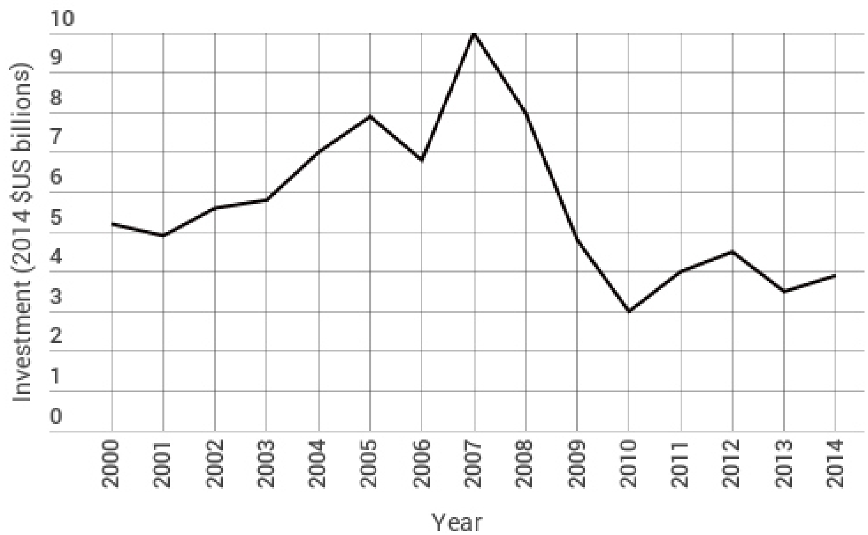
Figure 2.2: Types of PPPs in the Water Sector between 1990 and 2015.

Source: World Bank (2015a).

2.4 Drop in Water PPP Projects & High Rate of Project Cancellation/Distressing

According to the World Bank data, a severe drop in the number of water PPP projects occurred between 2008 and 2009 where the number of new projects with private participation that reached financial or contractual closure in 2009 declined by 46% compared to 2008. Annual investment commitments fell by 31% within the same period. To an extent, the drop has occurred across all infrastructure sectors due to the 2008 financial crisis; however, it remains as a prolonged feature in the Water sector.

As shown in *Figure 2.3* below, the same trend continued in 2010 and slightly improved



since then.

Figure 2.3: Private Participation in Water Infrastructure between 2000 and 2015
Source: World Bank Group (2015b).

Further to the above, by 2015, the percentage of cancelled/distressed projects in the water sector was highly increasing other infrastructure sector, with a percentage of approximately 26% of the total investment made in this sector, compared to 4% in electricity, 2% in telecom, and 13% in Natural Gas. Reasons for cancelling/distressing of these contracts varied between cited underinvestment by the concessionaire, disagreement on tariff adjustments, or because the provincial government created a new state-owned water utility to operate the services. The statistics of cancelled/distressed of various sectors is presented in Figure 2.4, where the gap between the water sector and other sectors can be clearly observed.

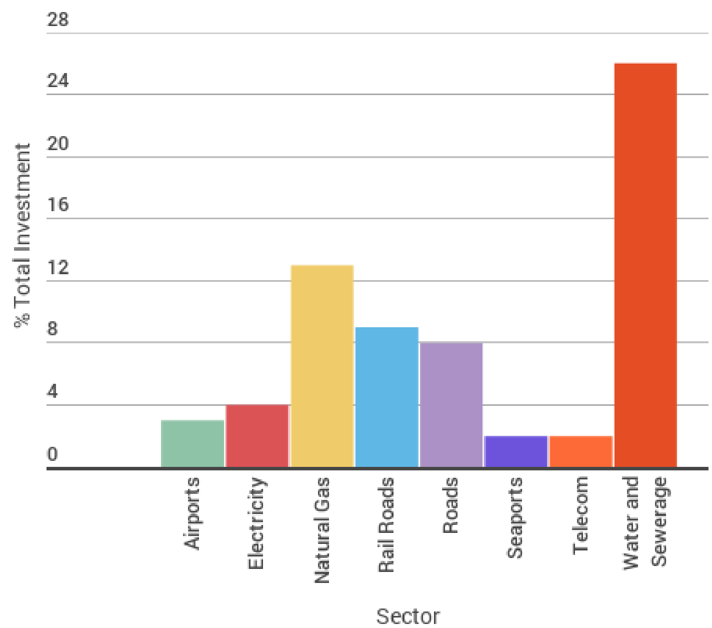


Figure 2.4: Percentage of Cancelled/Distressed Projects per Sector, for the period between 1990 and 2015.Source: World Bank (2015a).

2.5 Critical Review of Literature

2.5.1 Proponents versus Opponents of Private Sector Involvement in the Water Sector

The proponents and opponents typically supported their claims with figures that should strengthen each party's arguments. A critical review of the most common assumptions/allegations made by each party is presented under this section.

The proponents of water privatization have always linked the poor political condition in some countries to the deficiency in water supply management especially in third world countries. This is a very general assumption that ignores the fact that the same political bodies will be responsible in engaging private sector parties in new water PPP projects, which in fact imposes a risk to new PPPs. Fall et al. (2009) reported mixed cases of success and failure in water PPP in Africa due to the different setups. Fall (2009) noted that clarity of sector policies is a key to successful PPPs. Even in developed countries, like in the case of Atlanta (USA), Brubaker (2003) reported how the governmental changes represented by the change of the mayor, has impacted the progress of its water PPP project. As such, the assumption that the mis-management of political governments of water resources would only change if we switch to engaging the private sector is not always valid. Also, the assumption that private corporations will endeavour to lower their prices to gain more costumers is not always valid as this over-simplifies the issue. In Atlanta, the private investor, upon appointment, reported to the city a backlog of between 4,000 and 7,000 outstanding requests for service, some of which were three years old (Hardie, 1999). A construction boom in the service area created additional demands. This unexpected factor among others has caused the project to fail. After a certain point, the increase in water supply may require additional resources (facilities, equipment, services, etc…) to maintain the same level of service, which will result in additional cost to the private corporation. The claimed success of water PPP projects in some developed countries cannot be considered as a proof of the success of the same PPP scheme elsewhere, especially in developing countries where the socio-political conditions may significantly vary. Several experiences available in literature confirm the special nature of each project; several controversial cases have been reported by Segerfeldt (2005) and Bakker (2003).

The assumption that poor people are ready to pay more for an improved service does not explain the social and political tension that water privatization face in first world countries like in USA and Canada.

On the operation side, the assumption that the engagement of the private sector will lead to an immediate improvement to the service is not valid. Water spillage from pipes is a common source of under-performance due to the aging infrastructure where available records of previous maintenance activities is sometime missing or is not accurate. This was noted by Brubaker (2003) in the case studies of Atlanta, USA and Halifax, Canada. Even with the availability of such records, the rehabilitation/maintenance of water pipes is facing limited budget allowances. The engagement of the private sector is not foreseen to change things radically in this regard. The assumption that private corporations will have the tendency to handle water with care is not always accurate given that the private sector is engaged in a pre-determined contract value over a certain period of time with a pre-agreed level of performance. The increase of water supply may lead to increased effort (and cost) to comply with the operation contract requirements.

Assuming that private sector will allow for more investment in research and development is not always accurate. A relatively large amount of research is taking place in developing improved strategies for water pipe maintenance and rehabilitation; however, governments mostly fund such research.

The assumption that users, under the free water-pricing model, will have the option to seek an alternative in case of improper service is clearly not valid given the monopolistic nature of the water sector. For instance, in England and Wales, water companies remained monopolies even after privatization (Ouyahia, 2006) Also, the assumption that private entities will seek an improvement to their service for an increased use and earnings is not always accurate. The additional use of resources can lead to additional investment in facilities so as to handle such increase and maintain the operation contract requirements.

The proponents typically ignored the necessity of developing a water policy based on available resources and target achievements with respect to water access and quality. The arrangement and coordination of new proposed projects should follow such policy.

It was noted that the allegations sometimes made against building major infrastructure facilities (like dams) are generally unsubstantiated. As an example, the allegations made by Segerfeldt (2005) that the World Bank has led to many spectacular failures by investing in major public works like large dams is not substantiated. Building dams, like other engineering projects, should have the associated engineering studies starting from preliminary design till detailed design to allow for the proper assessment, analysis, and subsequent execution. Moreover, the reference by Segerfeldt (2005) to a major public works failure like in the Soviet Union that took place during the 1950s does not offer a scientifically acceptable basis for evaluation.

Linking a proper water policy to market-driven policies is not valid. In Chile, private ownership was introduced where landowners were given the right to own water and sell it at freely determined prices, where the model was proved to be successful (Segerfeldt (2005). However, the success of such model in Chile does not necessarily guarantee that the same model is valid elsewhere, as engineering requirements beside political and social conditions should be studied on a case-by-case basis. In any case, local residents are not expected to handle the overall planning of water supply but rather it should be by responsible organizations.

On the other side, the opponents have put most of their efforts opposing the concept of water privatization disregarding the occurring operation and management deficiencies under the current public scheme. Brubaker (2003) considers that many municipal utilities are ill-equipped to deal with new challenges in the industry and lack the necessary expertise at all levels. In-depth research on the matter is very limited.

Bakker (2010) offers the most notable effort towards a more rational assessment of the situation. Bakker's analysis came from a different starting point of the debate, through focusing on issues of governance, where many issues are common between public and private parties. However, Bakker generally implied a shared responsibility between the public and private sectors for the current on-going deficiencies in this sector. This ignores the fact that the majority of the services at its current conditions are being offered by the public sector with its known deficiencies.

2.5.2 Drop in the Investment in Water PPP

The research work addressing the drop in water PPP projects and its high cancellation rate is limited to industry reports / publications which are mostly driven by the ideological commitments of the authors or at least limited to the cases in-hand. There is a need for an overall review of PPP as a procurement scheme, where the reasons for such drop are to be assessed and delineated by industry experts to a list of risks associated with water PPP.

2.5.3 Concluding Remarks

The heated debate over water privatization remains far from being settled. Both proponents and opponents of water privatization are supporting their claims with figures that should strengthen each party's argument. However, in the lack of a common base of comparative analysis, these arguments remain not conclusive of any facts. This is accompanied by a severe drop in the number of Water PPP projects since 2008 and a high cancellation rate in comparison to other infrastructure sectors. Research addressing reasons for the drop or for the high risk associated with this sector remains very limited and where it exists, is mostly driven by the ideological backgrounds of the authors.

This situation was clearly described by Bakker (2010):

> *"Most of the debate has centered on the relative merits of the public and private sector in managing large-scale reticulated water-supply networks. Unbiased research is rare; an examination of comparative performance is often influenced by ideological commitments. It is thus somewhat predictable that proponents and opponents of water privatization rarely agree on research strategies."*

Research on this matter is not expected to resolve this debate, since there is no single answer for any single question. Instead, the motivation for a research on this subject should aim to seek an improved risk assessment methodology of water PPP projects.

2.6 Summary

This chapter presented the specific nature of the water sector, which includes its intensive capital investment, natural monopoly, and the sensitivity of the associated health and safety regulations.

The chapter also presented a definition of PPP as a contractual arrangement between a public sector agency and a for-profit private sector concern, presenting the various forms for such partnership.

PPP in the water sector was noticeably advanced in the early 1990s, as market-driven approaches for water resources management started to gain acceptance. Privatization and decentralization have become the main reform policies of the major international organizations (World Bank, International Monetary Fund, Organization for Economic Cooperation and Development). At the closing session of the International Conference on Water and the Environment (ICWE) held in Dublin, Ireland in 1992, the conference statement included a guideline that "Water has an economic value in all its competing uses and should be recognized as an economic good". PPP have been introduced as the most common scheme of project development.

The number of people served to some extent by the private sector was 5% of the world's population in 1999, increased to 10% in 2006, and 11% in 2008, and reached approximately 14% of the world's population, with around 960 million people being served (Pinsent Masons Water Yearbook 2012-2013). However, such numbers should be considered in conjunction with a severe drop in investment in water PPP between 2008 and 2009 with a minor rebound rate. Also, the cancellation rate of water PPP projects is about 26% compared to 4% in electricity, 3% in telecom, and 13% in Natural Gas. This has added to a heated debate between proponents and opponents of private participation in water infrastructure, a debate that is far from being settled. This chapter concluded with a critical review of literature as it was noted that proponents and opponents of water privatization were mostly driven by ideological commitments. The researcher analyzed the arguments made by both sides and suggested that research on this matter can allow for an improved risk assessment methodology of water PPP projects.

CHAPTER 3: RISK ASSESSMENT IN WATER PUBLIC-PRIVATE PARTNERSHIPS

3.1 Introduction

In chapter two, the debate over private sector involvement in water assets management was highlighted, where the assessment of the suitability of this procurement scheme for the water sector was observed to be mostly driven by ideological commitments rather than applying proper research basis. This is accompanied with severe drop in the number of water PPP projects was highlighted, which implies the risky nature of the water sector.

This chapter discusses the risk in water PPP. For which, it explores the concept of risk management in PPP in general, and the risk assessment methods, in research, and in industry practice.

3.2 Risk Management in Public-Private Partnerships

PPPs are risk-sharing investments in the provision of public goods and services (EIB, 2005). How risk is shared between the parties is central to the PPP arrangement (Chapman, 1997). An array of documents has been published with the aim of providing guidance for practitioners undertaking the Risk Management process.

A fundamental principle is that risks should be allocated to the party that is best able to manage the risk in a cost-effective manner, as pointed-out by Grimsey and Lewis (2002). The risk allocation in PPP projects is fundamentally different to that in traditional projects as the latter include finance and operational risks to the private party. Zou *et al*. (2008) describes the different types of construction contracts and their risk-sharing extent for government and private sectors as shown in Figure 3.1.

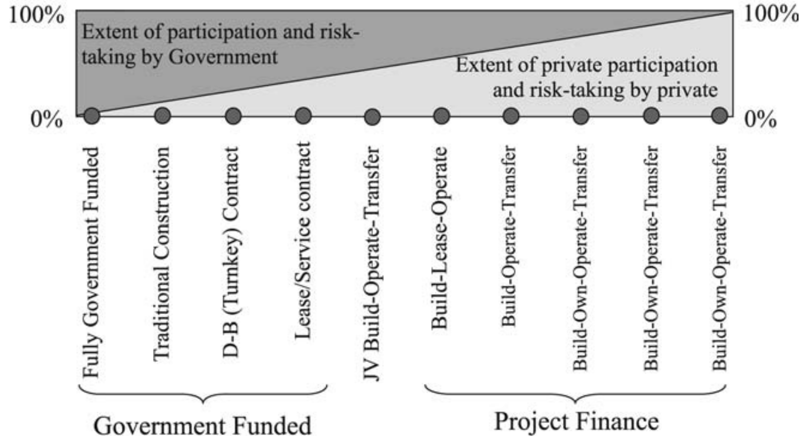


Figure 3.1: Risk-sharing Extent for Government and Private Sectors

A systematic risk management allows early detection of risks and in turn responses by stakeholders (Broome and Perry 2002; Akbiyikli and Eaton 2004)). Ng and Loosemore (2007) highlighted the drawbacks of inappropriate risk allocation and proposed a respective framework. Li *et al*. (2005) presented a process of negotiation (Figure 3.2) for risk allocation, which combines the approach, proposed by Al-Bahar and Crandall (1990) with the principle of risk sharing in PPP/PFI procurement supported by Grant (1996) and HM Treasury (2000).

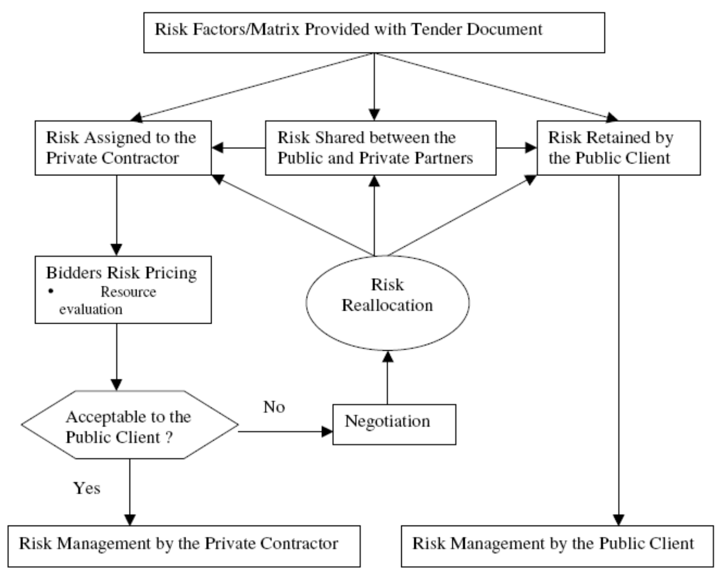


Figure 3.2: Risk Allocation in PPP Procurement
Proposed by Li et al. 2005

Wang *et al*. (2000) stated that proper assessment of project risks can only be achieved from a life cycle perspective starting at the feasibility study stage and carried-out right through the operation and transfer stages with continuous monitoring. Zou *et al*. (2008) studied several case studies through the life cycle of these projects, and proposed the framework shown in Figure 3.3.

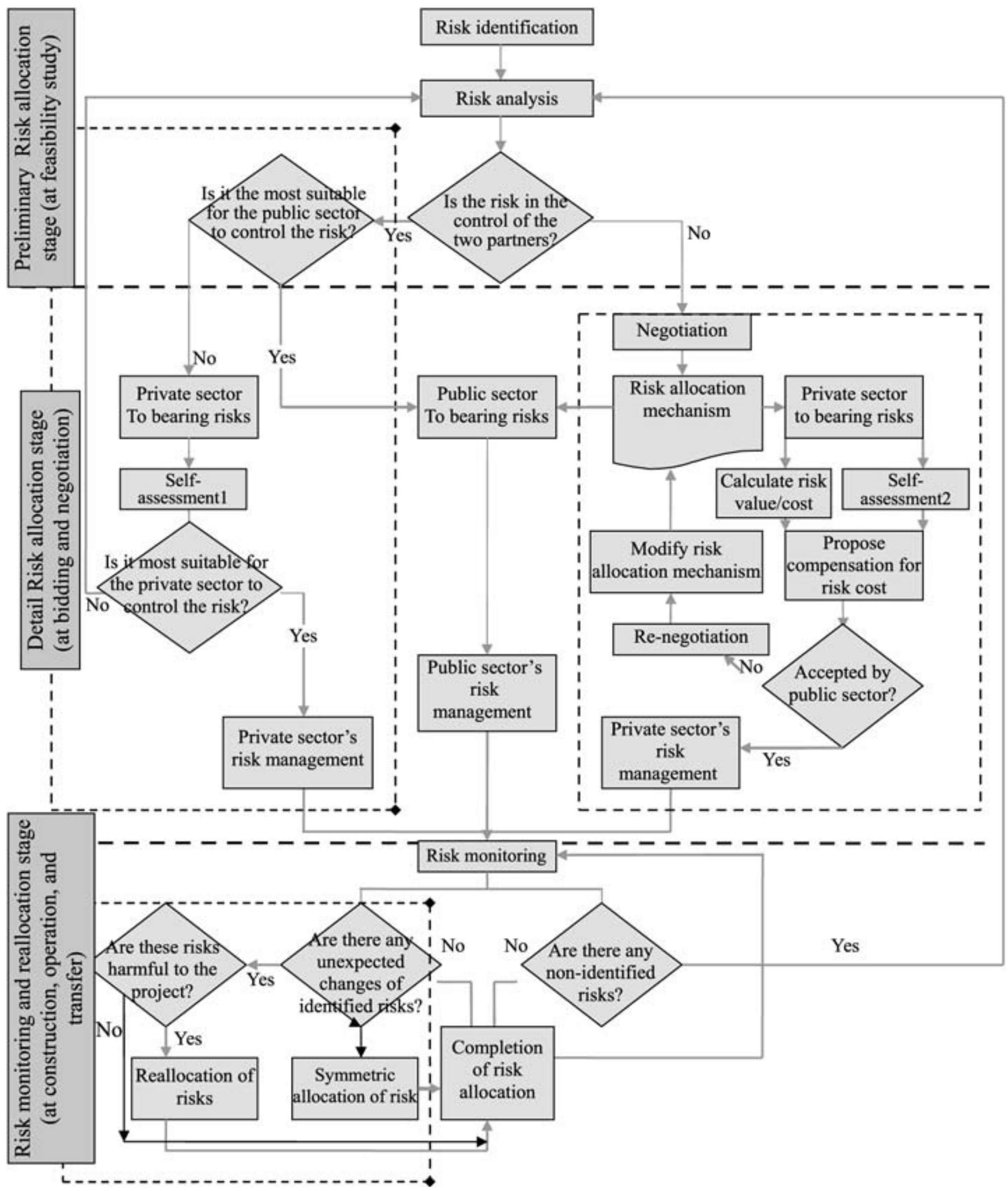


Figure 3.3: Risk Allocation Framework
Proposed by Zou et al. 2008

3.3 Risk Assessment in Public-Private Partnerships Projects

A systematic process of risk management can be divided into risk identification, risk evaluation and risk treatment, where risk treatment can be further divided into four actions: Risk retention, reduction, transfer, or avoidance (Berkeley *et al*., 1991; Flanagan and Norman, 1993).

3.3.1 Risk Identification

The most logical approach to identify risks in research work was to conduct a **literature review** where previous studies were used to identify potential risks. Voleker *et al*. (2008) conducted a literature review to identify the political risk perception in Indonesian power projects. Jin and Doloi (2008) conducted a literature review to identify "Environment risks" in their research on the interpretation of risk allocation mechanism in PPP. Chan *et al.* (2011) studied the risk assessment and allocation of PPP Projects in China at which a total of 34 risk factors were identified after conducting an extensive literature review. Wang *et al*. (2000) conducted a study to identify and evaluate the critical political and force majeure risks associated with China's BOT projects, which included identifying the critical risks through a comprehensive literature review.

Some researchers used a "**quantitative content analysis**" to identify risks in previous literature. The quantitative content analysis extends the approach of the qualitative form to yield numerical values of the categorized data (frequencies, ratings, ranking, etc.), which may be subject to statistical analyses. Xu *et al.* (2010) used this technique by conducting the comprehensive literature review and content analysis, a total of 34 risk factors for PPP projects were identified.

Some researchers used **pre-determined existing lists** to identify risks. UNIDO (1996) developed a checklist classifying risks under two major categories (general/country risks and specific project risks). Political risks, commercial risks and legal risks are classified in the first category, whereas construction/completion risks and operating risks fall into the second category.

Case studies have also been used as an effective approach to investigate PPP applications to capture specific project features, gain detailed understanding of its implementation, and draw useful implications. Stager (1996) summarized the problems during the execution of a Finance-Design-Build highway project in Turkey. Ng and Loosemore (2007) presented a review of risk allocation in PPP projects and a case study of the controversial $920 million New Southern Railway project in Sydney, Australia. It mainly analyzed the rationale behind decisions about risk distributions between public and private sectors and their consequences. Zheng (2010) studied the first PPP application in Taiwan's wastewater treatment sector which presented a study of the tender process, concession agreement, financial structure, payment mechanism, and risk management. Gupta and Sravat (1998) concluded the significant risks in an Indian power project as development and construction risk, operation and maintenance risk, fuel supply and transportation risk, foreign exchange risk, non-payment risk and regulatory risk occurred, with the political risk of local government. Singh and Kalidindi (2006) studied through a case study, the "Annuity Model" which is a traffic risk-neutral PPP model built to overcome the traffic revenue risk that was identified as one of the most critical risks impacting the commercial success of the Indian road projects procured through PPP mode. Lam (1999) studied previous projects that ran into daunting risks resulting in their cancellation, serious delay and cost overruns in attempt to draw lessons from them. Songer *et al*. (1997) studied through a case study the risk of revenue-dependent infrastructure projects.

Questionnaire surveys have been typically the research method used for risk evaluation and/or allocation while in some cases generated additional risks that should be considered. Wang *et al.* (1999) carried out an international survey among project sponsors, developers, consultants, lawyers, lenders, investors and contractors about critical risks concerned. Akintoye *et al.* (1998) carried out research on risk assessment/prioritization for private finance initiative (PFI) projects in the UK. The study noted that every party put the risks related to his line as the most significant. Questionnaire survey dominated most of the research work (Chan *et al.* 2011, Wang *et al.* 2000, Jin and Doloi 2008, Roumboutsos *et al.* 2008, Akintoye *et al.* 1998, Wang *et al.* 2004).

Voelker *et al.* (2008) conducted unstructured **interviews** to confirm/update the findings of the initial literature review.

Xu *et al.* (2010) developed a risk assessment model for PPP projects in China, where the concept was adopted from a previous research, where the risks were identified in stages; first through a comprehensive literature review and more risks were identified at a subsequent two-round Delphi questionnaire survey.

3.3.2 Risk Evaluation

For the most part, decision-makers tend to concentrate on single values of outcomes, such as profit, which have been calculated from single value estimates and variables (Flanagan and Norman, 1993). This approach is not suitable for construction projects that would include low and high risks, where the decision maker should be able to evaluate each and every risk that is identified for his project.

Qualitative: Using qualitative techniques, the negative outcome of an activity is expressed in terms of probability or likelihood, and impact or consequence. These are done subjectively, where the likelihood of occurrence and level of impact of risks can be assessed as low, moderate or high (Akintoye *et al.* 2000, DELG, 2000). Qualitative analysis can be considered for an initial screening of project risks, or when a quick assessment is desired.

Semi-Quantitative: Semi-quantitative assessment attributes numerical values to impact, probability, or frequency. Normally, the probability is assessed subjectively as in qualitative assessment, but the impact of a risk is assessed quantitatively in monetary terms (Akintoye *et al.*, 2000).

Quantitative: The assessments are done in numeric terms, by pricing the consequence using a monetary unit. Of these techniques, those considered to be of most relevance to the construction industry are listed as (Akintoye *et al.* 2000, DELG, 2000).

- <u>Sensitivity Analysis</u>

This is the simplest form of risk analysis. It seeks to assess the effect on a project by changing a single variable within it (Flanagan and Norman, 1993). In practice, this analysis is applied only to variables that are particularly important in terms of cost, time or economic return, or to the project as a whole. The technique has several weaknesses

(Woodward, 1995), such as: the variables are treated individually, which makes it difficult to assess their importance in combination, and that these is no indication in the severity diagram of the anticipated probability of occurrence. Sensitivity has been brought to be inferior to simulation for the very reason that probabilities are not used (Woodward, 1995).

- Probability Analysis

This is a more sophisticated form of risk analysis that overcomes the limitations noted in sensitivity analysis by specifying a probability distribution for each variable and then considering situations where any, or all, of them can change their initial values at the same time (Reutlinger *et al.*, 1970; Flanagan and Norman, 1993). Probability analysis has been deemed to be useful where there is a history of outcomes that can be aggregated to produce objective probabilities. When there is no historical data, it becomes highly subjective (Tweeds, 1996).

- The Monte Carlo Simulation

The Monte Carlo simulation is used to study the effect of the variability of input factors on an outcome (Newton, 1992). It consists of simulation by means of random numbers. It provides an extremely powerful method of incorporating probabilistic data. The Monte Carlo simulation will require sets of random numbers to be generated for use in testing various options. Simulation makes the assumption that parameters subject to uncertainty can be described by probability distributions (Flanagan and Norman, 1993).

- Decision Tree Analysis

A decision tree is a means of setting out problems that are characterized by a series of decisions. It shows a sequence of decisions and the expected outcomes under each possible set of circumstances. The stochastic decision tree approach provides another method of analysing decision problems over time. It combines the logic of decision tree analysis with the Monte Carlo simulation approach used in risk analysis. Obviously the accuracy of the "Decision Tree Analysis" method depends upon the accuracy of the expected outcome and the probabilities.

3.3.3 Risk Treatment

Risk treatment can be divided into four categories: avoidance, reduction, transfer, and retention, as described below:

- Risk avoidance requires altering the project original plan so as to avoid a certain activity that carries a very high risk.
- Risk reduction: Applying certain methods that reduce the probability of a risk occurring, or reducing the severity of the impact of a risk on the outcome of the project.
- Risk transfer: When selecting to move the ownership of a certain risk to another party. This may include moving the risk to a third part through a contract agreement
- Risk retention: Accepting to carry the responsibility for certain risks in the project which cannot be avoided or transferred.

3.4 PPP Risk Categories

Some researchers categorized risks in construction projects broadly into general groups (i.e. internal and external) while others classified risks in more details: political risks, financial risks, market risks, intellectual property risks, safety risks, etc. (Songer *et al*., 1997). Relevant to PPP, UNIDO (1996) developed a checklist classifying risks under two major categories (general/country risks and specific project risks). At which, political risks, commercial risks and legal risks are classified in the first category, whereas construction/completion risks and operating risks fall into the second category. Standard and Poor's considers several broad areas that can potentially affect a PPP project's creditworthiness. These are credit risk of the public sector entity, construction risks, revenue structure, operating risk, financial, and legal structure.

Similarly, Grimsey and Lewis (2007) identified six areas of risk associated with PPP projects, namely; public risk; asset risk, operating risk, sponsor risk, financial risk and default risk. Tiong *et al.* (1992) cited that BOT projects could be divided into five phases, namely `Pre-investment', `Implementation', `Construction', `Operations' and `Transfer'. A series of risks involved in a certain phase of BOT was summarised by

Woody and Pourian (1992) into five groups. These are start-up cost risk, operating risk, technology risk, market risk and political risk. Wang *et al.* (2004) conducted a survey and twenty-eight critical risks were identified, categorized into three (country, market and project) hierarchical levels. Ernst and Pham (1995) identified a number of risks with regard to BOT project financing which can be categorized into: construction risks; performance; technology risks; force-majeure risks; and economic performance risks.

Political and legal Risks: Wang *et al*. (2000) studied the political risks in China's infrastructures projects. The study identified from literature review a total of 34 risks which was filtered through discussions and interviews and was later submitted as a questionnaire to evaluate the criticality of these risks. The risks identified were categorized into: (1) Political and force majeure risks and, (2) Foreign exchange and revenue risks. Voelker *et al.* (2008) studied the political risk perception in Indonesian power projects. The study included a comprehensive literature review which generated an initial list of specific political risks, derived from MIGA (1985) and Sachs (2006), which could be classified as follows: Currency transfer, expropriation and similar measures, breach of contract; water and civil defence, war and civil disturbance, legal, regulatory and bureaucratic risks; and non-governmental action risks. The identified risks were filtered through subsequent interviews before being issued through a questionnaire survey to evaluate the risks and their allocation.

Financial Risks: These form a considerable set of risks in PPP projects and therefore was consistently part of the research work. Chen *et al.* (2011) identified the direct economic risks, which included interest rate fluctuation, foreign exchange fluctuation, inflation, and financing risk. However, a broader view would show that all the risks inherited in PPP projects would impact the financial model of the concessionaire. Zhang (2005) studied the concessionaire's financial capability in developing BOT type infrastructure project as an important prerequisite to the success of this type of projects. As the concessionaire is exposed to a wide range of risks, Zhang introduced from pervious literature the financial consequences of some risks and the mitigation measures. In his research, a common set of 35 financial criteria has been identified through a systematic research approach, and their relative significances were determined based on worldwide expert opinions solicited by a structured questionnaire survey. Lam and Chow (1999) explored the significance of the risk characteristics of BOT projects from the financial point of view. 'Interest rate fluctuation' was the most significant financial risk variable in the pre-investment phase. For the implementation phase, both the variables 'design deficiency' and 'time overrun' was found to be highly statistically significant. The variable 'time overrun' was found to be the most statistically significant in the construction phase. The majority of the risk variables were considered to be moderately significant in the operations phase. Zou *et al.* (2008) studied the Sydney Cross City Tunnel PPP in Australia and the financial risk resulted from less-than-expected appeal to users. Zou *et al.* (2008) also studied the Sydney Airport Railway Link, which ran into extra cost and high return on investment from the private sector side, which is resulted in high-ticket pricing and in turn less users and in turn less revenue. Kapila and Hendrickson (2001) studied the currency exchange rate risk on international construction firms and ways to manage this risk. Xenidis and Angelidis (2005) looked into risk allocation of financial risks. Sachs (2006) looked into quantifying qualitative information on risks (QQIR) is structured finance transaction.

Social Risks: In many incidents, the social risks led by public sector have led to serious results, which resulted in tense negotiations. Such negotiations typically led to one party carrying more obligations and responsibility, and in some cases the projects were cancelled as a result of such disputes. Obviously, such scenarios are more expected on PPP projects of social-related projects, and when multi-national companies lack the necessary local experience where new projects are being implemented. Zou *et al*. (2008) study of the Sydney Cross City Tunnel and the Airport Railway Link are good examples on how the lack of public appeal to use new facilities would adversely impact PPP projects. In some cases, failure to provide services raised public heat like the case of Dar el Salaam water supply project in Tanzania in 2005. Proponents of the project had promised that involvement of private sector (Biwater) would resolve the water supply crisis in Dar el Salaam yet the subsequent failure of Biwater to meet the expectations, however, the tense negotiations and the increasing public pressure led to project cancellation (Bakker, 2010). Another component of social risks, which is the soft aspect of risks, such as interpersonal communication, has generally received little attention to date in construction-related research (Edwards and Bowen, 1998). The soft aspects of risks may carry significant risks for companies involved in new markets.

Design and Construction Risks: Design is a significant risk in successful project development (Li, 2003) where the design deficiency may cause the risk of not meeting the necessary authority approvals or impacting the construction and maintenance costs as noted by Partnership Victoria (Victoria, 2001). Design variations (Dawood *et al.*, 2001) may increase project direct cost and time, and may impact the construction schedule leading to additional time and cost overrun.

3.5 Risk Assessment in Water Public-Private Partnerships

3.5.1 Research Work

Water supply projects procured through PPPs are exposed to a plethora of risks than other infrastructure projects. Shrestha and Martek (2015) studied the legal risks in water PPPs in China, throughout the life cycle of the project addressing the following stages: 1- Procurement, 2- Construction, and 3- Operation. The study concluded that legal risk is present at all three stages, at close to moderate levels, with risk significance greatest at the operational stage. Ameyaw and Chan (2013) studied the key risk factors for water PPP projects in Ghana. The study ranked identified risks using the Delphi technique, and concluded with the top five risks: foreign exchange rate, corruption, water theft, non-payment of bills and political interference. Choi *et al.* (2010) studied the risk factors affecting foreign investment in China's PPP water market. The study concluded with tariff review uncertainty, abolishment of the fixed-return policy, and government breach of contract, immature domestic banking/financial systems and uneconomic pricing of water as the main factors. Wibowo and Mohamed (2010) investigated risks and risk sharing practice in the Indonesian water sector. Zeng *et al.* (2008) studied the risks in China's BOT water projects, and concluded that tax, informal competition, inflation rate, interest rate volatility, raw water price instability, foreign exchange fluctuation, lower-than expected demand, and industrial policy change are the main risks impeding new projects. Xu *et al.* (2011) identified the important risk items affecting performance of PPP water projects. Harris *et al.* (2003) studied drivers for cancelation of PPP projects in developing countries, and find three key factors: price increases, difficulties in collection and poor project design. Vives *et al*. (2006) presented the eight most common principal factors associated with water PPPs as legal framework, fiscal space, political environment, macroeconomic conditions, institutional capacity, willingness to pay for services, tariff sustainability, and size and location of project.

3.5.2 Industry Practice

In industry practice, two financial models are typically developed; one named "Public Sector Comparator (PSC)" is typically developed by estimating the total project cost if the project is delivered by public sector, and another financial model named "Adjusted Shadow Bid (ASB)" is developed by estimating the total project cost if the project is delivered using private sector or Public-Private Partnership. The difference between the estimated total project costs under each model is the "***Value-for-Money (VFM)".*** In order for a governmental agency to proceed with a PPP project, a positive "value-for-money" assessment should be proved. If the adjusted shadow bid is less than the public sector comparator, there is positive value for money by procuring a project using private sector. An illustrative example is shown on Figure 3.4 below.

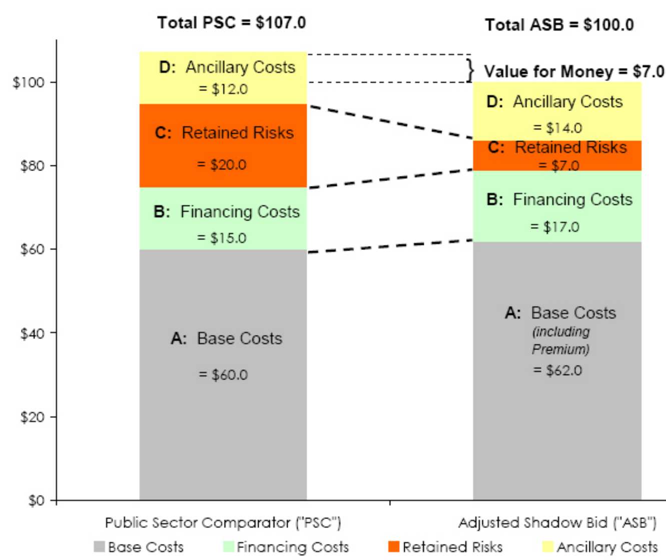


Figure 3.4: Illustrative Example of Value for Money Assessment

As shown on Figure 3.4, the magnitude of the cost components varies between the two different models. For the above example, the VFM estimated in percentage terms is as follows:

$$\frac{\text{Traditional Project Cost under PSC} - \text{Project Cost under ASB}}{\text{Traditional Project Cost under PSC}}$$

- ***<u>Example: Assessment of City of Regina Wastewater Treatment Plant Expansion</u>***

This section provides a published real case of assessment of a new water PPP project that was undertaken by the City of Regina, Canada. According to the Canadian PPP assessment guidelines, the decision to proceed with a new PPP project should be concluded after conducting three stages; screening assessment, strategic assessment, then concluded with the value-for-money assessment.

1. **Screening Assessment:** aims to determine the potential suitability of the project for PPP delivery. At a workshop in April 2012, the project was screened against a set of standard PPP-suitability assessment criteria as shown in Table 3.1.

Table 3.1: Screening Criteria

Criteria	**Assessment**	**Suitable for PPP?**
Duration and Technological Change	*Is the capital asset of an enduring, long-lived nature and is the service life of the asset at least 20 years?*	*Yes*
	Is there a significant long term maintenance, operation, or service need associated with the capital project	*Yes*
	Are the capital asset and service needs sustainable and the risk of technological change minimal over the entire service life of the P3	*Yes*
Legal Barriers	*Is the proposed P3 approach or the provision of the service free of any potential legal conflict with legislative or regulatory prohibitions or substantial restrictions (that cannot be changed in the short term)?*	*Yes*
Affordability	*Can payment be tied to measured performance?*	*Yes*
	Is there a potential revenue opportunity for the private sector partner, which can be also tied to performance?	*Yes*
Project Risk	*Are there risks associated with traditional procurement that might be better managed by a private partner?*	*Yes*
Project Size	*Can the project be bundled with one or more other similar projects to achieve economies of scale and a larger project size more suitable for P3?*	*Yes*
Specifications	*Can the capital asset and related services be defined in a performance or output specification?*	*Yes*
Integration	*Is the project relatively independent of other City projects, infrastructure, or control systems?*	*Yes, except for McCarthy Boulevard Pump Station*

Human Resources	*Does the project, if delivered by a private partner, obviate any current City staff positions?*	*Yes*

2. **Strategic Assessment:** This stage undertakes a more detailed examination of the risks, costs, market of services provides objectives, and constraints. The intent of the strategic assessment is to examine not just PPP models, but also all models under consideration. For this project, this was accomplished through three stages:

   a) A "market sounding" to determine the capacity of the market to participate in various delivery models. At an initial stage started in August 2012, eight firms representing designers, constructors, and investors were interviewed to examine the interest to the project. The outcome showed the potential of this project to attract competition. At a subsequent stage carried in December 2012, more research was done with more focus on the DBOM and DBFOM models. The information obtained was to be utilized for the preparation of the procurement documents and on the evaluation. Overall, it was determined that any of the models under consideration can be expected to attract sufficient competition from the marketplace, and therefore market interest is not a governing factor in selection of the delivery model for the Project.

   b) A "qualitative risk assessment" was undertaken to identify the project's risks and assess the relative risk-mitigation benefits of the various delivery models. Each alternative model presents a different risk profile due to the different allocation of risks between the city and the contractor. The main target of this exercise is to try to identify the delivery model with the least project risk, which in turn makes costs more certain. As such, a risk workshop was conducted to identify the key project risks, assess the probability and impact of the risks, qualitatively, for each model, and prepare the project team for a future quantitative risk assessment to be done as part of the value for money assessment. Approximately 50 different project risks were considered, with the workshop panel providing a consensus view on the probability of each risk occurring, and the impact if it occurred. From this data, a total project risk score was calculated for each delivery model. The total risk scores provide a basis for comparing the overall risk profiles of the delivery models. The higher the total risk score, the higher the overall project risk score profile. Plotted on a continuum, the results were as follows:

Figure 3.5: Results of Qualitative Risk Assessment - Total Risk Scores

Based on this analysis, it was foreseen that DBB (Design-Bid-Build) presents the highest overall project risk, and DBFOM the lowest. The risk profile is different for each delivery model because of the different allocation of responsibilities and risks between the city and the contractor, as defined in typical contract documentation.

c) A multi-criteria analysis to qualitatively assess the delivery models on a number of weighted criteria derived from project objectives and constraints. The qualitative assessment of the delivery models was conducted using a weighted-criteria technique where the assessment criteria were developed based on previous experiences.

Each procurement model was assessed against twenty-one criteria on a comparative basis relative to the baseline DBB model. The results indicated that all of the alternative models are believed to address the criteria better than DBB, with DBFOM having the greatest benefit. The general scoring outcome showed that the more that a delivery model allows the transfer of project responsibility and risk to a contractor, the better it meets the City's criteria. However, it is noted that despite their overall high scores, the two PPP models (DBFOM, DBOM) scored lower than DBB in the risks associated with the "social" category due to potential public concern with the transfer of WWTP operating responsibility. The report suggested that the concern is not on the transfer itself (i.e. the ability to undertake or the effectiveness of the transfer), but rather a potential reduction in public support for the project if delivered as a PPP.

3. **Value for Money Assessment:** This stage could be considered as an extension to the strategic assessment as it includes quantification of project risks and a preliminary comparison of the relative cost of traditional procurement and PPP procurement through cash flow modeling. In completion of the risk workshop that formed part of the strategic assessment, the risk costs for the projects were estimated to develop an estimate of the risk that is retained by the city, and transferred to the contractor, in each model. The ten largest risks quantified for the DBB were as follows:

Table 3.2: Ten Largest Quantified Project Risks

Risk	**Description**
Resource Capacity	City is not able to adequately support the procurement
Facility Design	Design contains errors or omissions that are not discovered until the construction period, i.e. contractor-initiated change order risks
Major maintenance / rehabilitation	Major maintenance is deferred
Staffing	Unable to recruit and retain qualified WWTP operating staff
Delay by Owner (City)	Facility not constructed on time due to City-induced delays
Unknown condition of existing assets	There are unknown defects in the existing WWTP components that are intended to be reused
Construction - Operation coordination	Risk associated with operating the WWTP during the construction of the upgrade/expansion
Early Expansion	WWTP capacity needs to expand sooner than anticipated
Scope of changes during construction	Changes to the design are demanded by the operator (City in the case of DBB) during construction
Construction delay	Facility not constructed on time for all reasons other than City-induced delay

The estimated cost of each quantified risk takes the form of a risk distribution with a range of possible outcomes ranging from best case to worst case. To add the risks together into an estimate of total project risk, a Monte Carlo simulation is used. Figure 3.6 presents the total estimated project risk cost distribution (as NPV) for each delivery model. The figure illustrates, for example, that the estimated NPV risk cost for the DBB delivery model (in red) could be as low as $33.6 million and as high as $91.2 million. The figure also illustrates the two alternative models are expected to reduce the total project risk, since their distribution are to the left of the DBB distribution. The risk cost distribution is tallest and narrowest for DBFOM, meaning the total risk costs are more predictable than the wider distributions.

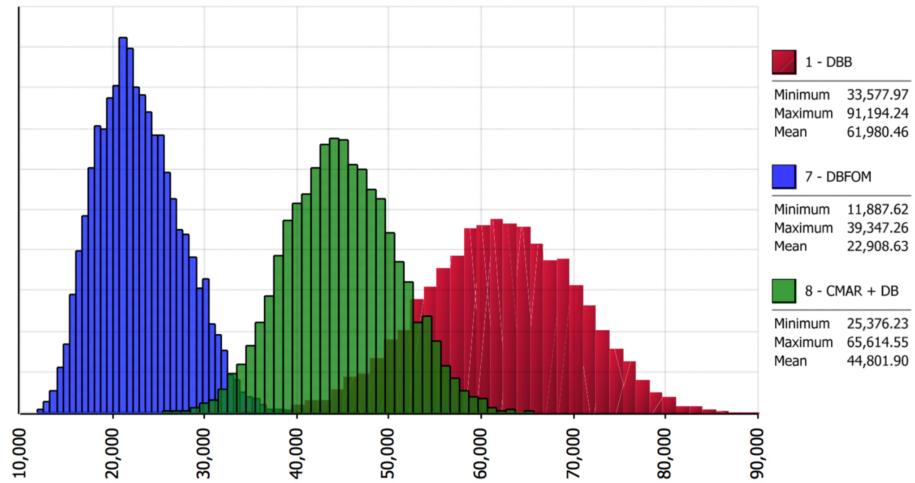


Figure 3.6: Total Project Risk Costs for Each Delivery Model (NPV, $thousands)

The cost estimates and risk cost estimates are added together to arrive at the estimated risk-adjusted net present value cost for each delivery model as noted in Table 3.3.

Table 3.3: Preliminary Value for Money Estimates (NPV, $thousands)

	DBB	**CMAR + DB**	**DBFOM**
Total Project Base Cost	452,872	434,059	460,174
Retained Risk	60,905	43,087	12,686
Risk Premium	767	1,198	6,369
Total Risk - Adjusted Project Risk	514,545	478,344	479,228
"Project VFM"		7.0%	6.9%

Echoing the strategic assessment, both alternative models (DBFOM and CMAR + DB) showed benefit over DBB.

The VFM from the City's perspective, however, does take a PPP Canada contribution into account. The contribution at 25% of eligible costs as defined by PPP Canada is estimated to be $51.2 million at the time of construction completion, or $44.3 million in net present value terms. Table 3.4 presents the VFM from the City's perspective considering PPP Canada contribution.

Table 3.4: *Impact of PPP Canada Contribution on VFM (NPV, $thousands)*

	DBB	CMAR + DB	DBFOM
Total Project Base Cost	452,872	434,059	460,174
Retained Risk	60,905	43,087	12,686
Risk Premium	767	1,198	6,369
Total Risk - Adjusted Project Risk	514,545	478,344	479,228
PPP Canada Grant			44,307
Total Cost Net of PPP Canada Grant	514,545	478,344	434,921
"VFM from City's prospective"		7.0%	15.5%

The VFM is illustrated visually on Figure 3.7. As noted in the figure, both alternative models (DBFOM and CMAR + DB) showed benefit over DBB, because their cost distributions are positioned to the left of DBB along the cost axis. The results in the form of risk distributions illustrate the possible range of project cost outcomes, from the best case through to the worst-case outcome. The relative cost-certainty of the models is illustrated, with narrow distributions being more cost-certain.

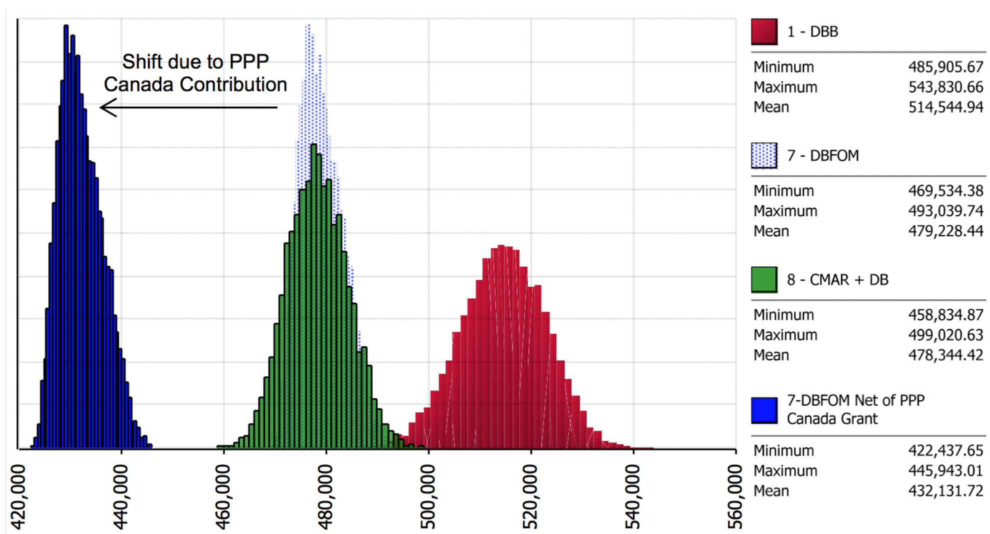


Figure 3.7: Total Risk-Adjusted Project Cost Estimates (NPV, $thousands)

The VFM from the City's perspective, taking the PPP Canada contribution into account, is highest for DBFOM. The impact of the PPP Canada contribution is referred to by PPP

Canada as the "incrementally" of the grant. The chart below illustrates the VFM of the DBFOM model.

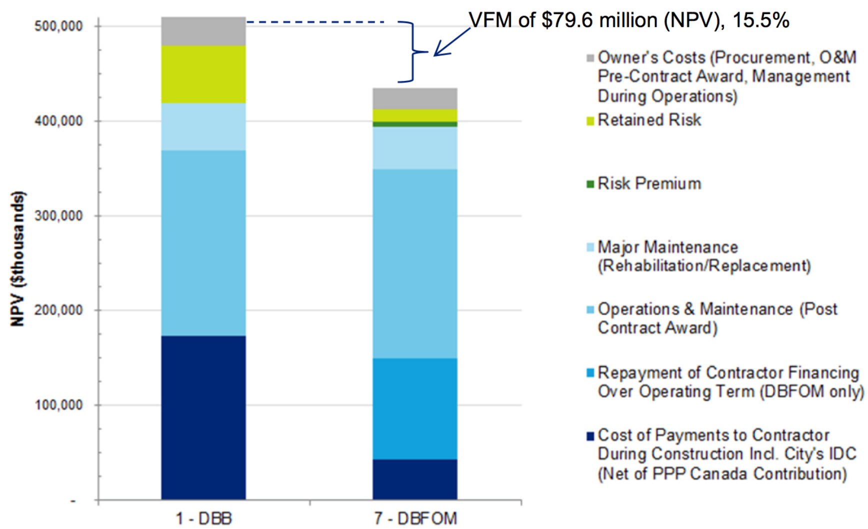


Figure 3.8: VFM From City's Perspective for DBFOM Model (Expected Value of Risk)

3.6 Critical Review of Literature

- **Scarcity of Water PPP Studies:** Research specific to water infrastructure is generally rare. Ameyaw and Chan (2015) noted that some of the water sector-specific studies are relatively dated. This is particularly significant given the large drop in the number of water PPP projects post 2008, where research work addressing this fact was not identified throughout the literature review process.

- **Generic rather than specific list of risks:** Cheung and Chan (2011) compared the risk factors across transportation, water/wastewater, and power PPPs in China. The study concluded that the critical risk factors that are frequently encountered in water/wastewater projects differ from those of the other two infrastructure projects. However, the literature review showed that research identification has typically adopted a generic set of risks without giving consideration to the special features of water projects.

  In industry, the situation is not any better as specifically noted in the case of Infrastructure Ontario hiring a consultant for generating a general risk matrix to facilitate establishing the VFM analysis of future PPP Projects (Infrastructure Ontario, Build Finance Risk Analysis and Risk Matrix, dated 2007). While this list was meant as a starting point, it is still advisable to generate sector-specific lists adopting benchmark values for an improved risk assessment.

- **Subjectivity in risk identification:** In research work, most of the risk lists were based on limited survey samples. Most of the conducted studies addressed China projects because of its active role using PPP to develop its water infrastructure. The results of such results may not be applicable in other geographical areas.

  In Industry, the risk identification exercise is based on the input of the technical consultant hired to conduct the VFM analysis through a risk workshop. This makes the analysis highly subjective as presented earlier in this chapter under the "Assessment of Wastewater Treatment Plant Expansion & Upgrade Project" conducted by the City of Regina, Canada. The use of previous experiences to achieve benchmarking values of risks across a wider scale of experts is necessary for an improved risk assessment.

- **Risk Assessment:** Methods for the assessment of the significance of the risks, researchers have gone from fairly simple qualitative to implementing sophisticated techniques while industry, for clear practical reasons, has adopted simple semi-quantitative techniques. The consideration of more advanced semi-quantitative techniques, like Analytical Hierarchy Process, which is simple to use and considers interdependency between the risk elements, may encourage industry to utilize the same technique given its practicality for industrial applications, which would allow for a far-improved evaluation of risks.

3.7 Summary

This chapter is intended to provide a review of risk assessment in PPP with particular focus on water infrastructure.

The chapter introduced the concept of risk management in PPP. A fundamental principle is that risks should be allocated to the party that is best able to manage the risk in a cost-effective manner. The researchers considered that risk allocation in PPP projects is fundamentally different to that in traditional projects as the latter include finance and operational risks to the private party. In that respect, several procedures have been recommended for the successful negotiation of risk allocation.

The chapter also studied the risk assessment in PPP, where a systematic process of risk management can be divided into risk identification, risk evaluation and risk response, where risk response can be further divided into four actions (retention, reduction, transfer and avoidance). The review of literature showed that risk identification has been undertaken through various methods, simply through the review of previous literature, or by using pre-determined existing lists, or through case studies, or through questionnaire survey, which have been the most common method. In some cases, a mix between the above methods has been considered. Risks are evaluated through qualitative, semi-quantitative, or quantitative methods.

The review of literature showed that some researchers categorized risks broadly into general groups (i.e. internal and external) while other researchers classified risks in more details: political risks, financial risks, market risks, intellectual property risks, safety risks, etc. Some research work was concentrated on certain categories of risk like the research conducted on political, financial, commercial, social, and design and construction risks.

Specific to risk assessment of water PPP projects, the amount of research work was found to be limited. The industry practice typically incorporates risk assessment as part of the value-for-money analysis. In order for a governmental agency to proceed with a PPP project, a positive "value-for-money" assessment should be proved. The study of a "real-case" assessment of a potential new project showed that the "value-for-money" stage comes after conducting a "Screening Assessment**"** to determine the potential suitability of the project for PPP delivery, and also after a "Strategic Assessment" which examines not just PPP models, but also all models under consideration.

The critical review of literature indicated the need for additional scope-specific studies on water infrastructure where water-specific risks should be considered rather than depending on generic lists or earlier PPP studies. This observation is also applicable to industry where generic risk lists are generally implemented for the assessment of any type of PPP project. The critical review also commented on the subjectivity involved in risk identification given the limited sampling typically used in research and industry applications.

For risk evaluation, the critical review showed that research works mostly varied between adopting simple to complex techniques. The researcher is of the point of view that adopting advanced semi-quantitative techniques, that consider the inter-dependency between the various risk elements, may offer a common platform between research and industry allowing for an opportunity to close the gap and develop benchmark values for risks for the future reference of practitioners and researchers.

In chapter two, the limited, unsubstantiated evaluation of private involvement in the water sector was noted. In chapter three, the review of research work and industry practice showed the absence of an advanced risk modelling methodology of water PPP. Considering the research questions evolved in Chapter 2 and 3, the next chapter will discuss the research methodology adopted for the research. It will involve the systematic approach procedures upon which the research is based, the data is collected and interpreted, and the findings are evaluated.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Introduction

Ontology is concerned with the assumptions in conceptual reality and the question of existence apart from specific objects and events (Fellows and Liu, 2008). It answers the question 'what is'? e.g. the ontological argument regarding the existence of God. ***Epistemology*** is the branch of philosophy that is concerned with the presence of knowledge. Epistemology indicates that we know about something occurring because of the knowledge that we have about it. It answers the questions that begin in 'how' or 'what'?

Remenyi *et al.* (1998) notes that for an appropriate research design, researchers must consider to which research community they believe they belong. Recognizing the different views of ontological and epistemological philosophy can help to get the research work into perspective and ensure that it avoids making unsuitable claims for its results, overestimating what research can achieve by way of truth, certainty, and universality (Thomas, 2004).

In chapter two, the limited, unsubstantiated evaluation of private involvement in the water sector was noted. In chapter three, the review of research work and industry practice showed the absence of an advanced risk modelling methodology for water PPP, which is particularly significant given the heated debate over water PPP and the severe drop of Water PPP projects since 2008, which implies the risky nature of water PPP. This chapter discusses the research methodology adopted for the research. It involves the systematic approach procedures upon which the research is based, the data is collected and interpreted, and the findings are evaluated.

4.2 Research Paradigms

Burrell and Morgan (1979) discussing philosophical paradigms identified two ontological assumptions: ***nominalism* and *realism***, and two epistemological assumptions; ***subjectivism* and *objectivism***. Nominalism assumes that social reality is relative and that we see reality as a projecting of our minds and consciousness whereas in realism, ontological reality is separate from the individual perception of it and is independent of the human consciousness. The epistemology view of objectivism is that a scientific method is the best approach to uncovering the processes by which both physical and human events occur. Subjectivism, as described by Cohen and Manion (2013), is a theoretical point of view that advocates the study of direct experience taken at face value; and one which sees behaviour as determined by the phenomena of experience rather than by external objective and physically described reality. Combinations between estipemological and ontological positions was identified by Johnson *et al.* (1984) between all possible ways of integrating ontology and epistemology assumptions as presented in Table 4.1 below.

Table 4.1: Research Design Paradigms
Johnson et al. (1984)

Paradigm	Ontology	Epistemology
Positivism	Realist	Objectivist
Interpretivism	Nominalist	Subjectivist
Empiricism	Realist	Subjectivist
Rationalism	Nominalist	Objectivist

As shown on Table 4.1 above, the combination of objectivism and subjectivism with the major two ontological positions, realism and nominalism, generates a four-way classification scheme. Positivism combines realist ontology with objective epistemology; Subjectivism combines nominalist ontology with subjective epistemology. Other paradigms like empiricism combine realist ontology with subjective epistemology, and rationalism combines nominalist ontology with objective epistemology.

4.3 Philosophy of Research in Construction Management and Economics

Construction management can broadly be described as the application of the principles of economics and management systems to the business and production processes of organizations that operate in the construction industry (McCaughey and Edum-Fotwe, 1999).

Naoum (1998) stated that one of the problems of reading about research techniques is the terminology, adding that writers use terms that may be incomprehensible to other people. In literature, three methodological paradigms are typically outlined in the construction management research: Positivism, Interpretivism, and pragmatic approach.

What is the appropriate paradigm for construction management research, Positivism or Interpretivism? This has been a point of debate in the construction management research, as well as in social science in general. Seymour *et al.* (1995) claimed that the research community is largely dominated by positivists (rationalists as noted in their text). Seymour *et al.* suggested that research adopting positivist paradigm would ignore people's attitudes and beliefs and only concentrate on the casual understanding of the research topic. They suggested that research in construction management should take a shift from objective reality, which is adopted by positivists into subjective experience, which is adopted by interpretivists. While Runeson (1997) points-out that scientific research is about providing results that could be assessed which is not feasible when only a normative advice is provided to practitioners. Runeson also points-out that science is always about establishing casualty, about formulating conditional statements that can be tested, and differentiate between science and metaphysics. Wing (1997) pointed-out that research in construction management is unique; it deals with humans, systems, technology, law and economics. As such, Wing suggested that the research method should be adopted so as to be appropriate to the objectives of the research and the particular stage reached since different approaches would serve different functions in the knowledge discovery process. In agreement with Wing, an opinion was presented by Raftery *et al.* (1997) that it would be dangerous to advocate that a certain research approach is superior to others. Instead, they call for a "multi-paradigm" approach to construction management research.

4.4 Research Methods

Most of the research undertaken in construction management and economics used either qualitative or quantitative methods. Qualitative methods concentrate on exploring the nature and origins of people's views on the issues being studied (Easterby-Smith *et al.*, 2001) while quantitative methods seek to gather data and to study relationships between facts (Fellows and Liu, 2008). Positivist research is typically more quantitative as positivists typically use research methods such as experiments and statistical surveys, while interpretivisits use research methods which rely more on unstructured interviews or participant observation and thus may be equated with qualitative research methods.

In literature, it was noted by Bryman (1984) that the two main philosophical paradigms (Positivism and Interpretivism) and research methods (quantitative and qualitative) are treated simultaneously and are occasionally confused. Bryman mentioned that a clear symmetry should be made between epistemological positions and associated methods of research. Bryman (1984) concluded that there is no direct relation between methodology and research method. However, it is always important that the right research method is used for the research methodology of the study. Quantitative and qualitative research methods should never be thought of as opposites but rather as right tools for performing two different kinds of jobs. Yin (2009) suggests that the determination of the most appropriate research style to adopt depends on the type of the research operation. Table 4.2 below shows the two extremes of the research paradigms.

Table 4.2: The Characteristics of Research Paradigms

Variable	Extreme 1	Extreme 2
Ontology	Realist	Nominalist
Epistemology	Objectivist	Subjectivist
Methodology	Positivist	Interpretivist
Method	Quantitative	Qualitative

Mauch and Park (2003) provided the main features of quantitative and qualitative techniques as summarized in Table 4.3.

Table 4.3: Qualitative and Quantitative Techniques

Qualitative	Quantitative
Aims to provide full and accurate descriptions of phenomena in all their complexity	Aims to reveal or establish cause-and-effect relationships in or among experiences or occurrences
Offers particular value in the process of generating new concepts or theories	Focuses more on the testing of existing theories or generalizations
Relies on deduction	Relies on induction
Attempts to discover and show the assumptions that underlie events or actions	Focuses more on testing the operation of assumptions
Deals mainly with statements and questions couched in words and with details of settings	Deals chiefly with amounts and numbers as primary data
Tends to deal with small samples and uniqueness	Encourages studying large samples and prizes representativeness
Depends on thoroughness and depth of reporting to demonstrate significance	Utilizes statistical analysis, particularly employing probabilities, to demonstrate significance

According to Carter and Fortune (2004), most of the papers published in the Association of Researchers in Construction Management (ARCOM) annual conferences held in 2000 and 2001 applied quantitative methodologies. Loosemore *et al.* (1996) reached a similar conclusion as he reviewed the papers published by Construction Management and Economics journal between 1983 and 1993. In their research, Loosemore *et al.* found that 57% of the papers were conducted using quantitative methodology, 8% using qualitative methodology, 13% using mixed methodology, and 22% of the papers were discussion papers.

4.5 Research Strategy

Table 4.4 shows the five major research strategies (experiments, surveys, archival analysis, histories and case studies) developed to determine when to use each research strategy (Yin, 2009). The table also shows the three conditions relevant to each research strategy as follows: (a) the type of research questions, (b) the degree of control of the researcher over actual behaviour or events; and (c) the degree of focus on contemporary as opposed to historical events.

Table 4.4: Matching of Research Question Type and Research Strategy

Strategy	Form of Research Question	Is Control of behaviour required?	Is there focus on contemporary events?
Experiment	How, Why?	No	Yes
Survey	Who, What, Where. How many, How much?	No	Yes
Archival Analysis	Who, What, Where, How many, How much?	No	Yes/No
History	How, Why?	No	No
Case study	What, How, Why?	No	Yes

Source: adopted from Yin (2009)

4.6 Research Questions

The key research questions in the introductory chapter 1 of this research and issues regarding risk in water PPP discussed in the literature review (Chapter 2 and 3) are summarized in Table 4.5. The deductive reasoning column explains the discussion about what issues have been resolved and those remaining unresolved. The research gaps column indicates the unresolved issues and the corresponding research actions, which are then converted into the research questions in order to arrive to a solution.

Table 4.5: Research Questions

Issues learnt from literature	The deductive reasoning	Research gaps	Research Question(s)
1- Is PPP ***suitable for the Water sector,*** given its specific risky nature?	As noted in Chapter 1 and 2, the heated debate over water PPP projects between opponents and proponents of water privatization is far from being settled. Most of the debate has been centered on the relative merits of the public and private sector in managing large-scale water-supply networks.	Unbiased research is rare; an examination of comparative performance between public and private operation of water assets is often influenced by ideological commitments. It is thus somewhat predictable that proponents and opponents of water privatization rarely agree on research strategies of risk assessment.	• How can risk interrelations of water PPP projects be modelled?
2- After years of experience, are we now able to clearly identify the ***risks associated with water projects***?	The following items were noted in Chapter 3: • **Scarcity of Water PPP Studies:** Research specific to water infrastructure is generally rare. Ameyaw and Chan (2015) noted that some of the water sector-specific studies are relatively dated. This is particularly significant given the large drop in the number of water PPP projects post 2008, where research work addressing this fact was not identified throughout the literature review process.	• Water-specific studies are rare • Water-specific risks are not clearly identified in research	• What are the water-specific risks? • How to establish benchmarked values for risks associated with water PPP?

Issues learnt from literature	The deductive reasoning	Research gaps	Research Question(s)
	• **Generic rather than specific list of risks:** Cheung and Chan (2011) compared the risk factors across transportation, water/wastewater, and power PPPs in China. The study concluded that the critical risk factors that are frequently encountered in water/wastewater projects differ from those of the other two infrastructure projects. However, the literature review showed that research identification has typically adopted a generic set of risks without giving consideration to the special features of water projects. In industry, the situation is not any better as specifically noted in the case of Infrastructure Ontario hiring a consultant for generating a general risk matrix to facilitate establishing the VFM analysis of future PPP Projects (Infrastructure Ontario, Build Finance Risk Analysis and Risk Matrix, dated 2007). While this list was meant as a starting point, it is still advisable to generate sector-specific lists adopting benchmark values for an improved risk assessment. • **Subjectivity in risk identification:** In research work, most of the risk lists have been obtained based on limited survey samples. Most of the conducted studies	• Risk checklists are typically based on subjective opinions obtained during workshops with no benchmarked values.	

Issues learnt from literature	The deductive reasoning	Research gaps	Research Question(s)
	addressed China projects because of its active role using PPP to develop its water infrastructure. The results of such results may not be applicable in other geographical areas. In Industry, the risk identification exercise is based on the input of the technical consultant hired to conduct the VFM analysis through a risk workshop. This makes the analysis highly subjective as presented earlier under the "Assessment of Wastewater Treatment Plant Expansion & Upgrade Project" conducted by the City of Regina, Canada. The use of previous experiences to achieve benchmarking values of risks across a wider scale of experts is necessary for an improved risk assessment.		
3- The percentage of cancelled projects in Water PPP projects is higher in comparison to other utility sectors. What makes the water sector that risky?	Same like point 2 above	Same like point 2 above	• What are the main causes of Water PPP Projects' cancellation?

Issues learnt from literature	The deductive reasoning	Research gaps	Research Question(s)
4- Problems with water PPP, could it be the methodology used for risk evaluation?	For the assessment of the significance of the risks, researchers have gone from fairly simple qualitative techniques to implementing sophisticated techniques. Industry, for clear practical reasons, adopted simple qualitative techniques. The consideration of advanced semi-quantitative techniques may encourage industry to utilize the same technique given its practicality for application, which would allow for more benchmarked data, and in turn improved evaluation of risks.	There is very limited research done in developing semi-quantitative techniques that may allow researchers and industry experts to share their experiences.	• How can the risks associated with water PPP project be prioritized, through an improved risk assessment model?

4.7 Research Strategy for Each Research Question

Research Questions One and Two	What are the water-specific risks? What are the main causes of Water PPP Projects' cancellation?
Research strategy	Archival Analysis
Rationales	This is a "What" question to explore the risks associated with water PPP, and those risk events that led to the cancellation of previous PPP projects. Current studies are general (i.e. not specific to water), and where exist, are generally influenced by ideological commitments. As indicated in Table 4.4, the archival analysis is the preferred research method. A literature review was conducted to collect data from previous empirical studies and research work in order or explore and interpret recognized risk events that affect water PPP projects. The researcher will identify a set of risks affecting water PPP projects The research will also study the historical records of water PPP cancelled projects.
Research Question Three	How can risk interrelations of water PPP projects be modelled?
Research strategy	History "Literature Review"
Rationales	This is a "How" question to explore an improved model for the assessment of water PPP projects. The researcher aimed to conduct a literature review to answer this question. A literature review was conducted on PPP risk management, exploring how the concept is being adopted, available methods used for risk evaluation, in research and industry practice. The researcher concluded that with a good handle of water-specific risks along with adopting advanced semi-quantitative risk evaluation techniques, an improved risk assessment methodology for the water sector could be developed.

Research Questions Four and Five	How can the risks associated with water PPP project be prioritized, through an improved risk assessment model? How to establish benchmarked values for risks associated with Water PPP?
Research strategy	Questionnaire survey with statistical analysis
Rationales	These are "How much" questions to measure the phenomenon of qualitative risk effects on water PPP projects. Quantifying qualitative risk effects is dependent on the subject belief, perception, experience, judgement and predication of the experts who are experienced in the selected project cases and practitioners in water PPP projects. According to Table 4.4, questionnaire survey is the preferred research strategy. The experts' opinions are to be collected using the score of a Linkert scale 1 to 5 for ranking risks quantitatively. The researcher proposes the use of the Analytic Network Process (ANP) for the prioritization of the identified risk elements. The ANP is capable to handle the inter-dependency between the identified risk elements, which would offer an improved risk assessment methodology. A suitable sample of results obtained from the questionnaire would assist in establishing benchmarked values, which can be further enhanced with the increased use of the model among research and industry practitioners.

4.8 Selected Research Methods

4.8.1 Questionnaire Survey

Questionnaire survey was selected as the method of collecting data. The questionnaire is the broadest study, while case study is the deepest study, and interview is between them in the context of depth and breadth. The questionnaire is one of the most frequently used methods of data collection in exploration and evaluation research (Propper, 1989; Fellows and Liu, 2008; Clarke and Dawson, 1999). Tiong (1993) mentioned that many objectives have been achieved at PhD thesis level through questionnaire survey. Li (2003) stated several advantages for questionnaire survey over other research methods:

- It is capable of producing large quantities of highly structural data
- Large access to a lot of people
- It can be anonymous which make the responses honest
- Provides the responders with time to response which improved the quality of the results
- Allows for obtaining large answers from responders compared to interviews
- Eliminates possible bias of the interviewer
- Less costly compared to other similar methods
- Reduces the errors that may occur from the variability of the skills of the interviewers.

However, there are some risks associated with questionnaires like the possible lack of response and inability to check the responses (Robson, 1993).

4.8.2 The Analytical Network Process (ANP)

The review of the different risk analysis methods showed that the use of Analytic Network Process (ANP) would overcome the shortcomings observed in typical risk analysis methods, since the ANP is capable in handling the inter-dependencies between the various risk elements, a feature that is absent in other risk methods. Besides, it is easy to understand and apply, which makes it practical for the use in industry practice.

The Analytic Network Process is an extension of the Analytic Hierarchical Process (AHP), which was proposed by Saaty (1996). Unlike the AHP, where decision problems are formed in hierarchy, in ANP, hierarchical structures are formed as a multi-dimensional problem, which is arranged in at least three levels: Goal, Criteria, and Options. This arrangement exhibits a network structure that showcases different relationships in a decision problem. It allows the consideration of the interdependency between the various elements in a decision problem, which in turn allow for a better modelling of complex problems since the majority of real-life problems are non-linear, while the feedback link offers a precise determination of the priority of elements and a higher quality decision-making (Hsu and Kuo, 2011).

The Analytic Network Process has its place in the group of multi-criteria decision making (MCDM) methods when an extensive number of factors are involved (Boateng *et al*., 2015; Chemweno *et al*., 2015). The application of ANP in risks prioritization and modelling in megaprojects has been previously presented in Boateng (2014) and Chen et al. (2011).

4.8.2.1 ANP Network Model Construction

In this step, the water-specific PPP risks are to be structured to form the ANP model. As Figure 4.1 illustrates, the ANP network model is formed consisting of three clusters: 'Goal', 'Criteria', and 'Options'. Cluster 'Goal' contains only one element, which is "Risk Prioritization". Cluster 'Criteria' contains only one element, which is the "Impact on Cost" to the project, if the risk occurs. The cluster 'Options' contains the potential Water-Specific PPP Risk categories and their relevant elements. A detailed explanation of these risk categories considered under the "Options" cluster is discussed in Chapter 5. Finally, the outcome of the model showing the prioritization of the Water-Specific PPP Risks' priorities will fall under the "Potential High Risk Ranking".

The arrows in the model indicate the relationships between each element in the model, which shows how the model allows dependencies in the "Options" cluster showing dependencies for both; within each risk category (inner dependence), and between every two risk categories (outer dependence) so that elements at each level can be defined together with their relationships with other elements in the model (Saaty, 2000; Saaty and Vargas, 2012).

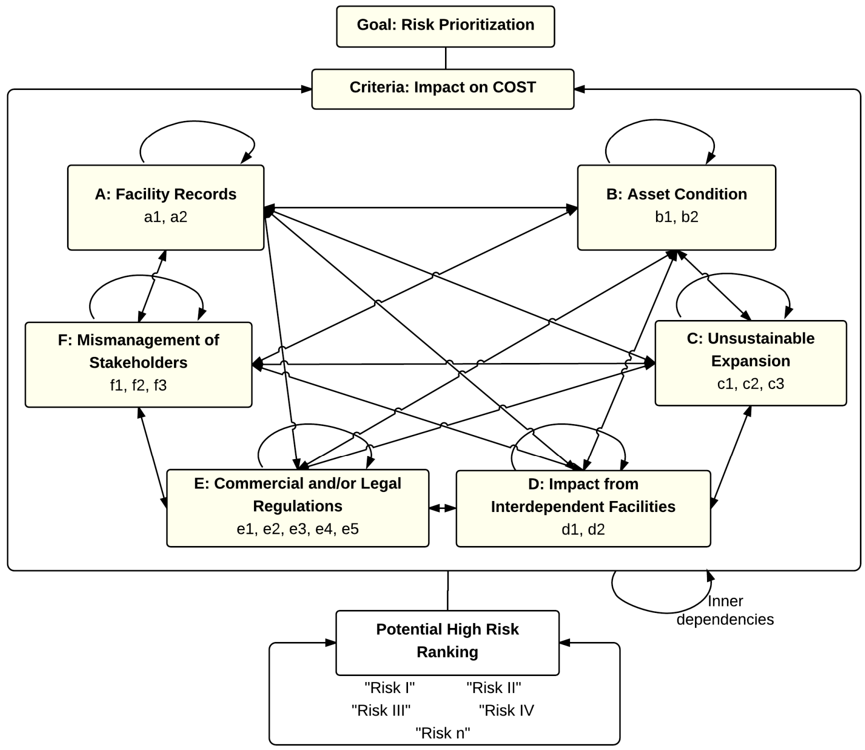


Figure 4.1: ANP Network Model for Risk Prioritization

4.8.2.2 Paired Comparisons

In a subsequent stage, pairwise comparisons between risk categories/elements are developed with respect to their relative importance to the Control Criteria: “Impact on Cost” to the project, if the risk occurs.

Typically, the correlation matrices are prepared on a 1-9 ratio scale to determine the relative preferences between every two elements of the hierarchy. A score of 1 indicates that the two elements have equal importance whereas a score of 9 indicates dominance of the component under consideration over the comparison component.

In some cases, for practical reasons, the respondent to the associated questionnaire survey is only requested to provide the assessment for the significance of each element with respect to the control criteria, instead of seeking the relation between every two risk elements with respect to the control criteria. In such case, the obtained data is transformed to reflect the target “Pairwise Comparison” between every two elements in the questionnaire survey. Such practical approach was followed in this research adopting the proposed scale presented in Table 4.6, where the obtained responses to the questionnaire survey were included under the "Comparisons of pair indicator scores" and resulted in developing the "Scales of pairwise judgement" that were considered in the ANP model.

Table 4.6: Fundamental Scale of Pairwise Judgment and Pair wiser Criteria

Scales of pairwise judgment	Comparisons of pair indicator scores
1= equal	1:1
2= equally to moderately dominant	2:1, 3:2, 4:3, 5:4, 6:5, 7:6, 8:7, 9:8
3= moderately dominant	3:1, 4:2, 5:3, 6:4, 7:5, 8:6, 9:7
4= moderately to strongly dominant	4:1, 5:2, 6:3, 7:4, 8:5, 9:6
5= strongly dominant	5:1, 6:2, 7:3, 8:4, 9:5
6= strongly to very strongly dominant	6:1, 7:2, 8:3, 9:4
7= very strongly dominant	7:1, 8:2, 9:3
8= very strongly to extremely dominant	8:1, 9:2
9= Extremely dominant	9:1

The results of each category are established similar to the comparison matrix described in Equation (1), where PR is the potential risks and R_{ij}, the comparison between risk variables i and j. If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i. The results of the comparisons are represented by dimensionless quotients to measure the preference of one element over the other.

$$PR = \begin{vmatrix} 1 & R_{12} & \cdots & R_{1n} \\ 1/R_{12} & 1 & R_{ij} & R_{2n} \\ \vdots & R_{ji=1}/R_{ij} & \ddots & \vdots \\ 1/R_{1n} & 1/R_{2n} & \cdots & 1 \end{vmatrix} \quad (1)$$

Once the pairwise comparison is completed, the vector corresponding to the maximum eigenvalue of the constructed matrices is computed and a priority vector is obtained. The priority value of the concerned element is found by normalizing this vector as described in equation 2.

$$\sum_{j=1}^{n} R_{ij} w_i = \lambda_{max} w_i \qquad (2)$$

By substitution, the maximum eigenvalue (λ_{max}) is calculated to derive a new matrix (W) by multiplying comparison matrix (R) with (W_i). Finally, the (λ_{max}) can be obtained by averaging the value. Computations of the process are listed in Equation (3) and Equation (4) respectively.

$$\begin{vmatrix} 1 & R_{12} & \cdots & R_{1n} \\ 1/R_{12} & 1 & R_{23} & R_{2n} \\ \vdots & 1/R_{23} & \ddots & \vdots \\ 1/R_{1n} & 1/R_{2n} & \cdots & 1 \end{vmatrix} \text{x} \begin{vmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{vmatrix} = \begin{vmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{vmatrix} \qquad (3)$$

$$\lambda_{max} = \frac{1}{n}\left(\frac{W_1}{w_1} + \frac{W_2}{w_2} + \dots\dots + \frac{W_n}{w_n}\right) \qquad (4)$$

The consistency ratio provides a numerical assessment. If the calculated ratio is less than 0.10, consistency is considered to be satisfactory. The conceptual model is then imported into the ANP software, *Super Decisions* (developed by Adams, W.J. and Satty, R.W.) for the pairwise comparison matrices to be solved.

4.8.2.3 Super Matrix Calculation

By developing the super matrix, the ANP captures the outcome of dependence and feedback within and between the risk categories and elements.

There are three super-matrices: unweighted super matrix, weighted super matrix and the limit super matrix associated with the network.

- The unweighted super matrix contains the local priorities derived from the pairwise comparison throughout the network.
- The weighted super matrix is obtained by multiplying all the elements in a component of the unweighted super matrix by the corresponding weight.
- Raising the weighted super matrix to its powers derives the limit super matrix and the multiplication process is discontinued when the number becomes the same for all columns.

The three steps aim to form a synthesised super matrix to allow for the resolution of the effects of the interdependences that exists between the elements of the ANP model. The general form of the super matrix is described below.

Table 4.7: Formation of Super Matrix and its Sub-Matrix

Super Matrix	**Sub-Matrix**
$\boldsymbol{W} = \begin{bmatrix} W_{11} & W_{12} & W_{13} & \text{---} & W_{1n} \\ W_{21} & W_{22} & W_{23} & \text{---} & W_{2n} \\ W_{31} & W_{32} & W_{33} & \text{---} & W_{3n} \\ W_{41} & W_{42} & W_{43} & \text{---} & W_{4n} \\ W_{51} & W_{52} & W_{53} & \text{---} & W_{5n} \end{bmatrix}$ ***Cluster:*** C_1 C_2 C_3 --- C_n ***Node:*** $N_{1(1\sim n)}$ $N_{2(1\sim n)}$ $N_{3(1\sim n)}$ --- $N_{n(1\sim n)}$	$W_{I,J} = \begin{bmatrix} W_1 l_{I,J} & \dots & W_1 l_{I,J} \\ W_1 l_{I,J} & \dots & W_1 l_{I,J} \\ \dots & \dots & \dots \\ W_i l_{I,J} & \dots & W_i l_{I,J} \\ \dots & \dots & \dots \\ W n_{I1} l_{I,J} & \dots & W n_{I1} l_{I,J} \end{bmatrix}$

Note: *I* is the index number of rows; and *J* is the index number of columns; both *I* and *J* correspond to the number of cluster and their nodes [*I, J* ϵ (1,2, …, m)], N_I is the total number of nodes in cluster *I*, n is the total number of columns in cluster *I*. Thus an *m* x *m* matrix is formed.

Where C_n denotes the N^{th} cluster, N_n (1~n) denotes the n^{th} element in the n^{th} cluster, and W_{ij} is a block matrix consisting of priority weight vectors (W) of the influence of the elements in the i^{th} cluster with respect to the j^{th} cluster. If the i^{th} cluster has no influence to the i^{th} cluster itself (a case of inner dependence), W_{ij} becomes zero. The super matrix obtained in this step is called the initial super matrix. The eigenvector obtained from cluster level comparison with respect to the control criteria is applied to the initial super matrix as cluster weight. This result is the weighted matrix.

4.8.2.4 Risk Priority Index (RPI) Calculation

This step aims to calculate the risk priority indices (RPIs) to support final decision-making. Although the RPI can be performed manually with equation 5, it was performed using the *Super Decisions* software in this study. Computation priorities command was used to determine the priorities of all the nodes in the network.

$$RPI_i = \sum_i W_{(C,T,Q)} * R_{ij} \qquad (5)$$

Where:

'RPIi' represents the global priority of the risk options i,

'W,' the weight of the criteria j with respect to project cost, time and quality, and 'Rij', the local priority

After computation, the RPIs can further be classified into five states of likelihood and consequence on project cost and assessed as either "very high", "high", "moderate", "low" or "very low".

- Very High and High Risk Events

High risk events can be so classified either because they have a very high likelihood of occurrence coupled with at least a high impact or they have a high impact with at least moderate likelihood. In either case, specific direct management action is warranted to reduce the probability of occurrence or the risk's negative impact.

- Moderate Risk Events

Moderate risk events can either be high-likelihood, low consequence events or low-likelihood, high-consequence events. An individual high-likelihood, low-consequence event by itself would have little impact on project cost. However, the combined effect of numerous high-likelihood, low consequence risks can significantly alter project outcomes.

Commonly, risk management procedures accommodate this high-likelihood, low-consequence risks by determining their combined effect and developing cost and/or schedule and quality contingency allowances to manage their influence. Low-likelihood and high-consequence events, on the other hand, warrant individualized attention and management. At a minimum, low-likelihood and high consequence events should be periodically monitored for changes either in their probability of occurrence or in their potential impacts. Some events with very large, albeit unlikely, impacts may be actively managed to mitigate the negative consequences should the unlikely event occur.

- Low and Very Low Risk Events

Risks that are characterized as low and very low can usually be disregarded and eliminated from further assessment. As risk is periodically reassessed in the future, these low/very low risks are closed, retained, or elevated to a higher risk category. Although, there is no standard for estimating risk probability value, the study uses a likelihood ratings proposed by Cooper (2005) as shown in Table 4.8.

Table 4.8: Likelihood Rating

Rating	**Likelihood description**
Almost certain	Very high, occurs frequently
Likely	High, (has before, will again)
Possible	Possible, but not common
Unlikely	Not possible (unlikely to occur)
Rare	Very low (very unlikely to occur)

4.9 Summary

The literature review in Chapters 2 and 3, studied water PPP, and risk assessment in water PPP, in research as well as in industry practice. This chapter established the research methodology adopted for the research, introducing the systematic approach procedures upon which the research is based, the data is collected and interpreted, and the findings are evaluated.

The chapter started by presenting the research paradigms introducing the ontological and epistemological extremes and their current application in construction management and economics. With respect to research methods, this chapter presented the difference between qualitative and quantitative methods. In qualitative methods, the concentration is in exploring the nature and origins of people's views on the issues being studied (Easterby-Smith *et al*., 2001) wile quantitative methods seek to gather data and to study relationships between facts (Fellows and Liu, 2008). Positivist research is typically more quantitative as positivists typically use research methods such as experiments and statistical surveys, while interpretivisits use research methods which rely more on unstructured interviews or participant observation and thus may be equated with qualitative research methods.

With respect to research strategies, this chapter presented the five main research strategies: Experiment, Survey, Archival Analysis, History, and Case study.

The chapter showed the development of the key research questions through the deductive reasoning of the issues noted through literature review, and the noted research gaps and the corresponding research actions, which are then converted into the research questions in order to arrive at a solution. The chapter presented the selected research strategy for each research question.

The chapter concludes with presenting the selected research methods: Questionnaire survey and Analytical Hierarchy Process, which will be utilized as the research methods in Chapter 5 and 6, respectively.

CHAPTER 5: WATER–SPECIFIC PPP RISKS

5.1 Introduction

Following the presentation of the research methodology in Chapter 4, this chapter presents the Water-Specific PPP Risks identified through a broad survey of literature that included empirical studies and official publications, covering journal articles, conference papers, research reports, text books, commercial or organizational documents, governments practice guidance, records, reports, and the like.

This chapter also presents the setup of the questionnaire survey, the background of the respondents, and the analysis of the questionnaire survey results and concludes with presenting the mean values of severity for the identified set of risks. Such results will be subsequently used for the development of the ANP network model in Chapter 6.

5.2 Identification of Risks associated with Water Public-Private Partnerships

The risks associated with water PPP were identified through an extensive literature review which included the coverage of available publications including technical papers, technical and commercial reports, World Bank water sector reports, press releases and relevant news information. A list of these identified risks, which were presented in an earlier publication (Korayem *et al.,* 2015), are summarized in *Table 5.1* along with the main references in literature, at which these risks were presented and discussed. A detailed description of each of the identified risks is presented in Section 5.3.

It is worth reminding that the risks elements considered in this research are those directly relevant to the Water PPP planning and subsequent operation and maintenance. Other potential common PPP risks covering the social, construction, political aspects of the project should also be considered for a successful PPP, however are considered beyond the scope of this research. Such demarcation should be reflected on the developed Water-Specific PPP Risk Model.

Table 5.1: Summary of Water-Specific PPP Risks Identified through Literature Review

	Hamilton, Canada	Halifax, Canada	Atlanta, USA	Mali	Gabon / Gambia / Chad	Senegal / Niger	Guainía	Chad	Cochabamba, Bolivia	Manila, Philippines	Buenos Aires, Argentine	Chile	General
Absence of maintenance records	t, u, v	i	o										a1, a7, a9
Absence of environmental data sampling records	t, u, v, d, e	f, g, h											a1, a9
Uncertainty of value of assets		i	n										a1
Uncertainty of cost of maintenance		i	n										a2, a7, a9
Potential increase in served population			k			r							a5, a1
Potential increase in usage			k										a2, a6
Increase in resources to meet environmental guidelines	c		l										a5, a4, a7, a3
Improper planning of interrelated projects					r		r		s	p			a1, a4
Uncontrolled performance of interrelated projects		f, g, h, j											a5
Overly complicated commercial model	b, x								s				a1
Tariff structure				r			r		s	q, p	p		a5, a1, a4, a3
Enforcement of right to water resources												y	a3
Significant change in current billing practice			m			r	r						a5, a2
Potential change in currency exchange rates				r	r	r	r	r		d	p		a1, a2, a3
Poor communication with stakeholders	a						r		s	q	p		a5, a1, a2
Potential disruption to current local businesses				r	r	r	r	r	s				
Underperformance of a local partner							r						

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1/2

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2/2

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5.3 Description of Identified Water-Specific Risks

A description of the water-specific PPP risks identified through the literature review is presented under this section.

5.3.1 Facility Records

The inadequate utility performance records for years in the past would prevent having meaningful comparisons between the public operator and its private successors. In Halifax, the disagreements between the public and private parties arose months after the initial agreement was signed. The private party claimed that potential problems with influent quality came to light only when the federal government issued its environmental screening report for the project. Prior to that, it relied on "out-of-date" data provided by the city and by local industry. The City of Halifax (Canada), insisted that it provided ample opportunities for testing and that it would have been reasonable for the consortium to do due diligence.

5.3.2 Asset Condition

- ***Uncertainty of Value of Assets***

Obtaining solid information about the state of existing infrastructure (i.e. underground pipes) is significant for a proper project evaluation and risk assessment of new investments. A clear identification of the asset condition is a major challenge, where the absence of records of existing systems is common. Without such information, it is difficult to establish a baseline to enable private firms to accurately bid on the work.

The most basic valuation problem in valuing assets-in-place is the use of discounted cash flow (DCF) techniques (Hertz, 1964). A common deficiency is that there is no indication of the confidence level on the determined capitalization rates (Ye and Tiong, 2000). Hertz highlighted the misleading nature of single-point estimates in investment analysis. It is important to reflect this uncertainty in model outputs to provide some assurance to the decision makers that the available information has been used with maximum efficiency (Hertz, 1964). The Asian Development Bank guidelines (1999) provide the financial evaluation methodologies recommended for water supply projects.

Absence of previous records has been a typical source of disputes in water PPP. In the case of Atlanta, where some parts of its infrastructure dates back to 1875, the private partner "Suez" complained that the initial contract, as it was signed, did not reflect the actual status of the system. The Reason Foundation explained: "Some of the blame must fall on UWSA (Public owner). All of the bidders knew about the lack or quality of data ahead of time before they bid. Furthermore, USWA has a lot of experience running old systems and it should have built that expertise into its proposal". In the case of Buenos Aires, the unexpected poor performance of the buried assets was one of the reasons that led to the project cancellation at the end. In the case of Hamilton, the municipal staff admitted that for the contractor to meet the required performance standards, the system requires investment of hundreds of millions of dollars, which does not form part of the contractor scope of work.

The assessment of infrastructure conditions by competing firms is impractical. Producing numerous feasibility studies would push up the costs of the bids and, by making the bidding process too expensive for small firms, which would reduce competition.

- ***Uncertainty of Cost of Maintenance***

Significant research has been conducted on the rehabilitation of distribution networks. The traditional strategies for rehabilitation (Ugarelli, 2008) varies between 1) Operative, 2) Inspection, Condition based, 3) Proactive; and, 4) Predictive. Numerous numbers of models were developed to assist in developing a rehabilitation strategy that reduces leakage, improved operative costs and environmental records.

Without a solid knowledge of the asset condition, as a result the lack (or incomplete) of historical breakage data of the assessment of the operation component becomes very hard, and was reported as a major source of dispute.

5.3.3 Unsustainable Expansion

It is essential that the relevant major construction projects, in particular those for water production and transmission, are well identified during the preparation stage. An early (or late) expansion of the system may cause a disturbance in the overall planning and may result in the Contractor's inability to meet the contract requirements. The following factors typically cause the need for facility upgrade and/or expansion:

- ***<u>Potential increase in served population</u>***

In Atlanta, the private partner inherited from the city a backlog of between 4,000 and 7,000 outstanding requests for service. This was accompanied with a construction boom in the service area, which created additional demands that was not accounted for during the bidding stage. Additional investment to meet the increase in demand was not envisioned during the bidding process.

- ***<u>Potential increase in usage</u>***

In some cases, the improvement of service has resulted in an increase of water usage by public while the company may not be prepared for investing on this direction. In some cases, the contract is only set for providing service. Inability to meet the stakeholders' expectations can draw major negative political implications on the project. In some other cases, preventing the use of private wells led to an unexpected increase in usage.

- ***<u>Increase in resources to meet environmental guidelines</u>***

The private operator is obliged to follow the performance criteria set in the contract. This may require replacement of inappropriate connections (which is considered as the most common source of physical leaks), which in some cases does not form part of the private sector scope of work. Also, it may have not been foreseen as a consequence of years of limited or inappropriate data collection. The timely implementation of such improvement has been a key factor in success. If not considered in the original private sector planning, the process may be delayed causing problems in the project delivery.

In some instances, the involvement of a locally experienced Contractor have helped improved the process like in the case of Côte d'Ivoire, SODECI, a governmental entity, has always been in charge of regular extensions of distribution networks which assisted when it became responsible for identifying and preparing the capital investment program.

5.3.4 Impact from Inter-dependent Facilities

A close coordination between the proposed project objectives and other inter-related projects is essential. Disruption on the program may have negative implications on the PPP project, due to one (or more) of the following factors:

- ***Improper planning of inter-related projects***

The effect of the delay in awarding (or completing) another relevant project may have a severe impact on the project in-hand. The delay may result in the contractor not being able to meet the contract specifications in terms of production or in terms of meeting the contract specified environmental regulations. The case of Manila is the most revealing, one of the reasons that led to the cancellation of the project was the government inability to complete the relevant river basin project. In the case of Atlanta, the public partner responsibility included flushing of the wastewater system. The private operator claimed that Atlanta did not perform as planned which prevented them from meeting the environmental criteria. Atlanta denied the accusation yet the city auditor confirmed that the city had indeed failed to re-invest savings in its utility by charging its water department an annual franchise fee, the city had transferred US$9.8 million a year to its general fund (Reinhardt, 2003).

A study conducted by the World Bank advises that the experience in Africa evolved to forming the so-called Public Assets-Holding Companies (AHCs). Mostly have been introduced in conjunction with the transformation of a public water supply utility into an AHC with the following main functions: (i) act as owner of the water supply assets and issue consolidated financial statements of the water operation; (ii) plan, finance, and implement major construction projects; (iii) act as owner of the affermage contract; and (iv) promote public acceptance of the reform. However, the delay in implementing extension programs by AHCs has caused in some cases major problems to the operator. In Guinea, the AHC's delays in implementing extension programs frustrated the operator, who was encouraged to seek financing for implementing its own projects which adversely impacted the operational performance. In Senegal, initial delays in implementing rehabilitation programs meant that the AHC had to compensate the operator for loss of revenues.

- ***Uncontrolled performance of inter-related projects***

In Halifax, Canada, the contract was set so that the city controls what goes into its sewer system. The city enforced a sewer-use bylaw to prevent hard-to-treat industrial pollutants from contaminating the influent but the city's regulation of discharges from some 5,000 sources will only be as effective as the monitoring and enforcement behind it with no clear identification in the contract. The latest information on the quality of influent quality was due to the inability to control over 5000 sources, which does not form part of the contractor's scope of work.

5.3.5 Commercial and/or Legal Regulations

- ***Overly complicated commercial model***

A suitable commercial model is essential for a successful delivery of the PPP project. Experience shows that the transfer of significant financing responsibilities to the private partners may create problems. This was obvious in the case of Cochabamba, Bolivia. The private investor, quickly after award, increased supplied water by 30 percent, simply through repairs and technical enhancements. However, the concession included operation of the existing water supply system and construction within two years of the US $214 million Misicuni Multipurpose Project (MMP), which used the River Misicuni for electricity generation, irrigation and water supply to the city. In order to meet these requirements, an average tariff increase of 35% was agreed upon during contractual negotiations. The government committee that negotiated the contract did not appreciate the financial implications when it insisted on the construction of the Misicuni dam, a project that was not deemed financially viable by the World Bank and international water companies. The government also insisted that the private sector sign and execute a contract for construction of a treatment plant that the consortium thought expensive and unnecessary.

In developing countries, the risk is more pronounced, as noticed in failed PPPs in Gambia and Chad, where the design of the capital budget was ill-matched with the PPP objectives (Fall *et al*., 2009). In the case of Gambia's joint power/water operation, 85 percent of the revenues were generated from the sale of electricity, but no financing was available for rehabilitating and extending the power production and distribution infrastructure, in particular to replace a generator that collapsed the day before the operator mobilized (Fall *et al*., 2009).

The World Bank recommends that the transfer of increased financing responsibilities and risks to private partners should be after consultation with key stakeholders and performing a detailed analysis of the impact on the customer tariffs and the review of the existing financial markets and water supply sector structures (Fall *et al*., 2009) where the following could be investigated: (i) splitting electricity and water operations in countries where these services are still provided by combined utilities; (ii) splitting water production and distribution in countries where cash generation and the local financial markets may not be able to finance major extensions; or where the bulk of financing for new infrastructure has been made available to governments by international and bilateral financing agencies in foreign currencies.

- ***Potential excessive increase in tariff structure***

This may have significant implications on the satisfaction of stakeholders and in turn the overall delivery of the project. In the case of Cochabamba, Bolivia, an "Increasing Blocking Tariff (IBT)" was issued to ensure that high-income households would pay around twice the amount per cubic meter for consumption above 12 m^3 than that the low-income users would pay. While the average tariff increase was 35 percent, the actual increase varied; lower-income consumers experiences increases of as little as 10 percent while higher-income consumers experienced tariff increases as high as 106 percent due to the increased tariff for their high level of consumption.

- ***Enforcement of right to water resources***

To make the project financially viable in the case of Cochabamba, Bolivia, the private sector was granted the exclusive right of water resources in Cochabamba. As a consequence, many private wells were shut down. This decision carried significant negative political implications.

- ***<u>Significant change in current billing practice</u>***

In Africa, billing to public agencies represents 15 to 25 percent of the total billing. Water bills owed by public agencies have been a constant source of conflict between private operators and governments. In Côte d'Ivoire, this has been a recurrent problem, solved only temporarily by the sector adjustment in the late 1980s. Some countries have introduced special arrangements to mitigate the associated financial risk to water utilities and protect the revenues. In some countries like Senegal and Niger, an upgrade of the internal plumbing of public buildings to limit water consumption has been introduced.

However, the improvement in billing administration has got several faces. It may lead to a reduction in consumption as a result of water rationing. However, in some cases, the opposite may occur, when the greater availability of water lead many consumers to increase their consumption, which creates increased water bills not only because of an increase in price but also because of an increase in volume.

- ***<u>Potential change in currency exchange rates</u>***

Water Projects include considerable fixed assets that are considered irreversible. This is typically accompanied with a potential risk of not fully recovering the billing accompanied with potential increase of demand as a result of increase in population, or demand. It is therefore prudent to ensure the commercial scheme has reduced the exposure to the risk of increase in exchange rates. Even in PPP where the investment program is financed by the partner government, the operator must still finance operating expenses to cover the expatriate staff and imported inputs (chemicals, spare parts, hardware, and software). These costs are in foreign currency, while the operator's revenues are in local currency only.

Financial problems plagued privatization in Buenos Aires, where a private investor won a 30-year water and wastewater concession in 1993. The private investor increased water coverage, billing collection, operating efficiency. Although it initially promised to reduce tariffs by almost 27 percent, over the years it obtained a number of price adjustments, the first because of the city's inadequate records and the unexpectedly poor condition of the water distribution network. However, the Argentine financial crisis of early 2002 wreaked havoc on the concession. The peso was "de-pegged" from the dollar and devalued, the private investor had trouble servicing its debt, most of which was denominated in U.S. dollars. When the government refused to raise prices to offset the devaluation, the consortium announced its desire to pull out of the agreement, and the matter went into arbitration (Brubaker 2003).

Guaranteed foreign exchange rate is typical where the foreign exchange risk is limited as the exchange rate to the Euro (or USD) is fixed, and the difference between inflation rates can easily be taken care of through a cost index formula. A study by the World Bank of seven African countries in the sample of PPP showed Cape Verde, Ghana, and Guinea—countries with floating local currencies—have faced a higher foreign exchange risk. In Guinea, the risk was mitigated by the external financing of the foreign exchange component of the operator tariff, on a declining basis. In Ghana, the management contract is financed from external sources and thus protected against foreign exchange risk.

5.3.6 Mis-management of Stakeholders

- ***Poor communication with stakeholders***

The use of PPPs for water supply services always leads to an emotional debate. Consulting local stakeholders helps to clarify the objectives of PPPs. At the design stage, several of the PPPs documents have paid particular attention to consulting with stakeholders, including various government departments, management and staff of the public utility, and the media. Typical fears include steep tariff increases, massive staff reduction, heavy foreign presence, or exclusion of the poor. Expanding the customer base has often been a key factor for contracts to achieve financial sustainability.

In Cochabamba, it was concluded that public officials should have better informed the public about the size and rationale for the tariff increase. Only after three months into the operation, significant public opposition emerged. A series of protests against the contract and the increase in water tariffs took place. Within weeks, public demonstrations prompted the government to roll back the rates and force a refund of the difference paid.

The protests continued and escalated to the point that the military was sent into Cochabamba to restore calm. In the deteriorating situation, the working personnel abandoned their offices and the government cancelled the contract.

- ***<u>Potential disruption to current local businesses</u>***

The operator should be closely associated with defining and implementing the rehabilitation and extension of distribution networks and with rehabilitating key plants. Experience shows that even for PPPs with public funding for investment, operators should play a role in implementing civil works.

The involvement of local private operators managed by nationals typically helps in dissipating the perception of foreign involvement in a socially sensitive sector and increases the acceptability of the PPP. This was witnessed in Côte d'Ivoire and Senegal. At the opposite extreme, the perception of foreign-managed operator was strong in Gambia, Chad, and Mali and was one reason that that led to termination of the contracts (Fall *et al*., 2009).

In Côte d'Ivoire, the asset capital became public in 1978 and rapidly became one of the largest companies quoted at the Abidjan stock exchange. It is owned by hundreds of local shareholders and the company's own staff has been crucial in establishing a sustainable partnership between an African government and an African private operator. Shares of the private operators in Senegal, Niger, and Gabon are also held by local partners and by staff. In these countries local minority shareholders play key roles as active Board members. Guinea's failure to foster local private management at SEEG was largely due to the structure of the company's ownership, with a 49 percent minority share held by the government.

- ***<u>Under-performance of local partner</u>***

In Chad, the PPP ran into early trouble partly because financing for a new power plant had not been secured on time and the construction contracts that were awarded to inexperienced contractors for a 350 km pipeline and power plant had to be terminated for poor performance (Fall *et al*., 2009).

5.4 Reasons for Cancellation of Water PPP Projects

A comprehensive literature review of previous experiences was undertaken to obtain a better understanding of the main reasons for water PPP projects cancellation. The literature review showed that the special features associated with water infrastructure have played a significant role in such high rate of cancellation. The study made by Brubaker (2003) was found generally conclusive of the main reasons for projects cancellation. The results of the cases studied by Brubaker are summarized in Table 5.2 below.

Table 5.2: Summary of identified Reasons for Cancellation of Water PPP Projects

Project	General issues associated with PPP Scheme	Specific Issues		
		Absence of performance baseline data	Uncertainty of the condition of the buried assets	Health and environmental regulations
Hamilton, Canada 1995	Rather than engaging in a competition, the municipality negotiated a sole-sourced agreement. Hamilton enjoyed host of savings beyond guaranteed, mostly due to staff reductions. Change in management occurred over the contract A 111-day strike took place against the operator's plans to facilitate automation	The contractors' environmental performance was difficult to assess after decades of inadequate sampling.	The municipality confirmed that the system requires hundreds of millions of dollars in expansion and upgrade, which is Hamilton's responsibility.	Municipal staff pointed-out that meeting performance requirements is often beyond operator's control.
Buenos Aires, Argentina 1993	The government refused to raise prices to offset the devaluation of the currency	City inadequate performance results (company received price adjustments)	Unexpected poor condition of the water distribution network (company received price adjustments)	

Project	General issues associated with PPP Scheme	Specific Issues		
		Absence of performance baseline data	Uncertainty of the condition of the buried assets	Health and environmental regulations
Cochabamba, Bolivia 1999	No competition in bidding Rise in cost of water lead to strikes and mass demonstrations			
Halifax, Canada 2003	Several management changes in the city and the contractor sides lead to inability to resolve problems	Contractor claimed that potential problems with influent quality came to light only when the federal government issued its environmental screening report for the project. Prior to that, it relied on out-of-date data provided by the city and local industry.	Control of hard-to-treat material to improve the quality of influent requires the control of 5000 sources, which cannot be guaranteed.	
Atlanta, USA 2002	Inherited from the city a backlog of outstanding requests for service, which the contractor was not able to accommodate. Failure to collect outstanding bills. Change of mayor in 2002 led to a change in relation between city and water contractor		Atlanta's aging system - some parts of it dating back to 1875 - proved to be in surprisingly bad shape. The city failed to re-invest savings in its utility	A general improvement in records except in some items.
Manila, Philippines 1997	Refusal to adjust the rates of water to enable the contractor to recover large foreign exchange losses.		Suffered from the government's delay in completing a river-basin project	

5.5 Summary of Water-Specific PPP Risks

This section summarizes the Water-Specific risks presented in Section 5.3. The risks elements and categories considered in this research are those directly relevant to the Water PPP planning and subsequent operation and maintenance. Other potential common PPP risks elements covering the social, construction, political aspects should be considered for a successful PPP, however are beyond the scope of this research. Such demarcation should be reflected in the developed Water-Specific PPP Risk Model.

Table 5.3: Summary of identified Water-Specific PPP Risks

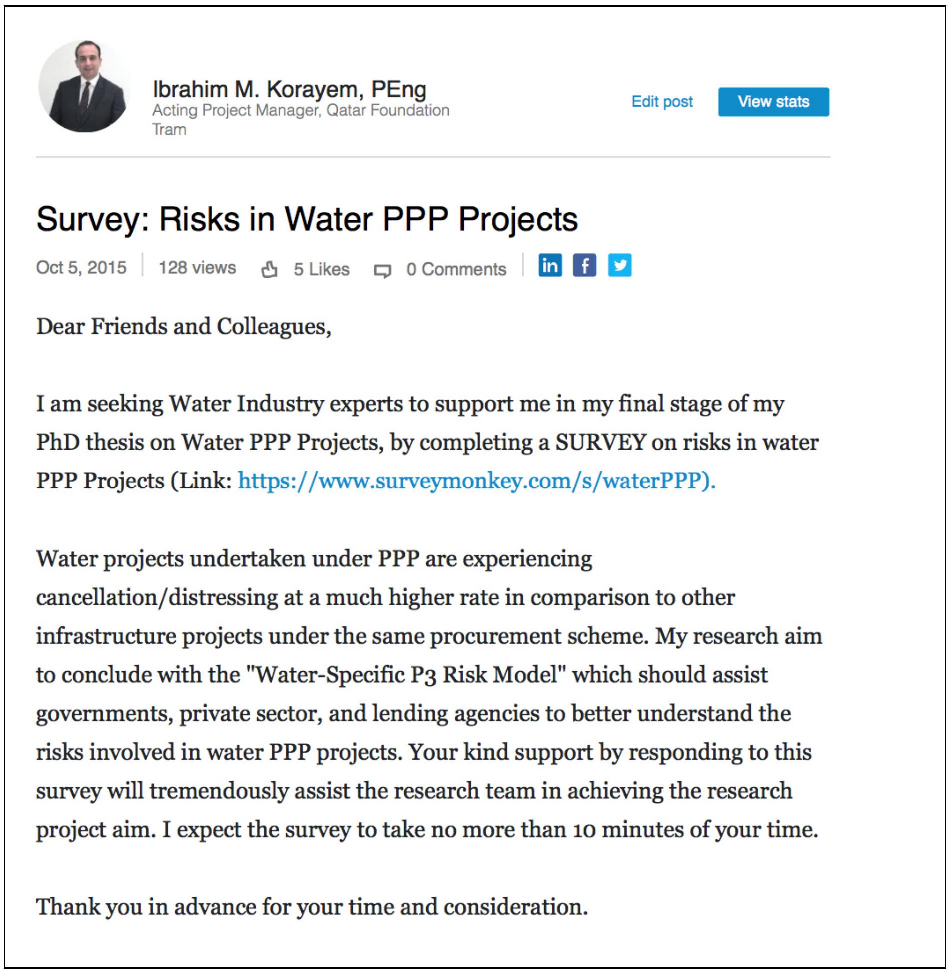
Water-Specific Risk Categories		**Risk Elements**	
Code	**Category**	**Code**	**Element**
A	Facility Records	a1	Absence of maintenance records
		a2	Absence of environmental data sampling records
B	Asset Condition	b1	Uncertainty of value of assets
		b2	Uncertainty of cost of maintenance
C	Unsustainable Expansion	c1	Potential increase in served population
		c2	Potential increase in usage
		c3	Increase in resources to meet environmental guidelines
D	Impact from Interdependent Facilities	d1	Improper planning of interrelated projects
		d2	Uncontrolled performance of interrelated projects
E	Commercial and/or Legal Regulations	e1	Overly complicated commercial model
		e2	Potential excessive increase in tariff structure
		e3	Enforcement of right to water resources
		e4	Significant change in current billing practice
		e5	Potential change in currency exchange rates
F	Mismanagement of Stakeholders	f1	Poor communication with stakeholders
		f2	Potential disruption to current local businesses
		f3	Underperformance of a local partner

5.6 Questionnaire Survey

Following the identification of the set of risks associated with Water PPP project, a questionnaire survey was issued to investigate the severity of each of the identified risks.

The questionnaire survey was posted on-line through professional networks such as LinkedIn on 5 October 2015, accompanied with a brief of the research project, and requesting industry experts, with previous involvement in Water PPP, to collaborate by completing the associated questionnaire survey. A total of fifty-three (53) respondents with previous experience in Water PPP (as confirmed in their published professional profiles), have provided their responses to the questionnaire survey.

During the process, some inquiries about the project, or questions about the survey were raised by the experts and responded on time. Professionals with extensive experience were e-mailed and invited to take part in this survey.



Ibrahim M. Korayem, PEng
Acting Project Manager, Qatar Foundation Tram

Edit post   View stats

Survey: Risks in Water PPP Projects

Oct 5, 2015 | 128 views   5 Likes   0 Comments

Dear Friends and Colleagues,

I am seeking Water Industry experts to support me in my final stage of my PhD thesis on Water PPP Projects, by completing a SURVEY on risks in water PPP Projects (Link: https://www.surveymonkey.com/s/waterPPP).

Water projects undertaken under PPP are experiencing cancellation/distressing at a much higher rate in comparison to other infrastructure projects under the same procurement scheme. My research aim to conclude with the "Water-Specific P3 Risk Model" which should assist governments, private sector, and lending agencies to better understand the risks involved in water PPP projects. Your kind support by responding to this survey will tremendously assist the research team in achieving the research project aim. I expect the survey to take no more than 10 minutes of your time.

Thank you in advance for your time and consideration.

Figure 5.1: Questionnaire Survey Introductory Page

5.6.1 Professional Background of Respondents

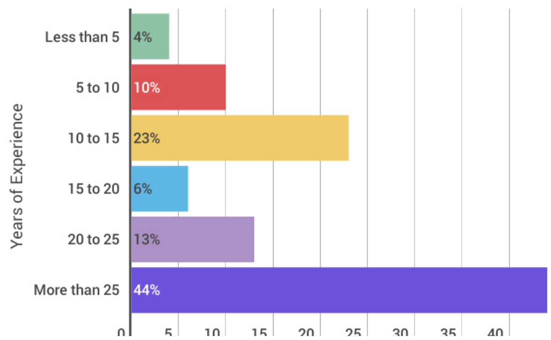
To generate confidence in the credibility of data collected, Table 5.4 provides a summary of the descriptive results and the analysis for the questionnaire survey. The aim of this summary was to provide an understanding of the profile and background of the respondents.

Out of the fifty-three respondents, about 65 percent of the respondents have 15 years of experience, or more. The majority of the remaining has 5 to 15 years of experience, with only 4 percent of the respondents having less than 5 years' experience. This shows that the respondents have deep experience in the water industry. About 64 percent of the respondents have worked as technical consultants in water industry, 40 percent of the respondents have worked with a private party, and over 35 percent of the respondents have worked with the government. This shows a diversity of the professional background between the respondents.

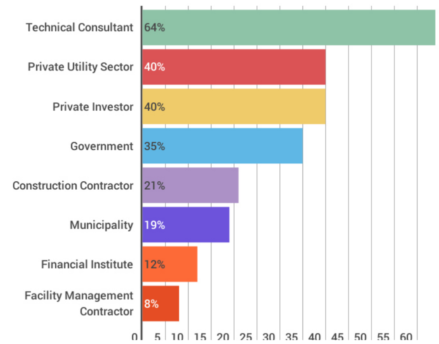
Over 75 percent of the respondents took part in a water management and operation contract. This would support the view that the respondents are aware of operation and maintenance challenges, which was observed during the literature review as a typical source of commercial disputes. A reasonable mix of expertise between traditional procurement and PPP models was noted. The majority of the respondents (43%) have worked in Africa. Almost a quarter of the respondents have worked in either in North America, Europe, or in Asia. This would generally indicate the diversity of the expertise of the respondents with respect to geographical areas of professional background.

This information indicates that he respondents were competent enough and capable of participating in the survey. A plausible conclusion therefore is that the respondents are sufficiently well vested in water industry.

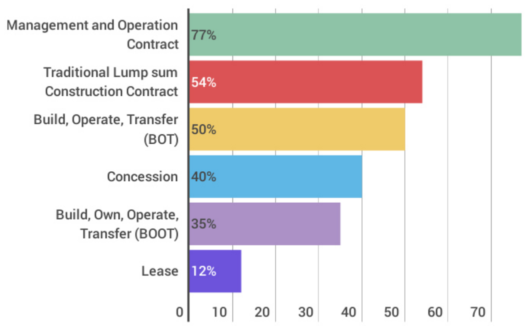
Table 5.4: Professional Background of Respondents



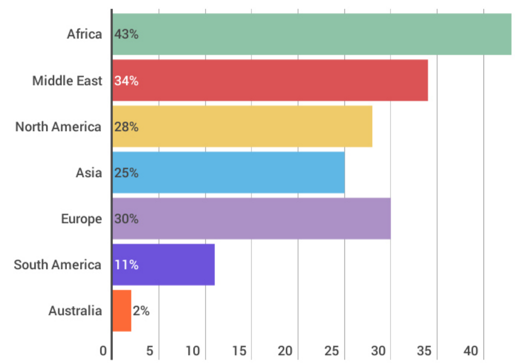
a) Years of experience



b) Previous employers



c) Types of contracts



d) Areas of previous expertise

The respondents were invited to indicate their perception towards the "identified" water-specific risks. The respondents were asked to rate the level of risks impact on project cost from very low to very high, where 1 represents very low; 2 = low; 3 = average or moderate; 4 = High and 5 = very high so that their opinions can be standardized to provide a fair idea of what could be the perceived levels of risk impacts on water PPP projects.

5.6.2 Standardized Quantitative Results and Analysis

To standardize the results gained from each participant of the questionnaire survey, the risks were coded, and the outcome was calculated and summarized into a manageable form to aid the subsequent Analytical Network Process (ANP) pairwise calculations.

Presented in this section are the results of the survey in the order of severity of each of the risk group/element.

Table 5.5: Summary of Respondents' Mean Scores of Risk Significance of Water-Specific PPP Risk Categories

Risk Category	Degree of Severity						Mean Value of Severity	Standard Deviation
	1	2	3	4	5			
F: Mismanagement of Stakeholders	2%	9%	19%	28%	42%		3.98	1.07
E: Commercial and/or Legal Regulations	4%	12%	21%	33%	31%		3.75	1.12
A: Facility Records	2%	15%	36%	25%	23%		3.51	1.06
B: Asset Condition	4%	15%	38%	28%	15%		3.36	1.03
C: Unsustainable Expansion of Facility/Utilities	6%	14%	39%	31%	10%		3.25	1.01
D: Impact from Interdependent Facilities	8%	19%	31%	29%	13%		3.21	1.13

Table 5.6: Summary of Respondents' Mean Scores of Risk Significance of Water-PPP Risk Elements

Risk Element	Degree of Severity						Mean Value of Severity	Standard Deviation
	1	2	3	4	5			
a1: Absence of maintenance records	0%	8%	23%	34%	36%		3.98	0.94
b2: Uncertainty of cost of maintenance	0%	11%	19%	40%	30%		3.89	0.96
d1: Improper planning of interrelated projects	2%	8%	27%	31%	33%		3.85	1.03
f1: Poor communication with stakeholders	6%	2%	21%	46%	25%		3.83	1.01
d2: Uncontrolled performance of interrelated projects	4%	13%	32%	26%	25%		3.55	1.11
c3: Increase in resources to meet environmental guidelines	2%	15%	34%	32%	17%		3.47	1
a2: Absence of environmental data sampling records	8%	13%	25%	38%	17%		3.43	1.14
f3: Underperformance of a local partner	11%	9%	26%	30%	23%		3.43	1.25
b1: Uncertainty of value of assets	4%	23%	25%	30%	19%		3.38	1.14
e1: Overly complicated commercial model	6%	15%	28%	38%	13%		3.38	1.07
e2: Potential excessive increase in tariff structure	11%	13%	28%	25%	23%		3.34	1.27
f2: Potential disruption to current local businesses	9%	13%	34%	30%	13%		3.25	1.13
c1: Potential increase in served population	8%	27%	25%	19%	21%		3.19	1.26
e3: Enforcement of right to water resources	13%	13%	31%	25%	17%		3.19	1.26
e5: Potential change in currency exchange rates	21%	6%	33%	13%	27%		3.19	1.44
c2: Potential increase in usage	8%	26%	28%	17%	21%		3.17	1.24
e4: Significant change in current billing practice	19%	11%	23%	36%	11%		3.09	1.29

5.7 Summary

This chapter presented the water-specific PPP risks, which were identified through an extensive literature review. The identified risks were grouped into six categories, namely, Facility Records, Asset Condition, Unsustainable Expansion, Impact from Interdependent Facilities, Commercial and/or Legal Regulations, and mismanagement of Stakeholders. A further assessment of the main failure cases in the water PPP sector was undertaken where the results reinforced the set of identified risks.

The chapter introduced the setup of the questionnaire survey. A description of the background of the respondents indicated that the respondents were competent enough and capable of participating in the survey. A plausible conclusion therefore is that the respondents are sufficiently well vested in water industry.

The chapter concluded with presenting the results of the questionnaire survey where the risk categories and elements were listed in order of significance, as seen by the respondents to the survey. This outcome should aid the subsequent Analytical Network Process (ANP) pairwise calculations, which will be presented in Chapter 6.

CHAPTER 6: INTRODUCING THE "WATER-SPECIFIC PPP RISK MODEL"

6.1 Introduction

Drawing on the questionnaire survey analysis, presented in Chapter 5, where mean values were derived for the severity of the identified risks on water PPP projects' cost, this chapter addresses the development of the substantive ANP model for the prioritization of the identified risks. Pairwise comparison was derived after converting the respondents' scores in order to prioritize risks. This chapter presents the calculation of the Risk Priority Index (RPI) as a project ranking method, with a commentary on the "Very High Risks".

The chapter presents the "Water-Specific PPP Risk Model" with an explanation to the reader on how to use it. Key research achievements are presented within this explanation, and are finally followed by a "Validation" of the model, based on the input received from key experts.

6.2 ANP Model Construction (Hierarchic Structure)

Following the categorization of identified risks (Chapter 5, Section 5.4), a network structure was constructed to create influence among the project objective, risk categories and elements. Risk categories: A, B, C, D, E, and F were considered as primary standards while sub-variables a1-2, b1-2, c1-3, d1-2, e1-5, and f1-3 were considered as secondary standards. The framework of ANP network process for all risks is shown in Figure 5.1. As shown on the figure, there is an outer dependency between the different categories and an inner dependency within each member category of risks in the risk prioritization structure. Indirect dominance comparison of variables was carried out according to their influence on project cost.

Figure 6.1: General ANP Network Structure

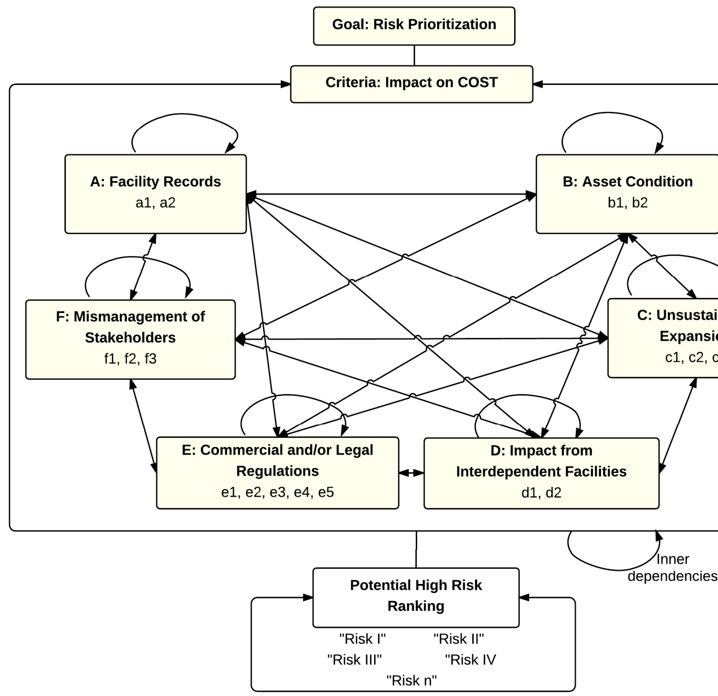


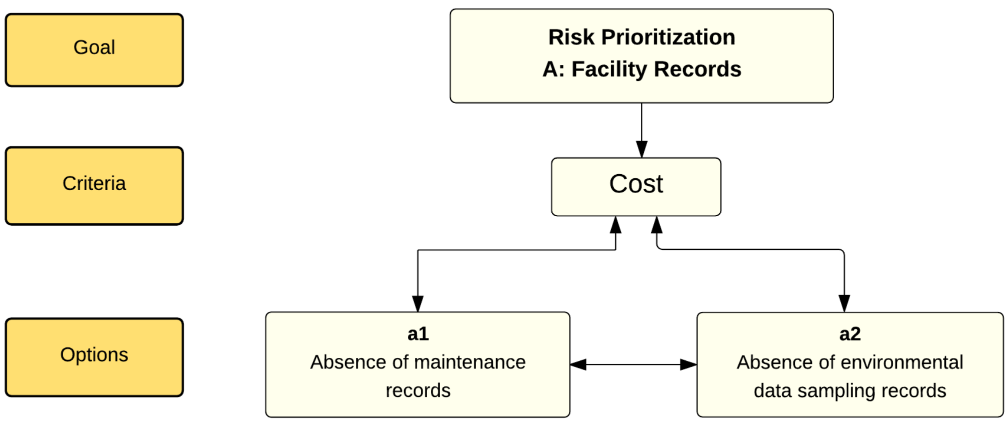
Table 6.1: Identified Risk Elements associated with Water PPP Projects

Water-Specific Risk Categories		Risk Elements	
Code	**Category**	**Code**	**Element**
A	Facility Records	a1	Absence of maintenance records
		a2	Absence of environmental data sampling records
B	Asset Condition	b1	Uncertainty of value of assets
		b2	Uncertainty of cost of maintenance
C	Unsustainable Expansion	c1	Potential increase in served population
		c2	Potential increase in usage
		c3	Increase in resources to meet environmental guidelines
D	Impact from Interdependent Facilities	d1	Improper planning of interrelated projects
		d2	Uncontrolled performance of interrelated projects
E	Commercial and/or Legal Regulations	e1	Overly complicated commercial model
		e2	Potential excessive increase in tariff structure
		e3	Enforcement of right to water resources
		e4	Significant change in current billing practice
		e5	Potential change in currency exchange rates
F	Mismanagement of Stakeholders	f1	Poor communication with stakeholders
		f2	Potential disruption to current local businesses
		f3	Underperformance of a local partner

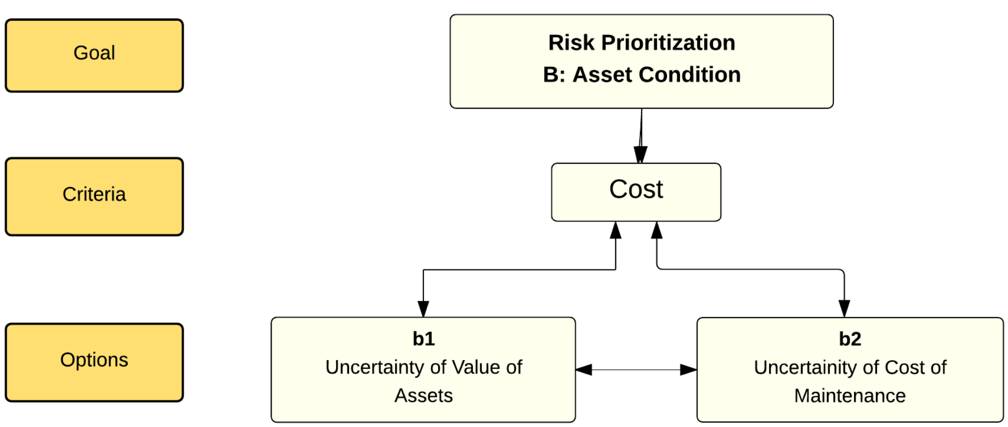
6.3 Establishing the Pairwise Comparison Matrices

The overall network model was decomposed into sub-network models. These include ANP network models for the various risk categories: - A: Facility Records risk category, B: Asset Condition risk category, C: Unsustainable Expansion risk category, D: Impact from Interdependent Facilities risk category, E: Commercial and/or Legal Regulations risk category and F: Mismanagement of Stakeholders risk category. The sub-network models are represented in Figures Figure 6.2-a to -f.

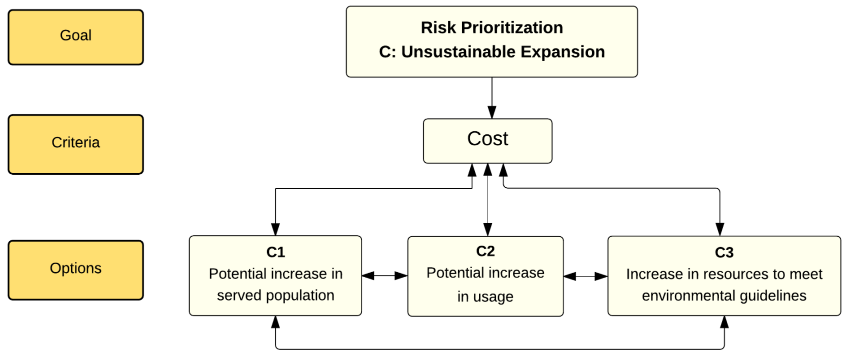
Figure 6.2: ANP Network Structure



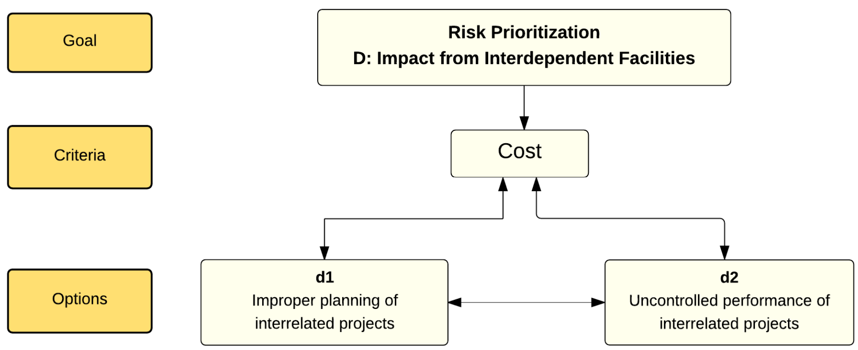
a) A: Facility Records



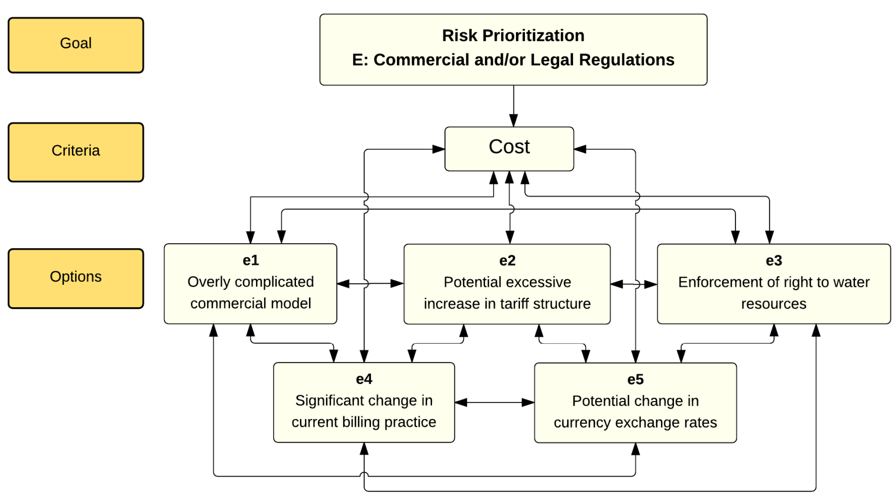
b) B: Asset Condition



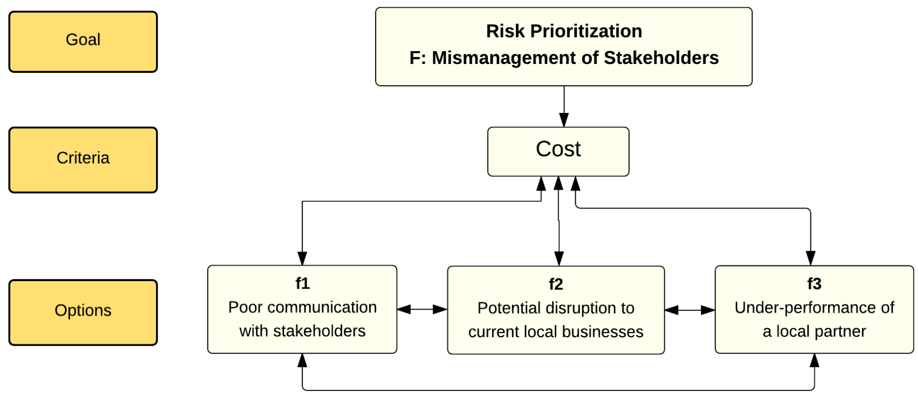
c) C: Unsustainable Expansion



d) D: Impact from Interdependent Facilities



e) E: Commercial and/or Legal Regulations



f) F: Mismanagement of Stakeholders

6.4 Pairwise Comparison

Once the ANP hierarchy is built, its various elements were evaluated systematically and compared to one another in pair. In making the comparisons, the rounded mean values derived from the questionnaire survey in chapter five were used against the ANP fundamental pairwise judgment scale titled "Scales of pairwise judgment" in Table 6.2 for judgments about the elements' relative meaning and importance.

Table 6.2: Fundamental Scale of Pairwise Judgment and Pairwise Criteria

Scales of pairwise judgment [a]	Comparisons of pair indicator scores [b]
1=equal	1:1
2=equally to moderately dominant	2:1, 3:2, 4:3, 5:4, 6:5, 7:6, 8:7, 9:8
3=moderately dominant	3:1, 4:2, 5:3, 6:4, 7:5, 8:6, 9:7
4=moderately to strongly dominant	4:1, 5:2, 6:3, 7:4, 8:5, 9:6
5=strongly dominant	5:1, 6:2, 7:3, 8:4, 9:5
6=strongly to very strongly dominant	6:1, 7:2, 8:3, 9:4
7=very strongly dominant	7:1, 8:2, 9:3
8=very strongly to extremely dominant	8:1, 9:2
9=Extremely dominant	9:1

Where:

[a] Saaty, 1996.

[b] Scores of indicators used to judge the relative meaning and importance of risk variables

The pairwise comparison matrices are then created using equation 1 the element $Po_{(ij)}$ of the matrix is the relative importance of the i^{th} criteria with respect to the j^{th} criteria. The matrix reciprocal, which is symmetric with respect to diagonal, is the inverse of one another. That is: $Po_{(ij)} = 1/\ Po_{(ij)}$., where $Po_{(ij)}$ is the comparison between item i and j. Item i, j =1, 2…n.

$$P_O = \begin{vmatrix} 1 & p_{o(ij)} & p_{o(13)} \\ {}^{1}/_{p_{o(ji)}} & 1 & p_{o(23)} \\ {}^{1}/_{p_{o(13)}} & {}^{1}/_{p_{o(23)}} & 1 \end{vmatrix} \qquad (1)$$

The values are inserted into the multi-criteria decision software called the *Super Decision* as shown on Table 6.3.

Table 6.3: Pairwise Comparison Data

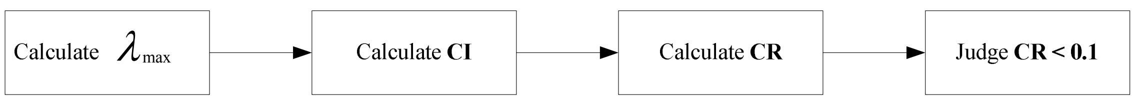
Risk Element*	a1	a2	b1	b2	c1	c2	c3	d1	c2	e1	e2	e3	e4	e5	f1	f2	f3
a1	1	2	2	1	2	2	2	1	2	2	2	2	2	2	1	2	2
a2	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
b1	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
b2	1	2	2	1	2	2	2	1	2	2	2	2	2	2	1	2	2
c1	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
c2	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
c3	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
d1	1	2	2	1	2	2	2	1	2	2	2	2	2	2	1	2	2
d2	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
e1	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
e2	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
e3	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
e4	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
e5	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
f1	1	2	2	1	2	2	2	1	2	2	2	2	2	2	1	2	2
f2	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1
f3	1/2	1	1	1/2	1	1	1	1/2	1	1	1	1	1	1	1/2	1	1

Notes: *: Refer to Table 6.1

6.5 Consistency test

The Consistency Ratio (CR) is a widely used consistency test method in both AHP and ANP. The CR is used to check the consistencies of the values obtained according to the pairwise comparison. In the ANP method, survey participants and decision makers or experts who make judgments or preferences must go through the consistency test. Reasons are because the final risk assessment and decision analysis could be inaccurate if the priority values are calculated from the inconsistent comparison matrix. Therefore, the consistency of each comparison matrix has to be tested before the comparison matrices are used to assess risk and analyze a decision. If the consistency test for the comparison matrix failed, the inconsistent elements in the comparison matrix have to be identified and revised; otherwise, the result of risk assessment and decision analysis would be unreliable. To determine the consistency of respondents' judgment on the risks impacts, a consistency ratio (CR) of the comparison matrices is calculated using the process in Figure *6.3*.

Figure 6.3: Calculation Process for the CR Method



Step 1: Calculate the maximum eigenvalue (λ_{max}) of one comparison matrix.

Step 2: Calculate the value of Consistency Index (*CI)*

Step 3: Calculate the CR using the formula $CR = CI/RI$ and

Table 6.4.

Step 4: Compare the value of CR with the consistency threshold 0.1 to judge whether the comparison is consistent.

Step 1: Calculate the maximum eigenvalue (λ_{max}) ***of one comparison matrix.***

After a comparison matrix has been formed, the normalized priority of the element can be compared by the computation of eigenvalue and eigenvectors with the Equation 2.

$$\sum_{i=1}^{n} a_{ij} w_j = \lambda_{max} w_i \qquad (2)$$

Where A is the matrix of pair-wise comparison,

w is the eigenvector, and

λ_{max} is the maximum eigenvalue of [A]

By substitution, the maximum eigenvalue (λ_{max}) is calculated to derive a new matrix (W) by multiplying comparison matrix (A) with (w_i). Finally, the (λ_{max}) can be obtained by averaging the value. Computations of the process are listed in Equation (3) and Equation (4) respectively.

$$\begin{vmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & a_{23} & a_{2n} \\ \vdots & 1/a_{23} & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{vmatrix} \text{x} \begin{vmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{vmatrix} = \begin{vmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{vmatrix} \quad (3)$$

$$\lambda_{max} = \frac{1}{n}\left(\frac{W_1}{w_1} + \frac{W_2}{w_2} + \dots \dots + \frac{W_n}{w_n}\right) \quad (4)$$

Step 2: ***Calculating the value of CI***

In order to determine the consistencies of respondents' judgments, the consistency ratios (C.R.) of the comparison matrices are calculated using the formula:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (5)$$

Where CI = Consistency ratio

λ_{max} = Maximum eigenvalue

n = Order of matrix [A].

If $C.I.$ = 0, means respondents' judgments satisfy the consistency.

If $C.I.$ > 0, means the experts have conflicting judgments.

If $C.I. \leq 0.1$, means there is reasonable level of consistency.

Step 3: ***Calculating the Consistency Ratio (CR)***

CR is the most widely used consistency index when conducting traditional consistency test. Based on matrix size, the CR can be calculated using the formula:

$$CR = \frac{CI}{RI} \quad (6)$$

Where R.I. is a random index as shown in
Table 6.4

When C.R. ≤ 0.1, it means the evaluation process satisfies the consistency

Table 6.4: The Average random Index

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49	1.52	1.54	1.56	1.58	1.59

Step 4: ***Judging the consistency***

The comparison is checked for consistency by comparing the CR value with the consistency threshold of 0.1. If CR ≤ 0, it means respondents' judgments satisfy the consistency. If not, then that means the experts have conflicting judgments. The inconsistent elements in the comparison matrix have to be identified and revised; otherwise, the result of risk assessment and decision analysis is unreliable. If CR ≤ 0.1, means there is reasonable level of consistency.

6.6 The Super Matrix Calculation

After completing the pairwise comparisons, the next step is to build the supermatrix. As discussed in Chapter 4, the supermatrices are computed in three steps. In the first step, the unweighted supermatrix is created directly from all local priorities of the potential risks as indicated in Table 6.5. In the second step, the weighted supermatrix (see Table 6.6) is calculated by weighing the local priority indices or the unweighted supermatrix with their affiliated priorities for project cost.

Finally, the weighted supermatrix is raised to limiting power in order to converge and to obtain a stable set of weights that represents the final priority vector. Stabilization is achieved when all columns in the supermatrix corresponding to any node have the same values as show in Table 6.7.

Table 6.5: Unweighted Super Matrix for Risk Elements associated with Water PPP Projects

Risk*	a1	a2	b1	b2	c1	c2	c3	d1	d2	e1	e2	e3	e4	e5	f1	f2	f3	Cost
a1	0.000	0.111	0.111	0.105	0.105	0.100	0.105	0.105	0.111	0.100	0.105	0.000	0.100	0.100	0.105	0.118	0.111	0.095
a2	0.056	0.000	0.056	0.053	0.000	0.050	0.053	0.053	0.056	0.050	0.053	0.000	0.050	0.050	0.053	0.000	0.056	0.048
b1	0.056	0.000	0.000	0.053	0.053	0.050	0.053	0.053	0.056	0.050	0.053	0.125	0.050	0.050	0.053	0.059	0.056	0.048
b2	0.111	0.111	0.000	0.000	0.105	0.100	0.105	0.105	0.111	0.100	0.105	0.000	0.100	0.100	0.105	0.118	0.111	0.095
c1	0.056	0.056	0.056	0.053	0.000	0.050	0.053	0.053	0.056	0.050	0.053	0.063	0.050	0.050	0.053	0.059	0.056	0.048
c2	0.056	0.056	0.056	0.053	0.053	0.000	0.053	0.053	0.056	0.050	0.053	0.063	0.050	0.050	0.053	0.059	0.056	0.048
c3	0.056	0.056	0.056	0.053	0.053	0.050	0.000	0.053	0.056	0.050	0.053	0.063	0.050	0.050	0.053	0.059	0.056	0.048
d1	0.111	0.111	0.111	0.105	0.105	0.100	0.105	0.000	0.000	0.100	0.105	0.125	0.100	0.100	0.105	0.118	0.111	0.095
d2	0.056	0.056	0.056	0.053	0.053	0.050	0.053	0.053	0.000	0.050	0.053	0.063	0.050	0.050	0.053	0.059	0.056	0.048
e1	0.056	0.056	0.056	0.053	0.053	0.050	0.053	0.053	0.056	0.000	0.000	0.063	0.050	0.050	0.053	0.059	0.056	0.048
e2	0.056	0.056	0.056	0.053	0.053	0.050	0.053	0.053	0.056	0.050	0.000	0.063	0.050	0.050	0.053	0.000	0.056	0.048
e3	0.000	0.000	0.056	0.053	0.053	0.050	0.000	0.053	0.056	0.050	0.053	0.000	0.050	0.050	0.053	0.000	0.000	0.048
e4	0.056	0.056	0.056	0.053	0.053	0.050	0.053	0.053	0.056	0.050	0.053	0.063	0.000	0.050	0.053	0.059	0.000	0.050
e5	0.056	0.056	0.056	0.053	0.053	0.050	0.053	0.053	0.056	0.050	0.053	0.063	0.050	0.000	0.053	0.059	0.056	0.048
f1	0.111	0.111	0.111	0.105	0.105	0.100	0.105	0.105	0.111	0.100	0.105	0.125	0.100	0.100	0.000	0.118	0.111	0.092
f2	0.056	0.056	0.056	0.053	0.053	0.050	0.053	0.053	0.056	0.050	0.053	0.063	0.050	0.050	0.053	0.000	0.056	0.048
f3	0.056	0.056	0.056	0.053	0.053	0.050	0.053	0.053	0.056	0.050	0.053	0.063	0.050	0.050	0.053	0.059	0.000	0.048
Cost	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000

Notes: *: Refer to Table 6.1

Table 6.6: Weighted Super Matrix for Risk Elements associated with Water PPP Projects

Risk *	**a1**	**a2**	**b1**	**b2**	**c1**	**c2**	**c3**	**d1**	**d2**	**e1**	**e2**	**e3**	**e4**	**e5**	**f1**	**f2**	**f3**	**Cost**
a1	0.000	0.056	0.056	0.053	0.053	0.050	0.053	0.053	0.056	0.050	0.053	0.000	0.050	0.050	0.053	0.059	0.056	0.095
a2	0.028	0.000	0.028	0.026	0.000	0.025	0.026	0.026	0.028	0.025	0.026	0.000	0.025	0.025	0.026	0.000	0.028	0.048
b1	0.028	0.000	0.000	0.026	0.026	0.025	0.026	0.026	0.028	0.025	0.026	0.063	0.025	0.025	0.026	0.029	0.028	0.048
b2	0.056	0.056	0.000	0.000	0.053	0.050	0.053	0.053	0.056	0.050	0.053	0.000	0.050	0.050	0.053	0.059	0.056	0.095
c1	0.028	0.028	0.028	0.026	0.000	0.025	0.026	0.026	0.028	0.025	0.026	0.031	0.025	0.025	0.026	0.029	0.028	0.048
c2	0.028	0.028	0.028	0.026	0.026	0.000	0.026	0.026	0.028	0.025	0.026	0.031	0.025	0.025	0.026	0.029	0.028	0.048
c3	0.028	0.028	0.028	0.026	0.026	0.025	0.000	0.026	0.028	0.025	0.026	0.031	0.025	0.025	0.026	0.029	0.028	0.048
d1	0.056	0.056	0.056	0.053	0.053	0.050	0.053	0.000	0.000	0.050	0.053	0.063	0.050	0.050	0.053	0.059	0.056	0.095
d2	0.028	0.028	0.028	0.026	0.026	0.025	0.026	0.026	0.000	0.025	0.026	0.031	0.025	0.025	0.026	0.029	0.028	0.048
e1	0.028	0.028	0.028	0.026	0.026	0.025	0.026	0.026	0.028	0.000	0.000	0.031	0.025	0.025	0.026	0.029	0.028	0.048
e2	0.028	0.028	0.028	0.026	0.026	0.025	0.026	0.026	0.028	0.025	0.000	0.031	0.025	0.025	0.026	0.000	0.028	0.048
e3	0.000	0.000	0.028	0.026	0.026	0.025	0.000	0.026	0.028	0.025	0.026	0.000	0.025	0.025	0.026	0.000	0.000	0.048
e4	0.028	0.028	0.028	0.026	0.026	0.025	0.026	0.026	0.028	0.025	0.026	0.031	0.000	0.025	0.026	0.029	0.000	0.050
e5	0.028	0.028	0.028	0.026	0.026	0.025	0.026	0.026	0.028	0.025	0.026	0.031	0.025	0.000	0.026	0.029	0.028	0.048
f1	0.056	0.056	0.056	0.053	0.053	0.050	0.053	0.053	0.056	0.050	0.053	0.063	0.050	0.050	0.000	0.059	0.056	0.092
f2	0.028	0.028	0.028	0.026	0.026	0.025	0.026	0.026	0.028	0.025	0.026	0.031	0.025	0.025	0.026	0.000	0.028	0.048
f3	0.028	0.028	0.028	0.026	0.026	0.025	0.026	0.026	0.028	0.025	0.026	0.031	0.025	0.025	0.026	0.029	0.000	0.048
Cost	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.000

Notes: *: Refer to Table 6.1

Table 6.7: Limiting Super Matrix for Risk Elements associated with Water PPP Projects

Risk *	a1	a2	b1	b2	c1	c2	c3	d1	d2	e1	e2	e3	e4	e5	f1	f2	f3	Cost
a1	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
a2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
b1	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
b2	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
c1	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
c2	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
c3	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
d1	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
d2	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
e1	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
e2	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
e3	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
e4	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
e5	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
f1	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
f2	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
f3	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
Cost	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333

Notes: *: Refer to Table 6.1

The results of the ANP priorities are demonstrated in Table 6.8 below.

Table 6.8: Results of ANP Priorities for Risks Associated with Water PPP Projects

Risk Element *	TRPI	IRPI	Rank
a1	0.06	0.99	3
a2	0.03	0.48	16
b1	0.03	0.52	10
b2	0.06	0.96	4
c1	0.03	0.52	8
c2	0.03	0.52	5
c3	0.03	0.52	9
d1	0.06	0.99	2
d2	0.03	0.52	12
e1	0.03	0.51	14
e2	0.03	0.51	15
e3	0.03	0.44	17
e4	0.03	0.52	7
e5	0.03	0.52	6
f1	0.06	1.00	1
f2	0.03	0.52	13
f3	0.03	0.52	11

Notes: *: Refer to Table 6.1

Legend: ***TRPI*** *= Total risk priority Index,* ***IRP1*** *= Ideal Risk priority Index*

The globalized priorities under each risk element is equivalent to the total risk priority index (TRPI), which can be expressed in ideal forms known as Ideal Risk Priority Indices (IRPIs) by dividing each TRPI by the largest value. For example, the IRPI for potential risk b2 will be as follows:

$$IRPI_{b2} = TRPI_{b2} / TRPI_{max}$$

That is $IRPI_{b2} = 0.03 / 0.06$

= 0.52 (in approximation)

Where $IRPI_{b2}$ is the Ideal Risk Priority Index for risk element “b2” with a value of 0.52; $TRPI_{b2}$ is the Total Risk Priority Index for b2 (0.03) while $TRPI_{max}$ representing the maximum value (0.06) among the Total Risk Priority Indices for the risk elements. The effect of this normalization is to make the maximum potential risk the ideal one with others in proportionate value. To demonstrate, a decision maker may then interpret the results to mean that impacts of risk on Water PPP for elements a2, b1, b2 to be as 48%, 52%, and 96% respectively as risky as that of f1.

6.7 Risk Ratings Mode

At this stage, potential risks were evaluated by selecting the appropriate "verbal" rating category on their level of impacts on Water PPP as Very high (5), High (4), Medium or Moderate (3), Low (2) and Very low (1). The idealized priorities (IRPI) calculated in Table 6.8 are used for risks rating. For example, a priority value greater than 0.62 is classified as having a very high risk impact on the project objectives and so on. The rating categories for the five scales are established in Table 6.9.

Table 6.9: ANP Model Input Data

Risk rating for Water PPP Projects		**VH**	**H**	**M**	**L**	**VL**	**Normalized Priorities**	**Idealized Priorities**	**Numerical Risks Rating (%)**
Very High	VH	1	2	3	4	5	0.42	1.00	>62
High	H	1/2	1	2	3	4	0.26	0.62	38-61
Moderate	M	1/3	1/2	1	2	3	0.16	0.38	24-37
Low	L	1/4	1/3	1/2	1	2	0.10	0.24	14-23
Very Low	VL	1/5	1/4	1/3	1/2	1	0.06	0.14	<14
Total priorities							1.00		

6.8 Risk Priority Index (RPI) as a Project Ranking Method of all Risks

The developed Idealized Risk Priority Indices (IRPIs) can be used to prioritize Water PPP projects from a risk prospective. The higher the IRPI, the higher the rank of the risks associated with Water PPP.

Table 6.10: Prioritization of Water-Specific PPP Risks

Risk Element	Ranking	IRPI %	Verbal Rating
f1: Poor communication with stakeholders	1	100%	Very High
d1: Improper planning of interrelated projects	2	99%	Very High
a1: Absence of maintenance records	3	99%	Very High
b2: Uncertainty of cost of maintenance	4	96%	Very High
c2: Potential increase in usage	5	52%	High
e5: Potential change in currency exchange rates	6	52%	High
e4: Significant change in current billing practice	7	52%	High
c1: Potential increase in served population	8	52%	High
c3: Increase in resources to meet environmental	9	52%	High
b1: Uncertainty of value of assets	10	52%	High
f3: Underperformance of a local partner	11	52%	High
d2: Uncontrolled performance of interrelated projects	12	52%	High
f2: Potential disruption to current local businesses	13	52%	High
e1: Overly complicated commercial model	14	51%	High
e2: Potential excessive increase in tariff structure	15	51%	High
a2: Absence of environmental data sampling records	16	48%	High
e3: Enforcement of right to water resources	17	44%	High

6.9 Commentary on Risk Prioritization Results

Since the risks have been described in details in Section 5.3, presented herein briefly the top four risks, identified in the survey results as being "Very High" risks.

f1: Poor communication with stakeholders: The use of PPPs for water supply services always leads to an emotional debate. It is therefore very essential to maintain a close and transparent relationship with all stakeholders, which is not limited to end users, but also government departments, management and staff of the public utility, and the media. The typical fears include steep tariff increases, massive staff reduction, heavy foreign presence, or exclusion of the poor. Expanding the customer base has often been a key factor for contracts to achieve financial sustainability.

d1: Improper planning of inter-related projects: Poor planning of other related projects can have a severe impact on new projects. The delay of inter-related project(s) may result in the contractor not being able to meet the contract specifications in terms of production or environmental regulations.

a1: Absence of maintenance records: Inadequate utility performance records for years in the past could prevent making meaningful comparisons between the public operator and its private successors. This was one of the key findings of the research, which proved to be hurting the successful progression of several new Water PPP projects.

b2: Uncertainty of cost of maintenance: Significant research has been conducted on the rehabilitation of distribution networks. Numerous models were developed to assist in developing rehabilitation strategies that reduces leakage, improved operative costs and environmental records. However, the absence of sufficient records and the non-uniformity of the water facilities construction and maintenance pose challenges on estimating the cost of maintenance, especially during the early bidding stage.

6.10 The "Water-Specific PPP Risk Model"

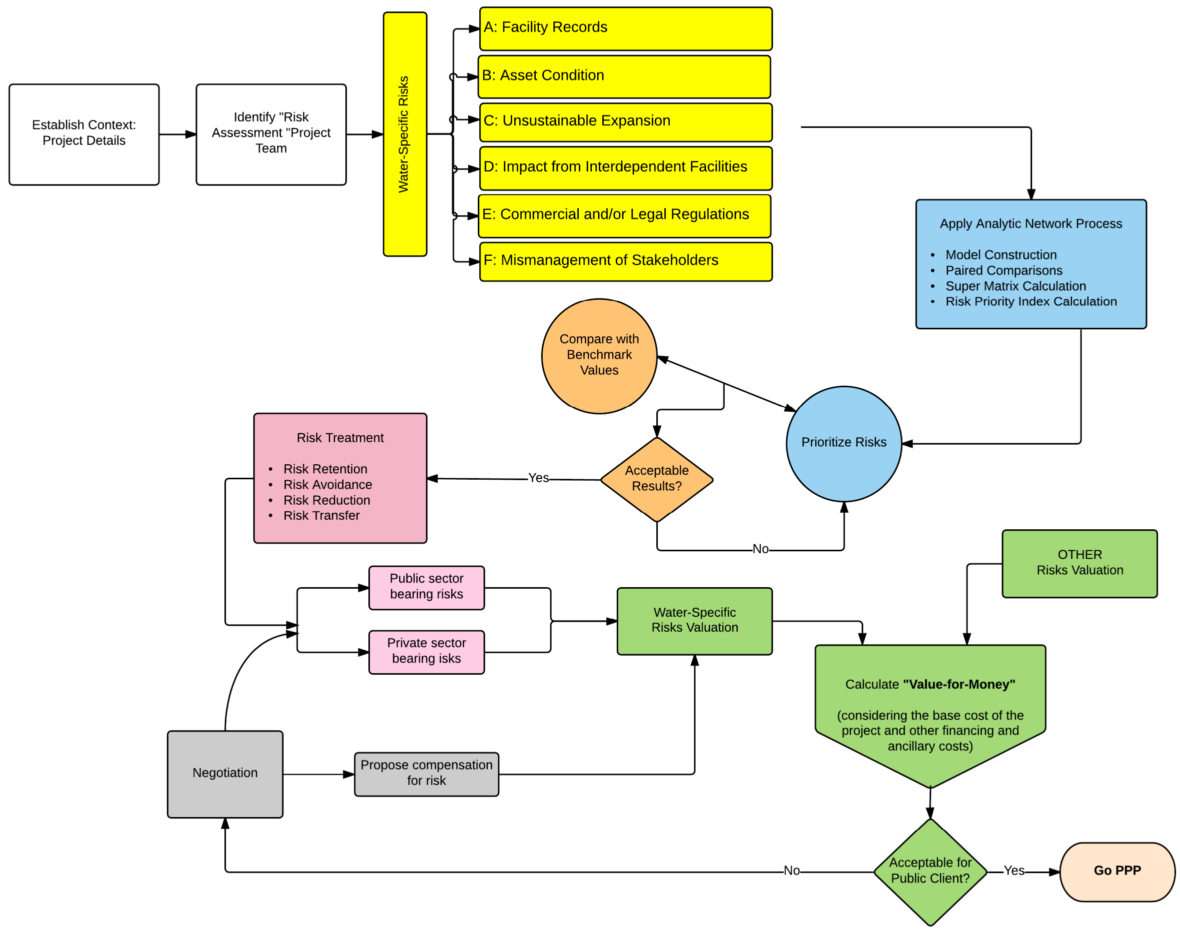


Figure 6.4: The "Water-Specific PPP Risk Model"

6.10.1 How to use the model?

- **Step #1: Establish the Project Context & Identify the Risk Assessment Project Team (White in the model)**

  The model is mainly designed to support the "Value-for-Money" analysis, where an estimate of the value of risk is required to assist in developing the associated financial model; named "Adjusted Shadow Bid (ASB)" estimating the total project cost if the project is delivered using private sector or Public-Private Partnership. As such, the project manager should carefully establish the project context; identify the risk assessment team who are directly involved in the water sector industry, and preferably aware of the project context. Inviting team members who are from the same country (or region) is advisable as it ensures the individual's awareness of the culture and governing laws.

- **Step #2: Risk Identification (Yellow in the model)**

  The model has benefited from the extensive literature review undertaken in this research, which was concluded with suggesting six water-specific PPP risk categories with underlying sub-risks. This would overcome the drawback noted, in research works as well as in industry, where risk assessments is generally based on generic sets of PPP risks with no consideration of the special nature of water projects.

  The use of these risk categories would reduce the exposure to unforeseen project conditions. However, it is important to note that the identified set of risks should not be considered as an exhaustive list. It would however offer a systematic approach for considering additional risks that may be considered applicable by the risk assessment team.

- **Step #3: Risk Prioritization (Blue in the model)**

  The model has benefited from the extensive literature review undertaken in this research with respect to risk prioritization. The review of the different methods of risk analysis suggested that the use of the Analytic Network Process (ANP) would overcome the shortcomings observed in other typical risk analysis methods. This is attributed to the ANP capability to take into consideration the interdependency amongst the identified project risks as oppose to other methods, which in turn would lead to an improved modelling of the identified risks. Besides, the ANP technique is relatively easy to understand and therefore can be easily implemented in industry practice.

- **Step #4: Risk Comparison (Orange in the model)**

  In typical industry practice, the risk assessment team is formed of a limited number of industry experts representing the various stakeholders. This model allows for the opportunity of recognizing previous risk assessments as it offers the priority risk indices, collected from the survey from over fifty industry experts. These values could be used as "benchmarked" values for risk priorities.

  Such comparison with benchmarked values is considered to be unique in this model, and offers a way forward for an improvement in risk assessment if the outcome of future risk assessment sessions is consistently being shared and included in the model as priority benchmarked values. The results of previous sessions can be further grouped by country, region, type of project…etc.

  Obviously, each project would carry its specific unique characteristics and therefore any comparison with the model risks' benchmarks values should be taken with caution. As shown in the model, if the risk assessment team is comfortable with the comparison results, they can move to the next step of risk treatment otherwise a re-assessment of the identified risks and associated priorities should be considered.

- **Step #5: Risk Treatment (Pink in the model)**

  Looking back at earlier stages, we can see that the risks have been identified (Stage 2), and Prioritized (Stage 3), then refined by comparison to benchmark values (Stage 4). The outcome could be considered as a list of risks that have been under a qualitative assessment, which qualifies per the Project Management Practice (discussed in details in Section 3.2), to proceed with the subsequent stage of "Risk Treatment". In this stage, the risk assessment team should consider methods like risk reduction, avoidance, retention, and risk transfer. With respect to risk allocation, it should be ensured that the side that owns the risk (public or private) is the party that is best to manage it.

- **Step #6: Calculating the Value-for-Money (VFM) (Green in the model)**

  The estimated cost of the water-specific risks together with the estimated cost of "Other" PPP risks would lead to estimating the "Adjusted Shadow Bid (ASB)", which is the cost estimate if the project is delivered using private sector or Public-Private Partnership. As explained earlier in Section 3.5.2, the Value-Money-Analysis can be estimated from the below equation:

$$\frac{\text{Traditional Project Cost under PSC} - \text{Project Cost under ASB}}{\text{Traditional Project Cost under PSC}}$$

  Where the "Public Sector Comparator (PSC)" is developed by estimating the total project cost if the project is delivered by public sector.

- **Step #7: Negotiation (Grey in the model)**

  In case the estimated VFM is not acceptable by the Public Sector, a cycle (or more) of negotiation can take place. The negotiation would include an adjustment to risk allocation, and a compensation for some of the risks undertaken by the private sector. The outcome of this stage should be fed back to the model for re-evaluation of the cost of risks until the VFM becomes satisfactory.

- **Step #8: Go PPP**

  An acceptable VFM is an indication of a feasible PPP project.

6.11 Data Validation

Validation is the task of demonstrating that the model has reasonably addressed the research project aim. In absence of real data that can examine the practical use of the model, the validation attempts concentrated in examining the experts' intuitions.

Essentially, using expert intuition to validate a model requires a careful selection of the validation team, who owns the technical and practical knowledge in the field of Water

PPP. The criteria developed for the selection of the members of the "Validation Team" included the following:

- The member should have not been involved in the earlier survey work conducted as part of this research for risk prioritization
- The member should have a minimum of 15 years' experience
- The overall validation members' experiences should be spread across various roles (Owner, Contractor, Operator,…etc.)
- The overall validation members' experiences should be spread across various geographical areas

After investigating a number of professional profiles, an opinion was mode to select five team members, whose profiles were found to be meeting the selection criteria, and noted as the "Validation Team".

The aim of the validation process was set to evaluate the usefulness of the model, the identified water-specific risks, and the opinion on the developed risk model, which was formulated into the following "Research Validation Questions":

1. After reading the research background and based on your experience, how do you see the need for the development of the "Water-Specific PPP Risk Model"?
2. How do you evaluate the "Water-Specific" PPP risks identified under this research?
3. What is your opinion of the "Water-specific PPP Risk Model" developed under this research?

Below are the responses received from the "Validation Team" on each of the "Research Validation Questions":

Question 1: After reading the research background and based on your experience, how do you see the need for the development of the "Water-Specific PPP Risk Model"?

Respondent 1	Very relevant, considering the risk perception by investors. The Water sector is seen as a very sensitive and risky sector, and investors and PPP proponents will need to appreciate sector-specific risks.
Respondent 2	Water related PPP wholly depend on professionalism of host government (ability to clearly communicate requirements for a project, ensure enforceability of legal structures, ensure access to capital/guarantees…etc.) thus such models have got to be country-specific.
Respondent 3	Looking to the need of investment in the water sector, it is greatly needed to have a water specific PPP model.
Respondent 4	As a quality management professional with extensive experience in potable water production I found your research interesting
Respondent 5	Very much needed. Can be implemented as a commercial software.

Question 2: How do you evaluate the "Water-Specific" PPP risks identified under this research?

Respondent 1	The risks are critical but not unique to the water sector. The risks that have been identified cut across all infrastructure sectors. Filtering out the risks of utmost importance for the water sector is valuable.
Respondent 2	Use standard risk valuation practices (probabilities/impacts) relevant for particular PPP
Respondent 3	The identified risks are quit realistic.
Respondent 4	Personal experience confirms much of what you report. The top survey result is particularly interesting. The only observation I can add to that finding is confusion over whether poor stakeholder communication is a feature or flaw in the average project. Either way much of any given project's overall performance can be linked to that single root cause.

Respondent 5	Better value to add risk mitigation measures. We assumed that based on those risks to give advice to Owner of assets what to do. Do you go on a concession or to make changes before PPP tender opening? i.e. to change legislation or financial model or whatever needed?
Question 3: What is your opinion of the "Water-Specific PPP Risk Model" developed under this research?	
Respondent 1	The risk model looks very interesting. It will come in handy for business case development for Water PPPs.
Respondent 2	Plausible, but... devil is in the details.
Respondent 3	The risk model has covered most of the aspects comprehensively.
Respondent 4	Valuable.
Respondent 5	Risk model Is OK. I will appreciate if you can divide in the model the three main RISKS (with three sub-programmes): • Technical risk • Legal Risk • Economical risk

6.11.1 Review of Comments made by the "Validation Team"

The outcome of the validation confirms the usefulness of the risk model, particularly the need for such model in industry practice. Naturally; the group has raised a number of remarks, which are consolidated under this section, with the researcher's response to each of the remarks.

1. **The model should be country-specific.**

   The researcher is in agreement with this remark. The risks associated with construction in general, and PPP in particular, is heavily reliant on the social, economic, and political conditions of the country in question. Roumboutsos and Anagnostopoulos (2008) have particularly addressed this topic by comparing risk allocation in the Greek PPP sector to the far more-advanced UK PPP sector, where they identified the difference in risk perception between the two markets. However, they concluded that such difference in risk perception is not only attributed to the maturity of UK the market over the Greek market, but also due to the different conditions between both countries.

In our research, extensive efforts were made to limit the model, and its associated survey, to certain countries, or geographical areas of similar conditions. A proposal was made to several major public and private entities with a request to engage their staff in responding to the survey. Unfortunately, such request was not accommodated by the approached entities for confidentiality reasons. Perhaps, the development of a "Country-Specific" "Water-Specific" PPP Risk Model will be more feasible in future, when the results of this research are published.

2. The identified risks are not specific to the water sector.

The identified risks were established based on an extensive review of water-specific PPP risks as demonstrated in this research, particularly Chapter 4, Section 4.6/7 and Chapter 5. A closer look at the identified risks in *Table 5.1* and Table 5.3 would support the same. It is natural that some of the identified risks are common with other infrastructure sectors procured under the PPP scheme. Perhaps further emphasis to readers about the development of water-specific risks is required, with no necessary change to the current risk model.

3. Model should adopt traditional risk valuation practices (probability/impacts)

The researcher considered the practicality of the proposed model and approach. The literature review included a detailed investigation of the industry practice (Section 3.5.2). This comment refers to the "qualitative assessment" carried-out as part of the Value-for-Money (VFM) analysis, however, it should be noted that The "Water-Specific PPP Risk Model" is not intended to replace the VFM analysis, but rather to support it, since the VFM analysis would have a more general assessment of the project risks that goes beyond the scope of the model. Accordingly, the normal valuation practices adopted in VFM analysis remains untouched.

The value of the Water-Specific PPP Risk Model is its capability to imitate the human mind conception of interdependency between the risk factors through the Analytic Network Process, which would offer an improved decision making process. In the future, the model would also be able to increase the reliability of the results through the establishment of benchmark risk values from previous projects.

The extent of the Water-Specific PPP Model in relation to the VFM analysis is clearly noted in the model.

4. Add risk mitigation measures to the model.

In line with risk management risk practices, the model has considered an overall strategy that includes risk identification, analysis, and treatment. Presenting specific risk mitigation measure for each specific risk was beyond the scope of this research.

5. Advice to owner about suitable procurement model, as an outcome of the model.

The model can be used for the assessment of several procurement models. This would require the assessor(s) to follow the model, for each proposed procurement model as part of the "Strategic Assessment" stage that precedes the Value-for-Money (VFM) analysis. Typically, and as noted under Section 3.5.2, the aim of the "Strategic Assessment" stage is to develop a risk profile of all models under consideration, not only PPP models. For example, the "Design-Bid-Build (DBO)" would be assessed, beside other potential PPP models like "Design-Bid-Finance-Operate (DBFO)", "Design-Bid-Operate (DBO)" …etc.

For the purpose of this research, a "generic" PPP model was assumed. The consideration of several PPP models would have extensively increased the number of survey questions, which would have hindered the progress of this research.

6. Split risks into technical, legal, and economical risks.

As part of the literature review, the various classifications of risks were studied, as noted under Section 3.4. The model was developed with special focus on water-specific risks. Hence, it was considered to establish risk groups unique to this sector like facility records, Asset condition, Unsustainable expansion, …etc. (Refer to Table 5.2 for the full list).

The proposed classification of risks is more applicable to the Value-For-Money analysis, which comes at a final stage, considering the overall risks, as opposed to the water-specific risks and categories considered under the "Water-Specific PPP Risk Model".

6.12 Summary

This section of the study proposes the use of ANP methodology to prioritize risks in water PPP projects. Risk sources were identified in literature, through source documents of past and experts' opinions, and accordingly were categorized into risk categories. A model for calculating Risk Priority Indices (RPIs) was designed and its components were explained and discussed in details throughout this chapter. The developed models were applied to six risk categories, and its sub-set elements, to evaluate their level of impacts on project cost.

Prioritization results revealed that poor communication with stakeholders, improper planning of interrelated projects, absence of maintenance records, and uncertainty of cost of maintenance have the highest average score in the hierarchy risks elements considered in this research. A brief discussion of each of the high risks was presented.

The relevancies of this chapter are that:

- It provides practitioners with a tool to evaluate and prioritize risks impact levels in new water PPP Projects; and,
- Provides researchers with risk areas and sub-areas, model to evaluate and prioritize risks and a methodology to quantify the qualitative effects of risk elements considering the inter-dependency between such risks.

This chapter presented the final outcome of the research, represented in the "Water-Specific PPP Risk Model". The model offers a suitable platform for addressing the risks associated with Water PPP Projects. Throughout the eight steps, suggested by the Author, the model is capable of deriving a reasonable level of confidence an estimated Value-for-Money, which is key in awarding a project under the PPP scheme. The model is unique in addressing special aspects:

- Recognizes the special nature of the Water Sector through the careful consideration of the Water-Specific risks.

- Utilizes the extensive study undertaken in this research by considering the identified Water-Specific PPP risks.

- Considers the value of past experience by offering benchmark priority preferences of risk identified in this research, which can be further expanded as more results become available.

- Considers the interdependency between the various risk elements through the suggestion of using of the Analytic Network Process (ANP) method.

- Offers an improvement towards bridging the gap between the academic and the practical approach to risk management: The model is easy to understand and use, which would encourage practitioners to apply it in their projects

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The literature review showed an intense debate over the involvement of the private sector in water infrastructure. This is accompanied with a severe drop in the number of Water Public-Private Partnerships (PPP) projects since year 2008, and a higher cancellation rate of water PPP projects in comparison to other infrastructure sectors. Based on the outcome of the literature review, the research questions were developed (Chapter 4, Section 4.5) and the research aim and objectives were formulated (Chapter 1, Section 1.4). Figure 1 below presents the research process introducing the research questions, aim, and objectives, leading to the development of the research plan (Chapter 1, Fig. 1.3).

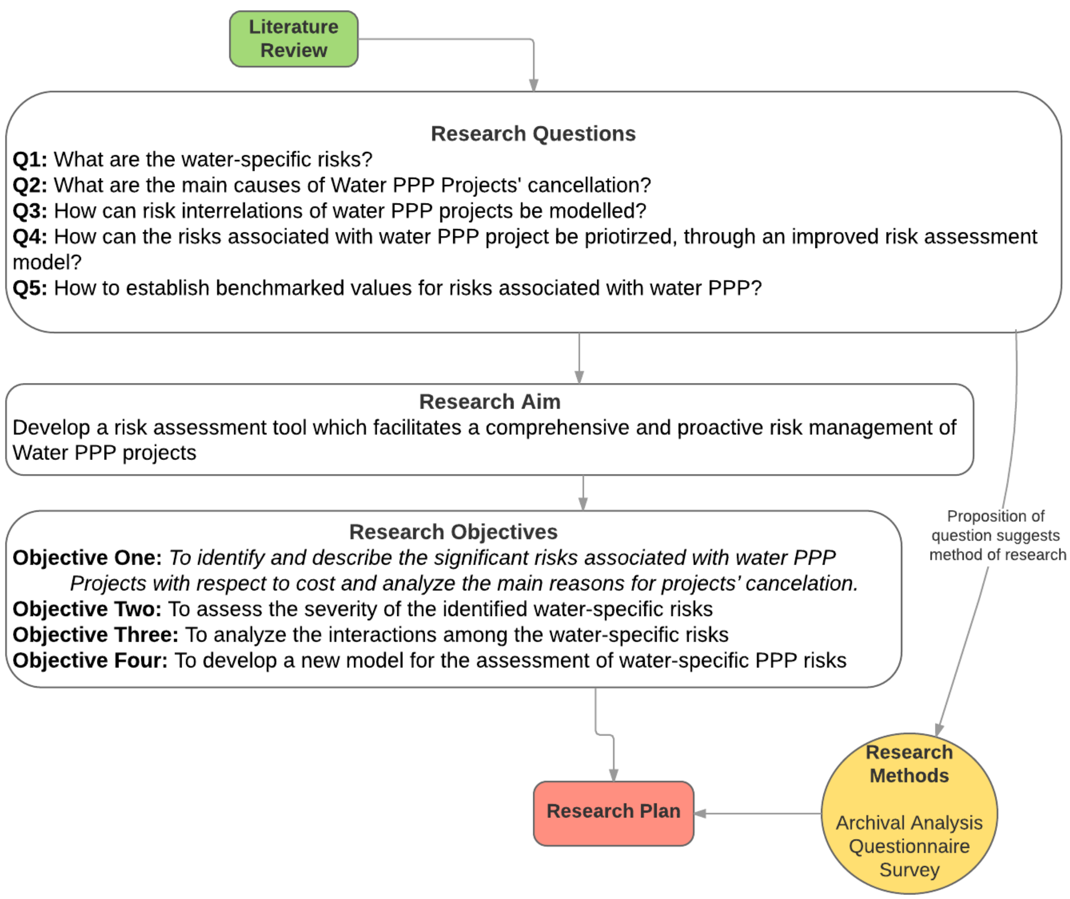


Figure 7.1: Research Process

The proposed research idea was reported to the research community (Korayem and Ogunlana, 2013). Professionals working in the water sector were consulted about the novelty of the research point and its benefit to the industry. The responses were positive and supportive of the research aim. Below are some excerpts of the professionals' comments:

- "You are doing a valuable work, all the best"
- "The study is useful for decision maker"
- "This would be a very useful research to give advice to decision makers"
- "…. We are busy looking at P3 developments with construction of dams. Would very much be interested in any info, that you assist and vice versa"
- "Would be very interested to participate on this"
- "…. I am currently working on an assignment of the ADB to develop investment guarantees for the WSS in Africa and would like to participate and contribute"

The six chapters presented so far have elucidated the literary, conceptual, methodological and substantive approach adopted in addressing the research agenda. In this chapter, the research is brought to a close by summarizing the issues addressed throughout the study. A summary of how the key research objectives were satisfied is presented followed by the main conclusions of the research. Finally, the thesis is brought to closure with recommendations for future research.

7.2 Review of Research Objectives

Objective One: *To identify and describe the significant risks associated with water PPP Projects with respect to cost and analyse the main reasons for projects' cancelation.*

- The risk identification commenced with a broad survey of literature that included current empirical studies and official publications, covering journal articles, conference papers, research reports, textbooks, commercial or organizational documents, governments practice guidance, records, reports, and the like.
- The literature review showed the specific nature of water infrastructure in comparison to other infrastructure sectors. Specifically, the irreversible nature of

its capital investment, the natural monopoly and the sensitive health and safety regulations associated with this sector (Chapter 2, Section 2.5). The literature review showed that such special nature of the sector was typically overlooked in the assessment of Water PPP projects, whether in research work or in industry practices (Chapter 3, Section 3.6).

- The critical literature review of the arguments of opponents and proponents of private sector involvement in the water sector facilitated a better understanding of the nature of this sector and in turn its risks (Chapter 2, Section 2.5.1). As an example, assuming that the private investor would endeavour to increase the usage of water network, or to consider lowering the prices so as to generate more revenue is not always valid as such increase will be accompanied with an increase in usage, which will be associated with an increased maintenance cost.

- A detailed review of the Value-for-Money analysis of a PPP project was undertaken. The risks identified in the case study were assessed (Chapter 3, Section 3.5.2). The critical review confirmed the need for a risk model specific to water PPP (Chapter 3, Section 3.6).

- The high cancellation rate of water PPP projects in comparison to other projects was generally overlooked in previous research work. To overcome this research gap, it was prudent to investigate the reasons behind project cancellation (Chapter 5, Section 5.3). Factors like the absence of performance baseline data, uncertainty of the condition of buried assets, and the potential "more" stringent health and environmental requirements were identified as the main reasons that historically led to the cancellation of Water PPP projects.

- The literature review of water maintenance and rehabilitation strategies showed a typical constraint of a fixed limited budget for maintenance accompanied with the need to maintain an acceptable performance of the network. This makes maintaining proper records of performance and maintenance very essential for proper operation.

- A review of the risk identification techniques adopted in literature was undertaken (Chapter 3, Section 3.3.1). Methods like literature review, quantitative content analysis, adopting of pre-determined risk lists, interviews, and questionnaire surveys were identified as the main risk identification methods.

- The literature review included studying research work on other PPP sectors which was gathered and grouped by risk categories like PPP political and legal risks, financial risks, social risks, and design and construction risks (Chapter 3, Section 3.4). These risks were referenced under "Other risks" in the model.

At the end, 17 water-specific risk elements were identified through cross-checking the multiple sources of evidence, and were well defined and described to ensure reliability and applicability to most of the water PPP projects. After the risks are identified, they were classified into six groups of like risks. Classification of the risks helps reduce redundancy and provides for easier management of the risks in later phases of the risk analysis process in the study (Chapter 5, Section 5.2).

Objective Two: *To analyse the interactions among the water-specific risks*

- The literature review showed the interdependency between the various risk elements involved in water PPP projects. For example, the increase of usage is expected to lead to an increase in revenue yet it is also associated with an increased pressure on the operator towards meeting the performance and environmental requirements, which in turn could be affected by the political situation and/or other inter-related delayed or underperforming projects. The literature review showed that the risk assessment methods that are typically adopted in research and industry are not capable of considering the interdependency between the various risk elements. In addition, the implemented strategies have typically considered limited survey results among the project team, which cannot offer reliable benchmarked priority assessments of the various risk elements.

- The review showed that with respect to the interdependency between the various risk elements, the Analytic Network Process would overcome the shortcomings observed in other "typically-used" risk assessment methods. In ANP, hierarchical structures are formed as a network structure that showcases interdependency amongst the risk elements. The interdependence of network elements allows better modelling and prioritization of risks elements.

- A network structure was constructed to create influence among the project goal, risk categories and elements. Risk categories: A, B, C, D, E, and F were considered as primary standards while sub-variables a1-2, b1-2, c1-3, d1-2, e1-5, and f1-3 were considered as secondary standards. The framework of ANP network process for all risks is shown in Figure 7.2. As shown on the figure, there is an outer dependency between the different categories and an inner dependency within each member category of risks in the risk prioritization structure. Indirect dominance comparison of variables was carried out according to their influence on project cost.

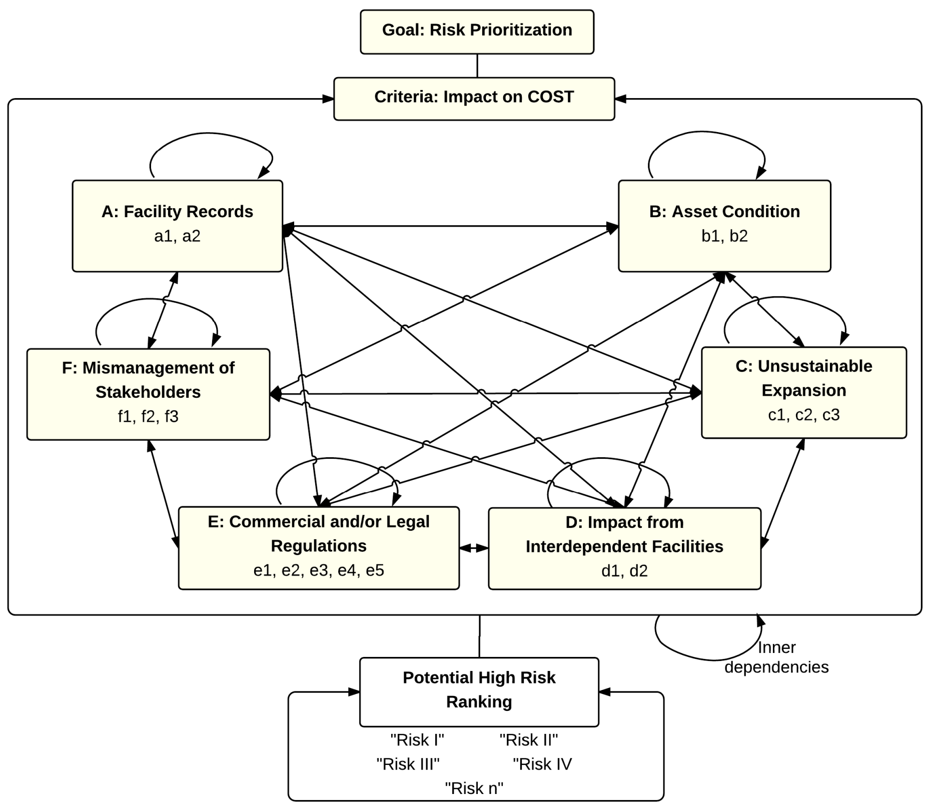


Figure 7.2: ANP Network Structure

Objective Three: *To assess the severity of the identified Water-Specific risks*

- Considering the identified water-specific risk elements, a research instrument in the form of a self-administered questionnaire was developed.

- The questionnaire survey was posted on-line through professional networks such as LinkedIn on 5 October 2015, providing the experts with a brief of the research project and requesting their collaboration in this research by completing the associated questionnaire survey (Chapter 5, Section 5.4). A total of fifty-three (53) responses were received. The professional background of the respondents showed that the respondents were competent enough and capable of participating in the survey (Chapter 5, Section 5.5). A plausible conclusion therefore is that the respondents are sufficiently well vested in water industry.

First, experts' decisions were solicited through a risk prioritization survey using a Likert type scale of 1 to 5 to score the level of risks impact on water PPP projects with respect to cost.

Second, risk prioritization was performed for the 17 risks identified during the literature review. The Analytical Network Process (ANP) was chosen against other alternative methods because of its explanatory nature and considering its capability to handle the interdependency between the various risk elements, which is a desired function of this research. The process of developing the ANP model includes: model construction, paired comparisons, criteria normalization through super matrix calculation, and risk priority index (RPI) calculation.

The risk assessment process allows for risk impact ranking and categorization into very high, high medium, moderate, low and very low impact categories.

Objective Four: *To develop a new model for the assessment of water-specific PPP risks*

The Water-Specific PPP Risk Model was developed as demonstrated in Figure 6.4. The model considered the following aspects:

- The concept of risk management in PPP (Chapter 3, Section 3.2): Considering that proper risk allocation at an early stage of the project is very useful. For which, the model considered an overall risk management strategy that includes the several risk management stages (risk identification, analysis, and treatment).

- Reference to benchmark risk priority indices through the research: These values can only be used with caution, as risks are specific to each individual project.

- Consideration of the interdependency between the various risk elements through the use of the Analytic Network Process (ANP) method.

- An improvement towards bridging the gap between the academic and the practical approach to risk management: The model is easy to understand and use, which would encourage practitioners to apply it in their projects

7.3 Conclusion

This study has successfully addressed an important research topic in the risk assessment literature — the risk assessment of Water PPP Projects. A model known as the "Water-Specific PPP Risk Model" was developed to assess the level of identified risks and the interactions of such risks impacting the performance of Water PPP Projects.

The "Water-Specific PPP Risk Model" suggested that risk in Water PPP could be categorized into six main groups. It can be emphasized that any organizational system can improve performance by ensuring these six risk groups have been properly assessed. Project managers involved in Water PPP projects must consider all of the risk elements during the entire project life cycle.

During the literature review process, it was evident that the interdependency between risk elements was not generally considered in pervious literature. The proposed risk model has successfully introduced the Analytic Network Process to consider such important aspect.

This research developed benchmarked risk priority indices, which can be used as a reference and would enhance the risk assessment process of Water PPP projects.

As noted by Boateng (2014), companies face ever-increasing challenges with respect to their investments. As such, there is heightened awareness on the importance of developing well-defined risk models. Regular and periodic review of the models through a formal model validation process can help management and stakeholders gain confidence in these critically important business tools. Companies also need to validate their models to keep pace with changes in market dynamics; the model validated yesterday may not still be valid today given the changes and shifts in the marketplace. Put simply, model validation is the quintessential tool in an organization's model risk management process.

7.4 Long Term Impact of the New Methodology

The research successfully developed a risk model that is directly related to Water PPP and can enhance the risk assessment and decision making process.

The Analytic Network Process (ANP) as a Multi-Criteria Decision Making Methodology- The model adopts the Analytic Network Process (ANP), which is a multi-criteria decision making methodology that can be applied by project consultants to facilitate risk identification workshops to conduct risk assessment based on the facilitator's skills and experience in risk elicitation to draw out judgments about uncertain events from the project team. The facilitator can conduct meetings with a smaller group of the most experienced project team members to elicit qualitative assessments of the major risks for the project. The likelihood and consequences of each risk event can be elicited from each team member. For simplicity, the facilitator has to use the discrete scale of 1 - 9 to represent the verbal judgment in pairwise comparisons which by applying ANP can generate a ranked list of risk priority values of consequences or risk priority indexes (RPI) considering the interdependency between the various risk elements.

Also, the ANP is capable of being used for the selection of the most suitable design or construction decisions among various alternatives, which can assist the decision makers with concluding with their investment decisions.

The "Water-Specific PPP Risk Model" and Risk Management- To reduce risks, companies can use the outputs of the new model for risk management in four steps: risk management planning, risk identification, risk analysis, risk response planning.

- Step 1: Risk Management Planning- Establish the team of experts to analyze the new potential water PPP project to assess the feasibility of this project; or to pro-actively test and improve the existing project plan such as forecasting and diagnosing the likely outcomes of the current plan.

- Step 2: Risk identification- The Water-Specific PPP Risk model can support risk identification. The model features the main risk categories and elements proposed for initial assessment. It is possible that the risk assessment team would identify other risks that have direct or indirect impacts on project outcome.

- Step 3: Risk analysis-The model recognizes interdependency between the various risk elements and can assist project managers in assessing all risks in a semi-quantitative manner. The risk prioritization stage should be considered for the assessment of risk impacts.

- Step 4: Risk Response-The model can be effectively used to support a proactive risk response as it suggests adopting a risk treatment technique, which would vary between risk reduction, avoidance, retention, and risk transfer. Special emphasis was made on risk allocation to ensure that the side that owns the risk is the best to manage it.

The "Water-Specific PPP Risk Model" and Project Management - The project manager now can better evaluate the risk elements of new projects. This involves the pre-assessment stage of risks and considers the interdependency between the various risk elements. The monetary value associated with risk is considered in the Value-for-Money analysis. A subsequent stage of risk monitoring and control by project managers would allow for identifying signs of unperceived risk emergence to avoid aggravation. Risk assessors and software developers can implement and further enhance such framework for an improved project outcome.

7.5 Contribution to Knowledge

In recognition of the special features of the water sector, this research successfully developed a risk model specific to this sector. Such consideration to the water specific features has been typically overlooked in previous research by implementing a generic approach considering generic PPP risk registers.

The private involvement in the water sector has been a subject of much debate where opponents and proponents of private involvement have been both demonstrating figures supporting their case. This research offered the decision maker the platform of applying a comparative basis for analysis through the consideration of the interdependency of the various risk elements associated with the water sector, where risk identification consists of an extensive literature review of previous research, case studies, industry publications, and interviews with industry experts.

The research in this thesis indicates for the first time the application of ANP to Water PPP risks. This would allow for further consideration of the interdependency between the various risks elements, which was overlooked in previous research work conducted on PPP. This approach could be considered in future research work in other infrastructure sectors.

Risk assessment of potential Water PPP projects typically considered the risk assessment to be undertaken through a limited-sized group of experts. This research included conducting a survey among industry experts to facilitate establishing benchmarked risk priority indices. Since risk remains specific to each project, the developed benchmarked values can only be used as a reference, but would certainly enhance the risk assessment process.

The model within this thesis has the capabilities of being used to simulate and support behavioural understanding, prediction and evaluation of risks for project planning and project performance improvement across a range of alternative PPP sectors. Some of the modeling constructs can be used for other project lifecycle models, such as an evolutionary risk-driven process.

The model has the capability to serve as a decision making policy tool with the ability to direct policy decisions by testing the effect of different policy scenarios. The insights generated will allow policy makers to make informed decisions regarding any future policy formulations concerning the risks effect on Water PPP project performance.

The model offered an improvement towards bridging the gap between the academic and the practical approach to risk management of potential Water PPP projects. The model is easy to understand which would encourage practitioners to apply it in their projects.

7.6 Limitations of the Findings

As with all survey based research there are bound to be limitations, which need to be acknowledged. Readers are therefore reminded of the potential effect of sampling, unsystematic (i.e. random) and measurement errors and their likely impact on the data collected, analysis undertaken and the conclusions drawn. These notwithstanding, the demographic profile of the respondents suggest that they have reasonable involvement and direct professional experience should accord some reasonable credibility to the quality of responses received.

It is also important to acknowledge the relatively small sample size used for the study. However, this should not nullify the conclusions drawn, given that the relevant variation statistics showed a reasonable deviation.

It is worth noting that the risks elements considered in this research are those directly relevant to the Water PPP planning and subsequent operation and maintenance. Other potential common PPP risks covering the social, construction, political aspects of the project should also be considered for a successful PPP, however are considered beyond the scope of this research. Such demarcation should be reflected on the developed Water-Specific PPP Risk Model.

Furthermore, the researcher still lacked some real data to demonstrate the validity of the risk model developed by the proposed approach. Due to confidentiality reasons, it was not possible for public sector officials and contractors to disclose real data. Therefore, applying a case with sufficient real data in the future research to test the approach is suggested.

7.7 Recommendations for Further Research

By this research, it is believed that academic professionals and industrial stakeholders could use the findings as a reflective document for initiating the establishment of an Association for the Risk Assessment of Water PPP Projects, which could develop the project managers' performance and for benchmarking and best practices during risk management. The following are recommendations for further research:

- **Water Industry Sub-systems:** The drinking water and wastewater infrastructure collectively known as the Water Sector. This study particularly concentrated on the drinking water component, which may include raw water collection, transportation, and treatment or could be limited to water distribution to the consumers (private houses, industrial, commercial, or institution establishments). The risk profile would vary depending on the project scope. Such differentiation was not feasible in this research but could be considered as a future research prospective.

- **Case Study / Life cycle of project** - Although the researcher has established the theoretical approach that is proved to be valid in developing a risk assessment model for water PPP projects, this theory still requires further research to assure its realistic representation. To enhance the model validity, the model parameters need to be calibrated by tracing and comparing the results with real project data in the future. The produced "Water-Specific PPP Risk Model" considers mainly the planning stage of the projects. A methodology like "System Dynamics" could be used for studying and management of dynamically complex systems by building and applying simulation models to complement the Water-Specific PPP Risk Model.

- **Sampling -** The results of the questionnaire survey remain limited to the collected sample. Further confidence in the results could be established if a larger sample, within a specific demographical area, can participate in a similar study. The researcher's effort to engage specific organizations in the research was not successful. While the research aim was considered valuable for such organizations, however, their participation was considered not feasible for confidentiality reasons.

  Further, the questionnaire survey was directed to water PPP practitioners. Someone may argue that some of the main risk factors, relevant to operation and maintenance, can be directed to governmental operators that can assist with the evaluation of risk elements, regardless of their expertise in PPP. Perhaps a new study can consider this direction, which would offer by far, more confidence on results, especially if limited to a certain demographic area.

- **Extension of Risk Criteria** - The developed "Water-Specific PPP Risk Model" considered the assessment of identified risks with respect to cost. This approach could be further extended to cover other criteria beside cost, like time and quality.

7.8 Summary

This chapter provided a review of the original research objectives and the extent at which they were achieved. Accordingly, the main conclusions have been presented and the limitations of the research have been acknowledged. Recommendations for further research have been proposed. In summary, the research has developed the "Water-

Specific PPP Risk Model", which represents a robust mechanism for risk assessment on the performance of Water PPP projects. The model could be used by project managers, to reveal the behaviour of risks, and maximize the performance over time. It is contended that the produced model has the potential for improving the outcome of Water PPP projects, when uses as a part of a wider sphere of risk management practices and procedures.

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