RISK ASSESSMENT AND ALLOCATION MODEL FOR PUBLIC-PRIVATE PARTNERSHIP INFRASTRUCTURE PROJECTS IN PAKISTAN

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Risk Assessment and Allocation Model for Public-Private Partnership Infrastructure Projects in Pakistan

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CERTIFICATE OF ORIGINALITY

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Khwaja Mateen Mazher

ABSTRACT

To overcome the budgetary constraints in the provision, operation and maintenance of public infrastructure and in recognition of the superior private sector skills and expertise, governments worldwide, including the Pakistani government, are increasingly turning to public–private partnerships (PPPs) for infrastructure delivery (economic and social). The initial impression of the option of PPPs may seem like a panacea for all public infrastructure needs; however, international literature has reported mixed results regarding their performance and success. PPP infrastructure projects are risky in nature, and inadequate risk management on projects is a principal cause of project distress or failure. Adequate assessment of risk is essential to assist stakeholders in planning for efficient risk allocation and mitigation and ensure success in business and projects. Furthermore, appropriate risk allocation and sharing is a critical success factor.

Although Pakistan has some experience in delivering infrastructure projects via PPPs, especially in power and transport infrastructure sectors, limited research is available to ascertain the situation in the local context. Moreover, the existing PPP body of knowledge and risk management literature can benefit from additional research in an effort to overcome certain limitations. Hence, the overall aim of this thesis is to develop an appropriate mechanism to enhance risk management outcomes in the context of PPP infrastructure projects in Pakistan. This aim was achieved with empirical investigations on the identification of risks and development of measures of effective risk management (ERM) to guarantee project success. The thesis also developed, demonstrated and validated risk assessment and allocation models to assist stakeholders in risk management decision making on projects.

Data for the achievement of the objectives was primarily collected via a questionnaire survey of 90 experts in the local industry, who were selected based on purposive sampling and semi-snowballing approaches. Eight semi-structured interviews, seven case-based surveys and expert reviews were also conducted to ground the study in an industrial and professional context. Self- and investigator-administered surveys were conducted. Various statistical tests and analytical approaches for risk assessment and allocation modeling were adopted. Statistical tests included: mean score ranking, inter- and intra-group agreement analysis, tests for reliability and validity and factor analysis. Fuzzy set theory (FST) in conjunction with simple additive weighting and fuzzy measure based fuzzy integrals were the utilized multiple-criteria decision-making methods for the risk assessment and allocation models.

Investigation to improve risk management outcomes on PPP projects resulted in identification and development of 30 ERM measures, all of which were rated at least *moderately important* on average. This outcome signifies the relevance of the proposed measures in terms of potentially influencing quality and outcomes of risk management efforts and guiding industry practitioners to deploy prevailing risk management guidelines, processes, tools and techniques effectively for achieving successful PPP projects. Factor analysis established six critical underlying dimensions for ERM as follows: (1) well-documented structured management approach; (2) comprehensive requirements and risk evaluation; (3) post-contract risk management; (4) knowledge-driven risk management; (5) risk assessment quality; and (6) public sector risk management. A conceptual framework for ERM on PPP infrastructure projects was also proposed to provide a systematic guideline to industry stakeholders and encourage implementation of the identified measures by clarifying their relationship with project parties, the project lifecycle and the risk management process.

Application of FST in risk analysis revealed 22 critical risk factors out of the 45-factor risk register developed for this study, that were categorized into seven critical risk groups (CRGs) of correlated factors using factor analysis. Risk factors that achieved a linguistic assessment of *high* impact reflect issues related to institutional capacity and local economy, which tallied well with outcomes reported in research on developing countries. Further analysis based on fuzzy measure and non-additive fuzzy integral combined with arithmetic mean helped obtain an overall risk index that indicated a *moderate* risk outlook for power and transport infrastructure sectors. Whereas, 'public sector maturity' and 'project finance' were assessed as *high*-impact CRGs in the power sector, 'project planning and implementation' and 'project revenue' were additionally rated as *high*-impact CRGs in the transport infrastructure sector. Case-based surveys revealed relatively better performance of the proposed model in mimicking experts' holistic project risk evaluations compared with the additive aggregation approach. The developed framework could be used to assess a country's condition or overall project risk at the initial project stage with minimal input of time and resources, thereby facilitating an efficient and robust risk assessment. Aggregate assessments at the CRG level could facilitate in highlighting key risk areas and may thus enable targeted and effective risk response planning and execution.

A comprehensive literature review augmented by industry experts' input identified 17 key risk factors that could exhibit diversity in risk allocation preferences (risk could be shared or allocated to a public or private party), which emanated from and could be attributed to contextual aspects (market, sector and project characteristics). A methodology in conjunction with non-additive fuzzy integral based multiple attribute risk allocation decision approach was proposed. Such methodology could effectively aggregate each stakeholder's risk management capability assessments on accepted risk allocation principles, which were derived from qualitative judgements and experience-based knowledge of experts. Data collected on the key risk factors from privately financed and developed power and transport infrastructure projects in Pakistan were used to demonstrate and validate the model. The model's output comprised the risk management capability index of each party for the key risks being considered, which could then be utilized to make an informed decision on allocation and sharing of risks. Comparison of results with an additive aggregation approach revealed the suitability of the adopted methodology as it performed better in modeling the risk allocation preferences of experts due to its capability to handle interdependencies in the risk allocation criteria. Analysis of the case studies advocated the need to investigate the allocation and sharing of key risks on a case-by-case basis to recognize the contextual factors and obtain an equitable and efficient risk apportionment for project stakeholders.

Research outcomes from this thesis have contributed to the body of knowledge for the risk management of local and international PPP infrastructure projects.

Keywords: Infrastructure public–private partnership; effective risk management; construction project success; decision making; fuzzy set theory; fuzzy measure and fuzzy integral; risk analysis; risk allocation.

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AHP	Analytical Hierarchy Process
ANP	Analytical Network Process
APM	Association for Project Management
BLT	Build-Lease-Transfer
BOO	Build-Own-Operate
BOOT	Build-Own-Operate-Transfer
BOT	Build-Operate-Transfer
BROT	Build-Rehabilitate-Operate-Transfer
CL	Contingent Liability
CPEC	China Pakistan Economic Corridor
CPPA	Central Power Purchasing Agency
CRF	Critical Risk Factor
CRG	Critical Risk Group
CSF	Critical Success Factor
D/B	Design/Build
DBB	Design-Bid-Build
DBFO	Design-Build-Finance-Operate
DBFOM	Design-Build-Finance-Operate-Maintain
DM	Decision Maker
EMDE	Emerging Markets and Developing Economies
ERM	Effective Risk Management
FA	Factor Analysis
FAHP	Fuzzy Analytical Hierarchy Process
FANP	Fuzzy Analytical Network Process
FHWA	Federal Highway Administration
FLINMAP	Fuzzy Linear Programming Technique for Multidimensional Analysis of Preference
FM	Financial Model
FMCDM	Fuzzy Multiple Criteria Decision Making
FSAW	Fuzzy Simple Additive Weighting
FSE	Fuzzy Synthetic Evaluation
FST	Fuzzy Set Theory
FTOPSIS	Fuzzy Technique for Order Preference by Similarity to Ideal Solution
GDP	Gross Domestic Product
GI HUB	Global Infrastructure Hub
GoKp	Government of Khyber Pakhtunkhwa
GoP	Government of Pakistan
GoPb	Government of Punjab
GoS	Government of Sindh
HK	Hong Kong
IPDF	Infrastructure Project Development Facility
IPF	Infrastructure Project Financing
IPP	Independent Power Producer

IT	Information Technology
JRM	Joint Risk management
KIBOR	Karachi Interbank Offered Rate
KMO	Kaiser-Meyer-Olkin
KPK	Khyber Pakhtunkhwa
LCU	Local Currency Units
LIBOR	London Interbank Offered Rate
MADM	Multiple Attribute Decision Making
MCDA	Multiple Criteria Decision Analysis
MCDM	Multiple Criteria Decision Making
MERM	Measure(s) of Effective Risk Management
MRMP	Multi-party Risk Management Process
MS	Mean Score
MSA	Measure of Sampling Adequacy
MV	Minimum Variance
NEPRA	National Electric Power Regulatory Authority
NTDC	National Transmission & Dispatch Company
OBOR	One Belt One Road
OGC	Office of Government and Commerce
ORI	Overall Risk Index
PCA	Principal Component Analysis
PDFL	Pakistan Development Fund Limited
PFI	Private Finance Initiative
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PPA	Power Purchase Agreement
PPI	Private Participation in Infrastructure
PPIAF	Public-Private Infrastructure Advisory Facility
PPP	Public-Private Partnership
PRM	Project Risk Management
PSC	Public Sector Comparator
PSDP	Public Sector Development Program
RAC	Risk Allocation Criteria
RATTs	Risk Analysis Tools and Techniques
RLNG	Re-Gasified Liquefied Natural Gas
RMC	Risk Management Capability
RMCI	Risk Management Capability Index
RMP	Risk Management Process
RMPr	Risk Management Practice
ROO	Rehabilitate-Own-Operate
ROT	Rehabilitate-Operate-Transfer
SAW	Simple Additive Weighting
SBP	State Bank of Pakistan
SCR	Sovereign Credit Rating

SPSS	Statistical Package for Social Science
SWOT	Strengths-Weaknesses-Opportunities-Threats
TDS	Tariff Differential Subsidy
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
UK	United Kingdom
UNCITRAL	United Nations Commission on International Trade Law
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
USA	United States of America
VDTF	Victoria Department of Treasury and Finance
VfM	Value for Money

CHAPTER 1 INTRODUCTION[1]

1.1 INTRODUCTION

The economic activity and growth of a country and its delivery of essential services for domestic and industrial purposes depends on investment in economic and social infrastructure (Allen and Overy 2010; East Asia Analytical Unit 1998; Martini and Lee 1996; Yescombe 2007). Traditionally, the provision of infrastructure has been nearly an exclusive responsibility of the government (Grimsey and Lewis 2007; State Bank of Pakistan 2007), where all the functions of long-term infrastructure network planning at central and regional levels, financing, construction, operations and maintenance and so on, were governmental activities (Grimsey and Lewis 2007). The dominant public sector role in infrastructure delivery can be attributed to the recognition of the political and economic importance of infrastructure, the belief that problems with the supply technology require strong and active government response and the notion that governments can succeed where markets apparently suffer (World Bank 1994). However, the reality is that public sector infrastructure projects are found to be inefficient, unreliable and suffering from poor fiscal control (ibid.). Many researchers provide several recent accounts indicating relatively poor performance (time and/or cost overruns) of traditionally procured infrastructure projects (Ahsan and Gunawan 2010; Bansal 2012; Beckett et al. 2009; Brown et al. 2009; DLA Piper 2009; Liu et al. 2015a; Raisbeck et al. 2010). According to the World Bank (2005), engaging a private firm

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Parts of this chapter have been included in:

[1] Mazher, K.M., Chan, A.P.C., and Zahoor, H. (2017). "A research framework for effective risk management in public-private partnership (PPP) infrastructure projects in Pakistan." *13th International Postgraduate Research Conference (IPGRC 2017)*, C. Pathirage, U. Kulatunga, Y. Ji, R. Gameson, C. Udeaja, C. Trillo, M. Takhtravanchi, and B. Allali, eds., University of Salford, Salford, UK

provides good alignment between government and private party interests with public interests, thereby adding value by transforming decision making and accountability. Engaging a private firm can create a focus on service and commercial performance, making it easy to access finance and boost policy clarity and sustainability (World Bank 2005). These observations and many other drivers compel current governments to consider and champion private participation in public infrastructure development. The benefits of introducing the discipline of the private capital markets in improving construction and operation efficiency to ensure project completion at best value while avoiding unnecessary delays have been recognized (Grimsey and Lewis 2007). In addition, more market benefits can be realized by merging the public and private sector resources in infrastructure projects rather than opting for a completely public or private (privatization) model (ibid.).

Delivering infrastructure projects by private sector participation via public–private partnerships (PPPs) is arguably an efficient approach of fulfilling public infrastructure needs (Bansal 2012; Beckett et al. 2009; Brown et al. 2009; DLA Piper 2009; Liu et al. 2015a; Raisbeck et al. 2010). This approach allows for increased integration of design, finance, construction, operation and maintenance into a single contract (Yescombe 2007) and provides a medium for tapping into private sector expertise (Marques and Berg 2011); meanwhile, the government can focus on policy, planning and regulation by delegating project operations (GoP 2010; World Bank 2016f). In addition, this method to project delivery also facilitates in the infusion of private capital for public service delivery, thereby enabling governments to cope with ever tightening budgets and public borrowing constraints (Allen and Overy 2010; UNESCAP 2008).

The PPP reference guide (World Bank et al. 2014) states that no single internationally recognized definition of the term “public–private partnership” exists; nevertheless, the following broad view definition of PPP was adopted:

"A long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility, and remuneration is linked to performance." (p. 14)

Pakistan's policy on PPPs defines the procurement arrangement as (GoP 2010):

"Public Private Partnerships (PPP) involve the financing, development, operation, and maintenance of infrastructure by the private sector which would otherwise have been provided by the public sector. Instead of the public sector procuring a capital asset and providing a public service, the private sector creates the asset through a dedicated standalone business (usually designed, financed, built, maintained and operated by the private sector) and then delivers a service to the public sector entity/consumer in return for payment that is linked to performance." (pp. 2–3)

While focusing on the provision of infrastructure, Grimsey and Lewis (2007) defined PPPs as:

"…arrangements whereby private parties participate in, or provide support for, the provision of infrastructure, and a PPP project results in a contract for a private entity to deliver public infrastructure-based services." (p. 2)

On the basis of the aforementioned definitions, the essence of PPPs lies in the public sector contracting for (purchasing) a stream of services under specified terms and conditions (and performance standards) rather than buying an asset.

The mechanics of such arrangements vary in terms of the division of responsibility between public and private sectors where no hard and fast rules exist (Grimsey and Lewis 2007). The exact layout of features regarding the nature of assets involved, the functions of public and private sectors in relation to these assets, the required services and remunerations, and other contractual details vary subject to government needs and project characteristics. In a PPP contract, the public sector party or the public authority is known by various terms, including grantor, contracting authority, public party, government procuring entity, procurer, public entity, institution or authority (Grimsey and Lewis 2002; World Bank 2018a; Yescombe 2007). It may be associated with the central, state or regional government or any other entity that is controlled by the public sector (Yescombe 2007). The private sector party (project company) is usually a special-purpose company, also known as the private party (Yescombe 2007). A private sector consortium is likely to include equity investors/sponsors, debt financiers, design and/or construction contractors and operators (VDTF 2001). The relationship between the two parties is not a legal partnership but a contractual one wherein the terms of the relationship are specified by the PPP contract (Yescombe 2007). These arrangements can be classified on the basis of the legal nature of the private sector's project involvement and the nature of contracted service, the manner of debt repayment and the public and private sectors' risk apportionment (Pantelias and Zhang 2010).

Flyvbjerg et al. (2002) argued that the public sector bodies encounter a very different and demanding situation with public–private sector contractual agreements. Adopting a private service provision indicates that the government assumes contractual and regulatory roles (Arndt 2000). The government must ensure that the public (taxpayers and users) obtains maximum possible value for money (VfM) and provide certain guarantees regarding the operating environment to protect private sector interests. Given the existing evidence of better performance of projects delivered through PPPs as opposed to traditional procurement strategies (noted above), an ample debate against PPPs also exist for being unable to deliver VfM and the high cost of arrangements to taxpayers by providing excessive profits to private companies (Beckers et al. 2013; Bel et al. 2017; Guasch et al. 2008; Hodge and Greve 2007; Kurniawan 2013; Ng and Loosemore 2007; Shaoul et al. 2006). Moreover, public and private sectors are exposed to additional risks due to the complexity of financing arrangements and the uncertainty inherent in the long concession period (Dey and Ogunlana 2004; Zhang 2005a). This situation is also due to the new risks arising from the context and greater risk transfer to the private sector. Effective project risk management is therefore a critical success factor and the key to project success, which is also true because risks have a direct bearing on project objectives (Baloi and Price 2003; Project Management Institute 2009; Thomas et al. 2006).

This thesis endeavors to identify significant factors and develop and present methodologies to influence prospects of project success by enhancing project risk management efficiency and outcomes in several ways. The study reported here focuses on identifying risk factors for PPP infrastructure projects and on proposing and validating relevant risk assessment and allocation models. Moreover, measures that influence the effectiveness of risk management efforts on PPP projects have also been established. Extant literature has addressed many risk management issues in PPP infrastructure projects, and efforts have been made in this study to add to the existing body of knowledge.

1.2 NECESSITY TO STUDY RISK MANAGEMENT IN PPP INFRASTRUCTURE PROJECTS

Risk is defined as an uncertain event or condition, the effect of which manifests as either benefit or loss to project objectives (e.g., scope, quality, cost and schedule) and to specific individual, group or organizational objectives (Loosemore et al. 2006; Project Management Institute 2013)[2]. Construction projects are inherently complex and involve significant risks (Smith et al. 2014). However, in comparison with traditional procurement methods, PPP projects are riskier due to long concession periods, high capital investment, complexity of contracts, the diversity of motives and interests of various project participants and nonrecourse financing arrangements (Dey and Ogunlana 2004; Yang and Dai 2006; Zhang 2005a; b). Studies have shown that these characteristics introduce many additional risks, including regulatory, political, financial, sponsor, market, interface, technical, operational and industrial relation risks (Loosemore and Cheung, 2015). The risks involved are diverse because they span across various phases of the project lifecycle (i.e., project identification and detailed preparation, procurement and project implementation (construction, operation and maintenance]) (Chan et al. 2011; Grimsey and Lewis 2002; Hodge 2004; Ke et al. 2011; Li and Zou 2011).

Risk management involves the identification and management of significant risks in a systematic manner that should follow an established process framework (Chapman and Ward 2003; Cooper et al. 2005; Project Management Institute 2013). Risk management strategy is utilized to avoid losses and use available chances (positive effects) through careful consideration and assessment

[2] The citation Project Management Institute (2013) refers to the fifth edition of the Project Management Body of Knowledge Guide. The sixth edition was published in 2017. However, as the research reported in this thesis started in late 2015, the fifth edition was utilized because it was the latest edition at that time.

of the situation and potential future scenarios to eliminate all risks and use all chances. This approach implies the recognition of the potential risks and management of a threat by aversion, evasion or reduction of associated negative effects (Schieg 2006). Traditional risk management faces greater challenges due to the longer contract period associated with long-term PPP projects vis-à-vis the short-term contract period of traditional projects (Xiong et al. 2017). Under such circumstance, comprehensively planning for potential risks over the long-term project becomes impossible or extremely expensive (ibid.). Effective risk management (ERM) relies on timely and representative forecast of the future; practical, reasonable and cost effective hedging tools; and flexible attitude and procedures as the accuracy of expectations decreases with time (Lee and Schaufelberger 2013).

For PPP infrastructure projects, Zou et al. (2008) argued the necessity of properly assessing the financial, political and public acceptance/rejection risks; ensuring VfM; and protecting the public (and end user's) interests. These aims can be achieved through balanced stakeholders' interests (government/public, private partners and end users) and optimal identification, assessment, allocation and management of risks form a life-cycle perspective (ibid.). High capital investment and the long planning and operating periods of such projects render the forecasting of cash flow difficult and expose the private sector to considerable financial, political and market risks (Ye and Tiong 2000a). Furthermore, the financial methodology of project financing (a principal source of financing such projects) requires precise projection of capital and projected costs, revenues, taxes, expenses and liabilities to establish the creditworthiness of the project company on a "stand alone" basis for the purpose of borrowing, even before the construction or generation of project revenues (UNCITRAL 2001). The magnitude of debt and equity that the project can support are determined via these projections, which must be conducted over a long period (20 years or more). Hence, risk identification, assessment, allocation and mitigation are central to project financing from a financial point of view (ibid.). Moreover, bridging the interests of the public authority, the lenders and the equity investors and promoting interparty collaboration and satisfaction of individual interests are all essential to guarantee successful completion and operation of a PPP project (Pantelias and Zhang 2010). Figure 1.1 depicts the relationship between risks and individual stakeholder objectives to explain graphically how the distribution of risks may affect stakeholders' objectives and interests as risks eventuate at the pre- and post-financial close stages of the project. The public authority measures a project's viability in terms of increased social welfare from project development and achieving the best VfM. Equity investors are mainly interested in profitability, whereas lenders assess the viability of a project in terms of the recovery of the issued debt (Darvish et al. 2006; Grimsey and Lewis 2002; Pantelias and Zhang 2010; Yescombe 2007). Osei-Kyei and Chan (2015) identified appropriate risk allocation (*transfer* to private partner or *retention* by public

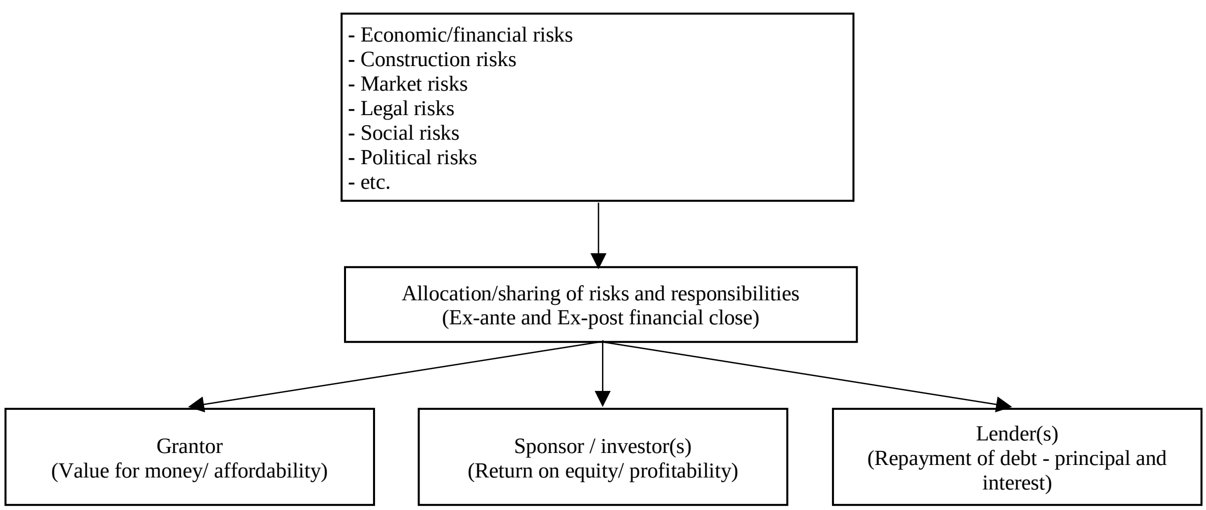

Fig. 1.1. Relationship between stakeholders' objectives and risks (adopted and modified from Grimsey and Lewis 2002)

partner) and sharing as among the most reported critical success factors for PPP project implementation. Such allocation directly influences the ability of and prospects for primary stakeholders to achieve their expectations with reference to their individual perspectives on risks (Darvish et al. 2006; European PPP Expertise Centre 2012; Grimsey and Lewis 2002; Organization for Economic Cooperation and Development 2008; Pantelias and Zhang 2010; Yescombe 2007).

1.2.1 Risk Management Research on PPP Projects and Its Limitations

A review of risk management research in the domain of international PPPs demonstrates the need to study the measures of ERM for specifying the factors that influence the quality and success of risk management efforts on PPP projects. This undertaking is important in the wake of many troubled or failed PPP projects that reportedly suffered such fate due to poor risk management (Abdul-Aziz 2001; Asian Business 1996; Chan et al. 2014; Choi et al. 2010; Dey and Ogunlana 2004; European Commission 2004a; Hayford 2013; Ke et al. 2009a; Lee and Schaufelberger 2013; Li et al. 2007; Loosemore and Cheung 2015; Marques and Berg 2010; Ogunlana 1997; Stemmer 2008; Tam 1999; Wibowo and Mohamed 2010; Ye and Tiong 2000b; Yuan et al. 2008a). Inefficiencies in projects may arise from inadequate specification of risk within the contract, non-identification of risks (Arndt 2000; Zou et al. 2008), poor assessment and allocation of risks (Arndt 2000; European Commission 2004b; HM Treasury 2012; Loosemore and Cheung 2015; Marques and Berg 2011; Thomas et al. 2003; Zou et al. 2008), re-allocation upon default of a party to shoulder a risk, lack of contractually allocated risk enforcement in the event of crystallization of a risk and high transaction costs in determining the allocation of risks following a risk event (Arndt 2000). Extant literature has identified several issues that correspond to potentially negative outcomes for ERM on PPP projects, such as those related to risk management maturity of project stakeholders, experience of delivering and managing projects under PPP arrangement, access to suitable risk mitigation resources, dispute resolution frameworks and collaborative risk management (Chowdhury et al. 2015; Fischer et al. 2010; Jin 2010; Jin and Zuo 2011; Ke et al. 2011; Pipattanapiwong et al. 2003; Yeo and Tiong 2000; Zou et al. 2009). Fischer et al. (2010) argued that in addition to the technical aspects of risk management in PPPs, the managerial aspects of risk management also require consideration. Hence, identifying the factors and important measures that influence ERM is necessary to avoid and manage the potential inefficiencies and enable stakeholders to identify, analyze and plan for a risk response as well as monitor and control risks adequately. The determination of the measures in this study seeks to specify strategies to enable ERM and encourage stakeholders to pursue project performance improvement by enhancing risk management outcomes.

Risk identification, analysis and response planning constitute some of the core processes of the project risk management process (Project Management Institute 2009, 2013). According to a review, Chan et al. (2011) indicated that an objective, reliable and practical PPP project risk assessment model and mechanism for fair interparty allocation of project risks are essential for project success. One notable limitation of the risk assessment models in the extant literature (Ameyaw et al. 2017; Ameyaw Effah et al. 2015; Wang and Elhag 2007; Xu et al. 2010b; Zayed et al. 2008) lies in treating project risk events/factors as independent of each other. This practice is in line with traditional multicriteria evaluations wherein the criteria are assumed to be independent; however, the condition of criteria independence is usually inapplicable in real-world problems (Liou and Tzeng 2007), thereby requiring further attention. Moreover, the privatization of infrastructure projects characterize substantial reallocation of responsibilities, risks and rewards between public and private sectors (Zhang 2005b). Such an arrangement is also supported by previous discussion. Zhang (2005a) contended that PPPs should not be regarded by governments as a mechanism for delivering infrastructure projects via the transfer of all the risks to the private sector and the shedding of all their responsibilities; instead, governments should consider that PPPs require proper risk allocation and management. Appropriate risk allocation and sharing (Osei-Kyei and Chan 2015) is interpreted on the basis of the premise that risks should be allocated to the party that has better capability to manage them (ADB 2000; Irwin 2007; Xu et al. 2010a). Despite the importance of such allocation, multiple studies have indicated inadequate risk allocation practices on PPP projects (Arndt 2000; HM Treasury 2012; Marques and Berg 2011; Zou et al. 2008). Furthermore, existing models that assist stakeholders in risk allocation and sharing present their own implementation challenges and limitations, such as those related to the adoption of comprehensive risk allocation criteria (RAC), ease of implementation, ignorance of RAC interactions in some cases and validation of models and their robustness.

Extant academic and institutional PPP literature details efforts undertaken over the years to identify relevant risks, determine the most critical risk factors (CRFs) and suggest risk allocation strategies that are derived from experts' preferences or different analytical models. Several contextual factors that influence risks and their management must be recognized. Such factors include country or market, sector and project characteristics; differences in the capabilities of project participants; and working practices and strategies (Ameyaw and Chan 2013; APMG International 2016a; Carbonara et al. 2015; GI Hub 2016; Ibrahim et al. 2006; Ng and Loosemore 2007; Nguyen et al. 2018; VDTF 2001). These contextual aspects can influence the significance of risks and therefore their optimum allocation on projects. Hence, the knowledge contained in the existing literature must be complemented with contextual aspects to utilize it fully.

Pakistan, a developing country, is facing an acute shortage of infrastructure in virtually all infrastructure sectors and ranks 116 out of 138 countries in infrastructure (Schwab 2016). PPPs have been recognized as a partial solution for fulfilling short-term public infrastructure needs. The country has witnessed considerable private sector investment in the power sector, followed by a relatively new founded interest in the procurement of transport infrastructure projects via PPPs. In addition to offering prospects for fulfilling infrastructure needs, as previously discussed, PPPs boast a relatively high-risk profile for all stakeholders, which can result in poor outcomes/failures if not identified and managed properly. PPP projects in Pakistan face multiple risks (Economist Intelligence Unit 2015; Fraser 2005; Sachs et al. 2007; Soomro and Zhang 2011); however, a systematic investigation of such risks is yet to be conducted. Noor (2012) reported that some public sector organizations had limited success with non-traditional form of procurement (PPP) and finances in Pakistan, whereas some others had almost no success at all with its adoption. Moreover, several indications in the literature have suggested that Pakistan lacks the capabilities and structure for PPP-based project procurement in most infrastructure sectors and bears low-risk management maturity in the construction industry in general (including clients, consultants and contractors) (ADB 2015a; Choudhry and Iqbal 2012; Economist Intelligence Unit 2015; Noor 2011; World Bank 2010). Systematic risk identification, allocation and management are essential to the successful undertaking of PPPs due to inadequate PPP experience and skills in many regions and countries (Reside 2009; Zhang 2005a; Zou et al. 2008).

Hence, the risks in the relatively young history of PPP-based procurement of infrastructure projects in Pakistan should be explored and models and strategies should be developed for the effective management of such risks. The present work expended efforts to overcome all the aforementioned limitations.

1.3 SIGNIFICANCE AND VALUE OF THE STUDY

Given the importance and role of PPPs in the context of the developing and under-resourced economy of Pakistan, the paucity of research in the national context and the identified limitations of extant research, this study identified several important objectives. According to the lessons drawn from the above review (see also Chapters 3–5), this study aims to identify ERM measures; ascertain and assess risks pertinent to the Pakistani PPP infrastructure industry; and propose, develop and validate models to assess risk and assist stakeholders in achieving a capability-based risk allocation for future projects. All these objectives seek to enhance the performance of the projects for public and private sector stakeholders. This work also concentrates on the identification and comparison of critical risks across different infrastructure sectors (i.e., power and transport infrastructures), which are the most active in Pakistan and in other developing countries, as evident from the Private Participation in Infrastructure Database of the World Bank (2018b). Furthermore, while the findings related to critical risks in different infrastructure sectors may be extrapolated only for other countries and regions with similar characteristics (e.g., emerging markets and developing economies), the proposed models and measures for ERM in relation to PPP infrastructure projects will have broader implications because the study design is intended to produce generic outcomes. The proposed models potentially provide superior capability to analyze data reliably and will assist decision makers in project risk assessment and allocation. The suggested models can be applied to any project, irrespective of the country and infrastructure sector contexts.

1.4 RESEARCH AIM AND OBJECTIVES

Given the research limitations set out above, this study seeks to conduct an empirical investigation into risk management in PPP infrastructure projects. This study aims to achieve this goal by delivering the following objectives:

1. To investigate the project delivery trends in infrastructure procurement in the Pakistani construction industry and evaluate the scope of applicability and issues related to the PPP model for infrastructure procurement;
2. To develop and evaluate the ERM measures for PPP infrastructure projects to enhance and complement the efficiency of risk management efforts on projects;
3. To identify risks, assess stakeholders' perceptions on risks and develop a risk assessment model for PPP infrastructure projects;
4. To determine the optimal RAC for PPPs; and
5. To develop a risk allocation model to assist in the efficient and equitable allocation and sharing of risks on PPP infrastructure projects.

1.5 RESEARCH METHODOLOGY

This research effort can generally be divided into four stages, as shown in Figure 1.2. Stage 1 consisted of an initial literature review and informal discussions with a few PPP professionals and experts. This stage aims to develop an understanding of the current scenario with respect to the state of PPP project procurement strategy in Pakistan and the need to conduct research on related risk management issues. Stage 1 also assisted in the formulation of the objectives of this research and a rough outline of the methodology to execute these objectives.

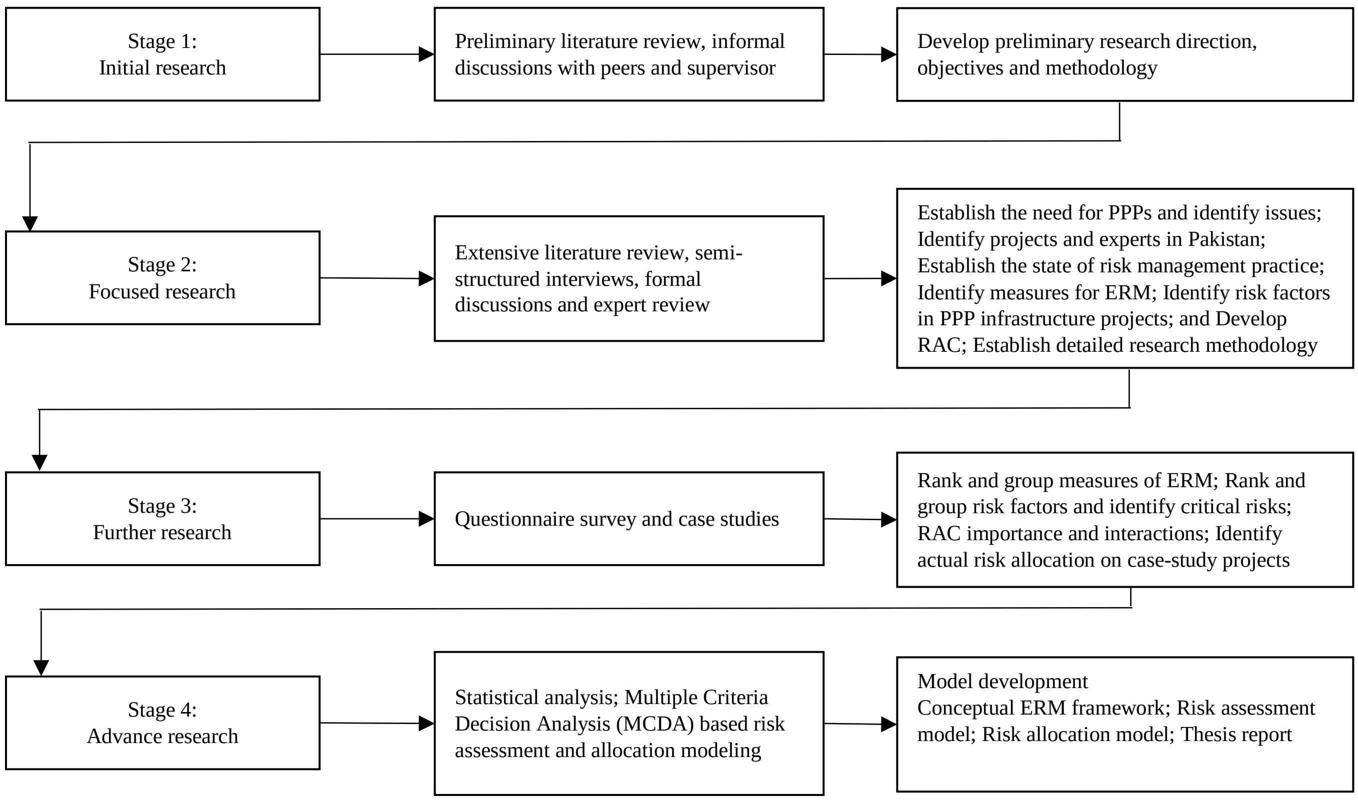

Fig. 1.2. Overall research procedure (adopted and modified from Ameyaw 2015)

Stage 2 involved an extensive literature review to develop an understanding of the state of the art for each objective of the research and the development of a detailed research methodology. Semi-structured interviews were conducted in Pakistan to understand local risks and issues in the practice of risk management and PPP implementation along with collection of information on important projects in active infrastructure sectors (more in Chapter 3) and relevant professional contacts. Risk factors, ERM measures and the applicable RAC were identified and piloted at this stage. Stage 3 entailed actual data collection, whereas Stage 4 included data analysis, the formulation of results and the drafting of the thesis report.

1.6 APPROACH OF THE STUDY

This study covers the development of ERM measures and the identification, analysis and allocation of risk factors that are encountered during various phases of a PPP project, spanning project identification and detailed preparation, procurement and project implementation in PPP infrastructure projects in Pakistan. Research efforts were limited to the power and transport infrastructure sectors given their popularity for private investment in local and international contexts (see Chapter 3) and the constraints on access to experts for data collection. Furthermore, as explained in Chapter 3, most of the private investment for infrastructure development has been operationalized as concessions using the build–operate–transfer (BOT), build–own–operate–transfer (BOOT), build–own–operate (BOO) modalities and other variants of the PPP procurement strategy. However, as this research aims to identify and analyze risks, propose and validate models for risk assessment and allocation and issue recommendations for ERM efforts, a distinction based on the characteristic differences of each modality has been largely ignored and where necessary, has been automatically accounted for using project-specific case studies.

Notably a primary assumption in conducting this research is to deliver outputs that will complement and assist the experts and relevant decision makers (public and private sectors' stakeholders) while making important decisions related to the implementation and operational management of projects under the framework of PPPs in Pakistan. The findings are not intended to provide a comprehensive guide for novice individuals in the risk management of PPP infrastructure projects.

1.7 STRUCTURE OF THE THESIS

Chapter 1 introduces the basis and elaborates the significance of this study. A summary of the state of the art and the objectives to be accomplished is provided along with a brief overview of the methodology adopted in this study.

Chapter 2 provides a detailed description of the research methodology adopted to achieve the objectives of the study. Included discussions involve the adopted research approach, selected data collection and analysis methodologies in relation to the research approach, MCDA modeling techniques (for risk assessment and allocation modeling) and information on survey and data collection efforts.

Chapter 3 presents a general introduction on the country, the infrastructure needs and the issues and describes the current state of practice related to private investment in public infrastructure projects in Pakistan. This chapter details the active infrastructure sectors, individual projects that have been developed and executed and the PPP modalities being deployed. Furthermore, relevant drivers, barriers, risks and issues specific to the risk management of these projects from the published literature are summarized to provide a better grounding of the significance of this research.

Chapter 4 specifies the risk management process in general and in the context of PPPs. It further reviews extant literature and models with regard to risk assessment and allocation for PPP infrastructure and highlights the knowledge gaps to set the stage for further research.

Chapter 5 presents the status of risk management on PPP projects internationally by highlighting failed and stressed projects and establishing the inadequacy of risk management efforts as an underlying cause. Thereafter, the chapter proceeds with a discussion to identify and enlist potential measures for ERM from an extensive review of the published literature and interviews with experts. The factor development methodology and detailed factor descriptions are provided. A conceptual framework for ERM on PPP infrastructure projects is also presented.

Chapter 6 seeks to develop a list of risk factors relevant to the Pakistani PPP projects. This aim is achieved through a comprehensive literature review and interviews with the experts in Pakistan. This chapter reviews studies that have previously identified risks in PPP projects, the methodology adopted for the review, the interview results and how the final list of suitable risks was developed along with the risk classification framework adopted for this study.

Chapter 7 presents the detailed analysis, results and validation of ERM measures based on empirical and validation questionnaire surveys.

Chapter 8 provides the analysis and results of the empirical risk assessment exercise to identify critical risks on PPP infrastructure projects in the Pakistani context and further presents the development and validation of the project risk assessment model.

Chapter 9 explores the development and validation of the model for risk allocation and sharing on PPP infrastructure projects. This chapter also includes two project case studies from different infrastructure sectors and a comparative analysis of model results versus actual risk allocations. It also highlights risks that require special attention to ensure VfM for both sectors.

Chapter 10 concludes this research by summarizing the outcomes along with a discussion on the limitations of the study and possible future research directions.

1.8 CHAPTER SUMMARY

Shortage of infrastructure (economic and social) and the need for efficiency in public infrastructure project delivery have been key motivators for adopting PPPs. However, the risks associated with this mode of project delivery demand careful management from the involved stakeholders to ensure successful fulfillment of organizational and project objectives. Several gaps in the knowledge were briefly highlighted to support and justify the need to undertake this study, which principally relate to the lack of existing research in the Pakistani context and the limitations of the existing risk management decision support models and frameworks. Therefore, this study sets out to explore risks and their management in the context of the Pakistani PPP infrastructure project industry and endeavors to present models and frameworks to assist relevant stakeholders in critical decision making. The overall approach of this work and the chapter framework of this thesis were also discussed to provide a structured guide for readers.

CHAPTER 2 RESEARCH METHODOLOGY[3]

2.1 INTRODUCTION

This chapter deals with the adopted research methodology and explains how it becomes relevant to the objectives defined in Chapter 1. Data acquisition and data analysis methods and information on risk assessment and allocation modeling techniques are presented to address all the objectives of this research. The chapter also includes relevant discussion on sampling methodology and participating respondent experts and organizations.

In the reviews conducted by Tang et al. (2010a) and Zhang et al. (2016), research methods including case study, questionnaire survey, literature review, and interview were all affirmed to have been adopted in PPP research. Zhang et al. (2016) also inferred that multiple research methods were generally adopted in research studies and further contended that this endeavor makes a study more rigorous and convincing as more research methods allow the cross validation of the research findings. This is good for research studies in the constriction management field (ibid.). In this research, data were principally collected using a questionnaire survey protocol, where the questionnaire survey forms were developed on the basis of an extensive literature review and semi-structured interviews of PPP experts. Case study surveys were adopted where necessary for the

[3] Parts of this chapter have been included in:

Mazher, K.M., Chan, A.P.C., Ameyaw, E.E., Zahoor, H., Choudhry, R.M., & Edwards, D.J. (under review). "Measures of effective risk management for infrastructure public-private partnership projects." *Engineering, Construction and Architectural Management*.

Mazher, K.M., Chan, A.P.C., Zahoor, H., Khan, M.I. and Ameyaw, E.E. (2018). "Fuzzy integral based risk assessment approach for public-private partnership infrastructure projects." Journal of Construction Engineering and Management, 144(12), 4018111.

Mazher, K. M., Chan, A.P.C., Zahoor, H., Ameyaw, E.E., Edwards, D.J., & Osei-Kyei, R. (accepted). "Modelling capability based risk allocation in PPP projects using fuzzy integral." Canadian Journal of Civil Engineering.

development of risk assessment and allocation models. The validation of research findings and proposed models was also performed. The software tool Statistical Package for Social Science (SPSS) v 23.0 and Microsoft Excel 2015 were employed for various analyses, such as mean score ranking, inter- and intra-group agreement analyses, tests for reliability and validity, factor analyses and other assessments performed for the demonstration of the application of fuzzy multiple criteria decision-making methods. The fuzzy measure and Choquet integral analysis for the risk allocation model was implemented using the Kappalab package (Grabisch et al. 2015) for the GNU R statistical system (R Development Core Team 2005).

2.2 RESEARCH APPROACH

According to Creswell (2013), three approaches to research are available, namely, qualitative, quantitative and mixed methods research approaches. Rather than representing distinct categories, the qualitative and quantitative approaches to research lie on a continuum with the mixed methods research approach positioned in the middle as it incorporates the elements of qualitative and quantitative approaches. The difference between two extremes is more than that of working with words or numbers and involves multi-characteristic considerations rooted in the intersection of philosophy or philosophical worldviews (postpositivist, constructivist, transformative and pragmatic), design (quantitative (e.g., experiments), qualitative (e.g., ethnographies) and mixed methods (e.g., exploratory sequential)), and specific methods of research (questions, data collection, data analysis, interpretation and validation) (ibid.). The qualitative research approach is applied to determine and understand the meaning that individuals or groups attribute to a social or human problem. The testing of objective theories through the examination of the relationship among the variables is enabled by using the quantitative research approach. The combination of the characteristics of the qualitative and quantitative research approaches is available in the mixed methods research approach that aims to develop a complete understanding of the research problem (ibid.).

An exploratory sequential mixed-methods design was adopted for this research (Fig. 1). Creswell et al. (2003) proffered that a mixed-methods approach is the most effective for research in management and organizational studies. In a sequential mixed-methods design, the qualitative phase leads the research process to support and enhance the succeeding quantitative phase. Given the need to understand the aspects related to risk management from extant literature and the real-world practice of PPP projects, a pluralistic approach toward inquiry (set within the context of a pragmatic philosophical worldview) was adopted. Accordingly, qualitative methods were first employed for the identification of the measures of ERM, risk factors and relevant risk allocation criteria from in-depth literature reviews and semi-structured interviews. Such endeavor was then followed by a quantitative questionnaire-based data collection approach to determine the relative importance of the measures of ERM and the probability and severity ratings of risk factors. Case-based surveys were conducted to demonstrate and validate the models developed for risk assessment and allocation. A post analysis survey to validate the research findings was also conducted for the measurement of ERM. The mixed methods research approach has been popularly employed in PPP research (Ameyaw and Chan 2016b; Banihashemi et al. 2017; Gannon and Smith 2011; Hu et al. 2015; Ng et al. 2012; Yang et al. 2009).

2.3 RESEARCH METHODS FOR THIS STUDY

Given the research approach and design for this study, the specific data acquisition and data analysis methods adopted have been presented in Table 2.1. Subsequently, the details of each data

Table 2.1. Research methods, analysis techniques and purpose

	Research objectives	Research methods	Analysis techniques	Purpose
1.	To investigate the project delivery trends in infrastructure procurement in the Pakistani construction industry and evaluate the scope of applicability and issues related to the PPP model for infrastructure procurement;	▪ Literature review	▪ Content analysis	To establish background on the characteristics and nature of, and need for, PPP projects in Pakistan and to understand possible issues (barriers and risks) impacting such projects.
2.	To develop and evaluate the ERM measures for PPP infrastructure projects to enhance and complement the efficiency of risk management efforts on projects;	▪ Literature review ▪ Semi-structured interviews ▪ Pilot study	▪ Content analysis	▪ To collect and consolidate relevant factors
		▪ Questionnaire survey	▪ Cronbach's coefficient	▪ Reliability test
			▪ Kendall's coefficient of concordance/Chi-square test ▪ Spearman's rank correlation coefficient	▪ To check stakeholders' overall level of agreement and among different groups
			▪ Mean score ranking	▪ Identify most important factors
			▪ Values of correlation coefficient ▪ Anti-image correlation matrix ▪ Kaiser-Meyer-Olkin ▪ Bartlett's test of sphericity	▪ To check appropriateness for factor analysis
			▪ Factor analysis	▪ Obtain underlying variables (principal factors) or independent common factors

Table 2.1. Research methods, analysis techniques and purpose

	Research objectives	Research methods	Analysis techniques	Purpose
3.	To identify risks, assess the stakeholders' perceptions on risks and develop a risk assessment model for PPP infrastructure projects;	▪ Literature review ▪ Semi-structured interviews ▪ Pilot study	▪ Content analysis	▪ To collect and consolidate relevant factors
		▪ Questionnaire survey	▪ Cronbach coefficient	▪ Reliability test
			▪ Kendall's coefficient of concordance/Chi-square test ▪ Spearman's rank correlation coefficient	▪ To check stakeholders' overall level of agreement and among different groups
			▪ Risk impact analysis and fuzzy ranking	▪ To rank risk factors and identify critical risks
			▪ Values of correlation coefficient ▪ Anti-image correlation matrix ▪ Kaiser–Meyer–Olkin ▪ Bartlett's test of sphericity	▪ To check appropriateness for factor analysis
			▪ Factor analysis	▪ Obtain underlying variables (principal factors) or independent common factors
			▪ Fuzzy Simple Additive Weighting ▪ Fuzzy Measure and Fuzzy Integral analysis	▪ To perform sectoral and project risk assessment and obtain overall risk index
4.	To determine the optimal RAC for PPPs; and	▪ Literature review ▪ Semi-structured interviews ▪ Pilot study	▪ Content analysis	▪ To obtain the essential risk allocation criteria

Table 2.1. Research methods, analysis techniques and purpose

Research objectives	Research methods	Analysis techniques	Purpose
5. To develop a risk allocation model to assist in the efficient and equitable allocation and sharing of risks on PPP infrastructure projects.	▪ Questionnaire survey	▪ Fuzzy Simple Additive Weighting ▪ Fuzzy Measure and Fuzzy Integral analysis	▪ To determine public and private sectors' risk management capability via formulation of risk management capability index for individual risks that are to be allocated or shared
	▪ 2 x Case studies		▪ To solicit risk allocation on actual projects (1 x each infrastructure sector) ▪ Comparison between recommended practice, actual allocation and model results

collection and analysis methodology have also been exhibited.

2.4 RESEARCH METHODS (DATA ACQUISITION)

2.4.1 Literature Review

Research efforts in any area are characterized by a detailed and a systematic review of the relevant theory and literature. The review of theory and literature should be critical and must deliver to the readers of the research report a summary of the 'state of the art' in terms of the extent of knowledge and the main issues relevant to the topic to inform and rationalize the research being undertaken (Fellows and Liu 2015). Literature review not only limits itself to the reading of the relevant research publications but also focuses on presenting the critiques of the extant work to identify the knowledge gap, summarize the research progress, and consolidate the research findings (Yeung 2007). Literature review is foundational to any research project. To highlight the knowledge gaps, summarize the existing literature and synthesize it such that a new perspective will emerge, the literature review should realize several important objectives that include the following: demarcate clearly the scope of the study with justification; position the extant literature in a broader scholarly and historical context; and go beyond reporting claims made in the existing literature and critically examine the research methods employed for a better understanding of whether the claims are warranted (Boote and Beile 2005).

For the reported research work, the desktop literature review focused on the critical sources of information including academic (e.g., journal and conference papers, post-graduate thesis and text books) and institutional (e.g., standards, guidelines and reports) literature and other relevant Internet-based information. Basically, the review process aimed at supporting and setting a foundation for the principle objectives of this research. A detailed literature review focused on determining the current procurement practices prevalent in the acquisition of public infrastructure projects in Pakistan; the drivers and barriers to the implementation of the PPP model of project delivery; the intrinsic and context specific risks; and the local risk management practices (objective 1, see Chapter 3). Furthermore, a comprehensive and a systematic desktop literature review was undertaken to determine risk management practices (internationally), shortcomings, failures, issues and inefficiencies in risk management and potential factors that may enable ERM on PPP infrastructure projects (objective 2, see Chapter 5). The in depth reviews of literature also helped in identifying risk factors specific to the PPP model of project delivery (objective 3, see Chapter 6) and in developing the necessary background on risk management, in general, and risk assessment and allocation research relevant to PPP-based project procurement, in particular (objectives 3, 4 and 5, see Chapter 4). The review led to the development of research methodology as well (this chapter).

2.4.2 Semi-structured Interviews

Kahn and Cannell (1957) defined interview as a purposeful discussion between two or more people. Interviews can be conducted using multiple modes, such as face to face, telephone or Internet/intranet based (Saunders et al. 2012). Interviews may take the form of a highly formalized and structured interaction to an informal and unstructured conversation. On the basis of this spectrum of formality and structure, Saunders et al. (2012) categorized interviews into structured, semi-structured and unstructured (or in-depth) interviews. A structured interview seeks high reliability and repeatability (David and Sutton 2004); hence, a questionnaire based on a predetermined and identical question set (the authors also referred to this as interviewer-administered questionnaires) is used to solicit information from all the participants (respondents) and the answers recorded on a standardized schedule usually with pre-coded answers (Saunders et al. 2012). In a semi-structured interview, the interviewer will have a list of themes and questions prepared; however, not all the questions may be administered in each interview, the choice of which may be based on a specific organizational context encountered in relation to the research topic. Some questions may be omitted, the order of the questions may be changed, or some additional questions may be required to explore the research question and objectives (Saunders et al. 2012), thereby providing some degree of probing or flexibility (Fellows and Liu 2015). Unstructured interviews, as the name suggests, do not use any predetermined list of questions and allow the interviewer to thoroughly explore an issue (Saunders et al. 2012). Interviews may be used to help gather valid and reliable data to fulfill the research objectives or to formulate a research question and objectives in case it has not yet been done (Saunders et al. 2012).

For the purpose of this research, a semi-structured interview approach was deemed more appropriate given the nature of the problem at hand and the need to incorporate expert judgments and opinions which would not be easily explored if a structured/unstructured approach was adopted. As the study set out to understand the issues related to risk management on PPP infrastructure projects in Pakistan, the preliminary understanding developed on the basis of a comprehensive literature review (mostly international literature) was required to be further enhanced and adopted to the local context of Pakistan. The purpose of the semi-structured face-to-face interviews was to collect the most current and necessary information from practitioners with direct hands-on experience such that any mismatch between theoretical and contextual aspects could be ratified. An important purpose of conducting the interviews was to determine whether the risk factors for assessment and allocation, RAC, and measures of ERM (described later in

Chapters 4, 5, and 6) identified from the literature review were appropriate, clear, sufficient, and representative. The interviews also enabled the researcher to learn more about the actual practices and issues related to PPP projects in Pakistan.

In total, eight industry experts were interviewed using a purposive sampling approach (Banihashemi et al. 2017; Ng and Skitmore 2002) such that only those individuals who have satisfied particular predefined criteria of actual PPP project development and/or execution experience, knowledge of matters related to project risk management and a minimum of five years of exposure to such projects were considered as respondents for the interview. All the interviewees occupied senior positions in their respective organizations and had sufficient experience to adequately respond to the subject. These experts came from the public (5 no.) and private (3 no.) sectors; had 5–15 years of experience of handling PPP power and transport infrastructure projects; and had undertaken various roles within the industry, such as deputy director, director, financial analyst, infrastructure specialist and chief operating officer. Given the experience of the interviewees in having managed/managing multiple projects and the representation of public and private sectors' interests from multiple infrastructure sectors, the responses obtained were deemed sufficient. The interviews were limited to eight only because of the restrictions of time and the inability to solicit commitment of more experts. Furthermore, the number of interviews was also deemed sufficient with reference to previous studies (Ng et al. 2012; Ng and Skitmore 2002; Wang and Yuan 2011; Yang et al. 2009) that employed a maximum of eight interviews for studying various issues in construction. Appendix A presents the details of the interviewees along with the summary of the responses. The questions asked included inquiries about the lifecycle risks that impact projects in each sector (power and transport infrastructure), an exploration of the way the respective organizations were practicing risk allocation on various projects, a discussion on criteria for determining the risk management capability of the public or private sector stakeholders, issues relevant to the efficiency of risk management efforts on PPP infrastructure projects in Pakistan and risks that need special attention with regard to allocation and sharing on projects. Projects for conducting case studies were also identified, and key contacts were collected for future data collection. Some discussion on specific issues (e.g., institutional aspects and country specific characteristics) on the most recent projects that the interviewees had worked on was also carried out, but the information was only recorded for improving an understanding of the local situation and was not reported as a part of the summary of the semi-structured interviews. Owing to the nature of the semi-structured interview methodology, some interviewees provided case specific details on many risks and ERM factors, as they were brought under discussion, which proved very useful in comprehending the specific concerns that were not apparent under the broadly defined factors. Voice recording was not allowed; therefore, notes were made during the interviews and immediately after the meeting to record the facts as fresh. Discussions about the findings from the semi-structured interviews were covered in relevant chapters ahead.

2.4.3 Questionnaire Survey

Chow (2005) deduced that a survey may be generally accepted as the most preferable methodology in construction management research that enables the collection of data in a standardized format from the samples of a population. Data collection via questionnaire survey is a widely used method in PPP research (Osei-Kyei and Chan 2017a; Tang et al. 2010a; Zhang et al. 2016). A questionnaire survey can incorporate open or closed questions (Fellows and Liu 2015). This method is relatively inexpensive, allows the evaluation of numerous respondents in a relatively short time, affords freedom to the respondents to carefully ponder over their responses and allows the respondents to answer at their convenience, among other benefits (Mangione 1995; Osei-Kyei and Chan 2017a). Fellows and Liu (2015) asserted that the questionnaire should be unambiguous, easy to answer and avoid soliciting unnecessary information and should not require extensive data collection from the respondents and that the answers should be requested in an unthreatening manner. Self-administered questionnaires may result in a low response rate; thus, respondents might not be typical of the target population, which may result in a biased sample (Mitchell and Jolley 2012). Furthermore, the absence of interaction between the researcher and the respondent can create interpretation differences due to potential ambiguities. Investigator-administered questionnaires can be employed to overcome these limitations (ibid.).

2.4.3.1 Structure of the Questionnaire

The developed questionnaire solicits input on the following primary concerns of the research:

a) the evaluation of the importance/significance of the measures of ERM;
b) the assessment of the risk factors relevant to the PPP infrastructure projects evaluated on the attributes of risk probability and severity;
c) the evaluation of the importance of the risk allocation criteria (RAC), interaction among RAC, ranking of interaction indices and other relevant preferences of the decision makers/experts; and
d) the evaluation of key risk factors based on the RAC to determine risk management capability (RMC) for the interpretation of an appropriate risk treatment strategy (risk allocation or sharing).

The questionnaire survey was planned to be executed in two parts. Part one (see Appendix B) aimed at collecting information against the first two primary concerns. The questionnaire was divided into three sections for the first part. Section A requested the respondents to provide background information indicating their organization, designation, experience in industry specific to PPP projects, relevant infrastructure sector, the most recent project they had worked upon and contact details. Section B solicited the perceptions of the respondents regarding the probability and severity of individual risk factors, informed by their experience. Section C requested the respondents to provide their input to indicate the importance of the identified measures of ERM. This endeavor enabled fulfilling the requirements of objectives two and three. Separate validation questionnaires were prepared for the measurement of ERM and the risk assessment model to complete the research requirements (see Appendices D and E). The finalized questionnaire complete with an introduction to the research and its objectives and all the sections mentioned above also included an appendix that contains definitions for all the measurements of ERM and risk factors to facilitate consistent understanding by the respondents.

For part two (see Appendix C), another questionnaire was designed, informed by the input of the experts and literature on risk allocation and sharing (see Chapters 4 and 9); it enlisted key risk factors that exhibit the greatest diversity in the risk allocation preferences of the stakeholders and hence are contentions from the risk allocation and sharing perspective. Case-based surveys were conducted on projects from power and transport infrastructure sectors to demonstrate and validate the proposed risk allocation and sharing model. This enabled the researchers to fulfill the requirements of the third and fourth primary concerns and helped in meeting the requirements of objectives four and five of this research. This questionnaire comprised an introduction section, a section to solicit background information on the participating experts, a section for soliciting the actual allocation of risks for the case-study projects, a section for determining the importance/significance of RAC and other information on RAC interactions and a section for soliciting respondents' input on RMC assessments against each key risk. Descriptions for each risk included in the survey were also provided in the appendix to the questionnaire.

Self-administered and investigator-administered questionnaire surveys were administered for this research. The main reason for the adoption of the investigator-administered survey was to increase the survey response rate, enhance the understanding of the contextual issues and to increase the reliability of the responses by clarifying the meaning/intent of the survey questions, wherever needed.

2.4.3.2 Pilot Study and Expert Review

Before the finalization of the questionnaires (parts one and two) for empirical data collection in Pakistan, the draft questionnaires developed were piloted with five experts from the interview panel to ensure suitability (content, logical sequence and length) and the comprehensibility and clarity of the questionnaire (Ameyaw and Chan 2015a; Fellows and Liu 2015; Yang et al. 2009). The respondents of this pilot study were requested to review and answer the survey form and offer their comments where necessary and to indicate issues with clarity or content of the questions posed at the improvement of the survey questionnaire. Given that no adverse comments were received, the questionnaire for the empirical questionnaire survey was then finalized.

Additionally, two international experts, one senior academic from Hong Kong with experience in PPP research and one industry expert representing a large transaction advisory firm in Australia, with 25 years of experience in working on PPP projects, were invited to review and comment only on the identified measures of ERM. Some changes were suggested to the wording of the titles of few identified measures, while one of the measures obtained inconsiderable support with regard to its significance (see Chapter 5). The suggested changes were accommodated in the finalized questionnaire. Figure 2.1 exhibits the detailed procedure that shows the steps for the development of the questionnaire.

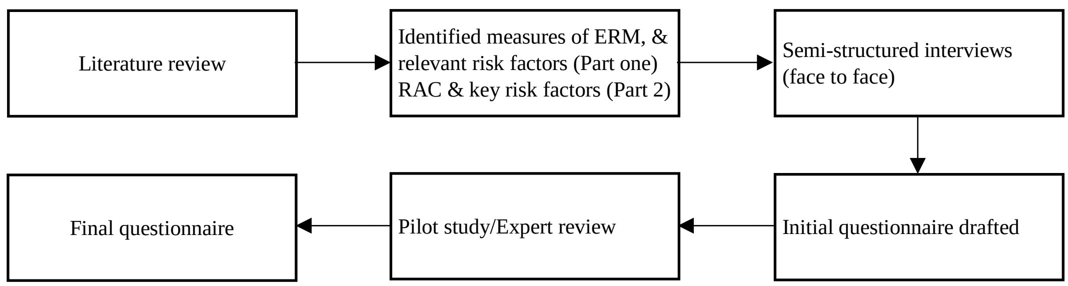

Fig. 2.1. Development of the empirical questionnaire survey form

2.4.4 Sampling Methodology

Surveys in essence produce information about an entire population; however, given that the populations can be far too large to be fully surveyed, surveys employ sampling to characterize the population such that it yields enough reliable data to draw inferences about the population at a required and specified level of confidence (Fellows and Liu 2015). Purposive sampling and a semi-snowballing approach (Saunders et al. 2012) were adopted to ensure that the respondents had sufficient working experience (implementation and/or execution) on at least one PPP infrastructure project and possess relevant exposure to dealing with PPP specific transactions and risks incurred. These criteria facilitate in ensuring that quality responses are received by allowing for the careful selection of industry experts. The combined sampling approach suits the local context well given that no comprehensive directories that enlist PPP experts and their attributes are available;

therefore, referrals from purposively identified experts were used to expand the data collection envelope. These approaches have been adopted in previous research as well (Ameyaw and Chan 2016b; Osei-Kyei and Chan 2017a). Experts from all stakeholder groups were contacted to participate in this research, including PPP units (federal/provincial), public authorities, lending institutions, investors, consultants, and project sponsors/companies.

2.4.5 Case Study

A particular contemporary phenomenon can be empirically investigated using multiple sources of evidence and within its real life context by employing a case study research strategy (Yin 2009). The approach facilitates the in-depth investigation of particular instances within the scope of the research (ibid.). PPP risk factors and their allocation are by nature context specific (at country or market, sector and project levels) as suggested by many researchers (see Chapters 1, 4, 8 and 9). Case study is an effective methodology to capture relevant project features in PPP applications (Gomm et al. 2000; Zhang et al. 2016). According to Zhang et al. (2016), case studies have been popularly adopted in PPP research, which provides a suitable and effective method to enable the investigation of complex PPP features in the unique and sophisticated project specific context.

Case studies were undertaken on actual projects while fixing risk allocation as the unit of analysis in this research for the development and validation of the risk allocation model (see Chapter 9). Research data were obtained through an investigator-administered questionnaire. This scenario allowed the researchers to explore the contextual details on allocation and sharing of project risks and the circumstances that surround the risk allocation decision making. Secondary data were collected in the form of project documents and other related sources (where available). Case-based surveys were also conducted for the demonstration and/or validation of the risk assessment model (see Chapter 8). Ameyaw et al. (2017), Hu et al. (2016), Lam et al. (2007), and Zayed et al. (2008) previously employed similar methodologies for the demonstration and validation of models.

2.5 RESEARCH METHODS (DATA ANALYSIS)

Several statistical tests were run on the data collected through the questionnaire surveys and analyzed using various software platforms, such as Microsoft Excel 2015, SPSS v 23, and specialist software for assessment via fuzzy measure and fuzzy integral. A detailed description of each of the tests is provided below.

2.5.1 Tests for Reliability and Validity

It is important to establish the reliability *("… the extent to which the instrument yields the same results in repeated trials")* and validity *("… the extent to which an instrument accurately measures the target it was designed to measure")* of the questionnaire instrument in a research driven by questionnaire-based data collection (Andrew et al. 2011). For internal consistency reliability, the Cronbach coefficient test (discussed below) was applied. An increase in reliability and validity is followed by a decrease in measurement error (ibid.). Wong and Aspinwall (2005) corroborated that content validity cannot be judged numerically and can only be subjectively assessed by the researchers. Construct validity can be established by testing the extracted factors for unifactoriality (Black and Porter 1996). These approaches for reliability and validity testing were adopted from Yang et al. (2009).

2.5.2 Cronbach's Coefficient

Cronbach's alpha coefficient, Cronbach's alpha, or simply Cronbach's α is a method for measuring the internal consistency reliability of a group of items/variables in how well they measure a single, unidimensional latent construct (Andrew et al. 2011). It depicts the correlation between the item responses in a questionnaire. Factors extracted from questions with two possible answers and/or multi-point formatted questionnaires or scales may be evaluated for reliability by calculating the coefficient value (Santos 1999). In this research, two constructs were assessed and measured on a scale that includes the identified risk factors and the measures of ERM. Cronbach's α value ranges from 0 to 1, and values at 0.7 or above are considered desirable in social sciences (Andrew et al. 2011).

2.5.3 Mean Score Ranking

Mean score (MS) ranking was employed to determine the relative significance of the measures of ERM that were rated on a pre-defined scale. Multiple researchers have used this analysis technique in construction management research to study the drivers, risk factors and other aspects in construction management research under various relevant themes (Ameyaw and Chan 2015b; Chan et al. 2009; Zhang 2005c). The MS ranking index can be simply determined by using the following formula:

$$\text{MS} = \frac{\sum(f\ x\ s)}{N}, \tag{1}$$

where *s* is the score/rating of the respondent (on a pre-defined scale), *f* is the frequency of the responses, and *N* is the total number of the responses.

A seven-point Likert item scale (1 = not important [NI], 2 = very low importance [VLI], 3 = low importance [LI], 4 = moderate [M], 5 = important [I], 6 = very important [VI], and 7 = extremely important [EI]) was used for the assessment of the measurements of ERM to ensure higher statistical variability among the responses (Ahire et al. 1996; Ameyaw and Chan 2015b). The scales adopted for the linguistic assessment of risks (probability and severity), the importance of RAC and the assessment of RMC will be explained later.

2.5.4 Risk Impact Analysis

The impact of risk is usually quantified by calculating the square root of the product of the evaluated risk factor's average probability of occurrence and the average severity of risk. Many studies have used this methodology to develop a risk index to aid in ranking the risks and to determine the most significant (top ranking/critical) risks (Ameyaw and Chan 2015b; c; Chan et al. 2014; Xu et al. 2010b). The risk impact was calculated as follows:

$$\text{Risk Impact} = (\text{Probability x Severity})^{1/2}. \qquad (2)$$

The simple product of probability and the severity of the risk will give us what is better known in literature as the 'Expected Value' (Cooper et al. 2005). Taking the square root of the product facilitates in obtaining an index that reflects the priority/significance of the risk on the scale originally adopted for the assessment of the probability or severity.

2.5.5 Agreement Analysis

Two tests were applied to determine the agreement on the rankings of factors between the respondents in general and to check the agreement on the rankings between the respondents from different groups. Kendall's coefficient of concordance is a non-parametric test (Chan 2011), which determines the extent to which a set of raters or judges agrees with one another when assigned to rank a set of objects (factors/variables) given three or more sets of ordinal data (Tavakoli 2013). Given that the total number of attributes evaluated was more than seven, Chi-square was used instead as a near approximation of Kendall's coefficient of concordance to determine the agreement between the respondents (Siegel and Castellan 1988). Furthermore, Spearman's rank correlation coefficient (non-parametric test) was determined to check the agreement in the rankings between the respondents from different groups. If the Chi-square and test coefficient (r_s) values are significant at a pre-determined significance level (e.g., 0.05) (or the values are higher than the predetermined critical values at the significance level), then no significant disagreement emerges between the respondents (within a group and between the groups, respectively) (Siegel and Castellan 1988). These tests have been previously adopted in similar studies (Chan et al. 2011; Chileshe and Kikwasi 2014; Ke et al. 2011; Yang et al. 2009).

2.5.6 Factor Analysis

Factor analysis (FA) is a dimension reduction technique of multivariate statistics (Chiou et al. 2005) that reduces many interrelated variables to a small number of groups (Brown 2015). The pattern of correlations within a set of observed variables is explained by underlying variables or factors, the identification of which is the focus of factor analysis (SPSS Inc. 2010). It assists in identifying a smaller number of factors that can explain most of the variables observed by simplifying a larger matrix of correlations (Kline 1994). Principal component analysis (PCA) is generally applied as a method to reduce data and to convert a large number of variables (or factors) to a smaller number of variables (without any prior information on the occurrence of any underlying constructs to which the variables potentially belong) (Dawson 2016). The appropriateness of applying FA for the extraction of factors is determined by evaluating multiple indices including the values of correlation coefficient, Bartlett's test of sphericity, anti-image correlation matrix and Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy (MSA) (Hahs-Vaughn 2016). According to the author (ibid.), correlation coefficient values should be 0.30 or greater to ensure sufficient relationships to justify the investigation of the potential underlying components. Bartlett's test of sphericity is conducted to reject the null hypothesis that the observed correlation matrix equals the identify matrix, thereby requiring statistically significant test results. The KMO-MSA is an index of shared variance in the variables, and its value ranges between zero and one with large values providing another evidence that the variables are factorable, while the MSA values on the diagonal of the anti-image correlation matrix should be large (ibid.). Various steps in conducting FA include (Chan et al. 2004) establishing the variables of interest (i.e., measurements of ERM and critical risk factors relevant to PPP infrastructure projects), computing the correlation matrix for all variables, extracting and rotating each variable (SPSS provides seven methods for factor extraction and five methods for rotation and three methods for computing factor scores [SPSS Inc. 2010]), and interpreting and labeling principal (grouped) factors as underlying factors. PCA was employed for factors extraction followed by varimax rotation as similar procedures for conducting FA have been applied previously in PPP and construction management research in general (Ameyaw and Chan 2016b; Chou and Leatemia 2016; Osei-Kyei and Chan 2017a; Ozorhon and Cinar 2015; Yang et al. 2009).

2.6 FUZZY SET THEORY

Zadeh (1965) pioneered the use of fuzzy set theory (FST) and introduced the concept of fuzzy sets to characterize and manipulate data that exhibit imprecision or non-statistical uncertainty. Let X be a classical set. Fuzzy set $\tilde{R}$ in X is defined by membership function $u_{\tilde{R}}$: $X \rightarrow$ [0,1], which associates a real number in the interval [0,1] to each element x in X. The function value $u_{\tilde{R}}(x)$ defines the degree/grade of membership of x to $\tilde{R}$, which ranges from no membership (0) to full membership (1), with an intermediate degree of membership in between the two extremes. The concept of linguistic variables is employed as a means to approximately characterize complex or ill-defined phenomena (such as in the case of humanistic systems) (Zadeh 1975a). Unlike a numerical variable, a linguistic variable's values (or terms) are words or sentences in natural or artificial language, for example, the terms '*very important*' and '*extremely important*' that may be used to assess the '*importance*' (linguistic variable) of an attribute or entity. The linguistic values can be represented by fuzzy numbers (Zadeh 1975b). Triangular and trapezoidal fuzzy numbers are used to manage the vagueness by defining boundaries/intervals instead of crisp values (Trivedi and Singh 2017). Membership functions with triangular shape are the most common among the various shapes that are used to describe membership functions (Tah and Carr 2000; Xu et al. 2010b). Moreover, the TFN representations of subjective opinions are easy to use and intuitive (Chou and Chang 2008). For a triangular fuzzy number (TFN) $\tilde{R}$, its membership function $u_{\tilde{R}}(x)$ can be expressed as follows (Hsieh et al. 2004; van Laarhoven and Pedrycz 1983):

$$u_{\tilde{R}}(x) = \begin{cases} (x-L)/(M-L), & L \leq x \leq M, \\ (U-x)/(U-M), & M \leq x \leq U, \\ 0, & Otherwise, \end{cases}$$

where, for TFN $\tilde{R}$, L, M and U are the lower, modal and upper values, respectively. The TFN is denoted as $\tilde{R} = (L, M, U)$. Let $\tilde{A}$ (L_1, M_1, U_1) and $\tilde{B}$ (L_2, M_2, U_2) be any two TFNs. The arithmetic operations are expressed as follows (Chen and Hwang 1993):

Addition: $\tilde{A} \oplus \tilde{B} = (L_1, M_1, U_1) \oplus (L_2, M_2, U_2) = (L_1 + L_2, M_1 + M_2, U_1 + U_2)$

Subtraction: $\tilde{A} \ominus \tilde{B} = (L_1, M_1, U_1) \ominus (L_2, M_2, U_2) = (L_1 - U_2, M_1 - M_2, U_1 - L_2)$

Multiplication: $\tilde{A} \otimes \tilde{B} = (L_1, M_1, U_1) \otimes (L_2, M_2, U_2) = (L_1L_2, M_1M_2, U_1U_2)$ for $L_i > 0$, $M_i > 0$, $U_i > 0$

Division: $\tilde{A} \oslash \tilde{B} = (L_1, M_1, U_1) \oslash (L_2, M_2, U_2) = (L_1/U_2, M_1/M_2, U_1/L_2)$ for $L_i > 0$, $M_i > 0$, $U_i > 0$.

Ray (2015) inferred that the fuzzy membership function for a square root of a TFN can be derived using an α-cut method. For any TFN $\tilde{R}$, the square root can be obtained as follows:

Square-root of $\tilde{R}$: $\sqrt{\tilde{R}} = (\sqrt{L}, \sqrt{M}, \sqrt{U})$.

The input data of the proposed risk assessment and allocation models are actually the values of linguistic variables. In FST, fuzzy numbers corresponding to individual linguistic terms are obtained via conversion scales. The process of determining the exact number of conversion scales is generally intuitive; where reduction of analytical discrimination capability or complexity may be induced with the adoption of too few or too many conversion scales, respectively (Chen and Hwang 1993; Chou et al. 2008). According to Miller's (1956) “seven plus or minus two” principle, the scales of seven were adopted for the assessment of risk probability and severity (Table 2.2), while the scales of five were adopted for the assessment of the importance weight of RAC and RMC for each risk factor (Table 2.3). This numerical approximation system employed provides a systematic and consistent method to convert linguistic terms into their corresponding fuzzy numbers (Chen and Hwang 1993). It was considered that the larger number of risk factors can be better evaluated using a conversion scale of seven, while the assessment of RMC can be more conveniently performed using a scale of five (see Chapters 8 and 9).

Table 2.2. Linguistic terms and the associated TFNs for risk probability and severity assessment

Linguistic terms	Fuzzy number
EL (extremely low)	(0.000, 0.000, 0.150)
VL (very low)	(0.000, 0.150, 0.300)
L (low)	(0.150, 0.300, 0.500)
M (moderate)	(0.300, 0.500, 0.700)
H (high)	(0.500, 0.700, 0.850)
VH (very high)	(0.700, 0.850, 1.000)
EH (extremely high)	(0.850, 1.000, 1.000)

Table 2.3. Linguistic terms and the associated TFNs for risk allocation and sharing

Linguistic terms (RMC assessment)	Linguistic terms (RAC importance weight)	Fuzzy number
Very low (VL)	Very low importance (VLI)	(0.000, 0.000, 0.250)
Low (L)	Low importance (LI)	(0.000, 0.250, 0.500)
Moderate (M)	Moderate (M)	(0.250, 0.500, 0.750)
High (H)	Important (I)	(0.500, 0.750, 1.000)
Very high (VH)	Very Important (VI)	(0.750, 1.000, 1.000)

2.7 FUZZY MULTIPLE CRITERIA DECISION MAKING

The process of decision making involves a series of steps that include the following: identifying the problem, constructing the preferences, evaluating the alternatives and identifying the best alternative (Tzeng and Huang 2011). Complications arise in this process when evaluating the available alternatives against multiple criteria, such as issues related to the weight of each criterion, preference dependence, and conflicting criteria, that must be resolved using sophisticated methods (ibid.). Depending upon how the assessment is structured, project risk assessment and risk allocation can be modeled as multiple criteria decision making (MCDM) problems (Ameyaw and Chan 2015c; Lam et al. 2007; Xu et al. 2010a).

In real life situations, when evaluating alternatives, the criteria (some or all of it) may be subjective in nature (Liang and Wang 1991), such as while making a decision to buy a house. Such a decision may include subjective criteria such as security, cleanliness of streets and the neighborhood in general, quality of construction and quality of the building finishing in addition to the objective criteria of cost and distance to the closest market and office. The measurement of subjective criteria may not be precisely defined for the decision makers (DMs); hence, in such situations, precision-based evaluation may be impractical. The evaluation data of the alternatives (different houses) against each criterion and the weight of the criteria may be expressed in linguistic terms (e.g., very poor, poor, acceptable, good, very good or low, medium and high). The integration of various linguistic assessments and weights in such problems can be handled via fuzzy multiple criteria decision-making (FMCDM) method. Bellman and Zadeh (1970) investigated the decision making problem in a fuzzy environment and initiated work in the FMCDM. Given such a problem, consider a finite set of alternatives and evaluation criteria, represented by $A = \{a_1, a_2, \dots, a_n\}$ and $X = \{x_1, x_2, \dots, x_m\}$, respectively (Marichal 2000a). Based upon the evaluations, each alternative a_j which belongs to A is associated with a profile of partial scores $h^j = \{h_1^j, h_2^j, \dots, h_m^j\} \in \mathbb{R}^m$, where, for all i=1, 2, …, m, h_i^j represents the evaluation of alternative a_j w.r.t criteria x_i, with $h_i^j \in H_i \subseteq \mathbb{R}$. It is hypothesized that all the evaluations are given on the same interval scale to ensure commensurability (Kojadinovic 2007). A global score can be attributed to each of the profiles using an aggregation operator that considers the weights of the importance of the criteria (w) (Marichal 2000a). For independent criteria, the most common aggregation operators are the weighted arithmetic means (WAM). The global score ($M_j(h)$) in this case is given by $M_j(h) = \sum_{i=1}^{m} w_i\, h_i$, where, $w_i \geq 0$ and $\sum_{i=1}^{m} w_i = 1$. The global score can be used to rank the alternatives or select the one that best satisfies the predefined criteria. For fuzzy problems, the global score

$\widetilde{M}_j(\tilde{h})$ can be obtained by calculating the summation of the product of relative fuzzy weight $\widetilde{w}_i$ and the average fuzzy assessment value $\tilde{h}_i$, as follows (Tzeng and Huang 2011):

$$\widetilde{M}_j(\tilde{h}) = \sum_{i=1}^{m} \widetilde{w}_i \, \tilde{h}_i. \tag{3}$$

In a group setting, several DMs/experts provide criteria assessments; hence, the mean operator is used to aggregate the experts' fuzzy assessments (Buckley 1985). Let $\tilde{R}_i^k$ denote the fuzzy assessment by expert 'k' for any attribute 'i'. The average fuzzy assessment ($\tilde{R}_i$) for q experts will be as follows:

$$\tilde{R}_i = \left(\frac{1}{q}\right) \otimes \left(\tilde{R}_i^1 \oplus \tilde{R}_i^2 \oplus \ldots \oplus \tilde{R}_i^q\right). \tag{4}$$

Defuzzification operation can be performed to obtain a crisp number that adequately represents the fuzzy number. The most commonly used method (i.e., center of the area method) was employed here (Chiou et al. 2005; Wang and Elhag 2007; Zhao et al. 2013). For TFN $\tilde{R}$, the defuzzified value (R') is given as follows:

$$R' = \frac{\tilde{R}}{3} = \frac{L+M+U}{3}. \tag{5}$$

Simple additive weighting (SAW) is the best known and most adopted multiple attribute decision making (MADM) (additive aggregation) method. Fuzzy simple additive weighting (FSAW), which is an extension of the SAW method, was adopted in this research (Chen and Hwang 1993; Chou et al. 2008; Lin et al. 2010; Tzeng and Huang 2011).

2.8 FUZZY MEASURE AND FUZZY INTEGRAL

In a multiple criteria decision-making method, the choice of a set of criteria to evaluate the alternatives is a value judgment in itself in terms of the selection of specific criteria, definition of the criteria, and the level of detail in which the criteria are presented (Rowley et al. 2015). The development of variables without interaction or dependence is impossible in the practical applications of multiple criteria decision methods (Marichal 2000a; Rowley et al. 2015). Marichal (2000a) contended that practitioners frequently assume the criteria to be independent and exhaustive due to the lack of a suitable tool to model interactions. The author described three different types of dependence that include the following: correlation, substitutiveness/complementarity and preferential dependence. Hence, the risk assessment and allocation models presented in this research utilize specific tools from the MCDA research that are designed to accommodate the various types of interactions in decision-making problems.

For the accommodation of interactions among criteria (given that mutual preferential independence is a weak assumption and is rarely applicable in practice), a monotone set function (μ: $2^m \rightarrow \mathbb{R}$) on X, called capacity (Choquet 1953) or fuzzy measure (Sugeno 1974), can be substituted to the weight vector (w) (Grabisch et al. 2008). The symbol g has also been used to represent a fuzzy measure (Feng et al. 2010; Sugeno 1974; Yang et al. 2008). A fuzzy measure satisfies the conditions: $\mu(\varphi) = 0$; $\mu(X) = 1$ (boundary conditions) and $\mu(A) \leq \mu(B)$ for all $A \subseteq B \subseteq X$ (monotonicity). The use of fuzzy measure (μ *or* g) allows to model the importance of each criterion and the subset of criteria (Grabisch 1996; Marichal 2000a). In such a context, a natural extension of the WAM is the Choquet integral with respect to the defined fuzzy measure. The term fuzzy integral is a general term for integral based on a fuzzy measure (Grabisch et al. 2000). A

Choquet fuzzy integral is one of the many families of fuzzy integrals based on a fuzzy measure that provides an alternate methodology for information aggregation (Chiang 1999). The Choquet integral of $h^j \in \mathbb{R}^m$ w.r.t μ is given as follows (Marichal 2000a):

$$C^{\mu}(h^j) = \sum_{i=1}^{m}\left(h^j_{(i)} - h^j_{(i-1)}\right)\mu\left(H_{(i)}\right), \tag{6}$$

where h^j is sorted in ascending order ($0 \leq h^j_{(1)} \leq \ldots \leq h^j_{(m)}$ and $h^j_{(0)} = 0$) and $H_{(i)} = \{x_{(i)}, \ldots, x_{(m)}\} \subseteq X$ includes only those criteria for which the score of alternative a_j is at least equal to its score on x_i (ibid.).

2.8.1 Methods to Evaluate Fuzzy Measures

The application of Choquet integral requires prior determination of fuzzy measure values that act to represent the importance of all the attributes and their coalitions in a MCDM problem. The number of criteria to be aggregated exhibits an exponential relationship with the number of coefficients involved in a fuzzy integral model; hence the richness of fuzzy integral (in being able to account for criteria interaction) is compromised by the complexity of the model (Grabisch 1996; Grabisch et al. 2000). In addition to identifying the weight of the importance of individual criterion, the weight of the importance of each subset of criteria must also be determined (ibid.).

For general fuzzy measures, measure values can be determined from supervised methods (where some prior knowledge is required to completely determine the aggregation operator based on *initial preferences;* thus, one must consider if this information can be easily obtained or if it is available) and unsupervised methods (which use information theoretic functionals but suffer from the curse of dimensionality, i.e., sufficiently large number of profiles (performance scores) are necessary to obtain accurate estimates) (Kojadinovic 2004; Krishnan et al. 2015; Rowley et al. 2015).

For the reduction of the complexity involved in fuzzy measure value estimation, several subfamilies of fuzzy measure were proposed, among which Sugeno's λ-fuzzy measure is one of the types (Ishii and Sugeno 1985; Krishnan et al. 2015; Onisawa et al. 1986; Tan et al. 2011). In this research, λ-fuzzy and general fuzzy measures were employed to obtain aggregate assessments for project risk assessment and risk allocation multiple attribute decision-making modeling, respectively.

2.8.2 General Fuzzy Measure

Fuzzy measures applications are curbed due to the exponential complexity that arises due to the need to determine 2^m parameters (Kojadinovic 2007). Direct and indirect techniques can be employed to obtain these parameters. The direct elicitation of fuzzy measures from DMs for large *X* is unlikely (Grabisch 1996; Marichal and Roubens 2000). Indirect techniques can be employed where the DM is able to provide certain preferences from which measures compatible with these preferences can be obtained. To reduce the number of parameters to be solicited from the DM and to enhance their interpretation and understanding, Grabisch (1997) introduced the concept of *k*-additive measure. Moreover, given that providing preference information on interactions among criterion pairs of two is easier for the DM, this research considered 2-additive measures only. The learning data (initial preferences of the DM) from which the fuzzy measure is to be determined consists usually of *" … a partial weak order over the set of alternatives, a partial weak order over* *the set of criteria, intuitions about the importance of the criteria, about their interaction, etc."* (Grabisch et al. 2008; Kojadinovic 2007; Marichal and Roubens 2000).

The behavior of Choquet aggregation and the fuzzy measure modelled interaction phenomena can be interpreted by several numerical indices (Marichal 2000b, 2004), which include the importance and interaction indices. For a given Choquet integral based model, if the analysis of these indices shows a discrepancy as opposed to the DMs' reasoning, then the initial preferences are enriched incrementally by additional constraints until a satisfactory model is found (Grabisch et al. 2008). Most fuzzy measure identification methods can be specified as optimization problems with a specific objective function and the preferential information requirements. The preference information provided by the DM can only constitute a region of feasible/admissible fuzzy measures. Additional selection principles or constraints are employed to identify the most desired fuzzy measures (Wu et al. 2014). Among the various methods available that have been discussed by Grabisch et al. (2008), the minimum variance (MV) method was adopted because it favors the least specific capacity (if any) i.e., the one for which the Choquet integral is closest to the simple arithmetic mean and leads to a unique solution (Grabisch et al. 2008; Kojadinovic 2007).

2.8.3 λ-Fuzzy Measure

A λ-fuzzy measure g_λ is a special type of fuzzy measure that was introduced by Sugeno (1974). It can be used to determine the values of fuzzy measure~~s~~ and gauge the relationship of criteria (Tan et al. 2011; Yang et al. 2008). It is the most widely used fuzzy measure (Yang et al. 2008), and its use avoids computational complexity in calculating the fuzzy measures using other more complex algorithms (Tan et al. 2011). The λ-fuzzy measure is constrained by a parameter λ that determines the degree of additivity among the criteria. If A, $B \subset X$ with $A \cap B = \varphi$, then an additional property (other than boundary conditions and monotonicity) satisfied by the λ-fuzzy measure is as follows (Feng et al. 2010; Sugeno 1974; Yang et al. 2008):

$g_\lambda(A \cup B) = g_\lambda(A) + g_\lambda(B) + \lambda . g_\lambda(A) . g_\lambda(B)$, where $\lambda \in (-1, \infty)$.

The fuzzy measure for any subset of X with only one element $g_\lambda(\{x_i\})$ is called fuzzy density, which is denoted as $g_i = g_\lambda(\{x_i\})$. The fuzzy measure $g_\lambda(X)$ can be formulated as follows:

$$g_\lambda(\{x_1, x_2, x_3, \ldots x_m\}) = \sum_{i=1}^{m} g_i + \lambda \sum_{i_1=1}^{m-1} \sum_{i_2=i_1+1}^{m} g_{i_1} . g_{i_2} + \ldots + \lambda^{m-1} g_1 . g_2 \ldots g_m$$

$$= \frac{1}{\lambda} \left| \prod_{i=1}^{m} (1 + \lambda . g_i) - 1 \right| \text{ for } -1 < \lambda < \infty. \quad (7)$$

On the basis of the equation above, given the boundary condition $g_\lambda(X)=1$, the unique solution for parameter λ can be obtained from the following:

$$\lambda + 1 = \prod_{i=1}^{m} (1 + \lambda . g_i). \quad (8)$$

The application of Eq. (7) with calculated λ values enables the calculation of the fuzzy measure of each subset of X (Chen and Cheng 2009). For the purpose of information aggregation, fuzzy density and fuzzy measure can be interpreted in terms of the importance of the attributes; hence, fuzzy density g_i and fuzzy measure g_λ of any subset of X represent the grade of the importance of a criterion and a set of criteria toward the final assessment, respectively (Laishram and Kalidindi 2009). The values of $\lambda > 0$ or < 0 imply synergy and redundancy among the attributes (criteria) respectively, while the value of $\lambda = 0$ indicates that the attributes are non-interactive and thus are additive.

2.8.4 Application in this Research

The justification of using the proposed analytical methods for fuzzy measure identification lies on the literature where researchers working primarily in the area of MCDM have highlighted the need to consider the existence of potential dependence/interactions among the criteria. This becomes important when choosing an aggregation operator to avoid problems related to redundancy/synergy (Grabisch 1996; Marichal 2000a). If a composite indicator such as safety performance is composed of two sub-indicators (i.e., number of accidents and amount paid due to accidents in a project), then attention must be paid during the aggregation of the sub-indicators as they are interrelated and move in the same direction (Yu et al. 2015). Merely adding the weights of these sub-indicators will lead to an incorrect estimation of the level of safety performance due to the inherent redundancy of these sub-indicators (ibid.). An example of students evaluation on statistics, probability and algebra (three mathematical subjects or criteria) can be used to better explain the three types of interaction phenomena (Marichal 2000a). Students performing well in statistics are usually good at probability; hence, the two criteria in this situation are positively correlated and present some degree of *redundancy*. Similarly, a pair of criteria can also present negative correlations (i.e., high partial scores along one criterion would usually mean low partial scores along the other, and vice versa), such as in the case of law and algebra (ibid.). The same logic and explanation apply to the problem studied in this research for project risk assessment (specifically the estimation of the overall risk index and the critical risk group index [will be discussed in Chapter 8]). Marichal (2000a) described dependencies between criteria due to *correlations* (as explained above) as one of the several types of interaction/dependency phenomena that may exist among criteria in MCDM problems. According to Marichal (2000a), the phenomenon characterized by positive correlation (redundancy/negative interaction/negative synergy) among a pair of criteria should be modeled such that the contribution of the pair is less than sum of the individual contributions of the criteria. For the case of -ve correlations (positive interaction/positive synergy), the opposite is true.

Decision-making models and frameworks that employ fuzzy measures and fuzzy integrals have been used previously for solving multi-criteria problems outside construction management research. Some of these works include the analysis of public attitude toward the use of nuclear energy (Onisawa et al. 1986), the evaluation of sustainable fishing development strategies (Chiou et al. 2005), airline service quality evaluation (Liou and Tzeng 2007), vendor selection problem (Yang et al. 2008), information system project selection (Chen and Cheng 2009), desirability rating analysis for the debt financing of PPP road projects (Laishram and Kalidindi 2009), location selection for manufacturing centers (Feng et al. 2010), the evaluation of health-care waste disposal alternatives (Dursun et al. 2011), supplier selection (Tan et al. 2011) and group personnel selection problems (Afshari et al. 2013). In these works, methods to determine the fuzzy measure and the specific aggregation operator used may vary depending upon the specific focus and preferences of researchers. Yu et al. (2015) and Feng et al. (2010) employed λ-fuzzy measure and fuzzy integral to evaluate the overall project performance and for decision making in locating manufacturing centers in China, respectively. The studies affirmed that the application of fuzzy measure and fuzzy integral resulted in the change of the ranks of alternatives when results for several case studies were matched with those obtained from additive methodologies or weighted average. The authors in each study also verified the results with experts, thereby establishing the ability of the proposed methodology to assist stakeholders in various MCDM problems. This also shows that considering use of linear models may have undesired implications for practice. Another recent application of λ-fuzzy measure and fuzzy integral in construction management research can be found in Patel and Jha (2017) who utilized the methodology to create a process for indexing construction project safety hazards. Several works in the risk management literature have pointed to the existence of correlations/interactions among risk factors (Dey and Ogunlana 2004; Loosemore and Cheung 2015). Given that this research deals with the aggregation of assessments over risk factors to obtain a composite risk index at a critical risk group level and for the overall project, the choice of methodology is thus justified.

Apart from redundancy and synergy, interaction phenomena among the criteria may have nothing to do with physical or underlying correlations (Marichal 2000a; Onisawa et al. 1986). As provided above, the interaction phenomena (dependence) among criteria are of several types that include the following: correlation, substitutiveness/complementarity and preferential dependence (Marichal 2000a). The case of substitutiveness/complementarity is defied by the opinions of the DM with regard to the importance of the criteria that are independent of the partial scores obtained by the alternatives being evaluated on these criteria (Marichal 2000a). Two criteria are said to be complementary if the importance of the pair is large, while the importance of any one is rather low. For substitutive criteria, the union of two criteria is not too significant, and the importance of the pair might be approximately the same as the importance of a single criterion (Marichal 2000a). The specific preference of DMs as in the case of preferential dependence, where the attribute ratings of alternatives may be perceived conditionally to influence the importance of other criteria and thus the preferences over the ranking of the alternatives, may also be influential (ibid.). Grabisch et al. (2008) provided an example of the evaluation of the students of an institute training econometricians, which demonstrates all the key concepts in sufficient detail. Interested readers are referred to the paper to review the example in more detail. For such situations, modeling complementarity/substitutiveness and/or preferential dependence among the criteria by accommodating DMs' preferences in the decision process that cannot be modeled via traditional aggregation methods is necessary. As it will become more clear later (in Chapter 4 and 9), the allocation of risks in contracts is itself a MCDM problem that is based on RAC that exhibits interaction effects; however, the criteria are not highly correlated (Xu et al. 2010a). Accordingly, general fuzzy measures (as discussed above) may be better in approximating DMs' preferences as the modeling process allows the DMs to specify the nature and intensity of potential interactions along with preferences on decision alternatives. Various methods are available for fuzzy measure identification that have been demonstrated in extant literature (Alfonso 2016; Brosig et al. 2014; Gurbuz 2010; Jover et al. 2013; Karsak et al. 2005; Rizzolo et al. 2011; Wen et al. 2016). Here, the MV method was adopted. The methodology was implemented using the Kappalab package (Grabisch et al. 2015) for the GNU R statistical system (R Development Core Team 2005).

2.9 EXPERT RESPONDENTS' PARTICULARS

A period of five months was allocated for the collection of the research data. The finalized questionnaire (first part) was then distributed to PPP infrastructure experts in Pakistan for completion in February 2017. Purposive sampling and semi-snowballing approaches were adopted (as explained above). A total of 140 questionnaires were distributed to experts who agreed to participate upon initial contact, and the responses were collected via mail (post) and e-mail and in-person. Some investigator-administered questionnaire sessions were also conducted to improve the response rate and obtain contextual details on how and why certain perceptions exist. The survey respondents were initially given two weeks to provide their input, and, thereafter, multiple reminders were sent at two-week intervals. In total, 90 completed questionnaires were received, giving a response rate of 64.3%. The response rate was deemed acceptable and in line with the previous studies conducted (Chan et al. 2011; Ke et al. 2011; Roumboutsos and Anagnostopoulos 2008; Wibowo and Mohamed 2010; Xu et al. 2010b). Table 2.4 reproduces respondent characteristics that include designation, sector affiliation and years of experience. The experts who

Table 2.4. Experts' profile

Attribute	Distribution	Frequency	Percentage (%)
Infrastructure sector	Public	35	38.83
	Private	55	61.17
Total		90	100
Years of experience (working and/or research in PPPs)	Less than or equal to 5	47	52.20
	6-10	21	23.30
	11-15	12	13.30
	16-20	7	7.78
	21 and above	3	3.33
Total		90	100
Number of PPP projects handled			
	Less than 10	58	64.44
	More than or equal to 10	32	35.56
Total		90	100
Area/sector of expertise (No. of experts)			
	Power	34	37.78
	Transport	48	53.33
	Both	8	8.89

participated belonged to a vast array of organizations that include PPP units (federal/provincial), public authorities, lending institutions, investors, consultants and project sponsors/companies. More of the respondents identified themselves as working in the private sector with over 61% of the responses. A total of 47.8% of the experts had more than five years of working experience on PPP projects, while nearly 36% had processed ten or more projects during their career. Numerous respondents claimed to be affiliated with the transport infrastructure sector. Given the inherent limitations of the questionnaire survey approach, diverse participation from an array of key PPP stakeholders, an acceptable response rate and the sufficient working experience of the participants cumulatively support the authenticity and reliability of the survey responses. Furthermore, the questionnaire survey aimed at establishing the significance and ranking of the identified measures of ERM and the assessment of risks. The results are not intended to be used as absolute values for any other purpose.

For the development and validation of the risk allocation model, the participating experts were selected on the basis of their knowledge and their experience of having worked on the selected case study projects. The case study surveys (second part) were conducted by the investigator for the selected projects, and the information on the research subject was collected in person. All the participating experts possessed substantial experience in delivering and managing PPP projects with an average PPP specific experience of 9.58 years. The experts retained senior positions in their respective organizations while serving in various capacities, such as director, deputy director, assistant director, chief finance officer, finance manager, chief operating officer, unit head and senior executive. For each project, six experts participated to render the needed assessments for the selected risk factors, with three representing the interests of the private sector (project company/investors) and the other three representing the public sector authority.

2.10 CHAPTER SUMMARY

Given the requirements of this research, a sequential mixed methods approach was adopted, where literature reviews and semi-structured interviews were initially conducted to establish the research questionnaire. The questionnaire was piloted, and then the data were collected over a period of five months. A response rate of 64.3% was deemed sufficient compared with other similar construction management research. Background information on the experts who participated in the research shows that experienced professionals from all key stakeholders (public/private) and infrastructure sectors provided their inputs for the assessment of the measurement of ERM, risk factors and case study projects. Given that quantitative analysis was employed in this research, several statistical tests were prescribed for that in this chapter. The general significance of FST, fuzzy measure and fuzzy integral-based modeling approaches in MCDA was provided, which sounds promising as the proposed analytical methods for risk assessment and allocation modeling may be more effective. Chapters 8 and 9 discuss the actual application of these analytical methods.

CHAPTER 3 INFRASTRUCTURE PPPs IN PAKISTAN[4]

3.1 INTRODUCTION

This chapter considers the role of the PPP method of infrastructure procurement in Pakistan and attempts to establish the following: its significance in the country's context, the progress made to date in all the relevant sectors of application, the drivers that continue to push the government to champion PPPs, the barriers that hinder efforts to successfully implement PPPs and the risks faced by PPP projects in Pakistan. The chapter also focuses on aspects related to risk management practices in the country's construction industry and highlights problems that may have a negative influence on the effective risk management (ERM) of the projects. This chapter draws on the extant academic and institutional literature and other data sources in publicly accessible domains to present adequate information related to each of the aspects mentioned above. The analysis should provide a sound background by elaborating on the current state of affairs, thus justifying the need to study risk management in PPP infrastructure projects in Pakistan.

3.2 NEED FOR INFRASTRUCTURE PROJECTS IN PAKISTAN

In terms of gross domestic product (GDP), Pakistan is the second largest economy in South Asia (World Bank 2015), and ranks 6th as the most populous country in the world, with a total population of 188.924 million as of 2015 (World Bank 2016a). Pakistan is a strategically located, lower

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Parts of this chapter have been included in:

[4] Mazher, K.M., Chan, A.P.C., and Zahoor, H. (2017). "A research framework for effective risk management in public-private partnership (PPP) infrastructure projects in Pakistan." *13th International Postgraduate Research Conference (IPGRC 2017)*, C. Pathirage, U. Kulatunga, Y. Ji, R. Gameson, C. Udeaja, C. Trillo, M. Takhtravanchi, and B. Allali, eds., University of Salford, Salford, UK.

middle-income country that borders Afghanistan (west), the People's Republic of China (northeast), India (east), and Iran (southwest) as well as about a 1000 kilometers of coastline along the Gulf of Oman and Arabian Sea (ADB 2015b). The country is blessed with abundant natural resources, such as coal, petroleum and natural gas reserves, hydropower potential and mineral reserves, among others (Qureshi and Akintug 2014; Taus-Bolstad 2003). Development has been uneven and below potential with short periods of high economic growth, which can be partly attributed to external economic shocks, disasters related to natural hazards (earthquakes and floods), inadequate implementation of economic reforms, political issues and domestic security challenges (ADB 2015b). Owing to the prevailing dismal conditions, half of the population is either subjected to absolute poverty or is vulnerable to it (ibid.).

Pakistan is facing an acute shortage of infrastructure in virtually all sectors and currently ranks 116th out of 138 countries in terms of infrastructure (Schwab 2016). Issues related to infrastructure can be classified into the broad categories of quantity, efficiency, financing and public sector capacity to build and operate infrastructure (Ahmed et al. 2013; State Bank of Pakistan 2007). Poor governance and lack of resources characterize the challenges being faced by Pakistan. These imply a shortage of public and private infrastructure investments, thereby resulting in the shortage of energy, high transmission and distribution energy losses, deficient road network, insufficient passenger and freight train services as well as urban mass rapid transit, inefficient irrigation, lack of access to safe water and basic sanitation services and inadequate oil and gas transportation networks (ADB 2015b; Mubin and Ghaffar 2008). According to the ADB (2015b), the country experienced a lower growth rate of 3.5% in the fiscal year 2010–2014 as compared to 5.1% in 2005–2009, which was attributed to a number of reasons, including intense energy shortages. Due to underdeveloped infrastructure, the infrastructure report by State Bank of Pakistan (SBP) estimated losses of up to 4%–6% of the GDP, which is equivalent to approximately USD6 billion (State Bank of Pakistan 2007). Logistical bottlenecks result in the increased cost of production of goods by about 30%, which in turn, leads to lowered export prospects (ibid.). Moreover, inter- and intra-regional inequalities in terms of access to even basic infrastructure has forced people to migrate to cities, thus imposing increased pressure on the already stressed urban infrastructure (Ahmed et al. 2013). A high, sustained and inclusive economic growth rate of 7% annually is required to improve the current situation and steer the country towards economic prosperity (ADB 2015b). The report further states that government's efforts towards addressing the main issues to achieve such growth include alleviating constraints related to inadequate infrastructure and connectivity as well as to deficient governance and institutions, among other issues. The earlier infrastructure report by SBP also emphasized the significance of improving the quality and service coverage in the areas of power, transport and logistics and water supply and sewage treatment facilities, in order to enhance the country's economy and quality of life (State Bank of Pakistan 2007).

Global experience indicates a direct correlation between economic growth and infrastructure development. According to the statistics developed by The World Bank, a 10% increase in infrastructure assets results in a direct increment of 1% in the GDP (Calderón et al. 2015). According to the State Bank of Pakistan, Pakistan requires investments at a rate of 10% of the GDP until 2020 to meet its infrastructure needs, as opposed to the existing 6% (average), which cannot be met entirely by public resources (Bhatti 2015; State Bank of Pakistan 2007). The Pakistan government's national strategy to develop a globally competitive and prosperous economy by 2025 encompasses the need for energy development and the modernization of transport infrastructure and greater regional connectivity, among other aspects (ADB 2015b). This is also in line with the ADB's priorities in the 2020 midterm review of strategy. The thrust of the ADB's country partnership strategy for 2015–2019 is directed at several key aspects and includes institutional reforms as well as the promotion of infrastructure development in order to: provide access to markets and basic public services, enhance connectivity and productivity, assist in attracting private investments and generate jobs. Hence, efforts are already underway to overcome the constraints that prevent Pakistan from achieving the goals of sustainable development and economic progress.

3.3 INFRASTRUCTURE PROCUREMENT AND PPPs

For public infrastructure projects, the government can choose from a variety of project delivery models to provide the requisite infrastructure and services. These models can be thought of as lying on a continuum of public–private mixes, with the extreme ends depicting traditional public project delivery (projects are financed and owned by the public sector, which also retains control over them throughout their lifecycle) and privatization (projects are privately financed, owned, and controlled and operate under overarching public laws and regulations). While both of these extremes are not PPPs, there exists a range of PPP options in between (Rall et al. 2010). The World Bank reference guide (World Bank et al. 2014) describes PPPs in broad parameters of asset involved, functions of the private sector (its responsibility) and the ways by which the private sector is paid (or remunerated). Assets involved can be new (greenfield projects) or existing assets (brownfield projects). Depending upon the type of asset and service involved, project phases or functions for which the private sector party is responsible may vary, often including design, build or rehabilitate, finance, operation and maintenance. Payment mechanisms can be centered around the "user pays" or "government pays" arrangement or a combination of the two. These parameters can be generally used to categorize PPP contracts. However, internationally, a consistent standard for defining PPPs and its different contract types does not exist. Various terminologies can be employed to refer to PPP or to its particular types, either as defined by law or by common usage. Some of the more common PPP arrangements include joint ventures, leasing, BOT/BOO arrangements, operations or management contracts and cooperative arrangements (Grimsey and Lewis 2007). As stated by the authors (ibid.), the "alphabet soup" of acronyms that define various modalities of PPPs forms a long list. Interested readers are referred to Grimsey and Lewis (2007) and Table 1.1 - PPP Nomenclature, in the PPP reference guide (World Bank et al. 2014), for more information.

The energy and transport infrastructure sectors obtain the largest share of global private investments in public infrastructure in both low- and middle-income countries (World Bank 2018b). Figure 3.1 shows the breakdown of sectoral percentages of investment (for data available from 1990–2017, as of June 2018) for PPP arrangements only and excludes divestitures (partial/

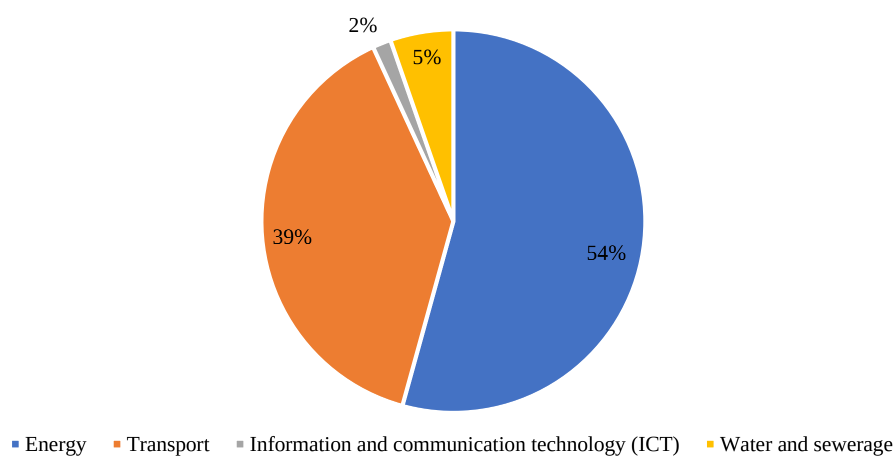

Fig. 3.1. Sectoral breakdown of investment in the PPP projects (low- and middle-income countries), (World Bank 2018b)

full), merchant, rental projects and those for which a modality is not specified. As can be seen, investments in the energy and transport infrastructure sectors lead other sectors by a large margin.

Further analysis at the subsector level reveals that electricity and road investments account for nearly 49% (nearly 84% of this investment is attributable to only power generation projects) and 19% (includes projects related to bridges, highways, tunnels and various combination of these) (Fig. 3.2) of the total investment, respectively. These trends may be explained by the critical dependence of an economy on energy and transport systems to survive and pursue goals of sustain-

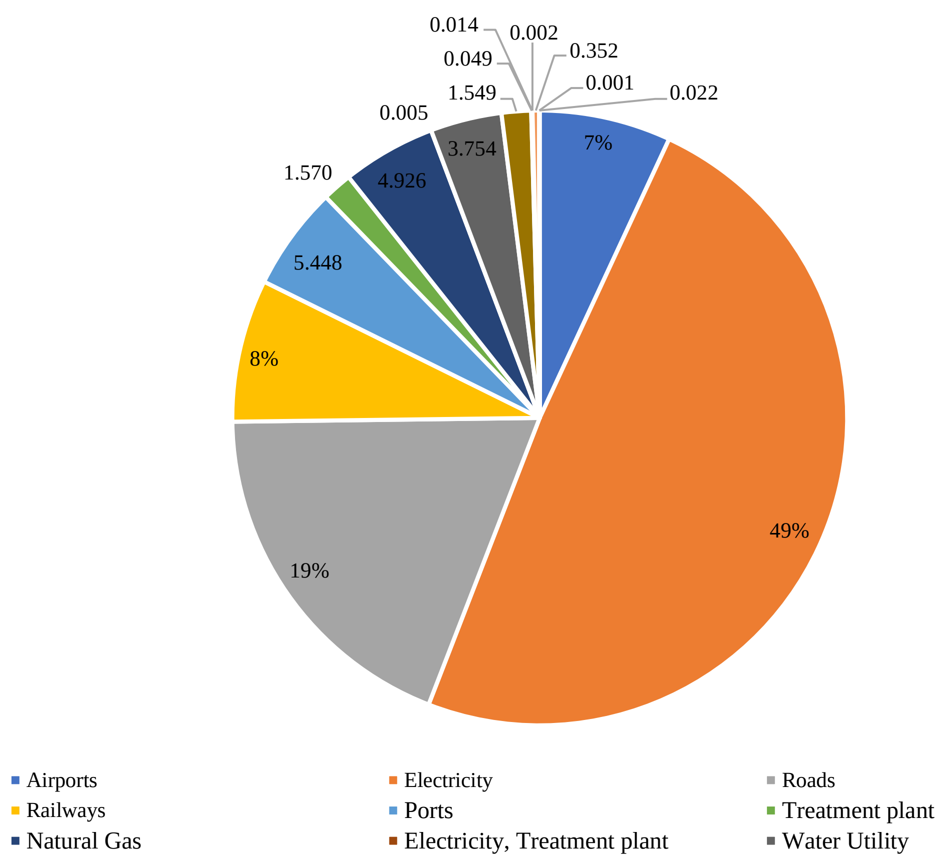

Fig. 3.2. PPP investment composition at the subsector level (low- and middle-income countries), (World Bank 2018b)

able development and progress. The situation in Pakistan is not so different as the power and transport infrastructure sectors are leading the adoption of the PPP mode of infrastructure delivery in the country.

3.3.1 PPPs for Infrastructure Procurement in Pakistan

The adoption of PPPs has been suggested as a suitable strategy to partly fill the void between Pakistan's infrastructure needs and available fiscal resources (ADB 2015a; GoP 2010; Noor 2011; State Bank of Pakistan 2007). The Medium Term Development Framework 2005–2010 estimated infrastructure requirements to amount to USD40 billion, out of which only USD22 billion had been committed by the government, whereas the remaining was envisaged to be obtained from foreign aid/loans or private investment (State Bank of Pakistan 2007). The report further stated that far more will be required in a longer run and that an increasing proportion will be non-budgetary. Clearly, the current global ranking of Pakistan in terms of infrastructure shows the continued need to enhance infrastructure facilities and address the underlying bottlenecks. In addition, the poor performance of projects delivered through traditional methods of procurement serves as another important driver to promote the adoption of PPPs (ADB 2015a; Noor 2011; Shaukat et al. 2011). Infrastructure procurement in Pakistan via traditional/conventional methods is met following the Design-Bid-Build (DBB) project delivery method and the specific modalities of the PPP (described as non-traditional/non-conventional), including the BOT, BOO and BOOT (Noor 2011). In another study by Shaukat et al. (2011), the DBB and Design/Build (D/B) methods were determined to be commonly employed in the building project procurement, with DBB being more common in the public sector building projects. The authors concluded that both the project delivery methods experienced cost and schedule growth, with the D/B projects performing better than DBB, especially in terms of schedule growth. Moreover, both provinces of Sindh and Punjab have been ineffective in containing cost and time overruns in traditionally procured infrastructure projects, with Punjab showing slightly better performance (ADB 2015a).

The concept of PPPs is not new to Pakistan given that a number of power projects have been developed using private investment (PPP arrangements) (ADB 2015a). However, the implementation of PPPs is lagging in other sectors, such as transportation and water infrastructure (Economist Intelligence Unit 2015). In recognition of the severe infrastructure shortage, the resulting energy shortages and transportation inefficiencies as well as its negative effect on economic growth, the Ministry of Finance established the Infrastructure Project Development Facility (IPDF) in 2006, which was meant to serve as a PPP unit, and mandated it to develop PPP policy and oversee its implementation. The revised PPP policy of 2010 provides support for all infrastructure sectors at the federal and provincial levels. Currently, a PPP law at the federal level does not exist, but a sufficient and somewhat old regulatory framework is provided by the PPP policy in conjunction with certain laws on concessions and other types of investments and a sector-specific National Power Policy 2013 (Economist Intelligence Unit 2015). The Government approved the "PPP Policy and Regulatory Framework for Private Sector Participation in National Highways, Motorways, Tunnels and Bridges" (Highways PPP Policy), in May of 2009 (Castalia Limtited 2010). Recently, the government also passed the Public–Private Partnership Authority Bill 2017, with the aim of providing the necessary regulatory and enabling environment for promoting domestic and foreign private investments in infrastructure and economic development via private sector participation (Butt and Saeed 2017). With the support and assistance of Asian Development Bank (ADB), the provincial governments of Punjab and Sindh are developing legal and institutional capacity in order to procure infrastructure projects using the PPP modality (ADB

2015a). Several projects have been executed at the federal and provincial levels, among which the power and transport infrastructure sectors are the most active.

As per the constitutional reforms of Pakistan, the devolution has made provinces responsible for developing most of their infrastructure, whereas the federal government is concerned with large projects and those that cross provincial boundaries (ADB 2015a; Economist Intelligence Unit 2015). Sindh and Punjab are the largest provinces of Pakistan, hosting 77% of the total population and account for 85% of the country's GDP (ADB 2015a). With the support and assistance of the ADB, the provincial governments of Punjab and Sindh have made some progress in developing regulatory frameworks, institutional capacities and necessary structures, in order to procure infrastructure using the PPP modality. The support from the ADB is essential as the infrastructure and social service needs cannot be adequately fulfilled by the limited provincial fiscal space. Both provinces have approved their respective provincial PPP policies. The Government of Punjab passed the PPP for Infrastructure Act in July 2010, whereas the Government of Sindh enacted a PPP law in 2010 in addition to the formulation of concession-management, financial, institutional and regulatory frameworks for provincial PPPs. Similarly, the Government of Punjab passed the PPP for Infrastructure Act in July 2010 and constituted a PPP cell and risk management unit. Currently, both provinces lack further development on these initiatives (ibid.). The provincial government of Khyber Pakhtunkhwa (KPK) also enacted the KPK PPP Act of 2014 (amended later in 2017) and set up a PPP unit under it (GoKp 2014, 2017). As of now, a number of projects are operational in the power sector, followed by some projects in the transport infrastructure sector.

3.3.2 China–Pakistan Economic Corridor and PPPs

The China–Pakistan Economic Corridor (CPEC) is a key sub-program that forms part of the much larger One Belt-One Road (OBOR) initiative program of the People's Republic of China. The plan proposes to build a connection between the city of Kashgar, Xinjiang to the southwestern Gwadar port situated in the city of Gwadar, Baluchistan, in the south of Pakistan (Chohan 2017; Irshad 2015). The CPEC is a collection of infrastructure projects amounting to over USD60 billion, which are planned to be executed (some of which have been executed already) across the country over a 5 to 10-year period; it includes roads, energy projects, storage facilities, port construction, urban design, transport initiatives and other elements in a multifaceted grand project (Chohan 2017). A huge bulk of investment under the CPEC program is allotted for the development of energy infrastructure projects (Malik 2015), in which all the energy projects shall be implemented under the Independent Power Producer (IPP) mode (Ministry of Planning Development & Reform 2016). This may be based on the BOO/BOOT models, similar to the previously delivered IPP projects (GoP 2006, 2015; World Bank 2018b). According to The News, some of the projects under CPEC will be financed through the Public Sector Development Program (PSDP) of the government of Pakistan (GoP) using public funds (Haider 2016). Realizing the fiscal constraints, the GoP has instituted the Pakistan Development Fund Limited (PDFL) to finance the multi-billion dollar projects following the PPP pattern. The company is intended to provide complementary long-term project financing to encourage private sector participation (ibid.). Amid the increased attractiveness of Pakistan to foreign investments, as evidenced by the rising number of available opportunities and the growing interest from the UK, France, Germany, Japan, (APP 2016; Hussain 2017; Mirza 2017; Rana 2015; The News 2017b), and other countries to become partners in CPEC-related/infrastructure projects, there may be more projects in the future to be funded internationally and executed through the PPP mode. Furthermore, several structural, economic and legal reasons relevant to China and the host project countries will compel many OBOR projects to employ the PPP model (Dentons 2016).

3.3.3 Infrastructure Sectors and Private Investment

3.3.3.1 Power

The energy sector holds two important and distinct industries, i.e., the power sector and the oil and gas sector (World Bank 2018c). The power sector projects can be further classified into three market segments: generation, transmission and distribution (ALSF and CLDP 2014; Vagliasindi 2013). The eradication of poverty and the promotion of shared prosperity intrinsically rely on access to affordable, reliable and sustainable energy. Even after substantial efforts to improve access in recent years, people in excess of 1.1 billion (almost all of them in developing countries) worldwide, lack access to electricity (PPP Knowledge Lab 2018a). PPPs have not been involved in delivering power projects in most developed economies, rather, privatized electricity markets in such economies exist, wherein private power generators sell electricity via the competitive electricity market to end consumers (Atmo and Duffield 2014). Many emerging countries have adopted a different model with single-buyer electricity markets, wherein a state electricity company establishes power purchase agreements (PPAs) in the form of PPP-style concession contracts with private power generators (ibid.). BOT contracts have become more popular, constituting the majority of new investments in the electricity generation sector, sometimes combined with leases for existing plants (Vagliasindi 2013). Management and outsourcing contracts have also become more common in recent years, with countries facing difficulties in attracting private operators due to issues related to the reluctance of governments in areas of cost-reflective tariff imposition and giving up control of the basic network infrastructure (ibid.). According to ADB (2000), the potential modalities of a contract required to develop, finance and operate a power plant include some variations of BOT and BOO for new plants and the Rehabilitate-Operate-Transfer (ROT) and Rehabilitate-Own-Operate (ROO) for existing plants (not applicable to competitive generation market). The seller of the power (i.e., the power producer or generator) is the owner of the power project and is sometimes referred to as IPP or the project company. The agreement governing the sale and purchase of electricity is known as the PPA. It is the central contract for any IPP, especially in emerging markets. IPPs provide a quick solution in the electricity sector through the provision of the needed generation capacity to support rapid economic growth (ibid.).

The Pakistan government made initiatives regarding private investments in the power infrastructure development with the assistance of the World Bank in 1987 and established the initial framework of incentives by 1988 (Fraser 2005). The efforts materialized into success with the development of the Hub power project (Hubco), the first private power project in Pakistan, reaching financial closure in 1995. It was also a huge undertaking in terms of the sheer size of the project, which can generate 1292 MW of electricity and cost USD1.6 billion at that time. As it was the first private deal in the power sector (in fact, it was the first private infrastructure project in the country), the project faced some issues in the political domain. The efforts also led to the development of the first power policy of 1994 (Fraser 2005). Since then, many projects have been procured under various versions of the policy. The latest revision of the policy in force is the Power Generation Policy of 2015 for hydropower and thermal power projects (the policy specifies the BOOT model for the hydropower projects and the BOOT/BOO model for the thermal projects), whereas the policy for the development of renewable energy for power generation of 2006 aims at providing support for small hydro, wind and solar technologies (again, both the BOO and BOOT models have been specified for the included projects) (GoP 2006, 2015). As per the PPI database, a total of 61 active power generation projects (Table 3.1) are listed based on various technologies, including diesel, waste, natural gas, hydro, geothermal, solar, nuclear, wind and coal, and one project is listed as distressed (No. 11), (World Bank 2018b). Many more projects are under development in the renewable and nonrenewable energy sectors. Although, there exists a dire need for investments in the transmission and distribution systems to overcome losses and improve networks (State Bank of Pakistan 2007), no PPP-type investments on these have been made so far.

Table 3.1. List of active PPP power projects

ID.	Project Name	PPP Type	Gross/Installed Capacity (MW)	Technology	Financial Close Year
1	Hub Power Company	BOO	1292	Diesel	1994
2	AES Lal Pir (Pakistan) Ltd.	BOO	362	Diesel	1995
3	AES Pak Gen (Pakistan) Ltd.	BOO	365	Diesel	1995
4	Agrilectric Larkana Power Plant	BOO	10	Waste	1995
5	Davis Energen Ltd.	BOO	18.5	Natural Gas	1995
6	Gul Ahmed Energy Ltd.	BOO	125	Other	1995
7	Japan Power Generation Company	BOO	135.6	Geothermal	1995
8	Kohinoor Energy Ltd.	BOO	120	Natural Gas	1995
9	Liberty Power Company	BOO	235	Diesel	1995
10	Power Gen Hydro	BOO	75	Hydro, Large (>50MW)	1995
11	Southern Electric Raiwind Diesel Power Plant	BOO	117	Diesel	1995
12	Tapal Energy Limited	BOO	126	Diesel	1995
13	TriStar Power Company	BOO	113.4	Diesel	1995
14	Altern Energy Ltd.	BOO	14	Natural Gas	1996
15	Fauji Kabirwala Power Company Ltd.	BOO	151	Natural Gas	1996
16	Northern Electric Power Project	BOO	6	Coal	1996
17	Quetta Habibulah Power Plant	BOO	140	Diesel, Natural Gas	1996
18	Rousch Independent Power Co. Ltd	BOO	412	Diesel	1996
19	Uch Power Ltd.	BOO	586	Diesel, Natural Gas	1996
20	Wak Port Qasim Power Company	BOO	450	Natural Gas	1996
21	Saba Power Company Ltd.	BOO	125	Diesel	1997

ID.	Project Name	PPP Type	Gross/Installed Capacity (MW)	Technology	Financial Close Year
22	Chashma-2 Nuclear Power Plant	BOT	330	Nuclear	2005
23	Orient Power Project	BOO	225	Natural Gas	2006
24	Atlas Sheikhupura NGCC Power Project	BOO	225	Coal	2007
25	Attock General Morgah LSFO Power Project	BOT	165	Coal	2007
26	Foundation Power Company Daharki	BOO	175	Natural Gas	2007
27	New Bong Escape Hydropower Project	BOT	84	Hydro, Large (>50MW)	2007
28	Saif Sahiwal NGCC Power Project	BOO	225	Coal	2007
29	Sapphire Muridke NGCC Power Project	BOO	225	Natural Gas	2007
30	Sheikhupura Diesel Power Station	BOO	225	Diesel	2007
31	Almoiz Bagasse-fired Cogeneration Plant	BOO	27	Waste	2008
32	Engro Qadirpur NGCC Power Project	BOO	227	Natural Gas	2008
33	Halmore Bhikki Power Project	BOO	225	Natural Gas	2008
34	Nishat Chunian Power Project	BOO	200	Other	2008
35	Nishat Power Project	BOO	200	Other	2008
36	HUBCO Narowal Power Project	BOO	220	Diesel	2009
37	Liberty Power Tech Faisalabad Project	BOO	200	Diesel	2009
38	Rasul Hydropower Plant	BOT	20	Hydro, Small (<50MW)	2011
39	UCH-II Power (Private) Limited	BOO	404	Natural Gas	2011
40	Zorlu Sindh Wind Farm	BOO	56.4	Wind	2011
41	CTGCP Jhimpir Wind Farm	BOO	49.5	Wind	2012
42	Fauji Jamphir II Wind Farm	BOO	50	Wind	2012
43	Fauji Jhampir I Wind Farm	BOO	49.5	Wind	2012
44	Fauji Kuttikun I Wind Farm	BOO	50	Wind	2012
45	Fauji Kuttikun II Wind Farm	BOO	50	Wind	2012
46	K-Water Star Patrind HPP	BOT	147	Hydro, Large (>50MW)	2012
47	SSJD Sindh Biomass Plant	BOO	12	Biomass	2012
48	Tapal/Fauji Gharo Wind Farm	BOO	50	Wind	2012
49	United Energy Group Wind Farms	BOO	150	Wind	2012
50	Yunus Jhampir Wind Farm	BOO	50	Wind	2012
51	Jhimpir Power (Private) Limited	BOO	49.6	Wind	2013
52	Sapphire Jhampir Wind Farm	BOO	50	Wind	2013
53	Gul Ahmed Wind Power Plant	BOT	50	Wind	2015
54	Gulpur Hydropower Project	BOO	100	Hydro, Large (>50MW)	2015
55	Khuti Kun Wind Farm	BOO	49.5	Wind	2015
56	MasterWind Sindh Wind Farm	BOO	50	Wind	2015
57	Metro Wind Power Project	BOO	50	Wind	2015
58	Engro Thar Coal-Fired Power Plant Phase 1	BLT	660	Coal	2016
59	Hawa Wind Power Plant	BOO	50	Wind	2016
60	China Power Hub Generation Company	BOT	1320	Coal	2017
61	Karot Hydropower Plant	BOT	720	Hydro, Large (>50MW)	2017
62	Suki Kinari Hydropower Plant	BOT	870	Hydro, Large (>50MW)	2017

Source: Private Participation in Infrastructure Database (World Bank 2018b)

3.3.3.2 Transportation

Transportation plays a key role in enabling economies to be more competitive, economic and social development and provision of opportunities for the poor; hence, the lack of a sophisticated transportation system breeds persistent underdevelopment (PPP Knowledge Lab 2018b). Transportation allows the people to easily access jobs, education and health services in addition to enabling the supply of goods and services around the world (ibid.). The transport infrastructure sector includes the subsectors of airports, ports, railroads, roads and urban transportation systems, which serve various freight and passenger transport needs in different ways (Amos 2004). PPPs can be an effective way to either build and implement new infrastructure or enable and facilitate the renovation, operation, maintenance or management of existing transport infrastructure facilities. For transport infrastructure, different models of private sector participation, where risks are shared between the public and private sectors, can be characterized as PPPs. This refers to concessions for existing (brownfield) and new (greenfield) transport infrastructure, management contracts and lease contracts (ibid.).

In Pakistan, the procurement of projects through private investments in the transport infrastructure sector started late. Perhaps the first road PPP project executed by the Government of Punjab was the Lahore–Sheikhupura–Faisalabad Dual Carriageway BOT Project in 2003 (State Bank of Pakistan 2007). There was one PPP project in 2010 (Economist Intelligence Unit, 2015). A total of 10 projects are currently under construction or in the operation phase, including the Hyderabad–Mirpurkhas Dual Carriageway, the Sir Agha Khan Jhirk Mulla Katiyar Bridge (over the Indus River), the Karachi–Thatta Dual Carriageway, the Karachi-Hyderabad Motorway (M9), the Kahna Kachha Flyover (Lahore), the Lahore Ring Road (southern loop), the Lahore–Sheikhupura–

Faisalabad Expressway, the Lahore–Islamabad Motorway (M2), the Habibabad Flyover (GT Road, Pattoki) and the Lakpass Project (Mastung). Of these, two projects are being procured using the Design-Build-Finance-Operate-Transfer (DBFOT) model, and the rest are based on the BOT modality. The World Bank's PPI database lists just one airport (BOO) and 13 port sector projects that were procured under various modalities of PPP, including ROT, Build-Rehabilitate-Operate-Transfer (BROT) and BOT. At present, several other projects at the federal and provincial levels are under the development phase. A list of highway projects currently under construction/operation phase is shown in Table 3.2. A list of port and airport projects obtained from the World Bank's PPI database is provided in Table 3.3.

Table 3.2. List of active PPP Highway/Bridge/Tunnel projects

ID	Project Name	PPP Type	Type	Length (Km)	Status
1	Hyderabad Mirpurkhas Dual Carriageway	Design-Build-Finance-Operate-Transfer (DBFOT)	Road/Highway	60 (+ brigdes and culverts)	Operational
2	Jhirk Mulla-Katiyar Bridge Project	DBFOT (Annuity based)	Road/Highway	1.2 (+25 Km approach road)	-
3	Karachi Thatta Dual Carriageway Project	DBFOT	Road/Highway	48 (+ brigdes and culverts)	Under Construction
4	Flyover Over Railway Crossing Kahna Kachha, Lahore	BOT	Road/Highway	1.5	Operational
5	Lahore Ring Road (Southern loop)	BOT	Road/Highway	22.2	Under Construction
6	Lahore–Sheikhupura–Faisalabad Expressway	BOT	Road/Highway	-	Operational
7	Habibabad Flyover	BOT	Road/Highway	0.867	Operational
8	Lakpass project	BOT	Road/Highway	0.180 through a mountain (+ approach road of 5.5 Km)	Operational
9	Karachi-Hyderabad Motorway	BOT	Road/Highway	136 (Conversion from 4 to 6 lanes)	Under Construction
10	Lahore-Islamabad Motorway	BOT	Road/Highway	337	Work in progress

Table 3.3. List of active PPP Port/Airport projects

ID	Project Name	PPP Type	Financial Close Year
1	Qasim International Container Terminal	ROT	1995
2	Qasim International Container Terminal	ROT	1995
3	Karachi - International Container Terminal	BROT	1997
4	Karachi - International Container Terminal	BROT	1997
5	Pakistan International Container Terminal	BOT	2002
6	Pakistan International Container Terminal	BOT	2002
7	Pakistan International Container Terminal	BOT	2002
8	Pakistan International Container Terminal	BOT	2002
9	Sialkot International Airport	BOO	2006
10	Gwadar Port Phase II	BROT	2007
11	Qasim Grain and Fertilizer Terminal	BOT	2008
12	Second Container Terminal at Port Mohammad Qasim	BOT	2008
13	Pakistan Deep Water Container	BOT	2010

Source: Private Participation in Infrastructure Database (World Bank 2018b)

3.4 DRIVERS PROMOTING THE INFRASTRUCTURE PPPs

The drivers promoting the PPP-based infrastructure project procurement in Pakistan are quite similar to what would be expected in any developing country in the world. As mentioned previously, Pakistan faces severe fiscal constraints that hamper its ability to fund and support its infrastructure needs solely from public funds. Moreover, existing research has shown how the construction industry, in general, is plagued with poor project performance as indicated by large costs and the delayed delivery of infrastructure projects. Problems related to poor governance, institutional capacity and lack of expertise in handling complex projects can be alleviated, in part, by integrating private sector management and control in the delivery of public infrastructure projects.

Mubin and Ghaffar (2008) and Khan et al. (2008) stressed the need to complement public resources by attracting private investors on a BOO/BOT/BOOT basis or other suitable models under the PPP umbrella. The State Bank of Pakistan (2007), Noor (2011) and ADB (2015b) largely recognized the "need for efficiency" (performance requirements of time, cost and quality) and "finances" as the driving factors pushing the adoption of PPPs in Pakistan's public infrastructure development. Fiscal constraints and natural disasters have also created many problems, with the (infrastructure) organizations abandoning many projects in order to free up capital to keep the operations running, as reported by Noor (2011). By adopting the PPP models, Pakistan can achieve the following: reforms and modernization of public services, the sharing of funds and risks with the private sector, the potential reduction in the burden of subsidies as a result of efficient private operations, the availability of uncommitted infrastructure funds for doing projects meant to uplift the socio-economic conditions of the country, utilization of new technologies and better allocation of public resources can also be achieved (State Bank of Pakistan 2007).

Other drivers, as mentioned previously, include the growing population and the need for infrastructure to provide basic services and support economic development (ADB 2015b; State Bank of Pakistan 2007). The lack of infrastructure (which hinder production or increase its costs) and poor security situation have caused a significant part of the textile industry, and its value added potential along with it, to transfer operations overseas (ADB 2016). For sustained economic growth at the rate of 7% or higher, the Pakistan government must ensure sufficient infrastructure availability in the power and transport sectors and other key areas (gas and urban infrastructure) to enable the industry to flourish (ibid.).

3.5 BARRIERS PREVENTING THE IMPLEMENTATION OF INFRASTRUCTURE PPPs

According to Khan et al. (2008), in the past, Pakistan had not been successful in exploiting the full potential of the BOT form of project procurement, as evidenced by the very low interest shown by multinational firms and ventures operating in Pakistan, to support the proposals initiated by the government. A poor sovereign credit rating (SCR), which is common in developing countries, leads to difficulties in securing debt financing for PPP projects (Chowdhury and Charoenngam 2009). Due to the lack of debt market maturity, securing long-term debt financing in Pakistan is a difficult and problematic process (ADB 2015a; Mubin and Ghaffar 2008). In relation to this, the government has to provide guarantees to attract private investments. Noor et al. (2012) identified multiple restraining forces (barriers) to non-traditional methods (BOT/BOOT/BOO) of procurement in Pakistan, which include a lack of understanding of the method (among all the stakeholders), resistance to change, issues related to project revenues, impact of environmental factors (regulatory, legal, political, economic, cultural, financial etc.) and long gestation period of PPP projects. The financial, economic and security situation of Pakistan is believed to have increased transaction costs and even the overall cost of doing business (Noor 2011). Inflation, foreign exchange rate changes, low rates of return and the international financial crunch were also reported to have a negative effect on investors' interest in the country's infrastructure projects. The poor security situation of Pakistan was also reported as the most important impediment to project procurement and implementation in the country. These issues, in conjunction with the risk of political instability and immaturity of organizations and institutions, lead to a lack of investor interest, both domestic and foreign. Other reported factors that hamper the implementation of PPPs include legal and institutional frameworks, risk and contract management practices, the level of understanding of alternate procurement methods and lack of investors' confidence (ibid.).

In a study by the Cambridge Economic Policy Associates for the World Bank, it was stated that the concerned government agencies (in Pakistan) lack an understanding of several relevant concepts, such as the rationale for PPPs, the involvement of the private sector in infrastructure delivery, the specific risk-sharing structures needed for PPP transactions and the distinction among the different forms of PPP arrangements (World Bank 2010). The public sector also has insufficient capacity to initiate, develop, prioritize, package and manage PPP projects. Most agencies also lack an understanding in identifying optimal projects for PPP-based delivery, negotiating with a private sector developer or operator and the dynamics of preparing PPP transactions (ibid.). In a recent ADB led review of provincial PPP frameworks (Punjab and Sindh) in Pakistan and the current status of implementation of provincial PPP projects, three major barriers were revealed, including (ADB 2015a): PPP pipeline development (government's weak PPP capacity, poor project development and problems with the selection process of development projects such as inherent bias/risk aversion); the lack of alignment among various provincial PPP policies, legislative documents and sector-specific regulations (if available); and the lack of off-budget viability gap funding.

For the road sector, the infrastructure report by the State Bank of Pakistan (2007) highlighted a number of impediments that prevent the influx of private investment and participation. These include the lack of sectoral policy framework, little experience and poor management by the executing authorities, law and order issues (government officials' interference with the operator, poor coordination among government departments), tolling issues, financial and legal impediments (investors and lenders reluctance) and land acquisition issues. Nevertheless, this situation is improving because a number of projects have been procured since then. For the water and sanitation sector, the issues reported included the following: affordability concerns in view of providing satisfactory services and the need for government support; user acceptance of commercial tariffs and the reliability and quality of services; reluctance of investors to sign deals with government bodies that lack financial strength and independence; the lack of local government/municipalities technical and operational resources and knowledge of PPPs to develop projects and regulate services; and poor state of existing infrastructure assets (State Bank of Pakistan 2007). Other more general issues limiting private participation include the lack of private investment and lending for long tenors and the market's inability to provide fixed-rate lending for infrastructure projects; some degree of reluctance in lending to various municipalities/public sector enterprises for not having fully honored guarantees in the past; and the lack of credible project management expertise in Pakistan; hence, leading to the hesitation by private investors in funding infrastructure projects. The high risks associated with infrastructure projects and availability of more attractive commercial financing opportunities leave little appetite in the private sector. Low banking sector depth, the prevalence of short tenor deposits and the highly underdeveloped debt markets also create problems in acquiring local currency financing, whereas large foreign currency loans to fund infrastructure development bring their own set of risks for the country (ibid.).

3.6 RISKS RELEVANT TO PPP PROJECTS

Pakistan is a developing country with little experience in PPPs in most of the infrastructure sectors, except the power sector. Hence, it faces multiple risks that may prove detrimental to the interests of the public and/or private sector stakeholders. Experience and a relatively long history of executing power projects help in managing and mitigating various risks as these help in identifying risks and assessing their possible impacts. The Hub power project, as mentioned above, and other projects that followed Hubco under the Power Policy 1994, faced political opposition when the succeeding government alleged corruption against the previous government in setting up some of the deals, which were considered extremely disadvantageous to the state. Consequently, concessions were renegotiated, resulting in several IPPs agreeing to lower tariffs in return for increased concession periods and other arrangements (Fraser 2005; Reside 2009). Other factors that led to this turmoil include poor planning and management by the government, depreciation of the local currency, lack of transparency in the prioritization of projects and problems with the state-owned power purchaser (Fraser 2005, SBP 2007). Atmo and Duffield (2014) identified key risks and discussed their relevance to the Hubco power project (and five other case studies from Indonesia, China and Vietnam), which include risks pertaining to political, currency, regulatory, financing, land acquisition, construction, operation, fuel supply availability, fuel supply price and demand accuracy.

In one of the organizational case studies conducted, Noor (2011) argued that a high perception of political risks exists among the investors, in terms of political interference for toll setting, thus posing difficulties in securing loans for projects, shorter lending terms and/or higher risk premium/interest rates that are ultimately reflected in higher toll rates. The same was also reported in a more general sense, wherein lending for projects in public sector organizations was considered difficult due to the lenders' concerns regarding the political viability of the projects, apart from the technical and financial insecurities. Other risks reported include late policy changes by the government, lack of clarity of client needs and bureaucracy that can lead to delays and procurement risk. Other risk factors affecting the construction projects in a general sense were reported to include occasional litigations, weak legal and regulatory systems and the existence of corrupt practices. Two BOT project case studies reported under the same organization also suffered from different risk scenarios, which collectively include procurement risk, late policy decision changes, land acquisition, public opposition and payment risk in terms of failure to implement the agreed toll rates. Financing risks, long processing times, delays in obtaining approvals and permits and potential corrupt practices were also reported in another organizational case study while covering PPP projects. The precarious security situation in the region and the country (at that time) was also reported to have increased the perception of security risks that discourage investors from undertaking infrastructure projects in Pakistan. Barriers related to environmental uncertainties (i.e., low rates of return, inflation and exchange rate variations, international financial crunch, political risks and frequent changes in government leading to changes in policies and a lack of investors' confidence in infrastructure investments), as explained above, are also considered as potential risks. Significant delays in project initiation due to financial issues have also been reported (ibid.).

The infrastructure report by the State Bank of Pakistan (2007) identified several risks for the power projects, including delays in financial closure as well as construction, operation, demand, management and governance and financial risks. The report also identified multiple impediments to private sector participation in highway BOT projects in Pakistan, which may be interpreted as risks, including competing routes, reluctance in making decisions and taking responsibility by government officials, opposition to BOT-type procurement by government authorities/agencies, delays in the approval of designs and in the clearance of the project by environment agencies, financial/legal impediments, delays and extra costs in the acquisition of land, interference with the operator by government officials, the lack of coordination and cooperation among the parties, toll implementation issues, and issues resulting from the lack of laws governing the implementation of BOT projects. Design and construction risks were also considered important for toll road projects.

Soomro and Zhang (2011), while studying critical failure factors in the transport PPP infrastructure projects, found that the M9 motorway project (in Pakistan) suffered a cancellation of concession due to the inability of the concessionaire to obtain financing for the project in the designated time, conflicts between the central and provincial governments over land ownership and privatization and corruption.

In another study on political risks by Sachs et al. (2007), out of a total of 14 Asian countries, the authors ranked Pakistan as 3rd in the "currency inconvertibility and transfer restrictions" and "expropriation" risk, 5th in "breach of contract" risk, 1st in "political violence" risk, 4th in "legal, regulatory, and bureaucratic risks" and 2nd in "non-governmental action/outside risks." However, the number of respondents for this study was very low.

Given that the Federal PPP law has not yet been ratified, general and sector specific laws are being employed for the management of existing projects "… which adds a non-negligible source of legal risk to all parties in PPPs." (ADB 2015a) Loopholes in the dispute resolution framework are also an issue. An outdated Pakistan Arbitration Act (1940) is in force, and the Regulation and Enforcement Act (2011) ensures enforcement of international arbitral awards does not apply to local courts (Economist Intelligence Unit 2015). The procurement risk was also specified because a relatively small number of potential bidders may restrict competition. Government payment risk is also an important risk within the Pakistan context (Economist Intelligence Unit 2015).

3.7 ISSUES RELATED TO RISK MANAGEMENT

Risk management maturity and the application of best practices seem to be low across the construction industry of Pakistan. Multiple studies have summarized the relevant issues. An investigation by Ali et al. (2007) concluded that although formal and prescribed risk management was lacking in the Pakistani construction industry, traditional risk management based upon intuition, judgment and experience was practiced. In an industry-wide survey on risk management systems by Choudhry and Iqbal (2012), they discovered that the clients (mostly public sector organizations), consultants and contractor organizations had an overall poor perception of the formality and adequacy of the existing risk management systems in their organizations. Most of the surveyed organizations were categorized between level 1 and level 2 for risk management maturity (on a four-level scale). The respondents also reported that with their awareness of the risks and their sources, the highest ranked barriers to effective risk management in Pakistan include the lack of formal risk management systems, lack of joint risk management, shortage of knowledge/techniques, complexity (of risk management techniques and procedures), a reactive rather than a proactive approach to risk management (crisis management), and centralized rather than decentralized systems, among others. Interviews revealed that most respondents had a rather vague idea regarding the aim of implementing an effective risk management system, and that their opinions on the motivation to do so were limited to the prevention of unfavorable consequences rather than seeing the process as value addition. Noor (2011) also found that the degree of awareness of risks and risk management in non-traditional (PPP) projects was relatively higher (vis-à-vis traditionally procured projects), where the stronger emphasis seemed to be attributable to the involvement of international financing institutions who attempt to safeguard each and every aspect of the risks. However, there is neither a systematic risk management framework nor a standard policy for risk management. A lack of policy incentives and guidelines across the infrastructure sub-sectors was also reported by Noor (2011). The author asserted a variation in practice with regards to risk allocation across different sectors. The power sector was very flexible in taking on risks and provided many incentives to the private parties, but the same was not observed to be true for other infrastructure sectors.

In the semi-structured interviews conducted (Appendix A) in Pakistan, it was revealed that the federal procurement organizations (involved in procurement of power generation and highway projects) followed standard concession contracts for procurement via PPPs. The variation in risk allocation practice, as reported by Noor (2011), was also observed in the interviews, and the respondent experts were skeptical about other's approaches to risk allocation, with the view of bringing VfM to the public. In any case, there is no indication of whether the risk allocation regimes adopted in various sectors are in accordance with the risk management capability of the participants (and thus efficient) who are involved in such deals. Moreover, the interviewees indicated that standard allocation in contracts is non-negotiable (specifically for power sector projects), which directly contradicts the fact that the risk management characteristics of participants vary across projects; hence, a standard risk allocation and sharing regime may not be suitable (see Chapter 1). Additionally, the practices with regards risk allocation strategies in the transport sector projects seem to vary across projects, as evident from the risk allocation profile of the Hyderabad–Mirpurkhas toll road in Sindh (Economist Intelligence Unit 2015; Iqbal and Badshah 2016; Shahneel 2012) and the case study project covered in this research (Chapter 9). The risk management guidelines published by the GoPb (2011) recommend the optimum allocation of risks based on negotiations (where the private party assesses the risks based on the government proposed risk allocation in the risk matrix, in light of their strengths and ability to mitigate and overcome them) between the public and the private sectors.

The timely resolution of disputes via the court system (ADB 2015a; Noor 2011; State Bank of Pakistan 2007) and the uncertainty in the enforcement of international arbitral awards (Economist Intelligence Unit 2015) also indicate issues that are relevant to effectiveness of risk management on projects.

One of the most fundamental drivers of adopting PPPs is to secure VfM in infrastructure provision (see Chapter 1). In order to achieve this, governments develop sophisticated ecosystems by introducing PPP-related legal and institutional reforms to facilitate the identification, structuring and execution of only those PPP proposals that can maximize VfM to the taxpayers (ADB 2015a). Such PPP development frameworks are extremely important, and efforts in this direction for Pakistan have achieved varying degrees of progress so far. The 2010 PPP policy of Pakistan mandates that the projects to be awarded must be viable and provide VfM. However, with regards to the application of this criteria, there is a general acknowledgement about the lack of technical capacity and consistency. Limited experience in such areas as risk allocation was also reported. On the provincial level, the report asserted the limited capacity of the Government of Sindh (GoS) units (PPP unit and risk management unit) to appraise, manage and report on the fiscal contingent liabilities. There is also a shortage of skills to carry out key tasks, including forecasting the utilization of assets, estimation of revenue/cashflows and risk allocation, among others. Weak PPP capacity was generally reported for both the provincial governments of Punjab and Sindh, in terms of identification of the project, undertaking project pre-feasibility/feasibility studies, transaction structuring, tendering and post-tender management of the projects. A need to establish wellgoverned, off-budget facilities to provide viability gap grants and risk-sharing solutions was also emphasized (at both federal and provincial levels) so that projects can be commercially viable while still securing VfM (ibid.).

Government guarantees or the retention of some risks by the government (where it is more practical or efficient for public sector to manage) shall be undertaken in a well-designed PPP to complete the transaction and reduce the upfront project costs (Castalia Limtited 2010). This results in creating contingent liabilities (CLs) for the government as the timing and/or magnitude of these explicit contractual financial obligations depend on the occurrence of uncertain future events, thereby creating fiscal risks. The appropriate application of risk allocation principles and rules for structuring CLs and contractual mechanisms are essential to managing CLs, as they can ensure that only the right risks are undertaken by the government (in accordance with the risk allocation principles) and that they are managed with minimal fiscal footprint at the lowest cost (ibid.). In a study by the Cambridge Economic Policy Associates for the World Bank (2010), it was argued that the GoP lacked a centralized management of CLs, including those arising from government guarantees that are issued to the private sector parties in IPPs and/or private sector lenders on publicly funded projects. It further contended that there was a lack of a standard evaluation process to assess the appropriateness, form and quantum of the guarantees (ibid.), whereas Castalia's investigation contended that the existing policies and processes to manage the contingent liabilities were largely incomplete and likely to be ineffective (Castalia Limtited 2010). There is a lack of consistent principles with the contracting authorities for allocating risks and structuring PPPs (potentially eroding VfM prospects for the Government). Except a few contracting authorities, the requisite tools and contractual mechanisms have not been developed to ensure consistent adherence to the stated principles. Furthermore, there is a lack of guidance to direct design of relevant contractual mechanisms with the aim of managing the fiscal impact and to arrive at the best risk allocation (ibid.). Hence, the risk is that the CLs are not considered systematically, and because of this weakness, the national budget, in case of IPPs, is exposed to significant CLs (World Bank 2010). The report concluded that there is a likelihood of project risks being assessed without considering all the guarantees that the government may have extended or may consider extending in favor of the private party. The report also stated that the government exerts limited efforts to negotiate the amount of financial guarantees with the private lenders, indicating that the optimal allocation of project risks, including those that are retained by the government, *"…is not well understood and likely to be underestimated."*

3.8 CHAPTER SUMMARY

This chapter provided the necessary background information to establish the significance and state of PPPs in the national context and further identified various drivers, barriers and relevant risks to the local promotion of PPPs. Pakistan has developed a relatively mature framework for the procurement of power generation projects via PPPs. However, the application of PPPs in other sub-sectors of the power sector and transport and water and sewerage sectors, for example, is deficient. The identified drivers indicate that PPPs will stay around and perhaps grow in the future as a key source of public infrastructure procurement. Meanwhile, the identified barriers provide a useful guide for the government to focus its efforts to attract the private sector to undertake infrastructure projects. Various risks that have already been identified in both the academic and institutional literature in the local context are reviewed and consolidated in this chapter. The risks appear to be diverse and spread across multiple domains, i.e., political, legal, governance, project finance, local economy and so on. The risks reported not only affect the stakeholders' objectives but also hamper the private sector's interest in infrastructure investment. Issues specific to the practice of risk management in the local context were also determined. The stakeholders' risk management maturity and the government's capacity to evaluate risks and assess CLs are determined to be low.

There is a great need to conduct a comprehensive study of risks and their management on local infrastructure PPPs as many of the sources cited in the review are old and the situation may have changed over time. These reviews comprised an important source of content for discussions in the following chapters of this research. Clearly, the findings on critical risks and measures of ERM are significant in informing the PPP practitioners, given the lack of relevant research and risk management immaturity of PPP stakeholders. Furthermore, the proposed risk assessment and allocation models can help the stakeholders by providing structured decision-making approaches to evaluate and process risks on projects.

CHAPTER 4 RISK MANAGEMENT IN PPP INFRASTRUCTURE PROJECTS[5]

4.1 INTRODUCTION

This chapter introduces the discipline of risk management, the process and its significance with a special emphasis on risk analysis and allocation in PPP infrastructure projects. The chapter begins with the definition of risks and defines the risk management process as per Project Management Institute (PMI) guidelines. Then, each process is described in detail while explaining the purpose of the process and the generic tools and techniques that are available to execute and assist the process implementation as well as the relevant details in the purview of PPPs. A brief discussion is then presented on the existing risk assessment and allocation research and models and their characteristics. Specifically, the limitations of the existing models are highlighted to set the stage for this research.

4.2 RISK AND RISK MANAGEMENT

Risk, in general, has been defined in terms of the effect that uncertainty has on objectives. The guide to project management body of knowledge (PMBOK) by the Project Management Institute (2013) defines project risk as:

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[5] Parts of this chapter have been included in:

Mazher, K.M., Chan, A.P.C., Zahoor, H., Khan, M.I. and Ameyaw, E.E. (2018). "Fuzzy integral based risk assessment approach for public-private partnership infrastructure projects." Journal of Construction Engineering and Management, 144(12), 4018111.

Mazher, K. M., Chan, A.P.C., Zahoor, H., Ameyaw, E.E., Edwards, D.J., & Osei-Kyei, R. (accepted). "Modelling capability based risk allocation in PPP projects using fuzzy integral." Canadian Journal of Civil Engineering.

"… an uncertain event or condition that, if it occurs, has a positive or a negative effect on one or more project objectives such as scope, schedule, cost, and quality." (p. 309)

In the construction-specific literature, Loosemore et al. (2006) contended in somewhat similar terms that *"To most managers, risk is concerned with unpredictable events that might occur in the future whose exact likelihood and outcome is uncertain but could potentially affect their interests/objectives in some way (normally adversely)."* (p. 8)

Both descriptions provided above recognize two specific dimensions of risks: the uncertainty and effect of risks. The uncertainty may be expressed in terms of the probability (or likelihood of risk occurring) and the effect may be understood in terms of impact (or consequence/severity of risk, extent of damage or loss) on the objectives (Project Management Institute 2013). Another important aspect of risk that has been recognized in the descriptions is that it includes a possibility of negative or positive effect on project objectives (loss or gain). Risks posing a possibility of loss are called "threats" and those that may result in a potential gain are termed "opportunities" (ibid.). In the case of PPP projects, as explained previously in Chapter 1, risks include all events and uncertainties that negatively influence the realization of project objectives and those of the individual stakeholders. This specific focus on "loss only" aligns well with the approach adopted in the risk management manual for infrastructure PPPs by the GoPb (2011), and by other PPP guidelines by United Nations (UNCITRAL 2001) and European Commission (2003). Events and circumstances are termed as "project risks" when they render the involved cost and benefits uncertain. This leads to a resultant possibility of a less than expected project return or outcome (GoPb 2011). The risk management manual further endorses viewing the adequacy of proposed risk allocation/sharing from a lenders' perspective, which provides the bulk of financing to implement the project and, hence, can be considered as the ultimate judge of the level of risk. Furthermore, project lenders (senior) do not have any potential upside gain in the project (perhaps because the interest rate is predetermined and is not related to project's profitability), but only downside risks that may negatively impact the borrower's ability to make payments under the loan agreement (Grimsey and Lewis 2002). Thus, viewing risks from a downside perspective has substance and logic to it. The terms "uncertainty" and "risk" can be distinguished in meaning (Kim 2012; Loosemore et al. 2006), however, for the purpose of this research, the terms are used interchangeably.

The Project Management Institute (2013) defines project risk management (PRM) as:
"... an approach by which uncertainty can be understood, assessed, and managed within projects." (p. 13)

Risk management assists in realizing better business and project outcomes by enabling the following: informed decision making in improving planning and design processes to prevent or avoid risks, exploration of available opportunities, planning for sufficient contingencies, improved risk resource allocation and orientation of project budgets to risk considerations and improved decision making regarding inter-party allocation of project risks. It helps reduce uncertainty and the overall project's risk exposure (Cooper et al. 2005). The science of risk management, as per VDTF (2001), aims to identify, prevent, contain and mitigate the risks in the project's interests.

A number of governmental and professional project management associations have developed or are in the process of developing risk management standards. Some examples of existing approaches to project risk management provided by Cooper et al. (2005) include the risk management chapter in PMBOK by PMI, USA (interested readers can also refer to practice standard for project risk management by PMI); the PRAM guide by Association for Project Management (APM), UK; the risk management standards association of Australia, AS/NZS 4360 (2004); management of risk by office of government and commerce (OGC), UK; and the integrated risk management framework by the Treasury Board of Canada (2001).

4.3 RISK MANAGEMENT PROCESS

The risk management process (Fig. 4.1) includes the systematic application of management policies, processes and procedures to various relevant tasks (Cooper et al. 2005), which include planning of risk management, identifying risks, performing qualitative and quantitative risk analy-

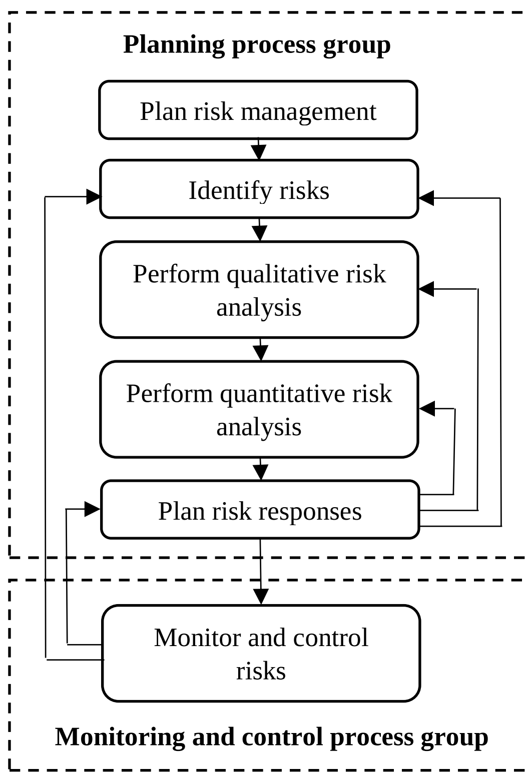

Fig. 4.1. Risk management processes and their general flow (adopted and modified from Project Management Institute 2009)

ses, planning of risk responses and controlling risks, in accordance with the specific risk management processes defined by the PMI (Project Management Institute 2013). These processes, along with the relevant tools and techniques, are discussed in detail below. The risk management cycle defined for PPP projects from the perspective of the public partner by APMG International (2016a) is not so different when compared to the generic processes defined above. The cycle starts at risk identification and proceeds sequentially to risk assessment. Thereafter, risk response planning and control are executed, which are subdivided into specific actions in line with the specified regime including preliminary allocation, early risk mitigation and risk allocation and structuring, while finalizing the contractual details. Finally, the public partner engages in risk treatment and monitoring and control of the retained risks as well as ex-post management of the transferred risks. Similarly, the guidance material (by Partnership Victoria for private provision of public infrastructure and related ancillary services) on risk allocation and contractual issues (VDTF 2001) also defines a matching risk management cycle with a slightly different terminology, which includes risk identification, assessment, allocation, mitigation, monitoring and review.

The PMBOK guide (Project Management Institute 2013) classifies the project management processes into five general process groups (independent of application area or industry focus), namely, initiating process group, planning process group, executing process group, monitoring and control process group and closing process group. Depending upon the project, these are often iterated (the process groups and the component processes) through the project lifecycle, and can exhibit intra- and inter-group interactions. The planning process group includes project management processes that are required to establish *"... the total scope of the effort, define and refine the objectives, and develop the course of action required to attain those objectives."* These processes develop the project documents and the project management plan, which is progressively elaborated as more information becomes available through a project lifecycle. The monitoring and controlling process group focuses on processes that are required to *"... track, review, and orchestrate the progress and performance of the project; identify any areas in which changes to the plan are required; and initiate the corresponding changes."* The other aspects of this process group include recommendation of corrective and preventive actions while controlling changes and when expecting problems, project monitoring against the developed project management and baseline plans and ensuring implementation of only the approved changes (ibid.). The risk management processes, specified above, have been categorized into the planning and monitoring and control process groups, as shown in Figure 4.1. The first five risk management processes have been classified into the planning process group; the *monitor and control risk* process provided feedback may necessitate a revisit to risk management planning group processes at any point in the project lifecycle. For example, the execution of risk response while responding to a particular risk event may require and initiate more analysis (another round of the processes of risks identification and the associated analysis processes for impact evaluation) (ibid.).

4.3.1 Plan Risk Management

This process aims to provide an overall project risk management strategy (in order to make decisions on how the risk management processes shall be conducted) and to integrate all other project management activities with the project risk management (Project Management Institute 2009). The risk management plan elaborates the interrelationships among project risk management, general project management and other organizations' management processes. It serves as a key element to communicate and obtain commitment from all stakeholders to ensure support to, and the effective execution of the risk management process over the lifecycle of the project. The risk management plan deliberates upon the methodology (approaches, tools and data sources for risk management), the roles and responsibilities, budgeting (estimate funds based on assigned resources and establishes protocols for application of contingency and management reserves), timing (of risk management processes and activities), risk categories, revised stakeholders' tolerances and reporting formats, among other important elements (ibid.).

4.3.2 Risk Identification

The purpose of this process is to identify all knowable risks to the project objectives and documenting their characteristics (Project Management Institute 2009). As explained earlier, these risks stem from various sources within and outside the project environment. All risks cannot be practically foreseen or identified at the outset of the project; hence, the risk identification process needs to be iterative, in order to accommodate the emergent aspects of the project and the environment, within which the project exists. Risks should be identified objectively (taking care of motivational and cognitive biases) and should be described in sufficient detail to enable understanding by various stakeholders (including those responsible for risk assessment and response planning), provide an understanding of the uncertainty and its causes and effects, and how they impact one or more project objectives, enable the identification of responsibility for the risk, and allow the development of specific risk response strategies (Project Management Institute 2009, 2013). Potential responses may also be identified at the same time and considered for immediate action if appropriate. The common tools and techniques employed to identify risks include (Project Management Institute 2013) "… documentation reviews, information gathering techniques (brainstorming, Delphi technique, interviewing, root cause analysis), checklist analysis, assumptions analysis, diagramming techniques (cause and effect diagrams, system or process flow charts, influence diagrams), Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis and expert judgement." According to Cooper et al. (2005), information sources that may be employed include empirical data and analysis, theoretical analysis, historical data, opinions and judgments of project team and other experts, and stakeholders' concerns. A comprehensive listing of potential risks to successful project outcome, usually in the form of a risk register, is an output from this process, which allocates the management responsibilities in handling these risks (ibid.).

As the first step of risk analysis, the identification of risks is important and also because it is impossible to manage a risk unless identified (Cooper et al. 2005; Dey and Ogunlana 2004). The unfavorable outcomes (with reference to BOT projects) have resulted in many cases due to the failure to identify certain events as risk factors (Dey and Ogunlana 2004). Conducting questionnaire surveys and interviews by incorporating brainstorming and Delphi techniques have been recommended (ibid.). The checklists of risks specific to infrastructure service projects delivered via PPPs may serve as a useful starting point (Dey and Ogunlana 2004; VDTF 2001). Risk identification should be implemented thoroughly on an individual project basis (ibid.), preferably using brainstorming sessions with experienced personnel (VDTF 2001). The government must also consider pre-construction risks, such as process risks, which are relevant to the bid phase and negotiation with the preferred bidders (ibid.).

4.3.3 Perform Qualitative Risk Analysis

The goal here is to prioritize risks by evaluating agreed-upon characteristics, such as the *probability* and the *effect* (severity) of each risk on project objectives (such as cost, quality or performance etc.) without considering the interactions among the risk factors and the overall risk due to their combined effect on project objectives (Project Management Institute 2009). This leads to a more focused approach in treating the identified risks and facilitates the structured action planning and resource allocation (Cooper et al. 2005). An important step is to categorize the risks according to their sources or causes, which may assist in focusing risk response measures on the root cause or common source to ensure maximum efficiency (Project Management Institute 2009). Risks identified as high priority will be an important focus in planning risk response process and may be subject to further analysis. The typical tools and techniques defined for this task include (Project Management Institute 2013) "… risk probability and impact assessment, probability and impact matrix, risk data quality assessment, risk categorization, risk urgency assessment and expert judgment."

According to the Federal Highway Administration (2013), the extent to which this prioritization exercise (to separate significant risks from insignificant risks) is important depends on the objective of risk assessment. Risk prioritization can assist a manager in focusing efforts in the proper direction; hence, it is significant to the management of risks in this perspective. However, it is less relevant if the objective is to conduct a financial feasibility analysis or a VfM assessment, where the goal is to value the full risk profile of the project and not just focus on a selection of individual risks (APMG International 2016a; Federal Highway Administration 2013). Qualitative risk assessment is also used to define a preliminary risk allocation for constructing the project financial model for the financial and VfM appraisal (APMG International 2016a).

4.3.4 Perform Quantitative Risk Analysis

While the qualitative risk analysis provides an insight on the influence of individual risks on the project's objectives, the quantitative risk analysis process provides a numerical estimate of the combined effect of risks on the project objectives; this process also helps in determining the likelihood of success in achieving project objectives and establishing the appropriate contingency reserves which satisfy stakeholders risk tolerance levels (Project Management Institute 2009). Risks related to individual project elements, such as specific line item costs or schedule activities, must also be defined at a detailed level to allow for an overall risk analysis on project objectives. Estimating the project's overall risk level helps differentiate between projects while considering the risk tolerance level of the stakeholders and also assists the stakeholders in establishing appropriate risk responses for high-risk projects (ibid.).

The available tools and techniques for this process include (Project Management Institute 2013): data gathering and representation techniques (interviewing, probability distributions), quantitative risk analysis and modeling techniques (sensitivity analysis, expected monetary value analysis, modeling and simulation typically performed using Monte Carlo technique), and expert judgment. In order to perform the project financial feasibility analysis and affordability assessment, quantitative risk analysis shall be used to establish cost and revenue (for user pays scheme) inputs and to obtain a set of risk adjusted projections which is used to establish the financial base case for determining the commercial feasibility (APMG International 2016a). The quantitative risk analysis may also be used to establish VfM that is inherent in alternative strategies for allocation of some significant risks (taking back respective risk, risk sharing or capping the risk transferred), where the qualitative assessment is unclear or of limited value (ibid.).

4.3.5 Plan Risk Responses

In this process, appropriate response actions are determined for the identified and assessed risks that have the potential to threaten the chances of achieving project objectives or those that offer opportunity (opportunities are not considered in this research), in consideration of the risk attitudes of the stakeholders and conventions specified in the risk management plan (Project Management Institute 2009). As a part of the process, risk treatment options are identified (to reduce the likelihood and consequences of each significant risk), cost benefit analyses are performed for all options and the best option is selected and risk action plans are developed and implemented (Cooper et al. 2005). Furthermore, the trigger conditions and the optimum time at which the response actions for contingent risks need to be undertaken should be specified (Project Management Institute 2009). The appropriate risk owner will be responsible for ensuring the efficient response action plan implementation. Response action execution may trigger additional risks, termed as the "secondary risks," and these need to be managed in a way that is similar to the risks identified initially. Response actions planned for various risks might not be able to completely eliminate the influence of risk events, and for some risks there might be no planned response actions; hence, the "residual risks" may remain and these must be monitored carefully. Separate risk response strategies are available for -ve and +ve risks, while for some risks, contingent response strategies are established (Project Management Institute 2013). Expert judgement can be utilized for establishing risk responses (ibid.).

In addition to planning and implementing risk response strategies for individual activities, strategies at the project level can also be prepared. Such strategies might include abandoning a high-risk project, setting up a business structure that allows sharing of risks, re-planning the project in a certain way to address concerns or pursuing the project despite high project threat (Project Management Institute 2009).

Risk transfer can be likened to the allocation of risks between the public and the private sectors in PPPs, in which the risk may either be completely transferred, retained (taken back) or shared between the parties. The insurance of risks or special financial products (such as swaps/hedges etc.) that cover price or interest rate risk are other forms of allocation of risks (Federal Highway Administration 2013). Other measures include avoiding, adapting and accepting the risk(s). A number of measures or strategies can be selected for a single risk with the goal of achieving an effective and efficient risk management strategy in combination, wherein effectiveness is considered in terms of the cost and combination of the measures as well as the extent to which the probability or the impact of the risk is mitigated. Risk management measures can be inventoried and evaluated via brainstorming sessions similar to risk identification exercise (ibid.). Risk allocation and sharing between the public and private sectors stakeholders is a crucial task in PPP risk management effort. These shall be discussed in more detail later.

4.3.6 Monitor and Control Risks

The purpose of this process is to properly implement, review and update the plans by tracking identified risks, monitoring residual risks, identifying new risks, implementing risk response plans at appropriate times and determining their effectiveness throughout project's lifecycle (Project Management Institute 2009). The effectiveness of all the risk management processes should also be reviewed in an effort to ensure continuous improvement. Some of the important tools and techniques for this process are as follows: (Project Management Institute 2013): "… risk reassessment, risk audits, variance and trend analysis, technical performance measurement, reserve analysis and meetings." The outcomes of this process manifest as updates to the risk register and the inclusion of new risk responses for risk treatment (Cooper et al. 2005).

4.4 PREVIOUS RESEARCH ON RISK IDENTIFICATION AND ASSESSMENT IN INFRASTRUCTURE PPPs

4.4.1 Risk Identification and Assessment

Based on a review of literature, Loosemore and Cheung (2015) advocated that all construction projects involve significant risks, however, characteristic long duration, scope and complexity of PPPs add to the overall risk portfolio which include regulatory, political, financial, sponsor, market, interface, technical, operational and industrial relation risks. Both the public and private sectors need to develop an understanding of these life-cycle risks in order to ensure long-term success (Ibrahim et al. 2006).

Akintoye et al. (1998) surveyed the perceptions of clients, contractors and lenders on risks associated with private finance initiative projects in UK and identified design risk, construction cost risk, performance risk, risk of delay and cost overrun risk as the top five most significant risk factors. They further contended that each group of respondents tended to rank those risk factors as significant which were paramount to their business objectives.

A questionnaire survey to determine public and private sector risk perceptions in Nigeria revealed unstable government, inadequate experience in PPP and availability of finance as the three most important risk factors (Ibrahim et al. 2006).

Roumboutsos and Anagnostopoulos (2008) studied risk perceptions among PPP stakeholders in Greece where professionals from construction, public sector and financing institutions rated different mix of risk factors as the most significant among top five. The factors include: delays in project approvals and permits, poor public decision-making process, construction cost overrun, change in tax regulation, operational revenues below expectation, public opposition to the project, operation cost overrun, poor financial market, late design changes, inadequate experience in PPP, change in construction legislation and archeological findings.

Chan et al. (2011) while studying risks in Chinese PPP projects determined government intervention, government corruption, poor public decision-making processes, financing risk and imperfect law and supervision system as the top five critical risks.

Hwang et al. (2013) examined the critical risks factors in PPP projects in Singapore and obtained lack of support from government, availability of finance, construction time delay, inadequate experience in PPP and unstable government as the top five ranked risk factors.

Osei-Kyei and Chan (2017b) studied and compared risk factors in PPP projects between Ghana and Hong Kong and found that country risk factors were ranked higher in Ghana (corruption, inflation rate fluctuation, exchange rate fluctuation, delay in project completion and interest rate fluctuation rated as top five). However, project specific risks were ranked higher in Hong Kong (delay in land acquisition, operational cost overruns, construction cost overruns, delay in project completion and political interference rated as top five).

Thomas et al. (2003) explored the perceptions of key stakeholders towards critical risks in the roads sector under BOT arrangement in India. Traffic revenue risk, delay in land acquisition, demand risk, delay in financial closure, completion risk, cost overrun risk, debt servicing risk and direct political risks were found to be very critical, in descending order.

Wibowo and Mohamed (2010) investigated the perceptions of both regulators and operators with reference to project risk criticality and allocation in Indonesia's water supply projects. The five most critical risks determined by the regulators include: non-availability of raw water, entry of new competitors, construction cost escalation, equipment defect-caused interruption and operation and maintenance cost escalation. While tariff setting uncertainty, breach of contract agreement, non-availability of raw water, construction time overrun and construction cost escalation, were rated as the five most critical risk factors by the operators.

The top five most significant risk factors influencing implementation of PPP water supply infrastructure projects in Ghana were reported as foreign exchange rate, corruption, water theft, non-payment of bills and political interference (Ameyaw and Chan 2015b).

It is apparent from the review of selected studies above that the critical risks vary depending upon country and sector characteristics. Furthermore, there is little research available that compares risks and their significance across infrastructure sectors (Cheung and Chan 2012) with only few works providing insights on some critical risks in power sector PPP projects (Rebeiz 2012; Schaufelberger and Wipadapisut 2003; Wang et al. 2000a; b; Xu et al. 2015). Risk based investigations in different infrastructure sectors is important as previous research has indicated reservations in generalization of findings of research studies to other sectors (Ameyaw and Chan 2015b; Wibowo and Mohamed 2010). Due to a lack of research in the Pakistani context, a dedicated study in the local context can contribute to risk assessment knowledge base with respect to a smaller and developing market (Roumboutsos and Anagnostopoulos 2008). The findings from such an investigation will also further enable international investors to make informed decisions when considering investing at sectoral level (power and transport infrastructure) (Osei-Kyei and Chan 2017b).

4.4.2 Risk Assessment Modeling

The need for an objective, reliable and practical risk assessment model has been stressed in the existing research on PPPs (Jin and Doloi 2008; Li and Zou 2011). Based on a review Tang et al. (2010a) emphasized the need to create comprehensive (incorporate various types of risks), accurate and practical (easier to be used) risk assessment models. In addition to assessing risks individually, it is important to assess the overall risk level of various risk groups and the project. This may enable stakeholders to better assess risks and their impacts, plan and develop mitigation measures and compare projects in-terms of their overall riskiness to either avoid very risky projects or to bring to focus those projects that require more attention (Ameyaw and Chan 2015c; Zayed et al. 2008; Zayed and Chang 2002). Evaluating project risk level may be especially useful for firms considering penetration into foreign PPP markets to promote various projects, where unfamiliarity with the geography, supply chain, local codes and business practices increase uncertainty (Rebeiz 2012).

According to Chinyio and Fergusson (2003), qualitative, semi-quantitative and quantitative methods are employed in risk analysis for PPP projects; however, the use of each method is driven by the availability of information on risk attributes such as probability and severity of different risks. Due to the unique nature of such projects and the fact that the history of such schemes is still young (applies more to countries that have recently adopted PPP schemes to deliver projects), the data required for a quantitative assessment may not be applicable for analysis or is unavailable altogether (Dey and Ogunlana 2004). Another limitation stems from the peculiar nature of many risks in PPP projects that restricts opportunities for adequate mathematical modeling, thus allowing only qualitative analysis of risks such as environmental risks, political and non-political risks, and delay in land acquisition etc. (Iyer and Sagheer 2010). Hence, risk analysis is a subject that is shrouded in vagueness and uncertainty (Carr and Tah 2001). The need for subjective assessment is indispensable for risk assessment of PPP projects (Dey and Ogunlana 2004).

A number of methodologies and models already exist that employ qualitative data (derived from subjective judgements of knowledgeable experts) and utilize tools such as analytical hierarchy process/analytical network process (AHP/ANP), multi-attribute utility theory and concepts from fuzzy set theory (FST) (Ameyaw et al. 2017; Ameyaw and Chan 2015c; Ebrahimnejad et al. 2010; Li and Zou 2011; Li and Wang 2016; Liu et al. 2013; Nieto-Morote and Ruz-Vila 2011; Valipour et al. 2015; Wang and Elhag 2007; Xu et al. 2010b; Zayed and Chang 2002; Zegordi et al. 2012). Existing models either only rank several identified risk factors or provide a composite risk index frequently based on arithmetic mean or weighted arithmetic mean aggregation operator (Table 4.1). The decision maker may not always have an additive measure to evaluate fuzzy objects and the criteria employed to evaluate an object may not always be independent of each other. Hence, assumptions of additivity and independency may not hold true, thus invalidating the applicability of a linear model (Onisawa et al. 1986). In traditional multi-criteria evaluations, criteria are assumed to be independent; however, the condition of criteria independence is usually not applicable in real world problems (Liou and Tzeng 2007).

Table 4.1. PPP risk assessment models

Author(s)	Risk ranking	Infrastructure sector	Sectoral risk assessment (overall risk index)	Project risk assessment (overall risk index)	Analytical method(s) used for risk modeling	Model validation
Ameyaw et al. (2017)	Yes	Water	No	Yes	Fuzzy Synthetic Evaluation (FSE)	No
Ameyaw and Chan (2015a)	Yes	Water	Yes	No	FSE	No
Ebrahimnejad et al. 2010	Yes	Power	No	No	Fuzzy Technique for Order Preference by Similarity to Ideal Solution (FTOPSIS) & Fuzzy Linear Programming Technique for Multidimensional Analysis of Preference (FLINMAP)	No
Li and Zou (2011)	Yes	Transport	No	No	Fuzzy Analytical Hierarchy Process (FAHP) / Analytical Hierarchy Process (AHP)	No
Li and Wang (2016)	Yes	-	No	No	FAHP	No
Liu et al. (2013)	Yes	-	No	Yes	FSE, AHP, Analytical Network Process (ANP)	No
Nieto-Morote and Ruz-Vila (2011)	Yes	-	No	No	FAHP	No
Valipour et al. (2015)	Yes	Transport	No	No	Fuzzy Analytical Network Process (FANP)	Yes
Wang and Elhag (2007)	No	Transport	No	Yes	Fuzzy weighted average	No
Xu et al. (2010b)	Yes	Transport	Yes	Yes	FSE	No
Zayed and Chang (2002)	No	-	No	Yes	Weighted average	Yes
Zayed et al. (2008)	Yes	Transport	No	Yes	FAHP	Yes
Zegordi et al. (2012)	Yes	Power	No	No	FANP and FTOPSIS	No

In this research, non-additive fuzzy integral based on λ-fuzzy measure has been employed for development of a multi-attribute project risk assessment model, as it has the ability to cater for certain kind of criteria (risks) interaction ranging from redundancy to synergy (Grabisch 1996). The proposed model was employed and demonstrated to obtain sectoral and project level risk assessments and was also validated using data from actual projects. Necessary background on the analytical method is provided in Chapter 2, whereas the demonstration and validation of the model is covered in detail in Chapter 8.

4.5 PREVIOUS RESEARCH ON RISK ALLOCATION IN INFRASTRUCTURE PPPs

4.5.1 Risk Allocation and Sharing in Infrastructure PPPs

Risk allocation refers to deciding who among the contracting agents will shoulder the financial gain or loss of a change in value from its estimated baseline (APMG International 2016b). In a PPP contract (vis-à-vis, conventional contracts), except the risks explicitly retained by the public sector, all other project risks rest with the private sector (Federal Highway Administration 2013). Therefore, PPP projects require an adequate and clear allocation of complex risks. Appropriate risk allocation (*transfer* to private partner or *retention* by public partner) and *sharing* was identified as one of the most important critical success factor for PPP project implementation (Osei-Kyei and Chan 2015). It directly influences the ability of, and prospects for, primary stakeholders (grantor, sponsor/investors and the lenders) to achieve their expectations with reference to their individual perspectives on risks (Darvish et al. 2006; European PPP Expertise Centre 2012; Grimsey and Lewis 2002; Oranization for Economic Co-operation and Development 2008; Pantelias and Zhang 2010; Yescombe 2007). A fundamental principle governing risk allocation is to apportion risk to the party that has the best ability to manage it. Where none of the parties have a superior ability or comparative advantage in managing a risk, it should be shared (ADB 2000; Irwin 2007). Although this mentioned principle seems appropriate, its exact application is difficult due to its vagueness. Moreover, Ng and Loosemore (2007) argued that multiple factors can influence the distribution of risks, including debt providers' requirements, bargaining power, commercial requirements, economics and company culture and policies. Medda (2007) asserted that risk allocation between public and private sector stakeholders in infrastructure projects is an uncertain task with high complexity associated with risk identification and their correct allocation. According to Corner (2005), one of the main benefit of transferring risk from the public sector is that it should provide incentives to private sector to render cost effective and higher quality services on time. Appropriate application of risk allocation principles determines if a project will be bankable and whether it will remain viable throughout the long-term contract (GI Hub 2016).

For PPP projects, inappropriate retention or transfer of risks by the public sector is sub-optimal (Arndt 1999). Appropriate risk allocation is critical because it: reduces economic costs; promotes sound management driven by incentives; reduces the need for renegotiations (Asenova 2010); lowers overall project cost; and provides value for money (VfM) (Oranization for Economic Co-operation and Development 2008). Poor risk allocation may: reduce participating bidders while fueling the opportunism of remaining tenderers (Zitron 2006); produce high risk premiums; increase the probability of risks occurring and severity if they do eventuate; introduce inefficiencies from unclear responsibility for monitoring and managing the risks; and potentially result in conflict and disputes (Ng and Loosemore 2007). If the risks remain improperly with the public sector, the government may have to increase taxes or reduce services to meet its contractual obligations (Department of Finance and Administration 2005). Despite its importance, multiple studies have indicated inadequate risk allocation practices on PPP projects (Arndt 2000; HM Treasury 2012; Marques and Berg 2011; Zou et al. 2008).

4.5.2 Risk Allocation Criteria and Risk Management Capability

Abrahamson (1973) developed five principles that should be considered while allocating risks in construction projects. The principles reflect on a party's ability in terms of: risk control; risk mitigation; incentive/threat of benefiting/losing from risk; and prospects of achieving efficiency from allocation (interpreted as resulting in low risk premium) (NPWC/NBCC Joint working Party 1990). Arndt (2000) while elaborating on risk allocation framework for private provision of infrastructure maintained that risks should be allocated to the party with the greater ability to influence its occurrence probability or degree of its consequence, have best access to suitable risk mitigation methods and is not significantly risk averse so as to charge a disproportionate risk premium. According to European Commission (2003) and Oranization for Economic Co-operation and Development (2008), risk should be borne by the party that can best influence and control the risk outcome, and that party should be able to bear the risk at the lowest cost. Loosemore et al. (2006) recommends five principles that indicate a higher ability of an entity to manage risks. The principles state that the risk taking parties: have been made aware of the risks being transferred to them; have the required capacity i.e., expertise and authority to avoid, minimize, monitor and control the risk; possess required resources to cope with the risks eventuating; have the necessary risk attitude to want to take the risk; and that they should be able to charge an appropriate premium for assuming the risk. Lam et al. (2007) proposed more comprehensive criteria for risk allocation while accommodating some of the attributes mentioned by other researchers. These include various aspects including the ability of a party to: foresee the risk; evaluate the likely magnitude of its consequences; control the chance of risk occurring; manage the risk in the event it materializes and sustain the consequences of materialized risk. Other aspects include a need to assess the party's potential of benefitting from assuming the risk and the owner accepting the risk premium being charged for transferring the risk. For PPP projects, perhaps one of the most insightful account of the principle of risk allocation based on the ability paradigm was provided by Irwin (2007). In order to maximize the total project value, a risk should be allocated along with the right to make necessary decisions to the party in consideration of its ability to: influence the risk factor; influence the sensitivity of total project value to the risk factor (anticipate and respond to risk); and/or absorb the risk (depending upon available opportunities for: diversification; absorbing the risk at low cost; spreading risk; and influence of risk attitude/preference). An individual party may not be best suited to managing a particular risk when considering the three aspects at once hence, potentially requiring tradeoffs to enhance the total project value. The risk management manual for PPP infrastructure projects by GoPb (2011) specifies that the party best able to manage controllable risks should normally be allocated the risk, otherwise it should be allocated to the party best able to insure uncontrollable risks. Uninsurable risks should rest with the party best able to bear their financial consequences. Xu et al. (2010a) identified nine critical criteria for risk allocation for PPP projects in China while Ameyaw and Chan (2016a) utilized the same criteria to study risk allocation on PPP water supply projects in Ghana. Efforts made to break down the ability maxim in order to achieve efficient risk allocation, as described above, have resulted in development of criteria that can be used to assess a party's RMC. These criteria suggest common aspects with little difference. Keeping in view the comprehensiveness of the RAC established in Xu et al. (2010a) and Ameyaw and Chan (2016a), this thesis adopts the same criteria (Table 4.2) for development of a risk allocation model (RAM) to evaluate adequacy of risk alloc-

Table 4.2. Risk allocation criteria for assessment of risk management capability

ID	RAC	Description
C1	Be able to foresee (predict) the chance/probability of risk occurrence and assess potential risk consequence/severity	It is critical that the parties possess sufficient experience and skills to identify risks and evaluate the probability and severity of risks materializing in a project's life-cycle, without substantially underestimating or overestimating risk outcomes. Posner and Rosenfield (1977) defined a superior risk bearer as the party that would charge the lowest risk premium, which among other factors, is likely to be achieved when a party has greater access to information about the risk in order to determine its probability and consequence.
C2	Be able to avoid, minimize, monitor and control the chance/probability of risk occurrence	This encapsulates the ability to avoid or minimize the chances of risk occurrence during a project's various lifecycle phases. For example, use of reliable equipment in a power plant to reduce the incidence of maintenance or incipient breakdown. Similarly, the contracting authority may be more suitable to acquire land specially where it has to use its legislative authority to secure the site (GI Hub 2016).
C3	Be able to minimize or control the loss if the risk occurs	This involves the party's ability to influence the consequence/severity of risk upon project objectives by executing suitable mitigation/response measures. A construction company is more aware of site conditions and work progress and can therefore influence the construction cost risk. It is responsible for construction means and methods and for managing the process diligently (Irwin 2007). Superior knowledge of a project's technical characteristics and/or structure and financing arrangements also position a party to better manage the consequences of a risk materializing (VDTF 2001).
C4	Be able to sustain, diversify or absorb the consequences of the risk that materializes	A party may be better able to diversify a risk depending upon the extent to which the risk factor is correlated with value of its other assets and liabilities (El-Amm 2003; Irwin 2007). Diversified project portfolios, if available, can help by allowing a party to take benefit of accumulated premiums from unmaterialized project risks to fulfil liabilities accumulated on another project in the portfolio, where any risk(s) has/have materialized (VDTF 2001). Risk consequences can also be sustained and absorbed via passing risks to others, by insuring or buying derivatives and spreading the risks, for instance, over taxpayers or shareholders (Irwin 2007).
C5	Be able to bear the risk at the lowest cost	Different stakeholders may have different opportunities/methods to manage and mitigate a specific risk, hence a different cost to that end. A party may be able to manage a risk at relatively low cost either by controlling risks (probability/severity) or sustaining/diversifying/ absorbing the risks.
C6	Be able to assume and manage the direct loss in case of risk occurrence	Ensuring continuity of the project and service delivery in the event of materialization of risk(s) is important (Arndt 2000). In order to select an appropriate project concessionaire, Zhang et al. (2002) contended that tenderers must have strong financial backing and capability to bear potential significant variation of construction and operation costs and revenues over the concession period.
C7	Be able to get reasonable and acceptable premium for assuming the risk	Risk premium is the amount of compensation made to an investor for assuming a particular risk associated with an investment proposal (VDTF 2001). Ideally, it would be equal to the expected value of a risk however, the risk preference of a party can significantly influence it (Arndt 2000). Additionally, the premium demanded needs to be reasonable so as to demonstrate VfM and hence justify risk transfer (VDTF 2001).
C8	Benefit from enhanced risk undertaker's credibility, reputation and efficiency in risk management	This criterion points out to incentives that a party may have to take on risks. A bidder keen on developing presence or expertise in a particular industry (infrastructure) sector may act by reducing its desired risk-adjusted return on projects, over a short term, to achieve its strategic aims (VDTF 2001). Also, the private sector considers the project as a whole and may be willing to take higher risks in certain areas for lesser risks in others. Alternatively, governments in developing countries may be more inclined to accept certain risks initially, to attract private investment and to create and grow the PPP market (Arndt 2000).
C9	The risk-taking party prefers to assume the risk (Risk attitude)	Risk attitude refers to personal and organizational preferences towards assuming/rejecting risks. For a party to be suitable to take on certain risks, it should not be significantly risk averse otherwise it might demand disproportionate risk premium (Arndt 2000).

ation in infrastructure projects in the power and transport infrastructure sectors in Pakistan. The RAC adopted for this research are explained in sufficient detail in Table 4.2.

All the above mentioned criteria apply to both the public and private sector stakeholders except risk premium criterion as it attempts to determine the reasonableness of the premium paid for transferring risks from the public to private sector (Lam et al. 2007; Loosemore et al. 2006). The RAC require qualitative judgement and experience based knowledge of experts to operationalize, as for example, the assessment of ability to control risk occurrence or obtain any benefit from managing a risk is hard to perform objectively, thus requiring the use of natural language expressions and the application of fuzzy set theory (FST) (Lam et al. 2007). Further, the RAC exhibit interactive effects due to the existence of potential tradeoffs. For instance, it is logical that a party well placed to influence a risk might not be well suited to manage or absorb it. A high overall evaluation of RMC should result only if a party is better suited to manage a risk on all the requisite criteria, adequately. This situation cannot be modelled with additive measures where a poor performance/score on one criterion can be compensated or masked by a good score on another criterion, thus potentially resulting in a non-representative overall evaluation. With the use of fuzzy measures, it is possible to take in to consideration the decision makers' preferences more holistically. These criteria can be employed in assessing and establishing the RMC of a party for individual risks so as to assist in risk allocation and sharing decision making.

4.5.3 Existing Models and Frameworks for Risk Allocation and Sharing

Preferred risk allocation matrices are available with different governments which may be generic or specific to sectors or types of project; however, these sources serve only to assist (serve as a starting point) the risk allocation process since project characteristics may dictate a different allocation of risks that would provide enhanced VfM (World Bank et al. 2014). Moreover, Quiggin (2005) argued that standard form of PPP contracts rarely provide prospects of optimum risk allocation in projects. Hence, a methodology that can help public and private sector experts to evaluate risks for allocation or sharing on individual project basis would be extremely useful. Contextual factors require consideration as it is widely acknowledged that risks and their management are influenced by market, infrastructure sector and project contexts (see Chapter 1).

Using risk allocation literature, Ameyaw and Chan (2016a) classified existing risk allocation models/frameworks in two categories. The first category attempts to understand preferred risk allocation via the dominating or majority opinions and preferences of decision makers or their risk perceptions and attitudes. It was argued that effective risk allocation may not be obtained by the use of majority preferences and opinions. Differences in perceptions regarding risk criticality and RMC of parties make the risk allocation decision difficult and may render majority preferences and opinions ineffective. The second category encompasses decision support or expert systems and utilizes a more critical approach. Specifically, it adopts theoretical frameworks (based on stakeholders' capability or transaction cost economics and the resource-based view of organizational capabilities) and various modelling approaches (game theory, artificial neural networks, fuzzy logic, multiple linear regression and fuzzy synthetic evaluation [FSE]). The review illustrated various limitations of the available approaches and models which lead the authors to present a FSE based risk allocation model for water infrastructure PPP projects. Some important risk allocation research not covered in the previous review includes models developed for: allocating risk in construction contracts using fuzzy TOPSIS approach (Khazaeni et al. 2012); risk allocation in Malaysian PPP projects using multi-objective optimization method (Alireza et al. 2014); identification of shared risks in PPP projects via application of hybrid fuzzy cybernetic analytic network process model (Valipour et al. 2016); and PPP risk allocation evaluation based on alternating offer bargaining game model (Li et al. 2017). In all the decision support or expert systems, except the game theory based research which models the bargaining process, the models predict optimum risk allocation strategy based on assessment of parties' suitability to carry risk (determined based on the RMC paradigm or other theoretical frameworks). This is achieved while employing different analytical approaches. In comparison to FSE and TOPSIS, most of the analytical approaches (including artificial neural networks, multiple linear regression, fuzzy logic and analytical network process) may require relatively more information input, either to implement and/or to effectively and adequately model the underlying decision problem. Both FSE and TOPSIS based risk allocation MADM models, though easier to implement, rely on aggregation operators based on additive measures which assume the RAC to be independent.

Whilst existing models/frameworks have contributed significantly towards superior understanding, approximation and prediction of risks allocation and sharing in PPPs, there remains a need to further advance and develop a decision support model that better conforms to decision makers' or experts' preferences. This is to assist the key stakeholders to achieve a workable and appropriate solution at the project development stage. Contextual factors also require consideration as it is widely acknowledged that risks and their management are influenced by country, infrastructure sector and project contexts. Hence, a methodology that can help public and private sector experts to evaluate risks for allocation or sharing on an individual project basis would be extremely useful. Arndt (1999) argued that the real world is more complicated than what can be modelled by any theoretical framework. Variations in description and meaning of risks as understood by each party, interpretational issues regarding terms for risk sharing mechanisms, difference in views of parties regarding their ability to control and manage risks and depth and maturity of the market for private infrastructure, may all influence risk management. Any decision support models need to be capable of adequately representing public and private sectors' preferences with regards to risks on individual projects. This will enable the model's output to accurately reflect stakeholders' distinctive perceptions, understanding and concerns, with respect to their capability and allocation and sharing of each risk on the concerned project. Existing models frequently employ methodologies where, to some extent, experts' inputs for model development and/or application are treated independent of their sector affiliations, thus there is a need to explicitly and adequately recognized this constraint in further research.

The risk allocation decision process can be likened to a MADM problem where a utility function can be employed to aggregate the RMC ratings for risks across identified RAC to obtain a final risk management capability index (RMCI) rating. This process can assist in evaluating multiple risks and identify which party possesses sufficient overall RMC thus informing the risk allocation decisions on projects. This process is subjective and implicit and requires qualitative judgement and experiential knowledge of experts (Ameyaw and Chan 2016a; Lam et al. 2007). Additionally, the criteria employed in such problems may interact, which may be due to correlations, substitutiveness/complementarity or preferential dependence (Marichal 2000a). Arithmetic mean and simple additive weighting are commonly employed aggregation procedures; however, these procedures are unable to account for criteria interactions (Rowley et al. 2015). Ignoring these potential interactions may lead to contestable results (Feng et al. 2010; Grabisch 1996; Yu et al. 2015). As elaborated previously, fuzzy integral based on a non-additive measure, such as the Choquet integral (Choquet 1953) can be applied as an aggregation operator for situations where the criteria interact. This consideration allows better approximation of decision makers' preferences by providing a mechanism to control the level of contribution of each criterion in aggregated evaluations based on the nature of specified underlying interactions among criteria. Given the subjective, multi-attribute and context specific nature of the risk allocation and sharing problem, the objective of the research reported in this paper is to propose and validate a methodology to assist experts in risk allocation decision making for PPP infrastructure projects. MV approach (see Chapter 2) was employed to obtain the requisite fuzzy measures for fuzzy integral based RMCI analysis. This research considers and investigates allocation and sharing of risks between public and private sectors only (rather than looking at the function from the entire supply chain perspective where risks will be allocated at multiple interfaces (Ng and Loosemore 2007; Zhang 2005a), which is consistent with the popular focus and existing practice in academic and institutional literature (Bing et al. 2005; Chan et al. 2011; GI Hub 2016; GoPb 2011; VDTF 2001). The demonstration and validation of the proposed model has been covered in detail in Chapter 9.

4.6 CHAPTER SUMMARY

This chapter established the risk management process adopted in this research and the significance of each of the component processes with special emphasis on risk analysis and risk allocation. The risk management process will be referred to in the upcoming chapters, in which the other objectives of the research are discussed with reference to it or its component processes.

The review of risk identification and assessment research reveals that critical risks have spatial and sectoral associations, implying that the critical risks vary across different countries or regions and across infrastructure sectors and that, so far, only a few studies have investigated the power sector domain. Furthermore, there is a lack of research that compares critical risks across different infrastructure sectors.

Based on the literature, risk allocation on PPP projects is a complex task and that its failure can lead to persistent issues for all stakeholders of the projects. Furthermore, the necessary and relevant RAC are identified and established for both the public and private sector stakeholders. These shall be employed later (in Chapter 9) to establish the risk allocation model.

It also became evident that research in the existing literature that models the project risk analysis and allocation process as MCDM/MADM problems rarely addressed the issue of criteria interaction, which leaves out the opportunity to find solutions to address the issue in hopes of better modeling the subject issues (risk analysis and allocation).

Efforts have been made in the subsequent chapters to address the highlighted knowledge gaps in this chapter.

CHAPTER 5 MEASURES OF EFFECTIVE RISK MANAGEMENT FOR INFRASTRUCTURE PPPs[6]

5.1 INTRODUCTION

This chapter begins with a summary of the status of risk management performance and outcomes in the construction industry within the context of international PPP infrastructure projects. A brief discussion of the projects that faced unfortunate outcomes is presented, along with a review of the literature, which attempts to diagnose the broad underlying reasons leading to such outcomes. Thereafter, the chapter moves on to focus on the literature, which establishes the possible venues to tackle the existing situation and improve the risk management outcomes on the PPP projects. The research reported in this chapter is based on a thorough literature review in the domain of risk management in general and the construction industry and infrastructure PPPs in particular. This review was conducted to identify the potential measures of ERM and propose a conceptual framework that explicitly specifies these measures in relation to the risk management process framework (see Chapter 4) and the PPP project life-cycle phases, as set out by the Project Management Institute (2013) and the European PPP Expertise Centre (2012), respectively. Relevant measures extracted from the review were discussed with experts in the field and integrated into a questionnaire for a much wider subsequent experts' survey and data collection.

Parts of this chapter have been included in:

[6] Mazher, K.M., Chan, A.P.C., Ameyaw, E.E., Zahoor, H., Choudhry, R.M., & Edwards, D.J. (under review). "Measures of effective risk management for infrastructure public-private partnership projects." *Engineering, Construction and Architectural Management*.

5.2 STATUS OF RISK MANAGEMENT IN INFRASTRUCTURE PPPs

As mentioned previously, traditional risk management faces greater challenges due to the longer contract period associated with long-term PPP projects vis-à-vis short-term contract period of traditional projects (Xiong et al. 2017). Under such circumstance, it becomes impossible or too expensive to comprehensively plan for potential risks over the long-term project. Transportation PPP projects, internationally, have occasionally met an ill fate where the projects suffered varied outcomes including: contract suspension (temporary); concession cancellation; nationalization; project halted; tender cancellation or loss of value for money (Soomro and Zhang 2011). These modes of failures may be just as applicable to other infrastructure sectors. Multiple other sources have reported problems in delivering PPP projects. The World Bank (Asian Business 1996) and Reijniers (1994) (cited in Zou et al. 2008) conducted investigation to uncover reasons as to why many partnered projects were held up and found poor risk sharing and management as a contributory factor. Tam (1999) reported failure in proper management of risks by the stakeholders as an important factor responsible for problems and failure of the Bangkok Elevated Transport System, the Bangkok Second Expressway System and the Bangkok Don Muang toll way. Lack of comprehensive risk assessment and management was argued to be an influential factor in driving the failure of several mentioned PPP projects including (Li et al. 2007; Li and Zou 2011; Zhang 2005a): Malaysian Privatized National Sewerage project, Parkeerschap Den Bosch, the Betuwe Railway in Netherlands, Sydney Airport Link, the Sydney Cross City Tunnel, the 9th Shen Yang Water Plant, the 4th Min Jiang River Bridge in Fuzhou City and Hou Shi power plant in Zhang Zhou City. Also, ineffective risk management has led to failures of multiple PPP projects in China (Yuan et al. 2008b). According to Wibowo and Mohamed (2010), water PPPs suffer due to lack of identification of risks and vague risk sharing or allocation. Lee and Schaufelberger (2013) analyzed five BOT projects and concluded that a project may not be successful because of the fault of the concessionaire in terms of its inability to understand risks and/or to adopt risk mitigation strategies. Dey and Ogunlana (2004) contended that, in some cases, insufficient risk management leads to failures in BOT projects. The resource book on PPP case studies, published by the European Commission Directorate General Regional Policy (European Commission 2004a), asserted that "poor demand or cost forecasting" was a critical factor leading to many unsuccessful transport projects; thus, it was stressed that both the parties conduct rigorous project analysis. Loosemore and Cheung (2015) criticized the current approaches to risk management practice and discussed multiple failed PPP cases, while attributing the causation of many of the failures to *"... surprisingly unsophisticated, linear and reductionist way in which risks were identified, assessed and managed."*

Table 5.1 covers some actual cases of distressed/failed (for more on definition of project failure, readers are referred to Soomro and Zhang 2011) projects delivered using various models of the PPP across various sectors and countries, with a brief mention of the causes leading to problems in these projects. It is evident that the problems reported have an essence of risk; thus, appropriate arrangements to adequately manage risks can potentially bear dividends for stakeholders. It should be borne in mind that risk management may not be a solution to all the problems because unprecedented/extremely uncertain events may have the potential to render even the most detailed plans ineffective. In such circumstances, capping the losses for the parties involved, renegotiations and resorting to default and termination may be the only feasible venues to evict greater losses. However, it is clear that a pro-active approach to management of risks in these projects (cases mentioned above and those cited in the table below) may have resulted in a different situation altogether.

Table 5.1. List of distressed/failed PPP projects (adopted and modified from Soomro and Zhang 2015a)

ID	Project name	Type	Concession period (years)	Problems faced	Source
1	Sydney Cross City Tunnel, Sydney, Australia	BOOT	30	▪ Expensive toll charges ▪ Low usage of the tunnel ▪ Public opposition at changing the existing road configurations to direct traffic to the tunnel ▪ Poor Governance by the private sector	Zou et al. (2008)
2	Sydney Airport Railway Link, Sydney, Australia	BOOT	30	▪ Scope variations lead to increase in cost ▪ Excessive ticket price ▪ Low usage ▪ Poor governance by the private sector (ticketing problems, poor marketing) ▪ Poor feasibility and design (overcrowded carriages at peak time, lack of luggage space, issues with passenger's comfortability) ▪ Inefficient risk allocation	Zou et al. (2008)
3	Fu-De Highway Project, Hengshui city, He Bei Province, China	BOOT		▪ Local government officials' corruption ▪ Excessive cost of relationship management ▪ Extension of concession period ▪ Poor project economic evaluation compromising public interests	Zou et al. (2008)
4-41	Blegrade Novisad Motorway, Czech Republic D47 Motorway, Czech Republic Horgos-Pozega Highway, Serbia M9 Motorway, Pakistan Mexican toll road program, Mexico Mumbasa container terminal, Kenya Trakia Motorway Project, Bulgaria Transgabonais, Gabon Jakarta Outer Ring Road, Indonesia	-	-	▪ Selection of an unsuitable concessionaire ▪ Concessionaire's insolvency ▪ Financial problems with the concessionaire at early stages of project ▪ High-interest debt ▪ Improper due diligence by the lenders ▪ Lack of coordination with parallel projects ▪ Lack of financing capacity of the lenders ▪ Loss of customer trust ▪ Ineffective commercial/business strategies	Soomro and Zhang (2015a)

ID	Project name	Type	Concession period (years)	Problems faced	Source
	BERTS, Thailand D5 Motorway, Czech Republic M3/M30 toll road, Hungary M7 toll road, Hungary M9 Danube toll bridge, Szekszárd, Hungary Pitesti-Bucharest-Lehliu (140 km), First Phase, Romania Argentina toll road program (first generation), Argentina Beiras Litoral/Alta Shadow Toll Road, Portugal 91 Express Lanes, California, United States of America Camino Colombia toll road, United States of America London Underground — Metronet, United Kingdom London Underground — Tubelines, United Kingdom M1/M15 toll road, Hungary Railtrack, United Kingdom Siza Rail, Democratic Republic of Congo Skye Bridge, Scotland, United Kingdom Tha Ngone Bridge project, Laos Zagreb-Gorican Motorway, Croatia Channel Tunnel, England, United Kingdom Channel Tunnel Rail Line (CTRL), United Kingdom Confederation Bridge, Prince Edward Island and New Brunswick, Canada			▪ Poor governance by concessionaire ▪ Poor quality of work by concessionaire ▪ Cost overruns ▪ Demand of higher subsidies/guarantees by the concessionaire ▪ Improper demand forecasting ▪ Inaccurate cost estimation ▪ Legal proceedings due to conflicts between partners ▪ Less revenue generation ▪ Low traffic demand ▪ Project's inability of market competition ▪ Slow and hindered project construction progress	

ID	Project name	Type	Concession period (years)	Problems faced	Source
	Highway 407, Ontario, Canada Railfreight Distribution, England, United Kingdom Rolling Stock Leasing Companies (ROSCO), United Kingdom Royal Dockyards (at Davenport and Rosyth), United Kingdom Wijker Tunnel, Randstad, Netherlands				
42	Dabhol LNG-Fired Power Plant, Maharashtra, India	PPA (BOT)	20	▪ Lost the support of newly formed state Government ▪ Contract dispute between the Government and the plant owners ▪ Project company accused of fraud, misrepresentation, violation of human rights, malfeasance and corruption ▪ Lack of transparency and competition in the bid process ▪ Project lacked financial viability according to the World Bank ▪ High project cost and expensive tariff	Tiwari and Ashish (2013)
43	Kaman Paygon BOT Project	ROT	15	▪ Breach of contract agreement turned to dispute between the government and concessionaire ▪ Loss of political support	Tiwari and Ashish (2013)
44	Pune water Supply & Sewerage Project	Construction and management contract	25 years	▪ Loss of political support from local and state Government ▪ Lack of transparency in bidding process ▪ Uncertainty in viability of the scheme	Tiwari and Ashish (2013) and Zerah and Graham-Harrison (2000)
45	Pagbilao power plant, Philippines	BOT	25 Years	▪ Environmentalists and local residents' strong opposition	Lee and Schaufelberger (2013)
46	Cochabamba Water System , Cochabamba, Bolivia	-	40 Year	▪ High tariff (affordability concerns) ▪ Public dissatisfaction	Cuttaree (2008)
47	INDAH Water Konsortium, Malaysia			▪ Lack of transparency ▪ Poor financial structure ▪ High tariffs ▪ Public outrage/opposition	Abdul-Aziz (2001)

ID	Project name	Type	Concession period (years)	Problems faced	Source
				▪ Poor governance/performance by the private sector ▪ Non-payments of consumers	

5.3 EFFECTIVE RISK MANAGEMENT IN INFRASTRUCTURE PPPs

Project success is a multidimensional concept that has captivated researchers for decades in an attempt to give a meaning to it, to enable evaluation of a project's performance. According to Baccarini (1999) two distinct components define project success: (1) project management success which focuses on project process with the significant aim of satisfying the cost, time and quality objectives, and the way project management process is executed; and (2) product success, which deals with the final outcome of the project's product - its quality and effects. Meeting stakeholders' needs and expectations is one of the indicators of project success (Project Management Institute 2013). Baccarini (1999) contended that it is necessary to meet both project success components, product and project management success, to satisfy the stakeholders. Critical success factors (CSFs), defined as the few critical aspects that dictate managerial success (Rockart 1981), have been identified for PPPs. However, Liu et al. (2015b) argued that most studies exploring the CSFs for PPP projects in the extant literature have focused on product success; therefore, the authors adopted a life-cycle view to explore the CSFs for PPPs from a project management success perspective. It can be argued that even though the literature provides an insight on factors that influence the success of product and project management, the view is still very broad, and it may be necessary to apply a more focused approach. This is indeed important because inadequate/ineffective application of project management process(es) (where risk management is among them) does in-fact lead to project failure. Existing literature specifies a systematic approach to implement risk management and prescribes a range of guidelines, standard processes, tools and techniques to be adopted (Akintoye et al. 2003a; Chapman and Ward 2003; Cooper et al. 2005; GoPb 2011; Loosemore et al. 2006; Project Management Institute 2009, 2013; VDTF 2001; Virginia Public-Private Partnerships 2015). Yet despite these individual knowledge resources, PPP projects have occasionally suffered failure due to poor risk management. Inefficiencies leading to such outcomes can generally be traced back to individual risk management process components and may be generated as a result of: inadequate specification of risk within the contract; lack of identification of risks (Arndt 2000; Zou et al. 2008); poor assessment and allocation of risks (Arndt 2000; European Commission 2004b; HM Treasury 2012; Loosemore and Cheung 2015; Marques and Berg 2011; Thomas et al. 2003; Zou et al. 2008); re-allocation upon default of a party to shoulder a risk; lack of contractually allocated risk enforcement in the event of crystallization of a risk; and high transaction costs in determining the allocation of risks following a risk event (Arndt 2000). Hence, a failure of risk management in PPPs, as reported in several works (previous section), is in the essence a record of ineffective application of the component risk management processes.

Effective risk management is a significant driver of PPP project success (Osei-Kyei and Chan 2017a; Thomas et al. 2006). Chapman and Ward (2003) contended that ERM involves "*... doing the right things with respect to the risk management process (RMP) so that the project is risk efficient in the corporate sense and all other project objectives are achieved.*" Here, as per guidelines of the Project Management Institute (2009, 2013), RMP refers to the component processes of: risk management planning; risk identification; risk analysis; risk response planning; and risk control (See Chapter 4).

5.4 FOCUS OF PREVAILING RISK MANAGEMENT RESEARCH

Prevailing literature reveals that PPP risk management has attracted substantial academic attention, wherein most research conducted focuses upon singular aspects of the generic risk management process including: risk identification and/or analysis (Akintoye et al. 1998; Chan et al. 2011; Ehrlich and Tiong 2012; Iyer and Sagheer 2010; Kokkaew and Chiara 2010; Lam and Tam 1998; Shen and Wu 2005; Thomas et al. 2006; Xenidis and Angelides 2005a); and response planning including risk allocation and mitigation (Ameyaw and Chan 2015a; Bing et al. 2005; Brandao and Saraiva 2008; Carbonara et al. 2014; Iyer and Sagheer 2011; Jin and Doloi 2008; Jin and Zhang 2011; Marques and Berg 2011; Pellegrino et al. 2011; Shan et al. 2010). A significant focus has been on the identification of risks, mitigation strategies and development of models to estimate/prioritize risks and for assessment of response strategies to select the most efficient response. Fischer et al. (2010) argued that in addition to the technical aspects of risk management in PPPs, managerial aspects of risk management also require greater consideration. Several sources in the extant literature have highlighted factors that may be interpreted to influence ERM, which have been covered either individually (Ke et al. 2012; Loosemore and Cheung 2015; Marques and Berg 2010) or variously investigated as: CSFs (Chileshe and Kikwasi 2014; Project Management Institute 2009); barriers (Chileshe and Kikwasi 2013; Choudhry and Iqbal 2012); difficulties/impediments (Chinyio and Fergusson 2003; Lee and Schaufelberger 2013); factors to assess organizational risk management maturity (Wibowo and Taufik 2017; Zhao et al. 2013; Zou et al. 2009); failure mechanisms (Soomro and Zhang 2015a; b); and uncertainty factors (Jin and Zuo 2011). Table 5.2 shows exactly how the existing literature variously attends to the concept of ERM.

It can be seen that none of these sources have explicitly addressed the issue of ERM holistically in the context of PPPs, i.e., the existing literature does not provide a comprehensive (if not exhaustive) list of factors that, if not adequately enabled and/or implemented, can negatively influence risk management outcomes on PPP projects and thus inhibit ERM. Given the lack of

Table 5.2. Selected literature on risk management focusing on risk management process(es) and practice

Author(s)	Research purpose and limitations	Focus	Specific to PPPs	Quantitative / Qualitative analysis
Choudhry and Iqbal (2012), Chileshe and Kikwasi (2013)	The studies identified and ranked multiple barriers to ERM and implementation of risk assessment and management practices in the construction industry, respectively. However, such issues were identified without a specific focus on projects delivered via PPPs.	RMPr	No	Quantitative
Chileshe and Kikwasi (2014)	The research identified CSFs for deployment of risk assessment and management practices from the perspective of a developing country. However, an emphasis on PPP projects is missing.	RMPr	No	Quantitative
Project Management Institute (2009)	The practice standard for project risk management by project management institute (PMI) enlists CSFs for project risk management and each of its component processes, however, it is not specific to construction industry/PPP projects.	RMP, RMPr	No	-
Chinyio and Fergusson (2003)	The authors explored various difficulties in risk analysis and management in PFI projects in UK by interviewing industry experts. Some solutions were also presented. This study, however, did not attempt to determine the significance and relative importance of the identified measures to address the issues.	RMPr	Yes	Qualitative
Ke et al. (2012)	While investigating the poor record of risk management on PPP projects in China, an absence of risk management culture was identified as a significant underlying factor. Some recommendations were made to alleviate the gap between risk management theory and risk management practice in PPP projects in China. However, the recommendations only focus on aspects of organizational risk management maturity.	RMPr	Yes	Qualitative
Soomro and Zhang (2015a, b)	Failure drivers and mechanisms in transportation PPPs, initiated by public and private sectors, were explored, which ultimately lead to loss to one or all the project stakeholders. Although, some of the identified failure drivers have characteristics of risks, thus suggesting a risk management problem, the studies on the whole do not attempt to investigate project risk management per se.	-	Yes	Qualitative
Loosemore and Cheung (2015)	The authors criticized the traditional reductionist and linear risk management approaches on projects and discussed multiple failed PPP cases. The study advocated systems thinking approach to make risk management more effective for PPP projects and discussed the barriers to its adoption.	RMP, RMPr	Yes	Qualitative
Zou et al. (2009), Zhao et al. (2013), Wibowo and Taufik (2017)	The studies present organizational risk management maturity models with the aim of enabling assessment of enterprise risk management capabilities and to provide an indication to enhance efforts in areas (risk policies/processes/culture/etc.) that warrant potential for improvement. These models	RMPr	Wibowo and Taufik (2017)	Quantitative

Author(s)	Research purpose and limitations	Focus	Specific to PPPs	Quantitative / Qualitative analysis
	focus only on organizational risk management characteristics and needs and identify several attributes/best practices that determine effectiveness of risk management at enterprise level.			
Jin et al. (2011)	The study identifies critical uncertainty factors that influence efficient risk allocation on PPP projects in terms of their relationship with specific characteristics of risk management service transaction and are grouped in to institutional, social and industrial, economic, and project-specific categories. However, these factors were studied with a specific focus of their influence on risk allocation only.	RMP (Risk response planning), RMPr	Yes	Quantitative
Marques and Berg (2010)	The authors analyzed the strengths and weaknesses of regulation by contracts (in PPPs) and argued that failure in any domain including access to the market, risk sharing approach, and monitoring of contract can jeopardize prospects of meeting citizen's expectations. The authors extend several recommendations while emphasizing efforts in preparing high quality PPP public tenders, transparent award criteria, efficient risk allocation, and adequate performance monitoring.	RMPr	Yes	Qualitative
Lee and Schaufelberger (2013)	The study identified main causes and consequences of risk mitigation failure in five case study projects and suggested individual risk mitigation measures in conclusion. In addition, it was emphasized that ERM was not possible without the active involvement and support of the host government. Collaborative working relationship between the partners was deemed essential for win-win outcomes.	RMP (Risk response planning), RMPr	Yes	Qualitative

RMPr: Risk management practice

research on this subject, this chapter identifies factors that may influence ERM (henceforth, the measures of ERM), by enabling adequate risk management planning; identification; analysis; response planning and monitoring and control of risks, to achieve both PPP stakeholders' and project objectives.

5.5 IDENTIFICATION OF MEASURES OF EFFECTIVE RISK MANAGEMENT

The measures of ERM were identified based on an in-depth review of risk management research and institutional literature, which was complemented with experts' opinions via semi-structured interviews and reviews.

5.5.1 Literature Review

A comprehensive literature review conducted (and content analysis of such) sought to understand and identify significant measures that may influence risk management outcomes on PPP projects. A diverse range of literature was scrutinized and synthesized, and included journal and conference papers, theses, books, government/industry reports, guidelines and standards. The focus was on extraction and synthesis of themes from the literature (either stated explicitly or implicitly) that would enable ERM on PPP projects. An open search on the Google Scholar search engine was used to obtain relevant publications on ERM. Key terminologies/phrases used included: barriers/ hindrances to risk management implementation; CSFs for risk management implementation; risk management failure; inadequate risk management; and effective risk management in the context of construction and PPP infrastructure projects. Google Scholar database was employed following its application by Olanipekun et al. (2017) – a decision justified by its greater inclusiveness and coverage when compared to other academic databases. Titles and previews transpiring from the search engine were briefly reviewed to filter pertinent material for further analysis. The titles of the studies reviewed can be generally categorized in to studies presenting frameworks/models for project risk management, modeling and assessment of risk management maturity of construction organizations, organizational risk management systems implementation, empirical analysis of local construction industry risk management practices, issues and challenges, PPP projects case studies, measures to mitigate PPP project risks, and other studies focusing on risk identification, assessment, allocation and mitigation. After a brief analysis of the gathered material and owing to the saturation upon repeated searches under different keywords/phrases, 47 documents (including journals, theses, conference papers, books, academic and institutional reports, etc.) were shortlisted based on visual examination for the detailed review.

In parallel, another comprehensive and more specific search was launched using the SCOPUS search engine (which is widely used in construction management research) to identify relevant published research under the domain of risk management in infrastructure PPPs (Hong et al. 2011; Ke et al. 2009b; Osei-Kyei and Chan 2015). Search terms included: risk; risk management; public–private partnership; private finance initiative; private infrastructure; public infrastructure; PPP; PFI; BOO; BOT; BOOT; DBFO; and DBFOM. The last seven abbreviations correspond to: public–private partnership (PPP); private finance initiative (PFI); Build–Own–Operate (BOO); Build–Operate–Transfer (BOT); Build–Own–Operate–Transfer (BOOT); Design–Build–Finance–Operate (DBFO); and Design–Build–Finance–Operate–Maintain (DBFOM). The search query was written following the format adopted by Osei-Kyei and Chan (2015). Title/abstract/keyword fields were utilized to search relevant literature using the search terms and the search period restricted to publications published between the years 1990 and 2016. The search ended in approximately 1023 results which were purposefully focused on journal papers only (Fig. 5.1).

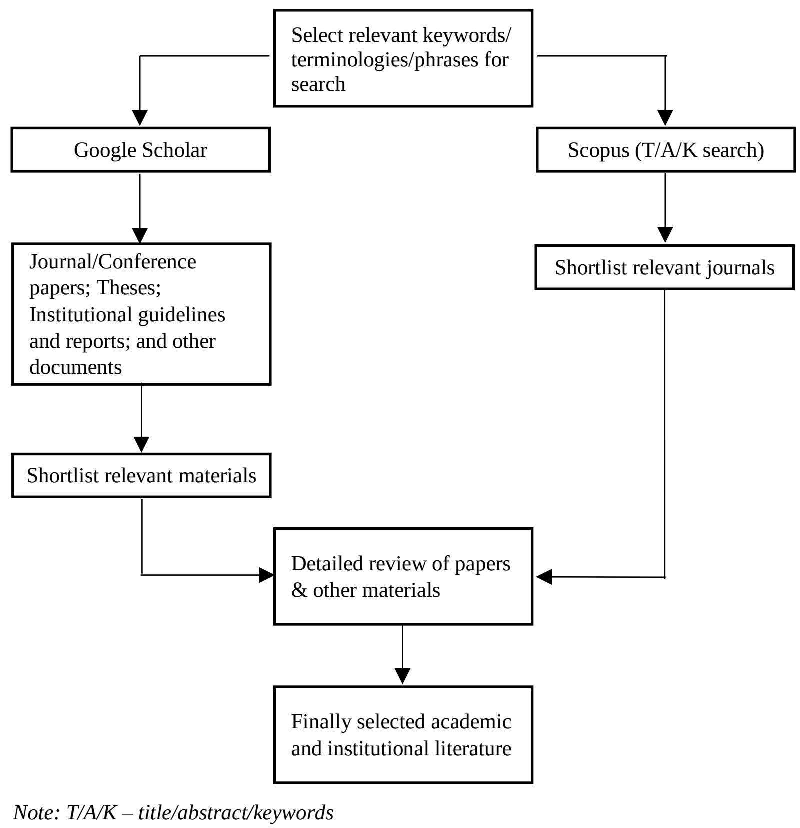

Fig. 5.1. Literature review framework (adopted and modified from Ke et al. 2009b)

Despite the utilization of specific keywords, some search results were not exactly relevant to risk management in PPPs, hence a brief review of titles and keywords, and where necessary the abstracts, was used to filter relevant journal publications first. Papers retained for further examination from this search belonged to journals including: International Journal of Project Management; Journal of Management in Engineering; Journal of Infrastructure Systems; Construction Management and Economics; Journal of Construction Engineering and Management; Engineering, Construction and Architectural Management; Built Environment Project and Asset Management; and many other popular construction journals that have been identified as major contributors to PPP based research (Osei-Kyei and Chan 2015; Tang et al. 2010b; Zhang et al. 2016). Extensive scanning was conducted on the selected materials obtained from both the search results. Finally, after accounting for duplicate items from both search results, 66 items were selected that could assist in identifying specific measures for ERM (Table 5.3).

Table 5.3. Source and frequency information for ERM measures literature review

Publication source/type	Frequency
Journal of Construction Engineering and Management (JCEM)	12
International Journal of Project Management (IJPM)	6
Construction Management and Economics (CME)	6
Engineering, Construction and Architectural Management (ECAM)	2
Journal of Management in Engineering (JME)	2
Journal of Infrastructure Systems (JIS)	2
Built Environment Project and Asset Management (BEPAM)	2
Industrial Management and Data Systems (IMDS)	2
Journal of Financial Management of Property and Construction (JFMPC)	2
Construction Innovation (CI)	1
Engineering Project Organization Journal (EPOJ)	1
International Journal of Construction Management (IJCM)	1
International Journal of Sustainable Construction Engineering and Technology (IJSCET)	1
Journal of Business Economics and Management (JBEM)	1
Journal of Civil Engineering and Management (JCiEM)	1
Journal of Professional Issues in Engineering Education and Practice (JPIEEP)	1
Public Money & Management (PMM)	1
Research in Engineering Design (RED)	1
Tsinghua Science & Technology (TST)	1
Conference papers	3
Books/book chapters	6
Theses	5
Reports and others (Government + Industry)	6
Total	**66**

The review revealed that substantial support was given to aspects of stakeholders' experience, capacity and maturity (Akintoye et al. 2003b; ADB 2012; Cheung et al. 2012; Chileshe and Kikwasi 2014; Hardcastle and Boothroyd 2003; Jin 2010; Liu et al. 2007; Wibowo and Taufik 2017) that can significantly influence the project's risk profile. In addition, collaboration among stakeholders to augment risk management has received noteworthy attention (Lehtiranta and Junnonen 2014; Matsumoto 2012; Pipattanapiwong et al. 2003; Zou 2012). Intra- and interorganization risk communication and reporting is also considered critical for risk management to function optimally (Cooper et al. 2005; Hardcastle and Boothroyd 2003). Similarly, continuous commitment by all stakeholders to the risk management function has been advocated as essential (Beckers et al. 2013; Chinyio and Fergusson 2003). Because risks must be investigated from a life-cycle perspective in PPP projects (Beckers et al. 2013; Fischer et al. 2010), which are inextricably linked to project's and stakeholders' objectives and requirements (Cooper et al. 2005), a comprehensive risks and requirements evaluation is necessary; where adequate assessment of these risks is possible only by application of appropriate tools and methods (Dey and Ogunlana 2004; Ke et al. 2012; Loosemore and Cheung 2015). Scholars have also emphasized the comprehensiveness and quality of project feasibility studies and the financial model (Cooper et al. 2005; Ke et al. 2008; Kurniawan 2013; Marques and Berg 2010). Multiple studies documented the importance of developing and maintaining project risk management plan and adopting good project management practices (Akintoye et al. 2003b; Chileshe and Kikwasi 2014; Cooper et al. 2005; Fischer et al. 2010). Risk management is also inextricably linked with development and administration of a sound and clear contract document, that protects the associated interests, which should be supported by an efficient negotiation process to incorporate all key stakeholders' perspectives (Akintoye et al. 2003b; Clifton and Duffield 2006; Cruz and Marques 2012; Fischer et al. 2010; Garvin 2010; Loosemore and McCarthy 2008; Marques and Berg 2010; Ye and Tiong 2003; Yeo and Tiong 2000). Administration of the contract takes center stage, once finalized and executed, to ensure adherence to commitments and to realize performance. Reliable risk assessment and mitigation requires multiple resources such as historical data, specialist consultants and advisors, and risk mitigation instruments (Asenova and Beck 2003; Chileshe and Kikwasi 2013; Chinyio and Fergusson 2003; Chowdhury et al. 2015; Jin and Zuo 2011; Ke et al. 2012).

Both, availability and reliability of these aforementioned resources may influence prospects of ERM on projects. Learning from risks is an important aspect towards improving risk management outcomes (Carrillo et al. 2008, 2006; Lehtiranta and Junnonen 2014). Third-party/gateway reviews are also suggested to be valuable to curb various potential biases (cognitive/motivational) and/or probable errors in the project estimates that may undermine risk management outcomes on projects (Beckers et al. 2013; Flyvbjerg 2013; Matsumoto 2012). Good management includes management of risks which is fundamental for effectively procuring goods and services and to achieve good outcomes in business and project (Chapman and Ward 2003). The concept of risk is central to activities undertaken by managers in a project such as *"... sensitivity analysis of a financial projection, scenario planning for a project appraisal, assessing the contingency allowance in a cost estimate, negotiating contract conditions or developing contingency plans."*, although, they may not use the term 'risk' while executing these activities (ibid.).

5.5.2 Semi-structured Interviews and Experts' Review

Semi-structured interviews were conducted with eight experts in Pakistan to identify factors that significantly influence risk management on projects – the ambition being to complement the literature review findings with expert opinion (see Chapter 2). The interviewees suggested ten factors including: proper planning and joint risk management; experience and institutional capacity of the public/private sector in managing PPP projects; expertise of foreign financial institutions; public sector's contract administration skills (concession agreement); characteristics of project sponsor (foreign/local, experience, risk attitude, capacity to absorb risks, etc.); quality of feasibility studies; availability of risk mitigation instruments; availability of reliable historical data on projects; development and use of comprehensive risk management plans; and availability of reliable specialist consultants and advisors. These factors identified concurred with the literature review. Five of the interviewees also reviewed the measures extracted from the literature review and demonstrated satisfaction with their relevance while three measures were considered to be less significant including: well-established project management scheme; increased confidence, trust, and cooperation among partners; and existence of independent risk management unit with the government. Two international experts were also invited to review the measures. The respondents broadly agreed with the relevance of the identified measures but suggested some minor revisions. For example, the measure of "risk audit" was replaced by the term "third-party reviews" as the later term is widely recognized by industry stakeholders and better reflects intent of the measure. Similarly, the measure "partner's risk management commitment" was renamed to "stakeholders' commitment to risk management". Another measure titled "existence of an independent risk management unit with government" was initially identified in the literature review but later removed because experts felt it was insignificant.

5.6 MEASURES OF EFFECTIVE RISK MANAGEMENT

Based on the review, semi-structured interviews and expert review, a total of 30 measures for ERM were obtained (Table 5.4). A brief review of extracted measures reveals that the attributes are distributed over the entire project's lifecycle and exhibit a multi-organizational focus.

5.6.1 Identification of Project's and Key Stakeholders' Objectives and Requirements

While identifying risks, it is essential to consciously elaborate upon the organization's and project's objectives to determine all significant risks. The realization of these objectives is linked to the risk management process through pre-defined success criteria that is adopted to measure

Table 5.4. Measures of ERM with reference source and frequency

ID	Measures of ERM	Reference sources	No. of references
MERM_12	Risk management maturity of project stakeholders	Beckers et al. (2013), Chileshe and Kikwasi (2014), Jin (2010), Ke et al. (2012), Keci and Mustafaraj (2013), Kwak (2002), Lee and Schaufelberger (2013), Liu et al. (2007), Yuan et al. (2008b), Zhang (2005d), Zhang (2005c), Zou et al. (2009)	12
MERM_22	Flexible and collaboration supportive contract	Clifton and Duffield (2006), Garvin (2010), Jin and Zuo (2011), Lee and Schaufelberger (2013), Matsumoto (2012), McDowall (2003), Motiar Rahman and Kumaraswamy (2005), Park et al. (2013), Pellegrino et al. (2011), Shan et al. (2010), Ye and Tiong (2003)	11
MERM_17	Experience of the private partner in conducting similar projects	Ahadzi and Bowles (2004), Akintoye et al. (2003), Dey and Ogunlana (2004), Jang (2010), Jin (2010), Keci and Mustafaraj (2013), Kwak (2002), Moro Visconti (2014), Yeo and Tiong (2000)	9
MERM_10	Risk communication and reporting	Cooper (2005), Delhi et al. (2012), Hardcastle and Boothroyd (2003), HM Treasury (2004), Jin and Zuo (2011), Keci and Mustafaraj (2013), Ng and Loosemore (2007), Project Management Institute (2009), Schieg (2006)	9
MERM_30	Stakeholders risk management commitment	Arndt (2000), Beckers et al. (2013), Chinyio and Fergusson (2003), Jin (2010), Jin et al. (2012), Keci and Mustafaraj (2013), Liu et al. (2007), Project Management Institute (2009), Schieg (2006)	9
MERM_1	Identification of project's and key stakeholders' objectives and requirements	Chileshe and Kikwasi (2014), Cooper (2005), Dey and Ogunlana (2004), Fischer et al. (2010), Jin and Zuo (2011), McDowall (2003), Ng and Loosemore (2007), Project Management Institute (2009), Yeo and Tiong (2000)	9
MERM_8	Quality of project's pre-feasibility/feasibility study	Akintoye et al. (2003), Cooper (2005), Flyvbjerg (2013), Jang (2010), Kumaraswamy and Morris (2002), Marques and Berg (2010), Ng and Loosemore (2007), Soomro and Zhang (2015b)	8
MERM_7	Adequate Administration/Management of the contract between the public and private sectors (concession agreement)	Akintoye et al. (2003), Cooper (2005), Fischer et al. (2010), Garvin (2010), Liu et al. (2007), Marques and Berg (2010), Matsumoto (2012), Monteiro (2008)	8
MERM_11	Collaborative risk management	Clifton and Duffield (2006), Cruz and Marques (2012), HM Treasury (2004), Lehtiranta (2013), Lehtiranta and Junnonen (2014), Matsumoto (2012), Project Management Institute (2009), Zou (2012)	8
MERM_18	Risk management personnel training and development	Chileshe and Kikwasi (2013), Chileshe and Kikwasi (2014), Chinyio and Fergusson (2003), Ke et al. (2012), Keci and Mustafaraj (2013), Monteiro (2008), Schieg (2006)	7
MERM_24	Increased confidence, trust and cooperation among the partners	Chileshe and Kikwasi (2014), Doloi (2009), Jin (2010), Jin and Zuo (2011), Lee and Schaufelberger (2013), Soomro and Zhang (2015), Yuan et al. (2008)	7

ID	Measures of ERM	Reference sources	No. of references
MERM_4	Comprehensive lifecycle based risk identification and assessment	Beckers et al. (2013), Dey and Ogunlana (2004), Fischer et al. (2010), Ng and Loosemore (2007), Project Management Institute (2009), Zou et al. (2008), Zou et al. (2009)	7
MERM_5	Explicit risk allocation in the contract	Akintoye, Beck and Hardcastle (2003), Cooper (2005), Cruz and Marques (2012), HM Treasury (2004), Lee and Schaufelberger (2013), Marques and Berg (2010)	6
MERM_26	Careful bid evaluation by the public authority	Akintoye et al. (2003), Dey and Ogunlana (2004), Jang (2010), Lehtiranta and Junnonen (2014), Marques and Berg (2010), McDowall (2003)	6
MERM_9	Quality of the project's financial model	Akintoye et al. (2003), Cooper (2005), Ke et al. (2008), Kurniawan (2013), Pantelias and Zhang (2010)	5
MERM_16	Experience of the public sector in managing PPP projects	ADB (2012), Ke et al. (2011), Keci and Mustafaraj (2013), (Soomro and Zhang 2011), Soomro and Zhang (2015)	5
MERM_21	Consideration of interrelation between risks	Dey and Ogunlana (2004), Iyer and Sagheer (2010), Loosemore and Cheung (2015), Marle and Vidal (2011), Project Management Institute (2009)	5
MERM_29	Learning from risks	Carrillo et al. (2006), Lehtiranta and Junnonen (2014), Liu et al. (2007), McDowall (2003)	4
MERM_13	Third-party review	Akintoye et al. (2003), Beckers et al. (2013), Flyvbjerg (2013), Matsumoto (2012)	4
MERM_14	Experience, skills and maturity of financial institutions (debt/equity providers, insurance companies)	Fischer et al. (2010), Hardcastle and Boothroyd (2003), Liu et al. (2007), Matsumoto (2012)	4
MERM_20	Availability of historical data on previous projects	Chinyio and Fergusson (2003), Jin and Zuo (2011), Ke et al. (2012), Keci and Mustafaraj (2013)	4
MERM_6	Efficient contract negotiations	Akintoye, Beck and Hardcastle (2003), Cooper (2005), Fischer et al. (2010), Yeo and Tiong (2000)	4
MERM_25	Availability of reliable specialist consultants/external advisors	Akintoye et al. (2003), Asenova and Beck (2003), Chileshe and Kikwasi (2013), Chileshe and Kikwasi (2014)	4
MERM_19	Application of appropriate Risk Analysis Tools and Techniques (RATTs)	Chileshe and Kikwasi (2014), Dey and Ogunlana (2004), Ke et al. (2012)	3
MERM_15	Availability of reliable risk mitigation tools and instruments (guarantees, insurances, hedges/swaps, etc.)	Chowdhury et al. (2015), Jin and Zuo (2011), Liu et al. (2007)	3
MERM_3	Comprehensive project risk management plan	Akintoye et al. (2003), Cooper (2005), Project Management Institute (2009)	3
MERM_2	A well-established project management scheme	Chileshe and Kikwasi (2014), Fischer et al. (2010), Project Management Institute (2009)	3
MERM_28	Retaining the contract negotiation personnel for contract administration	Loosemore and McCarthy (2008), Monteiro (2008)	2
MERM_23	Effectiveness of dispute resolution	Jin and Zuo (2011)	1

ID	Measures of ERM	Reference sources	No. of references
MERM_27	Explicit risk pricing in the bid	Clayton Utz (2006)	1

the achievement of objectives and influence of the consequences of risks on those objectives (Cooper et al. 2005). For PPP projects, governments are primarily tasked with setting up clear and explicit objectives, without which risk analysis cannot be performed sufficiently (Dey and Ogunlana 2004; McDowall 2003). The style and the content of output specification can be used to specify risk transfer protocol/requirements (McDowall 2003). Ambiguity of performance requirements was found to be a critical uncertainty factor for efficient allocation of risk of 'defects in design' in the development stage of PPP projects in Australia (Jin and Zuo 2011).

Stakeholder analysis helps the decision makers in understanding their needs and concerns by creating a documented profile of all concerned stakeholders (Cooper et al. 2005). This also helps in demonstrating the integrity of the process and that risk assessment encompasses all relevant stakeholders' objectives and expectations. Effective project risk management is influenced positively from robust communication and consultation with stakeholders (Project Management Institute 2009). Consultation with stakeholders may serve as an important source of information and forms a key aspect of the risk management framework for the government authority as it may potentially improve risk outcomes and assist in risk response planning and control (APMG International 2016c; Virginia Public-Private Partnerships 2015). It is recommended for the government to involve the end-users early in the project lifecycle, where the government itself is not the end-user, as any lapses in stakeholder consultation can lead to underestimation of certain risks, potential project delays, make it challenging to manage the contract and negatively impact public and private sectors' ability to mitigate certain risks including: land acquisition, construction permits, public objection to related fees, and objection and opposition to project by local residents and communities and operational staff, such as in the case of a school project (APMG International 2016c).

5.6.2 Comprehensive Project Risk Management Plan

Complexity of the risk sharing framework in a PPP project combined with a high degree of risk exposure make a comprehensive project risk management plan an essential requirement for successful PPP project implementation (Roy et al. 2014). Risk management plan is a central tool that is utilized by the implementing government authorities for monitoring and managing retained risks and responsibilities (World Bank et al. 2014). A risk management plan contains information on several aspects including: a listing of all government retained and shared risks and associated responsibilities including those that may undermine the sustainability of PPP; identification of needed information for the purpose of monitoring each risk; and the risk management strategies needed for mitigating the risk or its impact (ibid.). Relevant contents and significance of a risk management plan have also been discussed in Grimsey and Lewis (2007), Hong Kong Institute of Surveyors (2009), and National Treasury (2004).

As a good practice, the private partner can develop and implement a risk management plan which may also be a contractual requirement with insurers or the procuring authority (APMG International 2016a). The submission of a risk management plan is required by many government agencies as a part of the tender submission and contract deliverables by the contractors to evaluate the identified risks, the severity of those risks, the methods that will be adopted to deal with those risks, and the processes and structures to be put in place to continually monitor and manage risks throughout the project, including the role of the purchasing authority in managing its significant risks (Cooper et al. 2005).

5.6.3 Explicit Risk Allocation in the Contract

A PPP contract is structured to specify responsibilities and allocate risks to the contractual parties (World Bank 2005). Risk transfer can be achieved either by clear and explicit wording of the agreed contract agreement. It can also be done in an implicit manner if the responsible organization that will manage the risk is considered to have the necessary skills and expertise in that area (Cooper et al. 2005). Implicit allocation of risk in the form of unwritten or implied conditions can be a problematic approach. Express terms in the draft contract provided to the tenderers at the bidding stage assist tenderers in preparing plans for negotiation and their own risk management responsibilities and strategies (ibid.). Lee and Schaufelberger (2013) identified ‘unclear contract clause’ as a factor that led to risk mitigation failure on a high speed rail project in Taiwan and an expressway BOT project in Thailand.

A risk matrix is a useful tool at tendering, negotiations and post-contract stage, that can assist by providing explicit information on responsibility for each risk and an immediate view of project’s risk profile (Hong Kong Institute of Surveyors 2009).

5.6.4 Efficient Contract Negotiations

Efficient contract negotiations becomes important in context of: the optimum time at which to conduct negotiations (preferably before the appointment of the preferred bidder); manner in which the negotiations are conducted; and equitable sharing of risks and rewards (Akintoye et al. 2003b;

Cooper et al. 2005; Yeo and Tiong 2000; Yescombe 2007). Each party needs to appreciate and understand the interests and risks of others to conduct efficient negotiations (Fischer et al. 2010). It is important for both the public and private sectors to be vigilant in conducting negotiations to avoid unjustified risk transfer because it erodes the ability of the parties to manage risks that are beyond their control and hence, retards the achievement of objectives. A party's strong negotiating position or inexperience of the negotiating parties can result in unreasonable and imbalanced allocation of risks under the contract. This generates new risks to the project in particular where the a party lacks the knowledge and capabilities to manage such risk (Cooper et al. 2005). With reference to power purchase agreements, ADB (2000) noted that the governments have frequently ended up assuming some commercial risks and providing guarantees which was attributed to their limited contract related knowledge and experience and often because of the governments' inability to obtain assistance in negotiations by engaging suitable legal, technical and financial experts. Also, the private sector has accepted risks that should have been borne by the government, in an effort to avoid long negotiations and renegotiation of clauses. The report contended that government should develop capability to deal and negotiate with the private sector (ibid.). Meng et al. (2011) also discuss implications of public sector's weak negotiation capacity that can result in government ending up taking commercial risks which expose them to fiscal liabilities and reduce the private sector's incentive to pursue efficiency. It is however important to understand that each project participant exhibits its own perspectives on risk allocation and that a party's willingness to assume risk is shaped by its perception and subjective evaluation of the risk. Hence, the crux of the negotiation process is to consider risk allocation issues and the willingness of the parties to arrive at a compromise through sharing of risks and rewards (UNECE 2000).

Post-bid negotiations (after the appointment of a preferred bidder) are undesirable as they invite a host of problems to the PPP mandate (Yescombe 2007).

The manner in which the negotiations are conducted is also important. Akintoye et al. (2003b) suggested that continuous risk negotiation should take place from the initial estimation of risk to the final negotiation to avoid sudden procurement process disruptions only when such negotiation takes place at the end. Continuous negotiation throughout the process will encourage communication and information exchange between the public and private sectors (ibid.). The negotiation process assists in positive learning and a problem solving experience thus, enabling the stakeholders in achieving systematic convergence to mutually acceptable solutions while also providing a glimpse of each other’s needs and motivations (Yeo and Tiong 2000). According to Cooper et al. (2005), instead of conducting negotiations from the first page to the last page of the contract, it is better to start and discuss the most critical areas of the contract that present the greatest risk for the parties.

5.6.5 Adequate Administration/Management of the Contract Between the Public and Private Sectors (Concession Agreement)

Financial close does not signify the end of the risk management. The agreement between the public and the private sector is monitored during the construction and operation phase (Akintoye et al. 2003b). Typical contract duration in PPP projects ranges from 30-40 years indicating the long-term nature of the public and private sector relationship. Therefore, managing the partnership gets center stage which manifests itself in contract management practices (Garvin 2010). Not being able to implement an effective contract management strategy is a project risk in itself and it must be managed (Partnerships Victoria 2003). This function aims to: ensure protection of contractually established government/public interests; maintain contractually agreed risk allocation and achievement of best value; monitor project performance to ensure compliance and execution of appropriate action upon a failure to perform; conduct performance based payment administration; and ensure continuous improvement in contract performance and service delivery (Public Private Partnerships Programme 2007). Since the risks are shared through the contract, it is at the heart of relationship between the parties. The initial risk allocation must be managed throughout the project lifecycle to enforce, clarify and/or modify the risk allocation in the event of eventuality of unforeseen risks or consequences of those risks, and to ensure that the public and private sector bear and adequately mitigate the risks allocated to each party (APMG International 2016c). However, after finalization of the contract and procurement of services, many parties fail to monitor and oversee the proper implementation of contracts thus resulting in a failure to fulfill and meet contractual obligations. Failure to adequately manage will ultimately erode its VfM and may undermine project objectives (ibid.).

5.6.6 Quality of Project's Pre-feasibility/Feasibility Study

Quality of project's pre-feasibility/feasibility study is foundational to ERM as assessment of various project parameters is performed at this stage. Projects proposed to be developed under the PPP scheme or otherwise must be appraised to determine if the proposed project is a justifiable public investment decision (World Bank et al. 2014). Appraisal criteria typically includes, among other criteria, assessing a project's feasibility (under technical, legal, environmental and social sustainability and economic efficiency criteria) and economic viability via some of economic viability analysis. Firstly, a project must be defined which includes its physical outline, technology, outputs, target population, capital costs, operation and maintenance costs and expected revenue generation. Assessment of project viability serves as a critical input to subsequent steps in project appraisal. PPP financial modeling, commercial and fiscal viability analysis, and quantitative VfM analysis will depend on project definition whereas initial inputs for financial modeling and VfM analysis will depend on metrics developed for economic viability analysis i.e., cost and demand estimates. Technical feasibility, social and environmental sustainability assessment provides basis for risk analysis (ibid.). Kumaraswamy and Morris (2002) and Ng and Loosemore (2007) presented multiple case studies of PPP projects whose failure was attributed in part to overly optimistic feasibility studies. Zatar (2014) attributed inadequate feasibility studies as a prime factor causing underperformance in PPP toll road projects in terms of unrealistic traffic forecasts and undefined public contribution of funds. Also, an improper public sector comparator (PSC) can significantly and negatively impact the bid evaluation process and may result in a suboptimal choice of procurement or project delivery method (Soomro and Zhang 2015b).

5.6.7 Quality of the Project's Financial Model

The financial model (FM) is used for preliminary due diligence by lenders and also assists relevant stakeholders to: analyze the impact of risks; assess project's returns, cash flows, and financial robustness; negotiate risk allocation among the parties; and monitor PPP project over the concession period (Kurniawan 2013; World Bank et al. 2014). The diversity of project stakeholders' interests and complexity of project financing in PPP projects make FMs difficult to understand and vulnerable to errors. To avoid issues arising, apart from employing best practices and auditing the model (Kurniawan 2013), a manual describing the FM's assumptions and structure together with guidelines on model usage should be provided with the model (ADB 2008). Panko (1998) argued that model errors in the form of faulty spreadsheet formulas is a problem.

5.6.8 Risk Communication and Reporting

The risk planning process is influenced by risk communication and reporting (Cooper et al. 2005). Communication (reporting the outcomes of a risk management study) can be seen as exchange of information operating at two different levels, i.e., within the project team and between the stakeholders (ibid.). The former serves to provide reference documentation to lookup experts' assumptions that underlie each judgement and decision in order to maintain reasonableness and consistency in a large risk assessment of a complex project, which will be useful in case the results of the assessment process look suspicious. The latter serves several purposes. It is important to ensure that all parties are fully informed to avoid unpleasant surprises and for the end users, who must pay for the risk, to fully understand the risks and trade-offs to be made in a large project. Information about the risks and their allocation and management is required by the providers of finance and insurance support who are often particularly interested in residual risks and worst case outcomes after implementation of prudent risk management plans. Other uses include (ibid.): project managers accountability and auditability; a valuable database of corporate knowledge and information source for future projects; and record for post-implementation project evaluation. Reporting also serves as an important form of communication in a project and allows the public sector to monitor the project over time (ibid.). Moreover, the consortium will also be required to report on a number of aspects such as performance and consortium's financial health (ibid.). Reporting enables the public sector managers to confirm that the main issues of risks and their management have been deliberated over by the contractor at the outset of the project during early stage of planning. Reporting should also occur within the ranks of the public sector where public sector private finance management organizations report to the senior public-sector management on current status of risks and risk management (ibid.). Improved communication has also been stressed in the risk management framework presented by Akintoye et al. (2003a).

5.6.9 Collaborative Risk Management

Collaborative risk management has received much attention, albeit a difference of approach exists between researchers. Pipattanapiwong et al. (2003) stressed the need for moving beyond the single organization focus of traditional risk management and suggested a multiparty risk management process (MRMP). The involvement of a large number of stakeholders increases the probability and impact of risks due to differing objectives of the stakeholders. Owing to the single party focus of conventional risk management, even when the risks impact several parties, a situation may arise where the risk response planned by one party results in creation of more risks for the other parties thus creating a risk-response-risk chain. This happens when the perspectives on risk analysis and response evaluation of the other participants in the project are overlooked (ibid.). Owing to the inability of the contract language to clearly specify risk apportionment, potential of difference in contract clauses interpretation and inability to foresee all possible risks at contract signing stage, a joint risk management (JRM) strategy has been applied in the post-contract stage in both partnering and PPP contracts (Zou 2012) – such facilitates collaboration between the parties to manage unforeseen project risks (Rahman and Kumaraswamy 2004), and allows all the actors to collaboratively conduct risk identification, assessment and response planning for a project (Osipova 2008). Matsumoto (2012) suggested risk workshops to provide a venue where the public and private sectors can interact and learn from each other to collectively recognize project risks and determine appropriate allocation and response measures.

5.6.10 Risk Management Maturity of Project Stakeholders

Risk management maturity of project stakeholders is significant to ERM and represents an organization's ability and expertise in comprehending its risks portfolio, managing those risks and the availability/maturity of business processes/systems that are needed to manage and respond effectively to risks (Zou et al. 2009). Risk management maturity of the public and private sectors was identified as one of the characteristics of the risk management service transaction in PPP projects (Jin 2010). Poor risk management maturity of organizations has been reported as an important factor contributing towards poor project outcomes (Akintoye et al. 2001; Ke et al. 2012; Liu et al. 2007; Morse 2009).

5.6.11 Third-party Review

Bruzelius et al. (2002) and Matsumoto (2012) argued that politicians can have an influence in biasing forecasts to support project approvals. To improve transparency and reduce human ignorance or errors, it is advisable to conduct third-party evaluations to counter check various analysis and ensure representative and accurate statistics for decision making. Accountability and transparency can be enhanced by providing detailed audit points at each stage of the project life-cycle (such as the audit framework of NAO (National Audit Office 2006)), and specifying the role and scope of evaluation of third party organizations, *"... thereby preventing sloppy risk management and opaque decision-making processes"* by concerned government organizations

(Matsumoto 2012). Yescombe (2007) emphasized independent reviews at each key stage of the project by a regional or central government committee with the aim to ensure transparency and fairness in procurement and to learn from experiences for the future. Rai (2009) and World Bank et al. (2014) also emphasized on the function of supreme auditing institutions (SAIs) in the context of PPP projects and the elements to check when ensuring VfM and protection of public interests in PPP transactions. Gateway reviews as used in Australia (Queensland Treasury 2013), may also help in a similar manner. Some issues can be examined and rectified by the stakeholders via due diligence at the project procurement stage (Flyvbjerg 2013; Kurniawan 2013; Yescombe 2007). In order to ensure that the risks have been priced fairly, the senior debt provider should initiate proceedings for conducting due diligence at the negotiations stage (Akintoye et al. 2003b). The aim is to involve top experts in each particular field to support risk identification and assessment process. Assessment of the financial model is undertaken during due diligence to explore possible legal shortfalls, establish the reliability of all estimates, and to provide some insurance in case there are any big discrepancies. For conducting due diligence, external financial consultants can be employed to study the project's legal, technical, and financial aspects and to also audit the financial model (ibid.). The public authority also needs to conduct the due-diligence process which includes a detailed review of contracts to ensure that they are fit for purpose and that the terms do not create unplanned liabilities with respect to design, subcontracts, financing documents and insurance agreements, before the financial close (Yescombe 2007).

5.6.12 Experience, Skills and Maturity of Financial Institutions (Debt/Equity Providers, Insurance Companies)

Experience, skills, and maturity of the insurance and financial sectors become important in the context of risk management due to their involvement in PPP projects as primary stakeholders (Hardcastle and Boothroyd 2003; Matsumoto 2012). Insurance and financial sectors are active in the construction industry through provision of capital and security (Hardcastle and Boothroyd 2003). They assess the risk position of their clients, contractors and projects before they make a decision to support a scheme (ibid.). As discussed above, the financial institutions also conduct due diligence before the financial close is achieved to ensure that the business model is indeed viable. The lenders play an important role in reviewing the ability and credibility of the private operators to achieve the project objectives; hence continuous financial monitoring and intervention by the lenders during project operations (in order to protect their loans) contributes to stability of the business by managing the existing risks to pursue economic benefits (Matsumoto 2012). Improper due diligence by the lenders was identified as one of the failure drivers leading to failed transport PPP projects (Soomro and Zhang 2015a). One interesting study by Liu et al. (2007) highlighted that the insurance sector in mainland China lacks the experience to assess risks and determine adequate premiums due to the relatively young operating history of the construction insurance sector in China.

5.6.13 Availability of Reliable Risk Mitigation Tools and Instruments (Guarantees, Insurances, Hedges/Swaps, etc.)

For the specific case of China, Liu et al. (2007) reported limited availability of construction insurance products and services along with a lack of trust in the industry in using insurance services due to perceived difficulty in claim maturity with the insurance companies. In the context of infrastructure financing, "*risk mitigation instruments are financial instruments that transfer certain defined risks from project financiers (lenders and equity investors) to creditworthy third parties (guarantors and insurers) that have a better capacity to accept such risks*." (Matsukawa and Habeck 2007). These instruments serve as an invaluable support for developing country governments and local infrastructure institutions that lack creditworthiness or do not boast a proven track record for raising or attracting private investment. The report (ibid.) categorizes risk mitigation instruments as Credit Guarantee, Export Credit Guarantee and Insurance and Political Risk Guarantee or Insurance. Provision of risk mitigation instruments (credit/export credit guarantee, political risk insurance etc.) and the associated costs depend upon a variety of factors (Croce et al. 2017) hence, the availability of such instruments becomes an important consideration for ERM on PPP projects. Thomas et al. (2003) argued that respondents in India considered political risk insurance ineffective - supposedly due political risk insurance instruments being inadequate and the high costs of using such insurance. Hedging instruments (swap and forward contracts or options) can assist project parties manage financial risk associated with specific liabilities (Mandri-Perrott and Menzies 2010). The counterparties with the help of these instruments obtain certain rights and obligations at some future date which enable to offset exposures to certain risks such as variation in foreign exchange rate, large purchases of raw materials and other project inputs, interest rate movements, and counterparty risk (e.g., credit default) (ibid.). Hedging instruments come at a significant cost (Mandri-Perrott and Menzies 2010) and in some cases, these instruments might not be readily available in certain markets (Croce et al. 2017). Minimum revenue guarantee is one of the most common form of government support instruments in PPP projects that allows the public and private sector to share toll revenue risk

(Ashuri et al. 2011). Availability of government guarantees (such as minimum revenue guarantee and others) to the private sector is a matter of government policy.

5.6.14 Experience of the Public Sector in Managing PPP Projects

Because the public sector becomes a primary stakeholder in PPP infrastructure projects, experience in developing and managing PPP projects is an essential prerequisite. The World Bank (2016b) suggests that the government will always be held accountable and for that they need to develop and retain sufficient expertise to allow them to understand the PPP arrangement, carry out obligations, and to monitor and enforce the private sectors obligations. In anticipation of attracting foreign investments, lack of experience and knowledge may result in poor evaluation of government guarantees and support extended to the project, resulting in higher cost to the government and default of payments (Ke et al. 2011). Nelms (2012) highlighted the significance of risks *"limited project personnel PPP experience and familiarity"* and *"limited federal department and agency experience and familiarity with PPP"* in achieving public objectives at the front-end planning phase of PPP, for a high security Canadian federal facility project delivery.

5.6.15 Experience of the Private Partner in Conducting Similar Projects

Jang (2010) contended that an experienced private partner is required for success in PPP risk management. Risk management experience of the private partner in managing a risk was identified as a measure of one of the aspect or construct of risk management service transaction in PPP projects, which can serve to predict a cost efficient risk allocation strategy (Jin 2010). Yeo and Tiong (2000) emphasized the importance of an experienced prime promoter organization to lead the consortium. The consortium boasts a team of specialists that harbor complementary skills to meet all technical, financial, legal and political requirements. The internal capability of the consortium can help in reducing the overall risk (ibid.).

The very large size of PPP projects and long project lifecycle over which the risk exposure extends makes risk management a critical issue for the private sector partner and the project financiers (Loosemore et al. 2006). For the case of India, Roy et al. (2014) contended that the inexperience of infrastructure development companies in managing risks in PPP projects was a problem and was also expected to hinder efficient delivery of projects in the future. Tiong (1995) noted that in order to be awarded a concession, it is very important to bring in to the consortium, to share risks, experienced financial and technical consultants and other investors/stakeholders that by virtue of their experience and expertise and past track record are best able to shoulder risks. In this way, the creditability of the promoters and attractiveness of their proposal is enhanced (ibid.).

5.6.16 Risk Management Personnel Training and Development

The need for risk management personnel training and development was highlighted as being an important measure by Chinyio and Fergusson (2003) and Ke et al. (2012). Chinyio and Fergusson (2003) argued that training programs, conferences and seminars can help organizations to enhance their skills for risk assessment and that it could overcome the limited supply of experts on PFI risk assessment. Ke et al. (2012) with regards to risk management practice in PPP projects in China, reported low level of training in risk analysis and management and further determined that the senior and middle level managers in handling PPP projects exhibited *below moderate* experience and knowledge of risk management.

5.6.17 Application of Appropriate Risk Analysis Tools and Techniques (RATTs)

Application of appropriate risk analysis tools and techniques is important because decisions on using a specific tool/technique depends on the quality and type of information available, and the type of risk analysis suitable for the given case. Objective and quantitative analysis is possible in situations where sufficient historical records and other forms of quantitative information are available. Additionally, projects differ in type and uniqueness, hence, subjective judgement or analysis is essential in part (Dey and Ogunlana 2004). Some of the RATTs identified by the authors include: influence diagram, Monte Carlo simulation and sensitivity analysis. It is often required for the effects of impacts of risks to be converted in to monetary terms for conducting risk analysis (required for VfM and profitability analysis) however, the analysis results can vary with the analysis methods employed and the method utilized for quantification of the risks impacts in monetary format (Dey and Ogunlana 2004). Good risk analysis is dependent on the right understanding of how the risks are analyzed by each tool and technique. Powerful tools for cash flow analysis include Monte Carlo simulation and sensitivity analysis (ibid.), however the use of Monte Carlo simulation in PFI projects requires availability of good quality data to estimate probability and risk exposure information, which can limit its applicability (Akintoye et al. 1998).

5.6.18 Availability of Historical Data on Previous Projects

Lack of availability of historical data on previous projects poses a significant hurdle as it leads to inadequate modeling and analysis of risks (Thomas et al. 2006). This was also endorsed by Chinyio and Fergusson (2003) that the risk analysis in face of inadequate historical information is a "speculative guessing game". Ke et al. (2012) and Chinyio and Fergusson (2003) encouraged the development of PPP/PFI database to leverage the benefits of using historical/past information from previous PPP projects to support risk analysis and management. This point is quintessentially important for countries that have recently adopted the concept of private investment for infrastructure development.

5.6.19 Comprehensive Lifecycle Based Risk Identification and Assessment

In a research conducted at the Glasgow Caledonian University studying difficulties in, and solutions for, risk analysis and management to understand the impediments to efficient risk management in PFI projects, the interviewed respondents relayed thorough identification of risks in PFI projects as the biggest problem, especially in the public sector organizations (Chinyio and Fergusson 2003). It is important to understand that risk analysis, response planning, monitoring and control processes are highly dependent on risk identification and are only as effective as the adequacy of the risk identification process itself. It is important to conduct risk identification and assessment from a life-cycle perspective with continuous monitoring (Zou et al. 2008). Fischer et al. (2010) supported its significance by further elaborating that a risk can be potentially influenced more (in terms of its cause and effects) at the beginning of a project. Dey and Ogunlana (2004) and Zou et al. (2008) found that in many cases of PPP projects, undesirable outcomes resulted due to underlying factors that had not been identified as risks. Therefore, in order to prevent such failures, risk identification must be performed thoroughly. Brainstorming and conducting workshops were suggested as useful methods of understanding risks (Chinyio and Fergusson 2003).

5.6.20 Consideration of Interrelation Between Risks

It has been argued that traditional risk analysis and management methods treat individual risk as independent events however this is not the case in reality. Marle and Vidal (2011) noted this in their research and pointed out the potential lack of consideration of risk propagation through risk networks. Traditional risk assessment considers that risk eventuate due to singular root causes and then result in linear, traceable and predictable effects (Loosemore and Cheung 2015). The authors (ibid.) believe that the leading cause of many failed PPP projects can be attributed to *"... unsophisticated, linear and reductionist way in which the risks were identified, assessed and managed."* Based on a review, the authors summarized that a paradigm shift was required to overcome the limitations of reductionist approach towards risk management in PPP projects and suggested the application of systems thinking in improving the state of risk management on such projects.

5.6.21 A Well-established Project Management Scheme

Fischer et al. (2010) argued that risk management can only operate effectively as a part of a well-established project management scheme. The PMBOK standard guidelines by PMI (Project Management Institute 2013) provide ten knowledge areas where project risk management is the focus of one knowledge area. Outputs from other processes and knowledge areas under the PMBOK's project management framework are important prerequisites for effective project risk management (Project Management Institute 2009, 2013). Similarly, outputs of the risk management planning processes (the risk management plan), become a part of the project management plan.

5.6.22 Flexible and Collaboration Supportive Contract

Flexible and collaboration supportive contract is important at the post-award stage. Designing flexibility into the PPP contract aims to provide options for adjustments in face of future uncertainty (APMG International 2016c; World Bank et al. 2014), *"... to create certainty where possible, and bounded flexibility where needed…"*, rather than necessarily leading to renegotiation or contract termination (World Bank et al. 2014). Rigid contracts undermine trust between parties and also create friction in resolution of disputes (Jin and Zuo 2011). Changes may be initiated as a result of modification in laws and regulations, private partner initiated modifications, project enhancements or revisions in service requirements (Garvin 2010). According to Ye and Tiong (2003), a suitable tariff structure and adequately designed tariff adjustment mechanism can provide the requisite flexibility to manage risks in PPP projects.

5.6.23 Effectiveness of Dispute Resolution

Effectiveness of dispute resolution serves as an important risk mitigation mechanism and a measure of last resorts for the contractual partners. To ensure that a project is shielded from the negative influence of potential disputes between the parties, effective dispute resolution with immediate or interim relief to the contractor is the key (Kachwaha and Rautray 2016). According to the PPIAF (2009b), mechanisms available to resolve conflicts and disputes are a major part of the regulatory risk assessment by the private investors. Regulatory conflicts are common in the infrastructure sector for a number of reasons that can be attributed to the complex nature of the large projects, size of the investment and immobility of assets, changes in circumstances over the long duration of the contract, the public nature of services with a private partner, and due to several occasions for conflict. Typically, the conflicts may involve disputes between government authorities or regulators and private companies and will concern subjects such as tariff reviews, award of concessions, permits, operations and enforcement of obligations on either side (ibid.). A comprehensive legal framework for PPPs provides assurance to the private sector that contracts will be honored (Schwartz et al. 2008). Uncertainty regarding such frameworks leads to project investors and participants perceiving the project as unpredictable and highly risky (ADB 2008). Jin and Zuo (2011) also found that ineffectiveness of dispute resolution mechanism was perceived with high criticality for its influence on the decision making regarding allocation of risk of ‘adverse changes in law, policy or regulations’ on PPP projects in Australia.

5.6.24 Increased Confidence, Trust and Cooperation Among the Partners

Good inter-party relationships allow for: effective risk sharing and joint risk management (Motiar Rahman and Kumaraswamy 2005); conflict management and efficient dispute resolution (Doloi 2009; European Investment Bank 2015); and lowered transaction costs. Doloi (2009) contended that level of trust and confidence among the parties influences joint management of risks. Lee and Schaufelberger (2013) asserted that management of general risks (which are location specific) by the private sector is cumbersome and suggested that it should maintain good working relationship with the host government before and during the concession period. In the case studies of Bangkok Elevated Road and Track System (BERTS) project in Thailand and the M1/M15 motorway in Hungary, Soomro and Zhang (2015b) found that the public officials did not cooperate with the concessionaire with domestic issues leading to failure of the projects.

5.6.25 Availability of Reliable Specialist Consultants/External Advisors

Specialist consultants and advisors (experts in domains such as legal, financial, insurance, accounting etc.) may be hired at any stage and by any party for assistance where in-house skills are either short or are not available (Efficiency Unit 2008; European PPP Expertise Centre 2012; Kurniawan 2013; Yescombe 2007). Asenova and Beck (2003) contended that financial risk analysis in PFI projects relies heavily on external advisors but occasionally their lack of experience and/or communication problems led to a lack of satisfaction with the information provided by them. This problem can be more severe in countries with limited experience of private investment in public infrastructure development. With reference to power purchase agreements, ADB (2000) noted that governments often have been at an disadvantage in dealing with the private sector due to their inability to obtain assistance in negotiations by engaging suitable legal, technical and financial experts.

5.6.26 Careful Bid Evaluation by the Public Authority

Experts regard careful bid evaluation by the public sector as essential to ensuring project success. Primarily, careful evaluation of the expression of interest and tenders is necessary to establish the financial and technical capabilities of the consortium along with the level of understanding of the client’s requirements and assess the consortium’s risk management capabilities (Cooper et al. 2005; Hong Kong Institute of Surveyors 2009). According to McDowall (2003) the bidding process in PPP may significantly impact the risk profile and affordability of a PPP project. Whereas, a competitive bidding environment can ensure potential VfM in project delivery, albeit there are uncertainties associated with this competitive process such as potential deliberate underbidding and the need to evaluate VfM and scope of offered variant bids. Objectives in applying the risk assessment to the PPP bid evaluation process include (Cooper et al. 2005): obtaining an initial indication of where the major risks might arise in a project based on assumptions regarding how a project might be conducted, prior to receiving bids or detailed tender evaluation; developing a risk baseline to compare individual tender responses; assisting the project team to focus on potential risk areas in their evaluations of offers; obtaining a risk profile of each submitted tender based on consistent and justifiable basis; and for documenting the project team working regarding assumptions of potential risk areas and reasons for any adjustments to assessments thereof with regards to individual tender responses.

5.6.27 Explicit Risk Pricing in the Bid

Explicit risk pricing in the bid may play a significant role in assisting governments to efficiently decide on appropriate risk transfer in PPPs. Clayton UTZ (2006) contended that the private sector should explicitly and separately price risks in their tenders that they consider unsuitable to be transferred to them. This allows the public sector to evaluate VfM more effectively and to judge whether the bidder's preferred risk allocation is more efficient over the governments suggested risk allocation.

5.6.28 Retaining the Contract Negotiation Personnel for Contract Administration

Over the duration of the project, changes in perceptions of risk and problems associated with loss of corporate memory with changes in the project team that has the knowledge of risk allocation negotiations, is a matter of concern (Loosemore and McCarthy 2008). According to APMG

International (2016c), early involvement of the contract director in government's project management team will provide continuity and experience, which will further enable formulation of a sound PPP contract and a contract management strategy informed by good understanding of project and its risks. Monteiro (2008) while discussing ten recommendations for proper risk management in PPP projects stressed on early appointment of a contract manager, preferably before the end of competitive procurement, in order to allow the contract manager to get acquainted with the draft contract, contract management details and the risk allocation, among other aspects.

5.6.29 Stakeholders' Risk Management Commitment

Stakeholders' risk management commitment is a significant measure for ERM. Jin et al. (2012) operationalized stakeholders' commitment to risk management as attitude to risk, one's perception on ability to manage risks, and the perceived reward for bearing the risk. The research recommended that PPP stakeholders should consider partner's risk management commitment in addition to capability for optimal risk allocation. In addition, commitment to risk management function is also required in a more general sense (Beckers et al. 2013; Schieg 2006), to ensure that requisite efforts are implemented by all the stakeholders.

5.6.30 Learning from Risks

Learning from risks has received much attention within extant literature as an extremely important measure to progressively improve risk management outcomes. Dikmen et al. (2008) contended the view that learning from risks may result in risk management process enhancement and that organizational learning may be facilitated by a corporate risk memory. While supporting continuous improvement through learning from PFI consortium members and capturing project knowledge, respondents in a survey referred to the need for sharing of information on "*legal/contract documents (e.g. legal obligations, risk allocation and management)"* between projects, among other important issues (Carrillo et al. 2008). Robinson et al. (2010) and Virginia Public-Private Partnerships (2015) stressed the importance of "*knowledge transfer*" and "*capturing and feedback lessons learned*", respectively, in order to strengthen the risk management function on PFI/PPP projects. According to Carrillo et al. (2008), all projects require knowledge transfer and that this need is more critical for PFI (and hence PPP) projects. Reasons attributed point to exposure of the parties to a new form of procurement where all the parties are new to the process (this will be more critical for countries just adopting the paradigm and facing a shortage of knowledge), large cost commitments and long service periods. The authors hypothesized that knowledge transfer may help mitigate risks in such projects. Systematic retention of project experiences and systematic documentation of mishaps, mistakes, potential pitfalls enables a project company to deliberate over its projects and document the most effective solutions which helps to reduce project risks (Schindler and Eppler 2003).

5.7 CONCEPTUAL FRAMEWORK FOR EFFECTIVE RISK MANAGEMENT IN PPPs

The factors identified for ERM have implications for project stakeholders; hence, a conceptual framework for enabling ERM on PPP projects has been proposed. It is expected that the application of this framework throughout the PPP project lifecycle will allow the public and private sectors to achieve better risk management outcomes by meticulously planning for the project, selecting partners carefully, and promoting a collaborative working culture, among other significant measures. Observations of these dimensions clearly indicate that the measures of ERM for PPP projects have characteristics of being multi-organizational and exhibit a life-cycle orientation. For example, the experience of the stakeholders and their maturity are aspects that would influence risk management outcomes across the project lifecycle and are also relevant to all the stakeholders involved whether in the public or the private sector. Therefore, in order to provide a structure, the identified measures have been organized based on the lifecycle framework, with project phases as defined by European PPP Expertise Centre (2012), and further indicated in terms of their relevance to the public and/or private party and the relevant risk management processes (Fig. 5.2). For example, the "adequate administration/management of the contract between the public and private sectors (concession agreement)" would assist and ensure proper risk control (see Chapter 4) in terms of the proper execution of the predefined risk allocations during the project implementation phase, and the function itself is relevant to *both parties* to the contract. The mapping of each measure to project life-cycle phases, relevant/responsible stakeholder, and risk planning and/or control processes clearly indicates the significance of each measure from different perspectives, thus enabling better understanding and encouraging parties to exert efforts in the right direction.

It should be noted from the framework that some of the measures only benefit the public sector stakeholder (e.g., careful evaluation of bids) by enhancing risk management outcomes and perhaps protecting and/or improving VfM and other government objectives. There is not a single measure that applies only to the private sector, while most of the measures potentially benefit both the stakeholders. Thus, joint efforts are necessary to ensure the proper implementation of these measures which can help all the stakeholders enhance the overall project value and contribute to success of the project in an all-inclusive manner. Moreover, focused efforts are required from the very beginning of the project's lifecycle, because many of the identified measures are relevant from the beginning of the project related efforts.

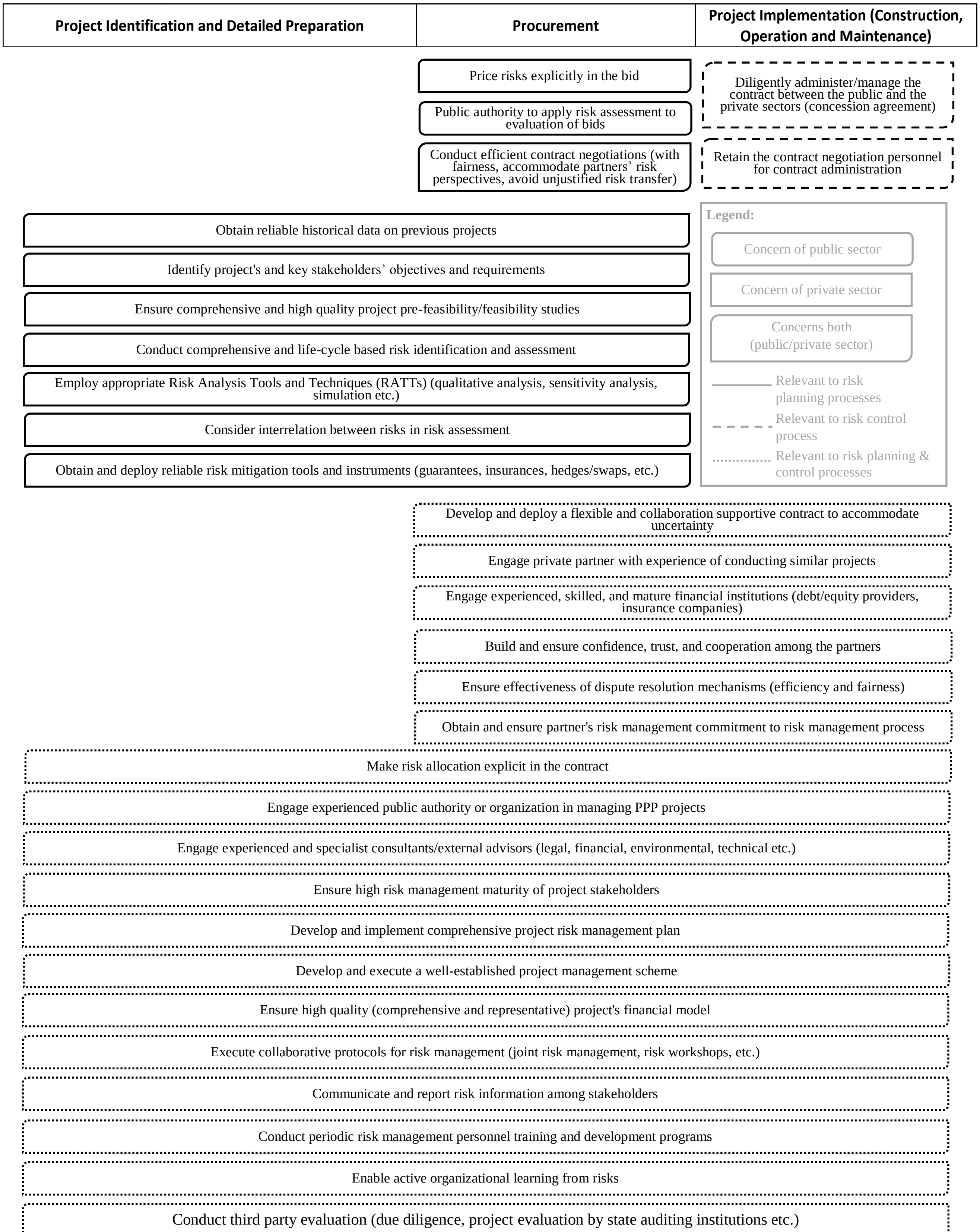

Fig. 5.2. Mapping of measures of effective risk management

5.8 CHAPTER SUMMARY

The review of risk management literature revealed that PPP projects suffer distress and/or failure, which has been identified in some cases to be a result of poor risk management by the stakeholders. This chapter identified the knowledge gap with regards to the ERM in PPPs and delineated a detailed methodology adopted for a comprehensive and meticulous literature review to facilitate the identification of relevant ERM measures. The identified measures were also validated by complementing the literature review with experts' inputs obtained via semi-structured interviews and expert reviews. In total, 30 measures of ERM were identified and discussed in detail to understand their relevance to the subject. The chapter also presented a conceptual framework that classifies the identified measures of ERM based on three categories, which identify the (1) relevant stakeholders that may influence and/or benefit from each measure, thus highlighting the responsibility and/or incentive to implement it; (2) the risk management processes that may be influenced (planning and/or control); and (3) the project life cycle phases where the identified measures have the greatest relevance and significance in terms of potentially improving the outcomes for the project. The classification is intended to provide clarity and to act as a useful guide for the stakeholders. Finally, the deliverables from this chapter facilitated the development of a questionnaire, which was later administered to empirically validate the significance of the identified measures and to determine principal factors that influence ERM on the PPP projects.

CHAPTER 6 RISKS IN INFRASTRUCTURE PPPs[7]

6.1 INTRODUCTION

As mentioned in Chapter 4, the crux of risk management lies in the successful identification of all relevant risks over the lifecycle of the project. Without adequate identification, the subsequent processes of risk management cannot provide any benefit to safeguard the project against unidentified uncertainties. Each stakeholder in a PPP project strives to identify risks that are relevant to achieving their objectives. A critical review conducted by Zhang et al. (2016) of the PPP publications from selected first-tier Chinese and international journals found risk management as one of the most popular research topic, which re-validates the findings in the earlier reviews conducted by Ke et al. (2009b) and Al-Sharif and Kaka (2004). Therefore, interest in this area has remained strong over time. Tang et al. (2010b) reviewed existing PPP research and advocated need to comprehensively identify risks and develop practical and accurate risk assessment models.

Risks are unique to every project and may vary with the infrastructure sector and the country or region under consideration (Ameyaw and Chan 2015b; Carbonara et al. 2015; Indonesia Infrastructure Guarantee Fund 2017). This condition implies that developing a standardized risk inventory may not be representative of every situation, but checklists can be developed as a generic list of risk groups that can be used for identifying risk events for a specific project (Indonesia Infrastructure Guarantee Fund 2017). Risk factors can also be developed at a high level of

Parts of this chapter have been included in:

[7] Mazher, K.M., Chan, A.P.C., Zahoor, H., Khan, M.I. and Ameyaw, E.E. (2018). "Fuzzy integral based risk assessment approach for public-private partnership infrastructure projects." Journal of Construction Engineering and Management, 144(12), 4018111.

definition to ensure they do not exhibit details that characterize a specific sector/project and to still capture and define the uncertainties encountered by the projects. Such an approach is common in academic and institutional literature (APMG International 2016a; Bing et al. 2005; Chan et al. 2011; VDTF 2001). For the purpose of this research, this approach is adopted to develop a list of risk factors for studying risks in PPP infrastructure projects in Pakistan. The resulting list of factors, along with their descriptions, is generic. Thus, this list can be used to examine issues in both the sectors (power and transport infrastructure), from the point of view of determining the project riskiness and risk allocation and sharing details.

The chapter starts with a discussion on the nature of risks relevant to PPP infrastructure projects, followed by a review of various classification schemes adopted in literature for risk categorization. A framework for classification of risks for this research is proposed, and a description of each identified risk factor is presented. Relevant risks are extracted from a comprehensive literature review, discussed with experts in the field and piloted and integrated into a questionnaire for subsequent experts' survey and data collection.

6.2 CLASSIFICATION OF RISKS

This classification refers to grouping of risk factors based on a pre-determined criteria to facilitate understanding of risks, allocation of risks between parties and actions required for management of risks (APMG International 2016a; Bing et al. 2005; Federal Highway Administration 2013; Hong Kong Institute of Surveyors 2009). To overcome the difficulty in finding order in a large list of project risks, the risk register can be structured in a manner that indicates the relationships among the identified risks (Federal Highway Administration 2013). Unstructured lists may result in listing redundant risks, listing risks that occupy different levels of abstraction and creating potential for double counting (ibid.). No standard method of categorization is available (Hong Kong Institute of Surveyors 2009). Various sources have adopted different regimes based on varied logics. To facilitate the coordination and management of risks, risks may be clustered depending on their nature (e.g., financial and technical), numerical attributes (e.g., probability, impact, and low, average and high criticality), and owner (Marle and Vidal 2011). According to Project Management Institute (2013) risks may be categorized by the source of risk, area of project affected or any other useful category (e.g., using the risk breakdown structure, work breakdown structure or project phase) to determine the areas of the project with high exposure to uncertainty. Some levels of overlaps are acceptable when defining categories and events, and some risks may be difficult to assign to one category as multiple underlying causes may be attributable to an outcome (APMG International 2016a). Market risk may manifest as lowered demand of services, which may also be unintentionally caused by a policy change in which case the danger may be regarded as a political risk (ibid.). Some of the existing classifications, as adopted in considerable academic and institutional literature, have been reviewed and are summarized in Table 6.1. The table shows that risks are popularly categorized or classified by the source of their origin. Thus, the risks identified in this research are also classified on the same basis. The risk classification scheme, as defined by Chan et al. (2011), is therefore adopted for this research with slight modifications (Table 6.2).

Systematic/country risks are related to the objective market environment of the host country, over which the project sponsors enjoy little to no control (Chan et al. 2011). However, the project sponsors exercise some control over risks under the specific project risks category (ibid.). This

Table 6.1. Classifications/categorizations of risks adopted in various sources

Author(s)	Risk categories
Wang and Tiong (2000)	Political risks, construction completion risks, operating risks, market and revenue risks, finance risks, legal risks, competition risk (before bid award)
Thomas et al. (2003)	Developmental phase, construction phase, operation phase, project life-cycle
Li and Zou (2011)	Feasibility study or Planning stage, tendering stage, financing stage, design stage, construction stage, operation stage, and transfer stage
Choi et al. (2010)	Legal and regulatory risks, financing risks, water market risks, creditworthiness risks
De Marco and Mangano (2013)	Financial, political/economic, construction, market
Chan et al. (2011)	Systematic risk category: Political risk group, economic risk group, legal risk group, social risk group, natural risk group Specific project risk category: Construction risk group, operation risk group, market risk group, relationship risk group, other risks
UNIDO (1996)	General (or country) risks: Political risks, country commercial risks, country legal risks Specific project risks: Development risks, Construction/ completion risks, Operating risks
UNCITRAL (2001)	Project disruption caused by events outside the control of the parties, project disruption caused by adverse acts of Government (“political risk”), construction and operation risks, commercial risks, exchange rate and other financial risks
*****Xenidis and Angelides (2005a)	Source of origin: State-rooted risks, concessionaire-rooted risks, market-rooted risks Lifecycle phase**:** Sponsor’s preparation for the bid, selection of a bidder, concessionaire formation-contracts signing, implementation, operation/maintenance, transfer
Grimsey and Lewis (2002)	Global risks, elemental risks
Bing et al. (2005)	Macro level risks: political and government policy, macroeconomic, legal, social, natural Meso level risks: project selection, project finance, residual risk, design, construction, operation Micro level: relationship, thirty party
Hodge (2004)	Finance, design and development, construction, operation, ownership
Department of Finance and Administration (2005)	Site risks, design, construction and commissioning risks, sponsor and financial risks, operating risks, market risks, network and interface risks, industrial relations risks, legislative and government policy risks, force majeure risks, asset ownership risks
Karim (2011)	Political, construction, legal, economic, operation, market, project finance, project selection, relationship and natural factor
Xu et al. (2010b)	Macro level risks, meso level risks, micro level risks
Wibowo and Mohamed (2010)	Political, macro-economic, operational, business, land and construction, and force majeure
ADB (2010)	Institutional risks, organizational risks, sector operations risks
Phillips (2008)	Design risk, site risk, construction risk, force majeure risk, revenue risk, O&M risk, performance risk, external risk, other market risk, political risk, default risk, strategic risk
Ameyaw (2015)	Political risks, financial risks, regulatory, legal and contractual risks, market/revenue risks, social risks, technical and operational risks, design and construction risks, relationship risks, water resource issues, natural issues

* Two different schemes of risk classification used in published works

categorical view though convenient but provides a simplistic picture of risk management by the project sponsors, which cannot be translated to an allocation strategy for risks. Consideration of VfM demands that risks be allocated depending on specific country (or market), infrastructure

Table 6.2. Classifications/categorizations of risks adopted in this research

Category	Risk factors
Systematic/ country risks	
Political risk group	Change in government and political opposition; Corruption; Expropriation/nationalization of assets; Government intervention; Political violence/government instability; Poor public decision-making process; Quasi-commercial risk;
Financial risk group	Delay in financial closure; Financing risk; Inflation; Interest rate fluctuation; Insurance risk; Variation in foreign exchange rate and convertibility issues
Legal risk group	Change in law/regulation; Imperfect law and supervision system
Social risk group	Public opposition
Natural risk group	Force majeure; Unforeseen weather/geotechnical conditions
Specific project risks	
Construction risk group	Archaeological discovery/Cultural heritage; Construction risk; Material/labor shortage or non-availability;
Operation risk group	Availability/performance risk; Environmental damage risk; Inability of debt service; Latent defect risk; Operation cost overrun; Payment risk; Pricing and Toll/Tariff review uncertainty; Supply, input or resource risk; Technology risk
Market risk group	Change in market demand; Competition risk; Unfavorable national/international economy
Other risks	Conflicting or imperfect contract; Delay in project approvals and permits; Design & construction deficiencies; Design/Construction/Operation changes; Development risk; Land acquisition; Lack of skilled experts; Lack of supporting infrastructure/utilities; Organization and coordination risk; Planning risk; Procurement risk; Residual asset value on transfer to the government

sector, and project contexts (APMG International 2016a; GI Hub 2016; UNIDO 1996; VDTF 2001; World Bank 2017). Specific risks from the *systematic/country risk* category are considered for sharing with or transferring to the private sector under given circumstances for increasing VfM. The argument also applies the other way around in cases in which some *specific project risks* have to be shared or retained by the public sector. Organization for Economic Co-operation and Development (2008) categorized the inherent PPP risks as endogenous risks (*"risks where the private partner can do something to ensure that the actual outcome approximates to the expected outcome"*) and exogenous risks (risks which the private partner or either party in many cases *"cannot control"*). The PPP certification guide by APMG International (2016a) contends that this categorization for risk allocation purposes may be misleading because the private partner may still be able to influence management of risks in a limited context if not completely. Hence, the analysis above indicates that categorization schemes alone are insufficient to provide complete understanding of risk allocation and sharing. Risk allocation and sharing are discussed in much detail in Chapters 4 and 9.

6.3 IDENTIFICATION OF RISK FACTORS RELEVANT TO PPP INFRASTRUCTURE PROJECTS

In this study, relevant risks for PPP infrastructure projects were identified using two methodologies: literature review and semi-structured interviews. The literature review focused on a systematic and comprehensive review of the published academic and institutional literature to generate a list of relevant risk factors that negatively impact the success of PPP projects. Risks were initially identified through comprehensive review of literature. Risk titles and descriptions extracted and developed from literature were checked for specificity to a particular infrastructure sector. This procedure was conducted to ensure a generic approach that captures the risk concerns of stakeholders across sectors. This approach is commonly used in extant academic and institutional PPP risk management literature (APMG International 2016a; Bing et al. 2005; Chan et al. 2011; VDTF 2001). For comprehensive identification of risks, semi-structured interviews were performed to establish the validity and comprehensiveness of the risk factors collected from the literature review. Finally, a list comprising 45 risk factors was adopted for the questionnaire survey.

6.3.1 Literature Review

A comprehensive literature review was conducted to identify the risk factors relevant to PPP infrastructure projects (Table 6.3). The detailed methodology for the literature review is documented in Chapter 5. After shortlisting journal papers specific to risk management studies in PPPs (from the SCOPUS-based search, Chapter 5), further review and analysis were conducted to filter out studies that specifically focused on risk identification and analysis and allocation. Then, relevant risk factors were collected and consolidated to develop a risk index/register. A total of 15 journal papers were selected for the purpose (Akintoye et al. 1998; Ameyaw and Chan 2015b; Bing et al. 2005; Chan et al. 2011; Chou and Pramudawardhani 2015; Ibrahim et al. 2006; Jin and Zhang 2011; Ng and Loosemore 2007; Özdoganm and Talat Birgönül 2000; Roumboutsos and Anagnostopoulos 2008; Shen et al. 2006; Thomas et al. 2003; Wang et al. 2000c; Wibowo and Mohamed 2010; Xenidis and Angelides 2005a). In addition to the academic literature review, institutional PPP literature (industrial and government guidelines and reports) was consulted to obtain existing risk registers (GoPb 2011; Government of the Netherlands 2002; Phillips 2008; VDTF 2001). The consulted literature was also carefully selected to ensure representation of dev-

Table 6.3. Risk factors identified in PPP projects in existing literature

ID	Risk factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Count
RF_01	Government intervention											x		x	x	x					4
RF_02	Quasi-commercial risk										x	x		x	x	x				x	6
RF_03	Poor public decision-making process						x	x	x					x	x						5
RF_04	Expropriation/nationalization of assets		x	x				x	x		x	x		x	x	x					9
RF_05	Inflation		x	x		x		x	x		x	x		x	x	x	x	x	x	x	14
RF_06	Interest rate fluctuation		x	x				x			x	x		x	x	x	x			x	10
RF_07	Variation in foreign exchange rate and convertibility issues		x	x		x		x						x	x	x		x	x	x	10
RF_08	Financing risk	x			x	x	x	x	x	x			x	x	x	x	x		x		13
RF_09	Delay in financial closure				x							x									2
RF_10	Insurance risk												x							x	2
RF_11	Change in law/regulation	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	19
RF_12	Conflicting or imperfect contract	x		x									x	x	x	x					6
RF_13	Imperfect law and supervision system				x			x						x	x	x					5
RF_14	Competition risk	x		x		x		x				x		x	x		x	x			9
RF_15	Change in market demand	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	18
RF_16	Pricing and Toll/Tariff review uncertainty			x		x		x			x	x		x	x	x					8
RF_17	Unfavorable national/international economy			x		x		x	x				x	x		x	x	x			9
RF_18	Payment risk	x		x								x		x	x	x					6
RF_19	Public opposition							x					x	x	x	x		x			6
RF_20	Availability/performance risk			x												x		x	x	x	5
RF_21	Residual asset value on transfer to the government	x						x	x		x			x	x	x	x	x		x	10
RF_22	Technology risk				x		x	x	x		x			x	x	x	x	x	x		11
RF_23	Operation cost overrun	x	x	x			x	x	x		x	x			x	x	x	x	x	x	14
RF_24	Archaeological discovery/Cultural heritage						x				x						x		x		4
RF_25	Inability of debt service	x		x	x	x		x													5
RF_26	Environmental damage risk	x		x						x							x		x	x	6
RF_27	Land acquisition	x		x	x		x	x	x	x		x		x	x	x	x		x		13
RF_28	Construction risk	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	18

ID	Risk factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Count
RF_29	Material/labor shortage or non-availability			x			x	x	x					x	x			x	x		8
RF_30	Delay in project approvals and permits		x	x	x			x	x		x		x	x	x		x		x		11
RF_31	Design/Construction/Operation changes													x	x				x		3
RF_32	Unforeseen weather/geotechnical conditions			x				x	x	x	x			x	x		x	x	x		10
RF_33	Lack of supporting infrastructure/utilities			x							x		x	x	x	x				x	7
RF_34	Organization and coordination risk						x	x	x				x	x	x						6
RF_35	Force majeure		x	x	x			x	x	x	x	x		x	x	x	x	x	x	x	15
RF_36	Procurement risk															x					
RF_37	Corruption							x						x	x	x					4
RF_38	Latent defect risk			x												x	x		x	x	5
RF_39	Planning risk	x												x		x				x	4
RF_40	Change in government and political opposition						x	x	x						x	x					5
RF_41	Political violence/government instability	x	x	x			x	x	x				x	x		x		x			10
RF_42	Supply, input or resource risk		x	x								x				x	x			x	6
RF_43	Design and construction deficiencies	x			x		x	x	x	x	x			x		x	x	x		x	12

eloped and developing countries. This selection resulted in an initial list comprising 51 risk factors. This risk index, which was derived from the content analysis of the selected studies and reports, enlists 43 identified risk factors (the factors were further reduced in light of experts' input, which is discussed below) along with an indication of the publications that have identified each risk and the frequency of each risk factor depicting the number of times each factor has appeared across the publications. Table 6.4 presents the selected references for the review in detail.

Table 6.4. Source and frequency information for review of risk factor literature

Number	Source	Year	Authors
1	ECAM	1998	Akintoye, A., Taylor, C., and Fitzgerald, E.
2	CME	2000	Özdoganm, I. D., and Talat Birgönül, M.
3	JCEM	2000	Wang, S. Q., Tiong, R. L. K., Ting, S. K., Ashley, D.
4	CME	2003	Thomas, A. V, Kalidindi, S. N., and Ananthanarayanan, K.
5	CME	2007	Xenidis, Y., and Angelides, D.
6	CME	2008	Roumboutsos, A., and Anagnostopoulos, K. P.
7	JFMPC	2006	Ibrahim, A. D., Price, A. D. F., and Dainty, A. R. J.
8	IJPM	2005	Bing, L., Akintoye, A., Edwards, P. J., and Hardcastle, C.
9	IJPM	2006	Shen, L. Y., Platten, A., and Deng, X. P.
10	IJPM	2007	Ng, A., and Loosemore, M.
11	IJPM	2010	Wibowo, A., and Mohamed, S.
12	IJPM	2011	Jin, X. H., and Zhang, G.
13	IJPM	2015	Chou, J. S., and Pramudawardhani, D.
14	JME	2011	Chan, A. P. C., Yeung, J. F. Y., Yu, C. C. P., Wang, S. Q., and Ke, Y.
15	Journal of Facilities Management (JFM)	2015	Ameyaw, E. E., and Chan, A. P. C.
16	Risk allocation and contractual issues	2001	Partnerships Victoria
17	Public private comparator	2002	Government of the Netherlands
18	Matrix of risks distribution - Roads	2008	Robert Phillips - PPPIRC
19	Risk management manual for public-private partnerships in infrastructure	2011	Planning and Development Department, Govt. of Punjab

6.3.2 Semi-structured Interviews

As explained in Chapter 2, eight semi-structured interviews were conducted with experts from the public and private sectors in the power and transport infrastructure domains in Pakistan. The experts were asked to specify risk factors that they thought were relevant to the Pakistani context (Appendix A). Most of the identified risk factors were consistent with those obtained from the literature review. The experts (five out of eight) were also requested to render their opinion on the initial risk factor list obtained from the literature review. Multiple comments were received. Finally, some factors from the overall input of the experts were merged due to similar meanings, whereas two new risk factors were added. Some of the received comments identified factors to be less significant in the Pakistani context; hence, these factors were removed. All the suggested changes were accommodated to ensure comprehensive coverage of the most relevant risk factors (Table 6.5). This process resulted in a final list comprising 45 factors for the research.

Table 6.5. Modifications to the risk factors based on local experts' opinions

Risk factors added	Insignificant risk Factors	Risk factors merged
Lack of skilled experts (technical, financial, legal, etc.)	Default and termination (of the project company)	Change in law/regulation
		Environment risk (Change/Amendments in regulations)
		Change in tax regulation
Development risk	Insufficient financial audit (of the project company)	Design/Construction/Operation changes by the public sector
		Design/Construction/Operation change by the private Sector
	Political discontent and early termination	Resettlement and rehabilitation risk
	Third-party delay/violation/default	Land acquisition

6.4 RISK FACTORS

The discussion below describes the risk factors adopted for this research.

6.4.1 Systematic/ Country Risks

6.4.1.1 Political Risk Group

6.4.1.1.1 Change in Government and Political Opposition

This risk refers to political opposition against existing projects from new governments that are elected from time to time. Some governments are ideologically opposed to the concept of PPPs (Estache et al. 2009), whereas new governments may attack previously signed contracts (by the previous ruling party) to impress their constituents (Tam 1999). This situation may be more relevant to developing countries where it may be more common for the governments to change frequently (ibid.). Lack of political support can be problematic for the project company as it is an essential element for a successful PPP project (Yescombe 2007). Government-initiated renegotiations took place in case of IPPs in Indonesia, Pakistan, the Philippines, and Thailand; in these IPPs, the Pakistan's case was further elaborated as renegotiations due to change in government that questioned the procurements under the previous government (Reside 2009).

6.4.1.1.2 Corruption

Corruption in government procurement is a common problem in developing and developed countries; however, the problem is more serious in the former rather than in the latter (Raymond 2008). Iossa and Martimort (2014) suggested that public institutions can be corrupt while harboring corruption at different levels of the chain of command. A review by the authors recognized the prevalence of corruption in PPPs. The authors further emphasized that incomplete contracting may favor corruption (and vice versa) due to high risk premium and that incomplete contracting can be strategically favored by non-benevolent authorities. Corruption refers to the acts of the representatives and officials of the government of soliciting or receiving unlawful consideration or commission or exerting or utilizing any unlawful influence to affect the awarding and agreement of the project to the developer (Wang et al. 2000c). Corruption can also adversely affect the private sector (Ke et al. 2011). Government cooperation and assistance are keys to the success of any PPP project in a developing country, such as China; however, this cooperation and assistance can be too costly for the investors in some cases due to bribery of some local government officials (ibid.). Negative effects on profits and the operation and management efficiency of the companies due to the time and cost spent in maintaining relationships with some government officers have also been reported. In addition to risk of uncertain expenses with regard to corrupt officials, the project developer runs the risk of government agency turning against it and the project (Macdonald 1997). Cobârzan and Hamlin (2005) discussed various forms of corruption related to public and private sectors, such as public officials demanding a bribe to issue various authorizations or private firms opting to bribe officials to quickly obtain authorizations, corruption related to land asset by bribing the local councilors (influence the cost [reduction] of land in a development project or decisions related to particular use of private land, etc.), firms employing different forms of corruption to obtain discretionary government incentives (subsidies, tax incentives, low interest rate credits and free lease) for driving down costs, private companies making false statements and overcharging the government in connection with products or services delivered and delivering inferior products to the government, conflict of interest (pecuniary or non-pecuniary interests held by civil servants and local councilors in any contract or proposed contract with the Council) and private companies paying off officials to obtain procurement or a concession contract or to influence other aspects of the project for their own benefits, etc. Corruption erodes expected gains (for the stakeholders) from the PPPs and burdens the consumers through increased tariffs (or pricing) and low-quality service (Ameyaw and Chan 2015b).

6.4.1.1.3 Expropriation/Nationalization of Assets

Wang et al. (2000c) defined expropriation risk as the event when the government expropriates a project without adequate compensation to the private party. This risk can be a case of nationalization of a facility wholesale (which is rare) or via creeping expropriation (common). In creeping expropriation, the government gradually takes over the facility and its operating profits by creating an environment through passing certain laws and regulations after project completion (ibid.). Expropriation of property by a sovereign government within its territory for public purposes is a right that is recognized by the basic principles of international law (Delmon 2009); however, governments do not enjoy an unqualified right to expropriate or nationalize assets, and appropriate compensation should be provided in the event the initiative is undertaken (Irwin et al. 1997).

6.4.1.1.4 Government Intervention

Government intervention occurs when the government interferes with the independent management activities of the private party and/or the activities of the regulator and violates contract provisions, thereby undermining service provision (Ke et al. 2011; Organization for Economic Cooperation and Development 2009). This interference may occur during constriction and/or the operation period of the project and potentially result in late changes in design, construction delays, low operational efficiencies, etc. (Ke et al. 2011). In some countries, government interests result in unfavorable interference with the concessionaire’s plans, which causes cooperation issues such as in the case in which rules that prescribe tendering and similar procedures for subcontract awards may direct hiring of subcontractors by the concessionaire

(Xenidis and Angelides 2005b). Despite possible reservations, a concessionaire being pressured by a government to partner with a local subcontractor is another form of interference (ibid.).

6.4.1.1.5 Political Violence/Government Instability

Irwin et al. (1997) examined a government's deliberate policy actions or inability of the government to maintain law and order in the country. Events stemming from political violence (e.g., war, revolution, insurrection, civil strife, terrorism and sabotage), political and social convulsions, political situation with strong opposition to governmental policies, frequent elections, coups and unsteady governments, can be dangerous to an investment's profitable operation (Irwin et al. 1997; Xenidis and Angelides 2005b). Ameyaw (2015) summarized several possible negative outcomes/influences, including lack of participation of good firms in project bidding, sponsor's discouragement and renegotiation of contracts and planned investments triggered by fear of loss of investments, expensive guarantees and clauses to obtain private investment and cancellation of operating contracts and accompanying costs (Ameyaw et al. 2015; Guasch 2004; MIGA 2009).

6.4.1.1.6 Poor Public Decision-making Process

This risk refers to several underlying reasons that may result in poor decision making and thus poor outcomes for the public. Sasch et al. (2007) reported that in China, decisions made by some local government officials are against the central government's policies, the interest of the public or long-term goals, which often lead to the failure of PPP projects. Projects that come about under such circumstances may be liquidated when key officials of the government or laws and policies change (ibid.). Focus on short-term goals, career achievement and personal interest of the local government officials have been cited as the possible reasons for such decisions. Lack of knowledge and/or experience of the local governments or public officials in managing PPPs (Ameyaw and Chan 2015b; Sasch et al. 2007) may be another underlying reason. Lack of experience also implies an inability of the government to negotiate guarantees and agreements with international lenders and private multinational firms, respectively (ADB 2000), which may lead to poor relations, extended negotiations and coordination and project implementation problems (Ameyaw 2015). Long negotiations and high transaction costs may result from a poor decision-making process (Li et al. 2005). Non-standardized procedures, bureaucracy and insufficient preparation and information asymmetry have been cited as other possible reasons for poor public decision making (Chan et al. 2011).

6.4.1.1.7 Quasi-commercial Risk

Governments interacting with the private infrastructure firms either directly or through some government-owned enterprise may act as their suppliers or customers (Irwin et al. 1997). In some arrangements, such as in the case of independent power projects, e.g., government-owned enterprises may be the sole supplier/consumer by supplying the fuel and purchasing the produced power. The risk reflects uncertainty over the willingness or capacity of the governments or government-owned enterprises to meet their contractual obligations as suppliers or purchasers of the inputs and services in terms of deliberate action, direct political interference or poor creditworthiness (Irwin et al. 1997). Sachs et al. (2007) argued that the lack of experience and knowledge of the PPP mode of transaction (with reference to Chinese PPP projects) or focus on short-term goals may cause the local governments to render unrealistic guarantees and supports to attract foreign investment. The contract is breached when the local governments are unable or unwilling to honor their obligations. This situation has implications for the private investors as for various reasons, it is difficult to obtain compensation. The private investors also cannot earn sufficient return on investment or even pay off debt in some cases (ibid.).

6.4.1.2 Financial Risk Group

6.4.1.2.1 Delay in Financial Closure

Another risk that is directly related to financing is the delay in financial closure. A failure in timely arrangement of finance for the project (debt and equity) leads to this risk (Thomas et al. 2003). Financial closure occurs when all the conditions of the lenders have been met and the loan facilities have been arranged (Wang et al. 2000a). Several reasons for this effect include disagreement over conditions of the concession agreement, inadequate guarantees from the government, delay in debt syndication and failure of the project company to raise the necessary equity in time (Thomas et al. 2003). Considerable delays between appointment of the preferred bidder and financial closure are undesirable because they increase project costs and service fees (Yescombe 2007).

6.4.1.2.2 Financing Risk

This risk refers to multiple problems, including lack of investors' interest (particularly for developing countries due to high risks and/or low profitability and immature financial market), uncertainty in continuous support by project financiers (debt and equity providers) and problems with the project's financial structure that may not be robust to ensure continuing viability of the project (Ameyaw 2015; Grimsey and Lewis 2004). Lack of private funds, stock markets immaturity and insufficient structure, etc. are some of the issues pertinent to raising domestic finance in weak economies (Xenidis and Angelides 2005a). The main concerns of the government in a privatized infrastructure project are addressed with a suitable capital structure and long-term commitment of project participants. These concerns include completion of construction within time and cost budgets, low total project lifecycle cost, reliable operation and performance and affordability of service and products of the project for the public (Zhang 2005b). The factors that affect total project cost and its financial viability are as follows (Zhang 2005b): the mix and relative amounts of equity, debt and other financial instruments; the source; and contractual conditions on these financial instruments.

6.4.1.2.3 Inflation

Inflation risk may result in potential damage to real returns of the private investor and pose a threat to debt serviceability. As a result, the interests of the sponsoring banks are also affected. Proper analysis of the impact of inflation on economic margin and cash flows is a key challenge (Moro Visconti 2011). Constriction and operational costs of the project can be seriously impacted by the effects of inflation. Covering the risk of inflation from lenders' perspective is important due to several reasons, including (Mandri-Perrott and Menzies 2010) reducing lenders' financial exposure and maintaining project cover ratios and the anticipated net benefits from the revenue stream.

6.4.1.2.4 Interest Rate Fluctuation

Changes to the underlying level of interest rates, which reflect movements in the lending indicator (e.g., London Inter-Bank Offer Rate(LIBOR)) and the margin over the indicator rate, affect borrowing costs, which gives rise to interest rate risk (Partnerships Victoria 2005). Given the usually large sums borrowed and the long duration of the infrastructure projects, this risk can be significant, and the project company may have to bear additional financing costs (if the interest rates rise) (UNCITRAL 2001). Long-term loans are quoted in relation to a floating interest rate that changes as time progresses (Mandri-Perrott and Menzies 2010; Yescombe 2007). The delivery of service under the PPP contract may be threatened in case the project company has a high leverage. Hence, exposure of the project company to changes in interest rates is not the primary pursuit of the public authority and the lenders or investors (Yescombe 2007).

6.4.1.2.5 Insurance Risk

The project owner and the lender will typically require the project company to carry a comprehensive insurance program during the operation and maintenance (O&M) phase of a PPP project; this requirement aims to shield the O&M operator against potential damages and the ensuing claims in relation to its responsibilities (AON 2015). This process requires that the bidders assess the risk of O&M activities and estimate the price of the requisite insurance program for the entire concession duration. The O&M insurance is renewed annually, and the cost is susceptible to market fluctuations; therefore, any miscalculations may cause losses for the project company (ibid.). The insurance for certain risks may become unavailable or available on unfavorable terms (Nwangwu 2016; VDTF 2001; Yescombe 2007). PPP project agreements usually contain the so-called "insurance benchmarking provision," which allows the project owner and company to share the risk of unexpected insurance premium fluctuations during the O&M phase (Nwangwu 2016). However, owing to the thresholds, in majority of the cases the cost sharing will not occur leaving the risk of fluctuation of premiums with the project company which has no control over the general insurance market fluctuations (AON 2015). Insurance premiums have increased recently, and some old project companies have suffered due to premiums much higher than expected (Yescombe 2007). One of the single largest cost risk that a project company may be exposed to after passing down the other risks to the subcontractors, is the insurance premium (ibid.).

6.4.1.2.6 Variation in Foreign Exchange Rate and Convertibility Issues

This risk can be significant in developing countries due to the instability of the exchange rates or economic transition in some countries (UNCITRAL 2001). Exchange values of the project cash flows may be vulnerable to changes in foreign exchange rates. This vulnerability is an issue when the cost of purchase of fuel or equipment and the payment of loan may be denominated in foreign currency, whereas local currency may be used in charging the price/fee from the customers (ibid.). Other risks that may limit the ability of the project company to make payments or service its debts include active or passive regulatory measures such as foreign exchange control or lowering of foreign exchange reserves, respectively (Irwin et al. 1997; UNCITRAL 2001).

6.4.1.3 Legal Risk Group

6.4.1.3.1 Change in law/regulation

Post contract changes in legal or regulatory regimes may have a negative material impact on the project. Such changes may include change in government policies with respect to laws and regulations, rates and methods of taxation, currency conversion and repatriation limitations, methods for tariff setting/approval, methods to address inflation, labor regulations, corporate regulations, requiring new licenses or changing the concession deed, changes in legislation for environmental requirements, nationalization of developed assets, import and export prohibitions, deprivation of the developer's rights (Arndt 2000; Lee and Schaufelberger 2013; Mandri-Perrott and Menzies 2010; Wang et al. 2000c), and other similar instances. Events of the nature specified above may result in additional costs to the project company and call for renegotiation of pricing levels to recover these costs. However, the contracts may be insufficiently flexible to accommodate or allow timely adjustments (UNEP 2006).

6.4.1.3.2 Imperfect Law and Supervision System

Prioritization of the process of development, procurement and review of PPP projects and establishment of a clear institutional framework for development, procurement and implementation of PPPs encourage a government to enact PPP laws (World Bank 2016c). In addition, these laws can be provided to cover inadequacies in the laws of the host country to enable successful PPP projects. Specific regulations allow the government to regulate a sector or business for protecting the rights and interests of consumers and investors, monitoring the performance of service providers and reducing information asymmetry and other interests (e.g., the environment, service standards, consumer services and asset maintenance and replacement) (World Bank 2016d).

Effective legal framework and good regulation are essential to develop an environment that provides confidence for private investment in infrastructure (UNEP 2006; Xenidis and Angelides 2005b). An enabling policy, regulatory and legal environment is essential to the sustainability of PPPs to minimize the incidence of corruption, should be reliable to promote and encourage private participation and investment and should instill confidence in investors that the laws and contracts will be respected and are enforceable in courts or arbitration if necessary (ADB 2008). The constitutional, legislative and institutional BOT (hence, PPP) project implementation framework should integrate seamlessly with the overall legal framework of a country and ensure the long-term sustainability of and transparency and fairness in projects (Xenidis and Angelides 2005b). Lack of provisions or a large number of laws regarding project issues, lack of clarity of liabilities and inadequate penalties and the similar, increase risks by creating an inadequate and complex legal framework; as a result, potential developers refrain from committing to projects; ultimately, the project success is inhibited (ibid.).

6.4.1.4 Social Risk Group

6.4.1.4.1 Public Opposition

Infrastructure projects are prone to provoking vociferous protests among local communities, which can be disastrous to the private concessions. The Lyon Périphérique Nord concession, A2 Motorway through greater Warsaw in Poland, and Vasco da Gama Bridge concession in Lisbon are some of the examples from Europe, where public opposition risk has been activated and lead to concession cancellation (due to high tolls), routing concerns and public protests (due to toll increases), respectively (European Commission 2003). Another example of Newbury Bypass has also been discussed for public acceptance, during which a single protestor stopped the construction single handedly for five days. A project’s construction may be slowed down due to public resistance to the project or may even lead to project abandonment (Rebeiz 2012). The M1/M15 motorway concession in Hungary has been subject to hidden protectionism (public/political skepticism against foreign investors who are from a more developed country and possess the potential to earn good profit on their investment) with poor repercussions for the project (ibid.).

Stakeholder (public) opposition has been reported as a main cause of PPP project failures (El-Gohary et al. 2006). World Economic Forum (2010) indicated that resistance by end users and other stakeholders to PPP projects occurs frequently in projects in which individuals are expected to be charged directly for services, such as in highways and water facilities (El-Gohary et al. 2006). Public opposition due to concerns regarding negative impacts of large projects on environment, public health and safety can delay construction and cause operation problems in a BOT project; as a result, the viability and profitability of the project is negatively affected (Xenidis and Angelides 2005b).

6.4.1.5 Natural Risk Group

6.4.1.5.1 Force Majeure

Certain events are beyond the control of project parties and may inhibit the ability of the parties to perform as per their obligations under the contract (World Bank 2016e); such events constitute the force majeure risk. This risk is related to exogenous factors that are unrelated to the performance of the private partner and include unforeseen natural and man-made events, such as fires, floods, storms, earthquakes, wars, hostilities, embargoes and import and export restrictions (APMG International 2016a; Wang et al. 2000c). Naturally, force majeure events are risk events that are very difficult to assess in terms of their likelihood and are impossible to assess in terms of impact (APMG International 2016a). Such events may be insurable or uninsurable and may expose a project to considerable stress (Ameyaw 2015).

6.4.1.5.2 Unforeseen Weather/Geotechnical Conditions

This risk is specific to the site and project characteristics. Castro-Nova (2016) identified various geotechnical factors/risks for transportation projects, such as groundwater/water table; soft clays, organic silts, or peat; highly compressive soils; rock faults/fragmentation; chemically reactive ground; contaminated material; slope instability; seismic risk; lateral spreading; liquefaction; settlement in general; settlement of bridge approaches; subsidence (subsurface voids); and landslides. Yescombe (2007) expounded ground condition risks and contented that it is the risk that geology of the site is not as expected, or characteristics related to past usage of the site (e.g., underground mining) may cause issues (i.e., design and construction problems). Ground condition risk will be significant for liner (e.g., roads) projects, brown-field sites, and sites with in-adequate access to conduct surveys (Yescombe 2007). Even with the possibility to conduct surveys, 100% certainty about ground conditions is not achievable (ibid.). Unexpected variations in weather patterns can cause considerable damage and delays to the projects as well.

6.4.2 Specific Project Risks

6.4.2.1 Construction Risk Group

6.4.2.1.1 Archaeological Discovery/Cultural Heritage

Discovery of fossils, archeological and cultural heritage or objects and structures of historical relevance at the project site may severely delay a project or even require revision of construction plans (Yescombe 2007). For specific locations with high exposure to such risks, the public authority may conduct surveys prior to the financial closure of the project. The project company may have to carry the risk of delay to a certain level, and any disruptions due to such findings will constitute a relief event under the PPP contract and construction subcontract (ibid.).

6.4.2.1.2 Construction Risk

While delays in completion can impact the generation of revenues from the completed project, cost overruns decrease profitability by increasing construction and financing costs (Lee and Schaufelberger 2013). Cost overruns in a PPP project may occur as a result of inefficient management of concessionaires or external uncontrollable factors (Mandri-Perrott and Menzies 2010; Xenidis and Angelides 2005a). Capital construction cost is a key factor that determines the financing of the project, and cost overruns can jeopardize the financial feasibility of the concession (European Commission 2003). Project management, financial planning and real economic cost of construction may be considerably affected by errors in forecasting (Mandri-Perrott and Menzies 2010). In addition, unexpected inflation and escalation in construction costs may lead to potential overruns. HM Treasury (2007) indicated that bias in the capital cost estimates is related to project planning and implementation. These factors include poor business cases characterized by inadequate project scope and objective definition and problems in the project's implementation phase due to insufficient management of the project (lack of cost control and failure to implement the planned risk mitigation instruments). Construction delays can also have detrimental effects on project costs (European Commission 2003). Sources of delay in construction can include adverse weather, change of mind of authorities, strikes and timely delivery of the right of way (European Commission 2003; Hardcastle and Boothroyd 2003). Construction risk is mostly assigned to the private party while also incentivizing them to complete the works on time (European Commission 2003).

6.4.2.1.3 Material/Labor Shortage or Non-availability

This risk is a result of lack of resource availability. Another contributing factor may be the failure of the subcontractors and suppliers to perform or lack of willingness to commit to a long-term responsibility as required in a PPP project (Li 2003). The risk will potentially result in project delays and/or increase in costs.

6.4.2.2 Operation Risk Group

6.4.2.2.1 Availability/Performance Risk

This risk directly relates to the ability of the project company to perform as per the requirements of the contract. Normally, two types of risks exist for which the project company is penalized in the event of their materialization. One is “availability risk” which is limited to failures that remarkably impact the ability of the client to use the facility (McDowall 2003). Critical failures to provide as per the true specification of the PPP contract qualify for unavailability deductions/penalties, while service quality covers all other failures under the PPP contract (Yescombe 2007), which is the second type of risk (“performance risk”). Performance during operations is measured using methods and tools described in project documents that specify performance standards for every O&M activity to ensure quality of the offered product or service and compliance with agreements. Inability to meet these standards may result in fines/penalties, reduction in demand for the product or service consequential loss in earnings, ensuing demotivation of sponsors for further investment, and legal implications between the partners or stakeholders with additional costs for resolving disputes (Xenidis and Angelides 2005a).

6.4.2.2.2 Environment Damage Risk

Impact on the environment (e.g., noise, excessive vibration, air pollution, aquifer pollution, wildlife threat, and deforestation) may be caused as a result of construction and/or operation activities of the project (Hardcastle and Boothroyd 2003; World Bank 2018d; Yescombe 2007). For certain pre-existing conditions or special compliance waivers, the public authority may retain the responsibility for such issues (Mandri-Perrott and Menzies 2010). Any unforeseen environmental issues may become a considerable liability for the project company and result in increased capital costs and serious delays (European Commission 2003).

6.4.2.2.3 Inability of Debt Service

Many factors influence the concessionaire's ability to generate sufficient revenue and honor its debt obligations, including the realization of forecasted demand and its growth, financial structuring, terms of debt agreements and promoter capability and escrow management (Thomas et al. 2003). The debt servicing ability of a concessionaire is principally related to the profit generated during operations (Xenidis and Angelides 2005a). A concessionaire encounters hindrance in meeting financial commitments to the shareholders and lenders on a commercially unsuccessful project; this situation causes claims and liabilities and may negatively affect the viability of the project (ibid.).

6.4.2.2.4 Latent Defect Risk

This risk is specific to brownfield projects and refers to unforeseen conditions that only become apparent after the signing of the agreement (financial close) and render reconstruction/refurbishment/maintenance work more expensive than what could have been reasonably anticipated (Yescombe 2007). Completion of detailed and well documented inspections of the facilities to be transferred before formalization of the concession contracts can minimize the risk of encountering unpleasant surprises (European Commission 2003).

6.4.2.2.5 Operation Cost Overrun

Operating risk refers to an increase in the operating cost of a facility as opposed to the initial projections, thereby diminishing the projected returns; consequently, the facility will not perform to the required standards (Grimsey and Lewis 2004). The risk may be related to procedures adopted for production and operation, quality and efficiency of project management, requirements for maintenance and upgrade, availability and quality of the inputs (Grimsey and Lewis 2004), inaccurate estimates and host country's poor economic conditions with corresponding increase in production costs (Xenidis and Angelides 2005a). This risk is probably the most difficult risk to predict, and the largest part of the operating costs are likely to be attributable to maintenance costs (Yescombe 2007).

6.4.2.2.6 Payment Risk

This risk refers to the unwillingness or inability of the consumer or the government to pay for the services delivered under the contract. This risk under "user pays" model is attributed to various factors, such as users' willingness to pay (e.g., if a previously untolled road is subject to tolls without clear new benefits for drivers) and reasonableness (affordability) of toll level as perceived by users (Yescombe 2007). For projects of PFI model (payment models based on shadow toll or availability), the credit issue is about the ability of the public authority to pay, especially when the authority is not a department of the central government. A sub-sovereign government entity (regional or local government entity, such as municipality) may have limitations of legal capacity and credit-risk issues unlike the central government (ibid.). The inability may also arise as a result of political issues or change in economic conditions with corresponding effect on public sector revenues (Federal Highway Administration 2012).

6.4.2.2.7 Pricing and Toll/Tariff Review Uncertainty

Achieving proper pricing for a product (or service) with precision for the prediction of its future value requires accurate calculation of potential demand/revenue ratio over the life of a project, which in turn affects the development of the pricing strategy that is in line with the provisions of the regulatory system in effect in the host country (Xenidis and Angelides 2005a). Data required for this process are either available from the host government or obtained from concessionaires' knowledge regarding the market of the host country. Inaccurate application of data or methods for estimation of the demand/revenue ratio, unreliable data for estimation of demand/revenue ratio, unforeseen future changes, and implementation of an inflexible fee scheme may result in an inadequate pricing policy (ibid.). Hence, determining adequate pricing is in itself challenging.

With various risks that threaten to influence the revenues (e.g., variations in inflation, input costs and legal regulations), payment adjustment should be allowed in the PPP agreements to ensure that the developer earns a reasonable rate of return and maintain the incentives (Mandri-Perrott and Menzies 2010). Wang et al. (2000a) contended that the tariff formulas for power projects in China are developed after the consensus of the officials from the public and the private sectors, and annual tariff reviews are conducted to adjust the pricing in accordance with the agreed formulas. However, re-negotiation and subsequent changes of the formulas are possible. This possibility therefore poses a risk to the private sector in terms of the adjustments being insufficient to offset the increased costs due to various reasons such as those described above. Pricing of infrastructure services is also influenced by social and political dimensions (Irwin et al. 1997), and timely adjustments may be retarded due to government interference (Ameyaw 2015).

6.4.2.2.8 Supply, Input or Resource Risk

PPP projects that provide an output or refine or process raw materials need critical inputs in some form to operate (Delmon 2009). Depending on the nature of the projects, such critical inputs may include fuel/coal/gas for thermal power plants, raw materials or electricity for industrial plants, or raw water for water treatment projects. This risk is less common in projects that provide a facility, such as a hospital or a highway. The risk occurs when the critical input is unavailable when needed or available at a price that is not conversant with the project's financial model. Issues related to quality of the input are also a concern. The necessary input can also be supplied by the grantor and/or offtake purchaser in which case, the provision for the input supply may be included in the concession or off take purchase agreement (ibid.).

6.4.2.2.9 Technology Risk

Technology risk implies the possibility of failure to deliver or meet the required output specification based on the technology inputs, or it may refer to obsolescence risk wherein technology inputs may be rendered out of date due to improvements in the technology (National

Treasury 2004). The risk results may manifest as high operation and maintenance cost, low levels of service and frequent facility breakdowns (Ameyaw 2015). This risk is common in information technology, in which the technology underpinning a certain service can become obsolete (Hardcastle and Boothroyd 2003). As a result, cessation of demand for services is possible.

6.4.2.3 Market Risk Group

6.4.2.3.1 Change in Market Demand

It is one of the most significant risk in determining the financial viability of the project and should be confronted adequately. The demand for the use of the product or services offered by a BOT (hence, PPP) project is not guaranteed (Xenidis and Angelides 2005a) and may be influenced by several parameters, including the economic environment (Federal Highway Administration 2012; Thomas et al. 2003; Xenidis and Angelides 2005a), connectivity, linked infrastructure and parallel facility, initial traffic projections (for road projects) (Federal Highway Administration 2012; Thomas et al. 2003), tariff/pricing (Federal Highway Administration 2012; Lee and Schaufelberger 2013; Thomas et al. 2003), reliability of historic information on demand and pricing, and unforeseen future events (European Commission 2003; Xenidis and Angelides 2005a). Subsidized pricing in the past may complicate this problem even further. The risk can negatively impact a project’s cash flow and thus the ability of the concessionaire to make debt payments and generate adequate equity returns (Federal Highway Administration 2012).

6.4.2.3.2 Competition Risk

Infrastructure projects delivered under the PPP scheme usually serve the public individually or as a part of an infrastructure network (Xenidis and Angelides 2005a). Competing facilities (existing or planned and new) present revenue risk for toll-based PPP projects (Federal Highway Administration 2012). The effect of public sector policies needs to be considered for projects that involve usage risk (Yescombe 2007). Changes to certain policies that are local to a project, termed as “network risk,” include imposing or removing tolls or other road-usage fees, changes in the layout of local road, traffic being taken from a toll road due to construction of other roads, or traffic management. Defining all network risks in advance is difficult. Some PPP agreements include a “non-competing” clause whereby the authority agrees either to not allow for competing facilities or to compensate for negative impacts on revenue of the PPP project in case a new competing facility is built (Federal Highway Administration 2012; Yescombe 2007).

6.4.2.3.3 Unfavorable National/International Economy

National economy plays a vital role because many external risks encountered by a project are a direct corollary of the overall state of the economy. Viability of a project may be affected in an weak economy with underdeveloped stock market and structural deficiencies (Xenidis and Angelides 2005a). Several problems may arise, such as government default on the guarantees, low service demand and financing issues. In the current global economic integration, shocks to the international economies may not be geographically limited and may negatively impact a PPP project (ibid.). Burger et al. (2009) studied the impact of the global financial crisis on PPPs and contended that it was particularly affecting the PPP projects in pipeline in terms of cost and access to finance.

6.4.2.4 Other Risks

6.4.2.4.1 Conflicting or Imperfect Contract

Well-managed and well-designed contracts are the key mechanism by which risks are allocated and controlled between the public and the private sectors (Boussabaine 2013). Contractual design also influences the incentives and penalties for the delivery and management of the contractual services. In addition, the notion of value for money largely depends on the precise terms and conditions of the contract and the planning, management, awarding and implementation of the contract over the life of the project (ibid). Assignment of risk in a contract is common among the number of difficulties involved in contract design (Crampes and Estache 1998). Failure of the private sector participation is primarily due to imperfect allocation of risks (Marques and Berg 2010).

Xenidis and Angelides (2005b) articulated that contract interpretation and enforcement issues and inconsistencies are attributable to non-explicit contract clauses or requirements and complexity, respectively. Project completion delay, claims and disputes between the parties and potential operation postponement for a long period are due to vague or inconsistent clauses or specifications or inaccurate phrasing in the contract. Another aspect is the need to ensure compatibility and complete integration of various contractual arrangements among the involved project parties and aversion of complexity and confusion about responsibilities due to varying contractual forms (ibid.).

6.4.2.4.2 Delay in Project Approvals and Permits

Public authorities conduct several checks and inspections and issue permits, approvals, authorizations and licenses throughout the lifecycle of a BOT project (Xenidis and Angelides 2005b). Reasons that hinder cooperation between public agencies and hesitation of low ranking officials to facilitate the process by undertaking responsibilities or initiatives cause delays in obtaining and renewing approvals; as a result, issues in project completion and operation and generating additional costs arise (ibid.). The delay in timely provision of various approvals from central and local government authorities on project-related issues may be due to that the government either does not approve the project related issues on time or cancels the pre-approved ones (Wang et al. 2000c). Licensing, permit and certification requirements vary with the size and scope of private sponsor and activities of project company in relation to individual PPP project; the project company will need to obtain permits and licenses necessary to perform design and constriction works and operate the facility (Delmon and Delmon 2010). Acquiring planning permits is a common reason leading to delays in financial closure of PPP projects. In some cases, the public authority may obtain the planning permits before the bidding phase of the project. However, this case is not always feasible, especially when bidders are offering different solutions to output specifications; consequently, more permits may be needed later when detailed designs become available. This situation may pose a risk of construction cost increase to the construction subcontractor due to potential design changes after financial closure (Yescombe 2007).

6.4.2.4.3 Design and Construction Deficiencies

Design and construction deficiencies may be attributed to the incompetency of the parties with the prime responsibility to design and construct the project (Ameyaw 2015). Flaws in design work can negatively impact the project in the construction and/or operation phase, thereby potentially leading to delays, cost overruns and environmental and safety issues (Federal Highway Administration 2012). Deficiencies in construction can result in an underperforming facility and manifest as a failure to achieve the performance specifications (Ameyaw 2015).

6.4.2.4.4 Design/Construction/Operation Changes

Design changes or variations can increase the direct cost and time of the project and may disrupt the construction works; ultimately, additional cost and time overruns are incurred (Li 2003). The likelihood of changes to the scope initiated by either the government or private partner is high during the construction phase because the best method of achieving the output specifications in the context of actual conditions becomes apparent (APMG International 2016c). Changes may be initiated via external factors, such as a change in law/policy/regulation governing the project or a change in requirements (variations to the output specifications) of the government that are not foreseen or quantifiable at the commencement of the contract (APMG International 2016c; Chan et al. 2011). Changes may also be initiated by the private partner due to various reasons, including improper design or poor planning (Chan et al. 2011; Ke et al. 2011). APMG International (2016c) mentioned that changes initiated by the private partner may be considerable, and majority of the changes should be to the means by which output specification is achieved and this should be at the cost and risk of the private partner. The government has interest in reviewing the proposed changes to ensure adequacy in terms of meeting the specified needs because the asset ownership is mostly retained by the government, and it has an interest from the perspective of post transfer asset operability (ibid.).

6.4.2.4.5 Development Risk

In this study, this risk refers to the changes in government policies that disturb projects in the pipeline and possibly amounting to scrapped projects. This risk results in loss of project development costs by the potential private investors. This risk has been identified in the interviews conducted with experts in Pakistan, which referred to a recent decision of the federal government to not entertain any more power projects based on imported fuel. This decision had led to problems with one province's commitments where several projects were already being developed/processed for subsequent approval by the federal government. This problem refers to lack of coordination between the provincial and central government; however, the end result is loss of effort, time and money.

6.4.2.4.6 Land Acquisition

This risk refers to a myriad of problems related to difficulty in acquiring the rights of the land and may result in increased project duration and cost (Chan et al. 2011). This risk also implies that the cost and time of land acquisition exceed the budget. Community relation issues can lead to or worsen the problem with right-of-way acquisition (Federal Highway Administration 2012; Hardcastle and Boothroyd 2003). The government may acquire the land through its authority of compulsory acquisition (Lindsay 2012). In some cases, the government will take the responsibility of land acquisition or the land is federal/state owned. However, land acquisition is rarely a private sector risk (Federal Highway Administration 2012).

6.4.2.4.7 Lack of Skilled Experts

During the semi-structured interviews, several interviewees revealed lack of skilled experts (technical, legal, financial and other domains) in Pakistan who can provide support toward adequate development, implementation and operation and management of PPP infrastructure projects. Nevertheless, international consultants may be hired for project support when necessary; however, this move can be expensive, and/or it may not be always possible.

6.4.2.4.8 Lack of Supporting Infrastructure/Utilities

This risk refers to the timely and at fair cost availability of basic utilities (e.g., water, electricity and gas) for the construction operation and management of the project and the availability of support infrastructure (Chan et al. 2011; Ke et al. 2011). The project may require connections to the project site, such as site links to water supply or a road connection, to provide access to toll road or bridge project and enable traffic to use it (Yescombe 2007). Support infrastructure such as collector/approach roads and connection to transmission and distribution grids are fundamental to the operations of transport and power infrastructure PPP projects, respectively. Hence, the availability and reliability of utilities and support infrastructure are an important issue to ensure performance of PPP infrastructure projects. A delay or failure to render such provisions may cause increased costs and/or lost project revenues.

6.4.2.4.9 Organization and Coordination Risk

The success of projects relies on efficient cooperation between various project authorities and agencies at various levels of the host country's administrative structure that are involved in development of a BOT (hence, PPP) project (Xenidis and Angelides 2005b). Dispersed authority among several public agencies, bureaucracy, poor organization and negligence or incompetence of the officials are the contributory factors inhibiting full cooperation among the various agencies. This situation can result in delays and extra costs due to deficiencies related to project development process (ibid.). Poor coordination and communication ability of the project company may lead to conflicts and disputes between project participants and increase in transaction costs (Chan et al. 2011; Ke et al. 2011).

6.4.2.4.10 Planning Risk

This risk refers to shortfalls in project development efforts (i.e., the technical, financial, legal and other pre-development studies), which possibly result in deviations from the planned outcomes or expectations (Department of Economic Affairs 2010). A relevant example will be the issues related to demand forecasts. A relationship exists among the viability, profitability and demand forecasts for a BOT (hence, PPP) project. The use of reliable data through appropriate forecasting techniques along with reliable historical data and the right inference process produces acceptable forecasting results, which enable the bidder to make a decision and submit a competitive tender (Xenidis and Angelides 2005a). Yescombe (2007) contended that around 10% of road concession projects are a financial failure while quoting the winner's curse (the winning bidder and often the public authority having an optimistic view of traffic) as the primary reason for this failure. Flyvbjerg et al. (2005) studied this issue in 210 transport infrastructure projects worldwide and found demand forecasts to be remarkably misleading for a large proportion of the sampled projects.

6.4.2.4.11 Procurement Risk

This risk refers to several instances leading to a failed or flawed procurement and includes inadequate competition/fewer proposers than anticipated, lowest bid exceeding affordability limits, non-responsive/low-quality bids or challenge in the procurement award (Federal Highway Administration 2012). These outcomes can be attributed various reasons, such as flaws in the procurement process, inappropriate risk transfer expectations and general market conditions. Other procurement issues reported include vague response requirements, requirements of excessive financial commitment, selection criteria that lack transparency, insufficient protection of design and proprietary information and the track record of the project procurement agency. The risk is significant due to costly bidding on PPP projects (ibid.). Factors leading to a low number of proposers on the projects may also include lack of suitably qualified and financially capable private parties or expectations of strict competition.

6.4.2.4.12 Residual Asset Value on Transfer to the Government

Residual value risk is relevant to projects that, at the end of the concession period, are scheduled to be transferred to the government, such as in the case of BOT or BOOT arrangements. Residual value risk is defined as the risk of loss in asset value as compared with what was originally estimated by the government, at which the private party agreed to transfer it to government at expiry or earlier termination of the service contract (Partnerships Victoria 2003). A road typically needs to function for another 10 years after it is handed back to the client (Hardcastle and Boothroyd 2003). The project company must establish plans to ensure that the facility is in a particular state at transfer.

6.5 CHAPTER SUMMARY

In order to conduct investigations in to risk assessment and allocation and sharing for PPP infrastructure projects, necessary risks were identified, and a comprehensive risk register was prepared. The exercise for risk identification started with a review of published academic and institutional international literature from developing and developed countries, from which 19 items were selected. A list of 51 risk factors was finally extracted from the review. Semi-structured interviews with power and transport sector professionals in Pakistan resulted in identifying two new risks, whereas some modifications were made to the initial risk register. In this procedure, some risks were merged, and others were removed due to being insignificant and having similar meaning, respectively. This step resulted in a finalized register of 45 risk factors, which was considered sufficient for the local context in Pakistan. The identified risks span the entire project lifecycle and relate to the concerns of public and private sector stakeholders. Furthermore, the risks were categorized into nine categories based on the "source of origin" criteria. The categorization helps in comprehending the groups of risks in terms of their nature, which is apparent from the group title. However, such categorization cannot be translated to a sufficient guideline for risk allocation and sharing. The "systematic/country group" highlights many risks relevant to political, policy, institutional and law and order domains that can be potentially influenced by government efforts, and these can have wide implications for many ongoing and upcoming projects. This category differs from the "specific project risk" category, in which more distributed rather than central level efforts are required to make a positive change.

Finally, the outputs from this chapter facilitated in the development of a questionnaire, which was later administered to empirically validate the importance and establish criticality of the identified risks and develop a sectoral and project risk assessment model.

CHAPTER 7 MEASURES OF EFFECTIVE RISK MANAGEMENT FOR INFRASTRUCTURE PPPs: AN EMPIRICAL ANALYSIS[8]

7.1 INTRODUCTION

As discussed in Chapter 5, inadequate risk management on PPP projects is a principal cause of project distress or failure. Hence, this research seeks to identify and empirically validate the measures of ERM in the context of PPPs. This chapter presents the empirical analysis and validation of the measures of ERM that were previously identified via the literature review and semi-structured interviews. As presented in the review, extant literature has identified several issues that may correspond to potentially negative outcomes for ERM in PPP projects, such as those related to risk management maturity of project stakeholders, experience of delivering and managing projects under PPP arrangements, access to suitable risk mitigation resources, dispute resolution frameworks and collaborative risk management (Chowdhury et al. 2015; Fischer et al. 2010; Jin 2010; Jin and Zuo 2011; Ke et al. 2011; Pipattanapiwong et al. 2003; Yeo and Tiong 2000; Zou et al. 2009). These issues have either been reported individually or in clusters and indicate important environmental, organizational and project parameters and conditions under which risk management takes place. Nevertheless, the issues have not been comprehensively studied with the aim of suggesting significant factors that influence ERM in the context of PPPs. Furthermore, extant literature lacks detailed quantitative analyses and does not provide insights on

Parts of this chapter have been included in:

[8] Mazher, K.M., Chan, A.P.C., Ameyaw, E.E., Zahoor, H., Choudhry, R.M., & Edwards, D.J. (under review). "Measures of effective risk management for infrastructure public-private partnership projects." *Engineering, Construction and Architectural Management*.

the significance and grouping of factors to achieve ERM. This chapter presents an analysis that determines the relative significance of and underlying relationships between the measures to extract the principal factors that determine ERM in PPP projects. The identification of the measures of ERM is a prerequisite for efficient planning and implementation of PPP projects to adequately account for risks and uncertainties and achieve successful project outcomes.

The collected data from the questionnaire survey were subject to various tests using Microsoft Excel 2015 and SPSS version 23.0, which include mean score ranking, agreement analysis, reliability analysis and factor analysis, to obtain underlying constructs and group similar factors. The research participants are experts in handling transactions in power and transport infrastructure PPP projects. Data were collected via a questionnaire survey distributed to PPP experts in Pakistan. A total of 90 valid responses were used for analysis.

7.2 DESCRIPTIVE STATISTICS AND AGREEMENT ANALYSIS FOR MEASURES OF EFFECTIVE RISK MANAGEMENT

The questionnaire survey conducted to obtain perceptions on significance of the measures of ERM required the experts to rate the relative importance of each measure according to a seven-point scale (1 = not important [NI], 2 = very low importance [VLI], 3 = low importance [LI], 4 = moderate [M], 5 = important [I], 6 = very important [VI], 7 = extremely important [EI]). The data collected on the measures’ significance was subject to MS ranking analysis to obtain the relative importance of the measures and determine the most significant measures (Table 7.1).

Table 7.1 Descriptive statistics of measures of ERM

ID	Measures	Mean	Standard deviation	Rank
MERM_9	Quality of project's financial model	6.18	1.03	1
MERM_7	Adequate administration/management of the contract between the public and private sectors (concession agreement)	6.07	0.92	2
MERM_3	Comprehensive project risk management plan	6.04	0.85	3
MERM_1	Identification of project's and key stakeholders' objectives and requirements	6.04	1.14	4
MERM_26	Careful bid evaluation by the public sector	6.02	1.01	5
MERM_6	Efficient contract negotiations	6.01	0.95	6
MERM_5	Explicit risks allocation in the contract	5.96	0.91	7
MERM_2	A well-established project management scheme	5.87	0.99	8
MERM_8	Quality of project's pre-feasibility/feasibility study	5.83	1.22	9
MERM_17	Experience of the private partner in conducting similar projects	5.76	0.98	10
MERM_23	Effectiveness of dispute resolution	5.74	0.94	11
MERM_14	Experience, skills and maturity of financial institutions (Debt/equity providers, insurance companies)	5.73	1.12	12
MERM_24	Increased confidence, trust, and cooperation among parties	5.72	1.03	13
MERM_25	Availability of reliable specialist consultants/external advisors	5.70	0.94	14
MERM_4	Comprehensive lifecycle based risk identification and assessment	5.57	1.11	15
MERM_15	Availability of reliable of risk mitigation tools/instruments (guarantees, insurances, hedges/swaps, etc.)	5.56	0.90	16
MERM_29	Learning from risks	5.50	0.97	17
MERM_27	Explicit risk pricing in the bid	5.44	1.07	18
MERM_12	Risk management maturity of project stakeholders	5.43	0.81	19
MERM_11	Collaborative risk management	5.43	0.93	20
MERM_10	Risk communication and reporting	5.41	0.91	21
MERM_16	Experience of the public sector in managing PPP projects	5.36	1.22	22
MERM_30	Stakeholder's risk management commitment	5.30	1.03	23
MERM_28	Retaining the contract negotiation team for contract administration	5.24	1.21	24
MERM_18	Risk management personnel training and development	5.23	1.08	25
MERM_21	Consideration of interrelation between risks	5.11	0.90	26
MERM_19	Application of appropriate risk analysis tools and techniques (RATT's)	5.03	1.08	27
MERM_20	Availability of historical data on previous projects	5.02	0.98	28
MERM_13	Third-party review	4.98	1.02	29
MERM_22	Flexible and collaboration supportive contract	4.87	1.04	30

Table 7.1 illustrates that all of the identified measures were ranked from *moderate* to *extremely important* (on average) while none of the measure was rated less important (on average). *Quality of the project's financial model* (MERM_9) was ranked as the most significant measure for ERM

whereas, *flexible and collaboration supportive contract* (MERM_22) received the least rating of 4.87. *Adequate administration/management of the contract between the public and private sectors (concession agreement)* (MERM_7), *comprehensive project risk management plan* (MERM_3), *identification of project's and key stakeholders' objectives and requirements* (MERM_1), *careful bid evaluation by the public sector* (MERM_26), and *efficient contract negotiations* (MERM_6), are other measures that received an average rating of *very important* (6) and above. Two sets of factors MERM_3, MERM_1 and *risk management maturity of project stakeholders* (MERM_12), *collaborative risk management* (MERM_11) possess the same mean score therefore, a higher ranking was attributed to each factor in the set exhibiting a lower standard deviation (Ameyaw and Chan 2016b).

Several measures recorded standard deviation values greater than one signifying some variation in perceptions of experts regarding importance of the measures of ERM. The largest values of standard deviation were obtained for *quality of project's pre-feasibility/feasibility study* (MERM_8), *experience of the public sector in managing PPP projects* (MERM_16) and *retaining the contract negotiation team for contract administration* (MERM_28). The critical value of Chi-square for 29 degrees of freedom at 0.05 significance level was 42.557. The computed value was 442.441 which is much higher than the critical value thus demonstrating consistency among the respondents. The general agreement between the two respondent groups i.e., the public and private sectors was determined using Spearman's rank correlation test. The value of r_s was 0.827 which is greater than the critical value of 0.306 at the 0.05 level indicating a general consensus among the public and private sector respondents on the rankings of the measures of ERM. These tests indicate a somewhat similar perception of respondents towards the significance of the measures to enhance risk management outcomes.

7.3 FACTOR ANALYSIS FOR MEASURES OF EFFECTIVE RISK MANAGEMENT

To reduce the large number of measures into a smaller number of independent factor groups or components, FA was performed. Correlation coefficients for most of the measures were found to be above 0.3 ensuring sufficient interrelationships (Hahs-Vaughn 2016). Bartlett's test of sphericity confirmed rejection of the null hypothesis with a large value of 1553.67 and a p-value of 0.000. KMO measure of sampling adequacy obtained was 0.753 which is considered acceptable and provides evidence to suggest factorability (Norusis 2003). The MSA values on the diagonal of the anti-image correlation matrix were also found to be higher than 0.5 (Field 2005) and ranged from 0.544 to 0.903, thus disregarding the need to remove any factors. Regards the general agreement on the ranking of factors among the groups (public/private), the need for homogeneity of the sample for FA is also satisfied (Hahs-Vaughn 2016). The communality values obtained for each measure were quite high and varied from 0.431 to 0.803 with one factor with a value of 0.176 (*explicit risk allocation in the contract* (MERM_5)) which was subsequently dropped from the analysis due to low factor loading. Following the guidelines by Costello and Osborne (2005), a clean solution was obtained with a six factor model that had low number of cross-loadings, individual factor loadings above 0.3 and each factor group containing at-least three items. Factor loading cut-off point is usually set at 0.4 (Zahoor et al. 2017), however, for more significant factors, a cut-off at 0.5 was set (Hair 2010).The extracted factor model explained 62.471% of total variance. The high factor loadings (with values greater than 0.6 for 15 measures of ERM) support the appropriateness of the sample size (Ahadzie et al. 2008). Table 7.2 reports upon the six factor groups along with their component factors, factor loadings, eigenvalues, and other attributes.

Table 7.2. Results of factor analysis

ID	Factor loading	Mean value	Eigenvalue	% of variance explained	% of variance explained (Cumulative)	Relative weight	Average (Ranking)
Factor 1 - Knowledge Driven Risk Management			9.817	32.723	32.723		5.435 (4)
	0.758	5.24				0.241	
MERM_28	0.720	5.30				0.244	
MERM_30	0.682	5.50				0.253	
MERM_29	0.659	5.70				0.262	
MERM_25							
Factor 2 - Comprehensive Requirements and Risks Evaluation			2.523	8.409	41.132		5.918 (2)
MERM_26	0.797	6.02				0.254	
MERM_9	0.723	6.18				0.261	
MERM_1	0.573	6.04				0.255	
MERM_12	0.572	5.43				0.229	
Factor 3 - Public Sector Risk Management			2.040	6.799	47.931		5.26 (6)
MERM_27	0.789	5.44				0.345	
MERM_13	0.686	4.98				0.316	
MERM_16	0.667	5.36				0.340	
Factor 4 - Risk Assessment Quality			1.624	5.412	53.343		5.304 (5)
MERM_20	0.767	5.02				0.189	
MERM_18	0.728	5.23				0.197	
MERM_10	0.622	5.41				0.204	
MERM_8	0.587	5.83				0.220	
MERM_19	0.525	5.03				0.190	
Factor 5 - Post-contract risk management			1.462	4.873	58.216		5.464 (3)
MERM_22	0.766	4.87				0.178	
MERM_23	0.735	5.74				0.210	
MERM_24	0.597	5.72				0.209	
MERM_15	0.555	5.56				0.203	
MERM_11	0.504	5.43				0.199	
Factor 6 - Well Documented Structured Management Approach			1.277	4.255	62.471		5.998 (1)
MERM_2	0.789	5.87				0.245	
MERM_7	0.573	6.07				0.253	
MERM_3	0.553	6.04				0.252	
MERM_6	0.524	6.01				0.250	

7.4 RELIABILITY AND VALIDITY TEST

The overall value of Cronbach's alpha was 0.926 suggesting a good internal consistency reliability of the instrument since values above 0.7 are regarded as sufficient (Andrew et al. 2011). Content validity was confirmed by conducting a detailed literature review, semi-structured interviews, expert reviews and pilot study in order to merge expert experience with the information extracted from the published literature. Construct validity was established by subjecting each extracted component to FA individually. If all the variables form a single factor again, then the factor is valid as a construct (Black and Porter 1996). All the six extracted factors were demonstrated to be unifactorial with satisfactory KMO values and a significant percentage of variance explained. In addition, internal consistencies of the extracted factors were also evaluated using Cronbach's alpha and all the values exceeded 0.7 (Table 7.3).

Table 7.3. Unifactorial test

ID	Number of variables	KMO	Eigenvalue	Variance explained (%)	Cronbach alpha
Factor 1	4	0.792	2.498	62.441	0.797
Factor 2	4	0.732	2.320	57.996	0.752
Factor 3	3	0.661	1.944	64.805	0.726
Factor 4	5	0.823	2.944	58.881	0.819
Factor 5	4	0.702	2.518	50.360	0.799
Factor 6	3	0.737	2.434	60.839	0.783

7.5 VALIDATION OF RESULTS

To validate the results, four additional international PPP experts with greater than 20-year experience of working in the construction industry and at least 15 years of experience (three out of four) in dealing with PPP transactions (from Australia, Hong Kong, UK and USA) were invited to participate in a validation exercise. All the experts were acting in the capacity of consultants and had worked on multiple PPP projects. The experts were requested to respond to a validation questionnaire (Appendix D) that was specifically designed to solicit their opinions and comments on the previously obtained rankings, factor groups and conclusions. Definitions for all measures of ERM were also provided to ensure a consistent understanding. While generally agreeing with the importance of the measures of ERM, experts highlighted several measures that in their opinion should have achieved a higher ranking than the one established from the questionnaire survey. Only one expert suggested a lower ranking for the measure *quality of project's financial model* (MERM_9). The difference in opinions on the rankings of these measures may be attributed to either difference in experts' perceptions and/or PPP implementation maturity of the jurisdictions of the primary and validation questionnaire surveys. Furthermore, no adverse comments were received regarding the factor groups and interpretations.

7.6 DISCUSSION

7.6.1 ERM Factor Group 1: Knowledge-Driven Risk Management

The factor group explains 32.723 per cent of total variance in the FA and ranks fourth based on average score of the factors within the group. It consists of four factors including: *retaining the contract negotiation team for contract administration* (MERM_28); *stakeholders' risk management commitment* (MERM_30); *learning from risks* (MERM_29); and *availability of reliable specialist consultants/external advisors* (MERM_25). Knowledge on various aspects of risk management is the key to achieve effective outcomes. Risk management knowledge may be either tacit or explicit in nature (Liu and Wang 2018), and it may be leveraged from different sources. From an organizational perspective, retaining key individuals that are involved in project procurement phase, for project implementation may be important when focusing on the tacit knowledge aspect of the project (as reviewed previously). Owing to the long life spans of PPP projects, continuity of knowledge is a challenge, hence, it is important to ensure that knowledge is retained and passed on when staff leave or the teams change between different stages of a project (GI Hub 2018). For PPP projects, the guide (ibid.) recommends that the procurement and contract management staff should interact with each other to some extent, before and after the financial close, so as to allow sufficient time for training and knowledge sharing.

From a long-term and explicit knowledge perspective, organizations must enable systematic learning from projects to acquire and learn from experiences and become effective for future actions on projects. A database of corporate knowledge that may only exist in the form of knowledge possessed by a project team and specialist advisers can be developed by collecting detailed information in a structured manner on all the aspects of a project. This method can be useful for other project risk assessments (Cooper et al. 2005). Organizational memories in the form of risk knowledge bases are used wherein records are continuously maintained on experiences related to risks and potential risk responses during project execution in a multi-project environment, such as that of a project company (Kahkonen and Artto 1997). A superior source of knowledge that may be leveraged for ERM include reliable external consultants/advisors for the projects. For projects, knowledge continuity can be ensured via external advisors over the long term particularly where government policies require the movement of public officers to different positions after a few years (GI Hub 2018).

The importance of technical specialist risk management consultants in risk facilitation was emphasized by one of the experts while reviewing the measures. The expert also articulated that an important measure of ERM is having and insisting that risks are given full attention by all stakeholders.

7.6.2 ERM Factor Group 2: Comprehensive Requirements and Risks Evaluation

This factor group accounts for 8.409 per cent of the total variance in the analysis and is comprised of four factors, namely: *careful bid evaluation by the public sector* (MERM_26); *quality of project's financial model* (MERM_9); *identification of project's and key stakeholders' objectives and requirements* (MERM_1); and *risk management maturity of project stakeholders* (MERM_12). All factors have acceptable loadings and the group ranks at second position. ERM demands that the project's and stakeholders' needs and requirements are identified early in order to plan for their optimum fulfillment while identifying and countering any potential variations in project parameters that lead to a departure from the planned outcomes. Organizations with a high level of risk management maturity (and concomitant policies and processes) can better identify and assess the requirements and their associated risks effectively. The bids evaluation phase also provides an important opportunity to assess risks posed to the project in terms of assumptions made by each bidder and consequently, a thorough evaluation at this stage may help in ensuring high value for money (VfM) contracts by selecting suitable project sponsors. According to one of the participating experts, it is also important to ensure that bid evaluation is done fairly.

Financial results of the project are simulated using the financial model that demonstrates anticipated cash flow under different scenarios (ADB 2008). The information obtained by the financial model enables key stakeholders to make informed decisions and understand how a project may be perceived by lenders, partners and consumers. For PPP contracts, a comprehensive and reliable project financial model is an important tool for analyzing the impacts of risks on stakeholder objectives throughout the project's lifecycle. Thus, the model plays a vital role in evaluating project risks in relation to stakeholders' requirements. One expert commented on the fundamental importance of a project's financial model for project finance cash flow modeling. The respondent contended that it is a contractual document and is too often forgotten and not taken as seriously as written documents. The respondent further argued that financial models become far too technical and cumbersome due to specialization in financial modeling and proliferation in IT in terms of hardware and software capability. The respondent also added that modelers, although technically capable, do not understand the real world of PPP and infrastructure projects. Another respondent concurred with the earlier findings of Panko (1998) and argued that model errors in the form of faulty spreadsheet formulas are problems. The model's quality as a representative of the problem at hand is also important.

7.6.3 ERM Factor Group 3: Public Sector Risk Management

This factor group ranks sixth and explains 6.799 percent of the total variance and comprises of: *explicit risk pricing in the bid* (MERM_27); *experience of the public sector in managing PPP projects* (MERM_16); and *third-party review* (MERM_13). The primary responsibility of the government is to protect public interest and provide services to the public while ensuring VfM. Achieving VfM is one of the main drivers for promoting public infrastructure development via PPPs (See Chapters 1 and 3). The three measures in this group correspond to enhancing public sector prospects of initially achieving and then maintaining the VfM throughout the project lifecycle. Since achieving and maintaining VfM is a stakeholder requirement, any variation in achieving or maintaining it derive from the failure of public executing entities to manage the underlying risks. Experience is a key aspect of risk management where the experience of managing risks on prior projects is especially important (Virginia Public-Private Partnerships 2015). All the processes of risk management from risk identification to monitoring and control can benefit from prior experience in managing similar projects. Third party reviews can provide counter checks on working of the public project execution authorities or other parties to ensure that project appraisals and various analysis are based on facts and valid assumptions and are free from mistakes and willful designs (Flyvbjerg 2013; Matsumoto 2012). Explicit risk pricing by the private party can enable government to not only evaluate VfM as contended previously, it may additionally provide an indication to the public authority about the adequacy of risk analysis by the private party, hence assisting in avoiding selection of a concessionaire that only bids low due to poor or inadequate assessment of relevant risks (Arndt 2000; Dey and Ogunlana 2004).

7.6.4 ERM Factor Group 4: Risk Assessment Quality

This factor group explains 5.412 per cent of total variance in the analysis and includes five factors, namely: *risk management personnel training and development* (MERM_18); *availability of historical data on previous projects* (MERM_20); *risk communication and reporting* (MERM_10); *quality of project's pre-feasibility/feasibility study* (MERM_8); and *application of appropriate risk analysis tools and techniques (RATT's)* (MERM_19). It ranks fifth among the factor groups. Risk assessment quality depends on the following: quality of input data and information, nature of assumptions made in the analysis, tools employed and availability of knowledge and skills to make best use of the available resources and methods. Chapman and Ward

(2003) defined uncertainty in projects as a function of variability and ambiguity. The former is related to performance measures, such as cost, duration or quality, whereas the latter is associated with *"... lack of clarity because of the behavior of relevant project players, lack of data, lack of detail, lack of structure to consider issues, working and framing assumptions being used to consider the issues, known and unknown sources of bias, and ignorance about how much effort it is worth expending to clarify the situation."* Individual projects can be plagued with problems due to incorrect forecasts and assumptions (e.g., revenues, expenditure, demographics or prices), incomplete comprehension of the dynamics of the market and unwillingness to be ready for adverse scenarios and volatility (Beckers et al. 2013). Outcomes, such as inadequate returns or, worst, project cancellation or abandonment after significant upfront investments, are confronted in poorly designed projects as a result of overestimation of revenue and growth potential while underestimating risks (ibid.).

While reviewing the measures, one expert argued that people working with risks should recognize what PPPs are and what they are not and understand the process of obtaining and analyzing data. Academic research is also needed to understand what the existing historical data on PPPs is based on and what its limitations are. To stress the importance of proper risk communication in PPP projects, one of the experts believed that risk communication and reporting are extremely crucial but are still not accomplished well because of the lack of understanding of risks. Thus, missing the communication and reporting of risks in terms of root causes and events that lead to certain outcomes, and simply reporting risk in outcome terms such as *delay, cost overrun or blow out or poor quality*. The respondent further argued that these are not risks and nothing can be done with such high-level terms. There is a need to identify and communicate the events leading to outcomes and that this is not done well at all.

7.6.5 ERM Factor Group 5: Post-contract Risk Management

The total variance explained by this factor group amounts to 4.873 per cent while ranking third and it is composed of five factors, namely: *flexible and collaboration supportive contract* (MERM_22), *effectiveness of dispute resolution* (MERM_23); *increased confidence, trust, and cooperation among parties* (MERM_24); *availability of reliable risk mitigation tools/instruments (guarantees, insurances, hedges/swaps, etc.)* (MERM_15); and *collaborative risk management* (MERM_11) which load well on to this group. Since the contractual relationship between the public and the private sectors is managed over an extended time, risk management at the post-contract stage is critical for all stakeholders.

Xiong et al. (2017) advocated the concept of ex post risk management (the period after affixing signatures for a project agreement) for PPP agreements in accordance with the incomplete contract theory. These agreements can be typically regarded as incomplete contracts where all the risks in an ex ante risk management (the period before affixing signatures for a project agreement) way cannot be resolved. Risks that are unresolved should be subject to ex post risk management. For some risks, ex ante forecasting and prespecification are costly. Hence, they should be left unresolved deliberately and subjected to ex post adjustments (ibid.). Most of the measures that are reported in this group correspond to the handling of uncertainties in an ex post manner. Contracts that define interparty relationship must cater for the possibility of changes and specify how these events should be handled without breaking down relationships. Collaboration in risk management and interparty trust and cooperation are essential in amicably managing differences. Mitigation of risk may be possible by transferring them to other parties via insurance, derivatives and government guarantees, if available and practical. In the case of failure to settle potential differences that may arise, effective dispute management protocols need to be in place to provide a timely relief to the parties. Flexibility, collaboration and good interparty relationships are also important because risk identification does not stop at the pre-contract stage. Nonetheless, new risks will become apparent or conditions may change in unanticipated ways in the future that need to be jointly managed.

The adequate administration of contract documents is also fundamentally important. Risk allocation and sharing do not culminate with the finalization of contracts. Many risks are structured and shared in contracts so that only the responsibility is designated. However, the mechanism of sharing the risk (such as relief event, compensation event, delay event, external reference, force majeure event, further interpretation, negotiation, extension, deductible, proration, extra work and delay costs, insurance, cost adjustment, relief event for the government and maximum reimbursement) and compensating a party may dictate a need for more information in the future on how the risk actually occurred, which will determine the quantum of the risk (Nguyen 2017). Hence, post-contract costs and efforts (stemming from how the risk-sharing mechanisms are prescribed in the contract and their type) and uncertainty in effectively managing such risks to protect vested interests may be of significance. This was highlighted by Nguyen (2017) in his study on contracts for highway toll concessions in the US. Sound contract management is also important because the risks that are initially shared at the start of the relationship, through contracts, must be managed over the project lifecycle to ensure that both the parties effectively manage their assigned risks and to enforce, clarify and/or modify risk allocation when unforeseen risks or their consequences arise on the projects (APMG International 2016c). The private partner must be incentivized by linking the revenue generation to the performance of its obligations under the contract as the very heart of risk transfer. Hence, VfM lies in the degree to which this incentivization can deliver required services so as to maximize the amount of revenue (APMG International 2016d). Accordingly, the effectiveness of risk transfer is dependent on adequately and appropriately specifying and monitoring performance requirements.

While sharing views regarding contract management, one of the experts emphasized its importance from both parties' perspective and argued that inadequate thoughts or resources are too often applied to this critical and, ultimately, longest phase of a PPP project.

7.6.6 ERM Factor Group 6: Well Documented Structured Management Approach

This factor group accommodates four factors that include: a well-established project management scheme (MERM_2); adequate administration/management of the contract between the public and private sectors (concession agreement) (MERM_7); comprehensive project risk management plan (MERM_3); and efficient contract negotiations (MERM_6), accounts for 4.255 per cent of the total variance in FA and ranks first among the factor groups. Risk management does not function alone as a separate process rather, it is one of the several project management processes in operation on any project, that interact with each other. Since the contract document provides the protocol for responsibility and risk sharing between the partners, sufficient execution of these protocols is essential to ERM from the perspective of both the partners.

According to Chapman and Ward (2003), formal risk management processes require appropriate documentation, which is a key process output. However, it also facilitates process operation and allows the assessment of performance of the process. Most importantly, it enables the management of uncertainty in terms of variability and ambiguity (for more details on variability and ambiguity as sources of risk, refer to Chapman and Ward 2003). According to the authors (ibid.), a documentation can serve a number of useful purposes, which include thinking clarity brought about by setting down thinking in writing. It also serves as an unambiguous vehicle for communication, mitigates staff turnover risk by providing records to new team members, provides a record that explains a rationale for key decisions, serves as a knowledge base by capturing corporate knowledge for future projects, and provides a framework for data acquisition. Documentation assists in integrating the expertise of teams of people, allowing them to make effective, collective decisions based on clearly articulated premises (ibid.). Risk management plan and risk registers (part of the risk management plan) are important documents in PPP project risk management. They provide key information of various risk parameters and risk management implementation procedures along with the statuses and records of risk management as executed on projects (Hong Kong Institute of Surveyors 2009). A structured management approach that uses the principles of project management in general and risk management in particular is directly related to the effectiveness of risk management outcomes. Good practices in project management, such as planning, coordinating, setting milestones and change control procedures, aim to directly manage uncertainty. As a result, much of the good project management practices can be considered effective uncertainty management practices (Chapman and Ward 2003).

7.7 CHAPTER SUMMARY

PPP projects globally have suffered performance issues and occasionally failure for reasons attributed to ineffective risk management. Normative literature highlights the CSFs for project success which includes both product and project management success. However, there is a lack of focused efforts to explore factors that influence project management process success, i.e., measures that can enable ERM on PPP projects. While existing guidelines, risk management processes, tools and techniques enable systematic execution of risk management on projects, their optimum deployment is dependent upon many environmental, project and organizational parameters that determine their effectiveness. Given deficiencies within existing literature, this research sought to explicitly highlight and quantitatively assess the specific attributes that can influence the effectiveness of risk management efforts in the context of PPPs. The measures identified were validated using a comprehensive research methodology based on literature review, interviews and survey of industry experts. Based on the MSR, the most critical measures for ERM include: *quality of the project's financial model* (MERM_9); *adequate administration/management of the contract between the public and private sectors (concession agreement)* (MERM_7); *comprehensive project risk management plan* (MERM_3); *identification of project's and key stakeholders' objectives and requirements* (MERM_1); *careful bid evaluation by the public sector* (MERM_26); and *efficient contract negotiations* (MERM_6) – all of which achieved an average rating of *very important* and above. Based on values of Chi-square and Spearman's rank correlation coefficient, the respondents agreed on the significance and ranking of the measures of ERM. The critical measures exhibit multi-organizational characteristics such that both the public and private sector stakeholders can contribute to their successful implementation on projects and influence the entire project life-cycle. Existing risk management body of knowledge can be complemented with a focus on the reported measures to ensure ERM on PPP projects. For instance, a comprehensive and well documented project's financial model can help stakeholders assess the impact of risks on their objectives and make appropriate decisions on how to allocate and manage risks. Similarly, appropriate contract administration efforts by stakeholders can ensure that the risk allocations are properly implemented. Designing a flexible PPP project contract that acknowledges the incomplete nature of long-term contracts along with establishment and implementation of collaborative protocols for post-contract risk management can ensure effective management of existing/emerging risks. Similarly, other identified measures also influence various aspects of the risk management framework from risk identification to risk monitoring and control.

FA revealed six critical underlying dimensions that influence ERM. Out of 62.471% of total variation explained, the factor *knowledge driven risk management* accounts for 32.723%, which emphasizes on harnessing the potential of acquired experiences, lessons learned, and risk management knowledge gained from projects. Other identified factor groups point towards the significance of comprehensive evaluation of stakeholders' and project's requirements, and the quality of risk assessments in relation to meeting the requirements. Other identified factor groups point towards the significance of: comprehensive evaluation of stakeholders' and project's requirements and the quality of risk assessments in relation to meeting the requirements; elements critical to post-contract risk management; well documented and a structured management process; and role of government institutions (and their project execution arms) for managing risks effectively.

In summary, the identified measures specify strategies to enable ERM therefore, stakeholders are encouraged to pursue project performance improvement. The findings will enable a better understanding of factors that influence quality and outcomes of risk management efforts, and guide industry practitioners to effectively deploy management policies, risk management processes, tools and techniques for achieving success on PPP projects. Furthermore, for countries with limited experience of procuring infrastructure projects using the PPP mode of project delivery, the identified measures highlight aspects that need due consideration. This may be especially true for

Pakistan because the local public and private sector stakeholders were determined to exhibit risk management maturity issues. Public sector infrastructure procurement organizations were also reported to suffer capacity shortfalls in the areas of conducting project preparation and appraisals as well as contract formation, management and administration (See Chapter 3). There may also be shortage of resources such as lack of historical data on projects, suitably skilled professionals and risk mitigation instruments. Results from this research clearly indicate that these dimensions are crucial to ensure ERM on PPPs.

CHAPTER 8 MODELING AND ASSESSING RISKS IN INFRASTRUCTURE PPPs[9]

8.1 INTRODUCTION

Adequate assessment of risk is essential to assist the stakeholders in planning for efficient risk allocation and mitigation and to ensure success in business and projects. However, it is problematic due to difficulty in quantification of certain risks, existence of interactions, and multi-attribute structure of the project risk assessment task. This chapter sets out to explore and achieve multiple tasks in order to provide deliverables under the third objective of this research. These include: evaluation of stakeholders' perceptions with respect to criticality of identified risks at sectoral and overall PPP local industry level; identification of critical risk groups (CRGs); and development of a model to assess the risk level of various CRGs, overall project riskiness, and the overall risk level of PPP projects in the country, while accounting for complex interactions between risks. Comparison of the proposed multiple attribute risk assessment methodology was conducted with an additive method to ascertain its performance and the results were further validated using actual case data. The developed framework can be used to assess a country's condition or overall project risk at the initial project stage with little input of time and resources, thus facilitating an efficient and robust risk assessment. Application of fuzzy set theory and fuzzy measure based non-additive fuzzy integral combined with arithmetic mean for sectoral and project risk assessment, identification of critical risk factors and comparison of sectoral risk analysis from a developing country perspective are some of the key contributions of this chapter.

Parts of this chapter have been included in:

[9] Mazher, K.M., Chan, A.P.C., Zahoor, H., Khan, M.I. and Ameyaw, E.E. (2018). "Fuzzy integral based risk assessment approach for public-private partnership infrastructure projects." Journal of Construction Engineering and Management, 144(12), 4018111.

The data collected from the questionnaire survey were subject to various tests using Microsoft Excel 2015 and SPSS v 23.0. These include fuzzy risk analysis and normalization analysis to select critical factors, factor analysis to group correlated factors, and fuzzy measure and Choquet fuzzy integral analysis to determine sectoral and case specific risk levels (ORI) and that of identified CRGs. The experts that participated in the research had rich experience in handling transactions in power and transport infrastructure PPP projects. As explained earlier, data was collected via questionnaire survey of PPP experts in Pakistan. A total of 90 valid responses were used for analysis.

8.2 ANALYSIS OF RISK FACTORS IN PPP INFRASTRUCTURE PROJECTS IN PAKISTAN

8.2.1 Reliability and Agreement Analysis

Since the industry experts assessed the risk factors on linguistic terms, there was a need to convert these linguistic assessments to quantitative form by using fuzzy numbers, before performing any further analysis. The linguistic terms assigned to rate degree of likelihood (probability) and severity of risks by each respondent were first converted to the corresponding fuzzy numbers (Table 2.2, See Chapter 2) and then these ratings were aggregated over all the respondents, using Eq. (4), to obtain average aggregate fuzzy probability and severity for each risk factor. Overall, the Cronbach coefficient of concordance came out to range between 0.932 to 0.959 for risk probability and severity values of all the risk factors, for sectoral analysis, showing a high reliability of the scale, where values greater than 0.70 are considered sufficient. In order to determine the overall agreement of respondents in risk assessment and consequent ranking, Chi-square test statistic was employed instead of Kendall's coefficient of concordance as the total number of risks being studied was greater than seven. The critical value of chi-square obtained from the chi-square distribution tables for degree of freedom value of 44 at a significance level of 0.05 is 60.481. This value is well below the computed chi-square values obtained from the test for risk probability and severity values, which range between 133.138 and 215.382, for sectoral analysis. Therefore, the assessment by the respondent experts on their rankings was found to be consistent which ensures that further analysis can be conducted as the completed questionnaires are valid (Ke et al. 2011). Afterwards, the spearman rank correlation coefficient was employed to analyze the respondents from the two groups (power and transport infrastructure projects) to determine if there in any substantially similar agreement among them. It was observed that the coefficient values for sectoral rankings on all the attributes of probability and severity ranged between 0.749 and 0.795, which is higher than the critical value of 0.347 at significance level of 0.01. From this result, it can be inferred that the ranking of risks on various attributes across the infrastructure sectors are not independent as these are positively correlated to a certain extent. This result allows for the data from both sectors to be lumped together for overall risk analysis of PPP projects (Ke et al. 2011).

8.2.2 Overall and Sectoral Ranking of Risk Factors

The complete analysis with rankings is shown in Table 8.1. The table shows risk rankings for each sector (power and transport infrastructure) and for combined analysis. In order to calculate the risk impact which is given by *(probability x severity)*$^{1/2}$ (Eq. 2) (Ameyaw and Chan 2015b; c; Xu et al. 2010b), the product of aggregate probability and severity values was assessed using fuzzy arithm-

Table 8.1. Overall and sectoral risk analysis

Identifier	Risk factors	Overall							Power sector				Transport sector	
		Fuzzy aggregated P_r	Fuzzy aggregated S_r	I_r	R	N	P_r	S_r	I_r	R	P_r	S_r	I_r	R
RF_09	Delay in financial closure	(0.463,0.633,0.788)	(0.533,0.701,0.832)	0.657	1	1	0.680	0.740	0.709	1	0.597	0.631	0.614	4
RF_27	Land acquisition	(0.39,0.554,0.708)	(0.573,0.739,0.861)	0.631	2	0.918	0.537	0.640	0.586	7	0.557	0.77	0.654	1
RF_08	Financing risk	(0.385,0.562,0.728)	(0.551,0.711,0.840)	0.625	3	0.900	0.536	0.707	0.615	4	0.571	0.728	0.644	2
RF_30	Delay in project approvals and permits	(0.389,0.561,0.721)	(0.482,0.660,0.813)	0.602	4	0.828	0.592	0.661	0.625	2	0.515	0.644	0.576	9
RF_03	Poor public decision-making process	(0.411,0.585,0.742)	(0.461,0.630,0.775)	0.600	5	0.821	0.573	0.598	0.585	8	0.581	0.629	0.604	6
RF_28	Construction risk	(0.381,0.556,0.724)	(0.468,0.646,0.794)	0.593	6	0.799	0.563	0.629	0.595	6	0.569	0.649	0.607	5
RF_01	Government intervention	(0.363,0.527,0.685)	(0.487,0.651,0.786)	0.580	7	0.759	0.548	0.652	0.597	5	0.483	0.633	0.553	12
RF_36	Procurement risk	(0.342,0.515,0.682)	(0.451,0.624,0.783)	0.564	8	0.708	0.488	0.586	0.534	13	0.51	0.678	0.588	7
RF_25	Inability of debt service	(0.257,0.426,0.604)	(0.572,0.739,0.862)	0.555	9	0.680	0.402	0.689	0.524	14	0.446	0.75	0.576	9
RF_05	Inflation	(0.425,0.603,0.758)	(0.343,0.511,0.677)	0.551	10	0.668	0.566	0.467	0.514	15	0.619	0.552	0.585	8
RF_18	Payment risk	(0.329,0.480,0.646)	(0.481,0.633,0.765)	0.551	10	0.668	0.547	0.703	0.62	3	0.407	0.574	0.483	26
RF_39	Planning risk	(0.301,0.463,0.629)	(0.464,0.635,0.789)	0.540	12	0.633	0.434	0.570	0.497	20	0.479	0.674	0.567	11
RF_16	Pricing and Toll/Tariff review uncertainty	(0.318,0.475,0.639)	(0.445,0.616,0.770)	0.539	13	0.630	0.482	0.627	0.549	10	0.467	0.607	0.532	17
RF_40	Change in government and political opposition	(0.339,0.505,0.673)	(0.412,0.577,0.722)	0.537	14	0.624	0.527	0.570	0.548	11	0.493	0.55	0.520	19
RF_17	Unfavorable national/international economy	(0.316,0.488,0.660)	(0.421,0.585,0.743)	0.533	15	0.611	0.423	0.530	0.473	26	0.572	0.683	0.625	3
RF_43	Design and construction deficiencies	(0.267,0.431,0.600)	(0.473,0.639,0.786)	0.522	16	0.577	0.414	0.577	0.488	23	0.442	0.676	0.545	13
RF_20	Availability/performance risk	(0.244,0.405,0.583)	(0.501,0.666,0.811)	0.519	17	0.567	0.394	0.658	0.508	18	0.407	0.703	0.533	16
RF_07	Variation in foreign exchange rate and convertibility issues	(0.383,0.544,0.705)	(0.335,0.492,0.651)	0.518	18	0.564	0.560	0.549	0.555	9	0.539	0.463	0.500	20

Identifier	Risk factors	Overall							Power sector				Transport sector	
		Fuzzy aggregated P_r	Fuzzy aggregated S_r	I_r	R	N	P_r	S_r	I_r	R	P_r	S_r	I_r	R
RF_23	Operation cost overrun	(0.314,0.483,0.652)	(0.386,0.557,0.708)	0.515	19	0.555	0.456	0.563	0.506	19	0.525	0.557	0.541	14
RF_41	Political violence/government instability	(0.253,0.411,0.584)	(0.473,0.632,0.775)	0.509	20	0.536	0.411	0.638	0.511	17	0.398	0.6	0.487	23
RF_06	Interest rate fluctuation	(0.341,0.508,0.679)	(0.344,0.503,0.675)	0.508	21	0.533	0.488	0.478	0.483	25	0.527	0.553	0.540	15
RF_37	Corruption	(0.313,0.469,0.639)	(0.372,0.558,0.665)	0.502	22	0.514	0.518	0.573	0.544	12	0.43	0.499	0.463	29
RF_44	Development risk	(0.287,0.447,0.618)	(0.376,0.540,0.694)	0.492	23	0.483	0.430	0.559	0.49	22	0.448	0.527	0.485	24
RF_13	Imperfect law and supervision system	(0.256,0.419,0.587)	(0.392,0.557,0.711)	0.482	24	0.451	0.408	0.533	0.466	27	0.424	0.548	0.482	27
RF_33	Lack of supporting infrastructure/utilities	(0.290,0.456,0.625)	(0.337,0.504,0.676)	0.481	25	0.448	0.491	0.532	0.511	16	0.411	0.485	0.446	34
RF_11	Change in law/regulation	(0.249,0.414,0.584)	(0.399,0.560,0.706)	0.480	26	0.445	0.425	0.575	0.493	21	0.378	0.536	0.449	32
RF_34	Organization and coordination risk	(0.299,0.465,0.635)	(0.316,0.486,0.660)	0.477	27	0.436	0.432	0.461	0.446	28	0.463	0.518	0.490	22
RF_38	Latent defect risk	(0.244,0.411,0.585)	(0.374,0.550,0.719)	0.475	28	0.429	0.359	0.523	0.432	30	0.459	0.597	0.523	18
RF_12	Conflicting or imperfect contract	(0.230,0.390,0.563)	(0.383,0.556,0.714)	0.465	29	0.398	0.343	0.535	0.427	32	0.42	0.578	0.492	21
RF_35	Force majeure	(0.200,0.358,0.535)	(0.424,0.592,0.743)	0.461	30	0.386	0.322	0.552	0.42	34	0.379	0.617	0.482	27
RF_32	Unforeseen weather/geotechnical conditions	(0.221,0.386,0.560)	(0.367,0.538,0.705)	0.456	31	0.370	0.368	0.514	0.434	29	0.366	0.54	0.443	35
RF_26	Environmental damage risk	(0.278,0.431,0.598)	(0.293,0.449,0.617)	0.444	32	0.332	0.369	0.470	0.416	35	0.477	0.431	0.454	30
RF_31	Design/Construction/Operation changes	(0.232,0.389,0.558)	(0.336,0.503,0.668)	0.444	32	0.332	0.378	0.486	0.428	31	0.403	0.495	0.447	33
RF_02	Quasi-commercial risk	(0.203,0.337,0.502)	(0.417,0.555,0.687)	0.437	34	0.310	0.405	0.578	0.483	24	0.292	0.52	0.387	41
RF_19	Public opposition	(0.231,0.383,0.555)	(0.325,0.481,0.648)	0.434	35	0.301	0.345	0.444	0.391	39	0.407	0.508	0.454	30
RF_45	Lack of skilled experts	(0.198,0.359,0.533)	(0.343,0.516,0.683)	0.432	36	0.295	0.373	0.480	0.423	33	0.36	0.547	0.443	35
RF_42	Supply, input or resource risk	(0.171,0.330,0.510)	(0.359,0.533,0.707)	0.423	37	0.266	0.333	0.503	0.408	36	0.34	0.567	0.438	37

Identifier	Risk factors	Overall							Power sector				Transport sector	
		Fuzzy aggregated P_r	Fuzzy aggregated S_r	I_r	R	N	P_r	S_r	I_r	R	P_r	S_r	I_r	R
RF_15	Change in market demand	(0.215,0.365,0.533)	(0.324,0.485,0.637)	0.422	38	0.263	0.305	0.420	0.357	42	0.43	0.547	0.485	24
RF_10	Insurance risk	(0.220,0.379,0.555)	(0.275,0.450,0.629)	0.417	39	0.248	0.359	0.458	0.405	37	0.379	0.449	0.413	38
RF_14	Competition risk	(0.214,0.363,0.531)	(0.290,0.451,0.622)	0.409	40	0.223	0.395	0.413	0.404	38	0.343	0.488	0.408	39
RF_22	Technology risk	(0.185,0.334,0.508)	(0.269,0.421,0.587)	0.381	41	0.135	0.328	0.446	0.382	40	0.363	0.422	0.391	40
RF_21	Residual asset value on transfer to the government	(0.200,0.356,0.530)	(0.231,0.390,0.560)	0.378	42	0.125	0.337	0.382	0.359	41	0.357	0.384	0.370	42
RF_24	Archaeological discovery/Cultural heritage	(0.127,0.250,0.422)	(0.349,0.497,0.659)	0.363	43	0.078	0.229	0.471	0.326	45	0.268	0.464	0.351	44
RF_29	Material/labor shortage or non-availability	(0.124,0.268,0.442)	(0.273,0.438,0.616)	0.349	44	0.034	0.272	0.440	0.344	43	0.277	0.435	0.346	45
RF_04	Expropriation/nationalization of assets	(0.072,0.176,0.342)	(0.478,0.621,0.730)	0.338	45	0.000	0.194	0.588	0.331	44	0.206	0.658	0.360	43

P_r = Risk probability, S_r = Risk severity, I_r = Impact, R= Rank, N = Normalized value etic operation $\otimes$, and then the square root of resulting fuzzy number was computed before defuzzifying to crisp value, using Eq. (5).

Combined analysis shows that five risk factors: delay in financial closure, land acquisition, financing risk, delay in project approvals and permits, and poor public decision-making process, have a *high* risk impact rating of 0.600 and above (with reference to Yang et al. (2003) and Zhao et al. (2013), it is interpreted by referring to any linguistic term in Table 2.2 (Chapter 2) that provides the highest membership to the assessed risk impact value), whereas 40 risk factors have an impact rating of 0.400 or above which can be linguistically expressed as *moderate* impact at the least. At the sectoral level, for the power infrastructure projects, only four risks exhibit an impact rating of 0.600 and above including delay in financial closure, delay in project approvals and permits, payment risk, and financing risk, whereas, another 38 risk factors achieved an impact rating of at least 0.400 (interpreted as at least *moderate*). For transport infrastructure projects, six risk factors with impact ratings equal to 0.600 and above include land acquisition, financing risk, unfavorable national/international economy, delay in financial closure, construction risk, and poor public decision-making process. In addition, another 39 risk factors achieved a risk impact rating of 0.400 and above. The top ranking risk factors relate to institutional capacity (UNECE 2008) and economic issues that characterize state of affairs of developing countries around the world (also evident from the literature review above).

Chan et al. (2011) classified PPP risks in to systematic/country risks (political, economic, legal, social, and natural risks) and specific project risks (construction, operation, market, relationship and other risks). Comparison of the top ten (arbitrarily selected to facilitate comparison and discussion) ranked risk factors reported here (Table 8.2) with top ranked risks in research coming

Table 8.2. Top ten risk factors identified in this research

	Overall		Power sector		Transport sector	
1	Delay in financial closure	SP	Delay in financial closure	SP	Land acquisition	SP
2	Land acquisition	SP	Delay in project approvals and permits	SP	Financing risk	S/C
3	Financing risk	S/C	Payment risk	SP	Unfavorable national/international economy	S/C
4	Delay in project approvals and permits	SP	Financing risk	S/C	Delay in financial closure	SP
5	Poor public decision-making process	S/C	Government intervention	S/C	Construction risks	SP
6	Construction risks	SP	Construction risks	SP	Poor public decision-making process	S/C
7	Government intervention	S/C	Land acquisition	SP	Procurement risk	SP
8	Procurement risk	SP	Poor public decision-making process	S/C	Inflation	S/C
9	Inability of debt service	SP	Variation in foreign exchange rate and convertibility issues	S/C	Delay in project approvals and permits	SP
10	Inflation	S/C	Pricing and Toll/Tariff review uncertainty	SP	Inability of debt service	SP

S/C = Systematic/Country risk category, SP = Specific project risk category

out of developing countries (Table 8.3 and 8.4) such as China, Nigeria, and Ghana (Chan et al. 2011; Ibrahim et al. 2006; Osei-Kyei and Chan 2017b) shows a greater significance of systematic/country risks. This is different from developed countries or regions (Table 8.3 and 8.4) where specific project risks tend to be more significant among the top ten risks, as reported in Akintoye et al. (1998) and Osei-Kyei and Chan (2017b) for U.K. and Hong Kong, respectively. Risk management research from Greece (Roumboutsos and Anagnostopoulos 2008) and Singapore (Hwang et al. 2013) (although developed regions) shows a similar trend to developing countries with a higher prevalence of systematic/country risks. Top 10 risks from Greece were not reported in Table 8.3 because the cited research did not provide an overall ranking of risk factors and analyzed risks separately with respect to stakeholders' perceptions i.e., construction sector, public sector and financing institutions. However, a total count of risks that lie in each category is shown in Table 8.4. A review of top ranking systematic/country risks of these jurisdictions (inclu-

Table 8.3. Top ten risk factors from previous research

	China		Ghana		Nigeria		Hong Kong		U.K.		Singapore	
1	Government intervention	S/C	Corruption	S/C	Unstable Government	S/C	Delay in land acquisition	SP	Design risk	SP	Lack of support from government	S/C
2	Government corruption	S/C	Inflation rate fluctuation	S/C	Inadequate experience in PPP	S/C	Operational costs overrun	SP	Construction cost risk	SP	Availability of finance	S/C
3	Poor public decision-making process	S/C	Exchange rate fluctuation	S/C	Availability of finance	S/C	Construction costs overrun	SP	Performance risk	SP	Construction time delay	SP
4	Financing risk	S/C	Delay in project completion	SP	Land acquisition/site availability	SP	Delay in project completion	SP	Risk of delay	SP	Inadequate experience in PPP	S/C
5	Imperfect law and supervision system	S/C	Interest rate fluctuation	S/C	Poor financial market	S/C	Political interference	S/C	Risk of cost overrun	SP	Unstable government	S/C
6	Operation cost overrun	SP	Political interference	S/C	Residual value (after concession period)	SP	Unavailability of labor and material	SP	Commissioning risk	SP	Lack of legal/regulatory framework	S/C
7	Interest rate fluctuation	S/C	High financing cost	S/C	Availability of appropriate labor/material	SP	Change in market demand	SP	Volume risk	SP	Site safety and security	S/C
8	Public credit	S/C	Construction costs overrun	SP	Financial attraction of project to investors	S/C	High financing cost	S/C	Risk of operating/maintenance cost	SP	Construction cost overrun	SP
9	Completion risk	SP	Political/public opposition	S/C	Corruption and lack of respect for law	S/C	Construction changes	SP	Payment risk	SP	Organizational and communication risk	SP
10	Inflation	S/C	Project approvals and permits delays	SP	Poor quality of workmanship	SP	Design deficiency	SP	Tendering cost risk	S/C	Strong political interference	S/C

S/C = Systematic/Country risk category, SP = Specific project risk category

Table 8.4. Category count for top ten risk factors

Category	Pakistan	China	Ghana	Nigeria	Hong Kong	U.K.	Singapore	Greece
Systematic/country risks	4	8	7	6	2	1	7	≥4
Specific project risks	6	2	3	4	8	9	3	≥5

ding Pakistan) suggests that both PPP implementation and operational maturity of countries may also play an important role in determining project riskiness, in addition to the developing or developed status of a country. According to UNECE (2008), the effects of lack of well performing institutions in many countries manifest as unusually lengthy negotiations between the public and private partners, slow closures of projects, inflexible risk sharing and wasted resources as a result of project cancellations. In PPP contracts, many systematic/country risks and some project specific risks are preferred to be allocated to the public sector (Chan et al. 2011; Ke et al. 2010a). Thus, an important implication of higher significance of systematic/country risks in developing countries (or those with low PPP implementation and operational maturity) is that the governments should be vigilant in controlling these risks. This is also important due to the fact that several project risks are interrelated (Dey and Ogunlana 2004; Loosemore and Cheung 2015) and thus government allocated risks may also influence other project risks such as the occurrence of delay in financial closure as a result of delays by government departments in issuing relevant approvals or permits. Thus, this research further validates the findings and PPP risks reported in previous studies. Notwithstanding the fact that the studies cited here have not used standard risk registers, it should be noted that the exact top ranked risk factors vary across countries which signifies the impact of contextual factors and their influence in shaping the individual risk profiles. Furthermore, risks' importance or criticality is dynamic in nature and is expected to change over time (Ameyaw 2015).

The risk factors' impact ratings were further normalized to identify the most critical risk factors for development of risk assessment model, as undertaken by Ameyaw and Chan (2015c). A total of 22 CRFs were obtained as the overall most significant with normalized values of 0.5 and above (Table 8.1), that were later utilized to develop the risk assessment model.

8.3 MODEL DEVELOPMENT AND ITS APPLICATION

In this section, a fuzzy multiple attribute risk assessment model is presented to facilitate sectoral and project risk assessment. The presented methodology has multiple practical implications in terms of enabling: identification of most critical risk factors that warrant management attention and further detailed analysis (Ameyaw and Chan 2015c), identification of CRGs for efficient planning and execution of remedial actions, assessment of overall risk level of the project by the stakeholders (Xu et al. 2010b), prioritization of projects based on risk level to decide projects worth promotion by the private sector (Zayed et al. 2008), and assessment of the local country conditions from a risk perspective before setting up the project structure and normal due diligence (Ameyaw and Chan 2015c).

8.3.1 Risks' Categorization

In order to obtain the independent common factors (CRGs), as mentioned previously, crisp risk impact values (on the 22 CRFs identified above), evaluated from defuzzified attribute ratings obtained from each respondent expert were utilized as inputs for the factor analysis. Correlation coefficients for many CRFs were found to be greater than 0.3 ensuring sufficient relationships to perform FA. The KMO value obtained was 0.663 which is greater than the minimum acceptable value of 0.5 (Field 2005). Bartlett's test of sphericity confirmed the rejection of null hypothesis with a value of 523.830 at a p-value of 0.000 (Norusis 2003). The MSA values on the diagonals

Table 8.5. Factor analysis results and sectoral and case study risk attributes values

Factor group	% of variance explained	Factor loading	Risk attributes (Power)		Risk attributes (Transport)		Risk attributes (Case study)	
			P_r	S_r	P_r	S_r	P_r	S_r
CRG-1 *Project planning and implementation*	43.904							
RF_23		0.852	0.456	0.563	0.525	0.557	0.561	0.683
RF_39		0.812	0.434	0.570	0.479	0.674	0.439	0.622
RF_37		0.798	0.518	0.573	0.430	0.499	0.617	0.622
RF_28		0.777	0.563	0.629	0.569	0.649	0.678	0.794
RF_36		0.722	0.488	0.586	0.510	0.678	0.378	0.561
RF_43		0.637	0.414	0.577	0.442	0.676	0.439	0.794
RF_27		0.530	0.537	0.640	0.557	0.770	0.500	0.678
RF_20		0.451	0.394	0.658	0.407	0.703	0.500	0.622
CRG-2 *Country economy*	11.454							
RF_06		0.860	0.488	0.478	0.527	0.553	0.561	0.561
RF_05		0.835	0.566	0.467	0.619	0.552	0.683	0.561
RF_07		0.832	0.560	0.549	0.539	0.463	0.678	0.561
CRG-3 *Public sector maturity*	9.504							
RF_03		0.812	0.573	0.598	0.581	0.629	0.739	0.561
RF_09		0.771	0.680	0.740	0.597	0.631	0.794	0.739
RF_16		0.503	0.482	0.627	0.467	0.607	0.378	0.500
RF_40		0.462	0.527	0.570	0.493	0.550	0.439	0.561
RF_30		0.326	0.592	0.661	0.515	0.644	0.617	0.622
CRG-4 *Project revenue*	6.319							
RF_18		0.940	0.547	0.703	0.407	0.574	0.439	0.739
RF_17		0.694	0.423	0.530	0.572	0.683	0.561	0.683
RF_25		0.579	0.402	0.689	0.446	0.750	0.439	0.733
CRG-5 *Project finance*	4.651							
RF_08		0.694	0.536	0.707	0.571	0.728	0.739	0.794
CRG-6 *Political stability*	4.594							
RF_41		0.789	0.411	0.638	0.398	0.600	0.378	0.561
CRG-7 *Government interference*	3.928							
RF_01		0.919	0.548	0.652	0.483	0.633	0.711	0.561

of the anti-image correlation matrix greater than 0.5 except in case of three factors with the lowest value at 0.3. A clean solution was obtained with a seven-factor model (Table 8.5), herein called the CRGs. The first four factors are interpreted as *project planning and implementation*, *country economy*, *public sector maturity*, and *project revenue*, each of which has multiple constituent interrelated risk factors. The remaining three extracted factors are interpreted as *project finance*, *political stability*, and *government interference*, which consist of one risk factor each. The labels for each CRG are derived based on the CRFs with high factor loadings (Ahadzie et al. 2008). However, since the interpretations of the labels for CRGs are subjective, there exists a possibility of variation in labeling by others (Osei-Kyei and Chan 2017a). Total cumulative variance explained by the model amounts to 84.354%. Construct validity was ascertained as the extracted factors were demonstrated to be unifactorial with satisfactory KMO values and a significant percentage of variance explained. The structure obtained from the factor analysis mainly lends itself in creating independent factors that serve as input variables for the determination of the sectoral ORI and that of the case study project. In addition, the established CRGs also enable determination of risk index values at the group level that may assist in informing and guiding better management of risks.

8.3.2 Case study: Risk Assessment of a Motorway BOT Project

Data for a case study project was collected from experts and analyzed to determine the risk index of various risk groups and overall project using the methodology discussed below. The project is a part of an 1100 km long high-speed controlled access modern motorway. At the time of collecting data for this research, the case study project (which is one of the several sections) was in tendering phase. The project section under consideration spans over approximately 300 km with multiple bridges, interchanges, and underpasses included in its scope and is expected to cost close to USD 2 billion according to latest estimates. The project is being implemented on BOT basis with a lease period of 18 years. Experts from multiple bidding consortia were contacted and three individuals from the private sector, having working knowledge of the project, agreed to participate. The experts were requested to evaluate the critical risk factors in terms of assessment based on individual risks' probability and severity. This was to be done based on experience of the respondents of working on projects in Pakistan and their perception on critical risk factors related to the project (Appendix E).

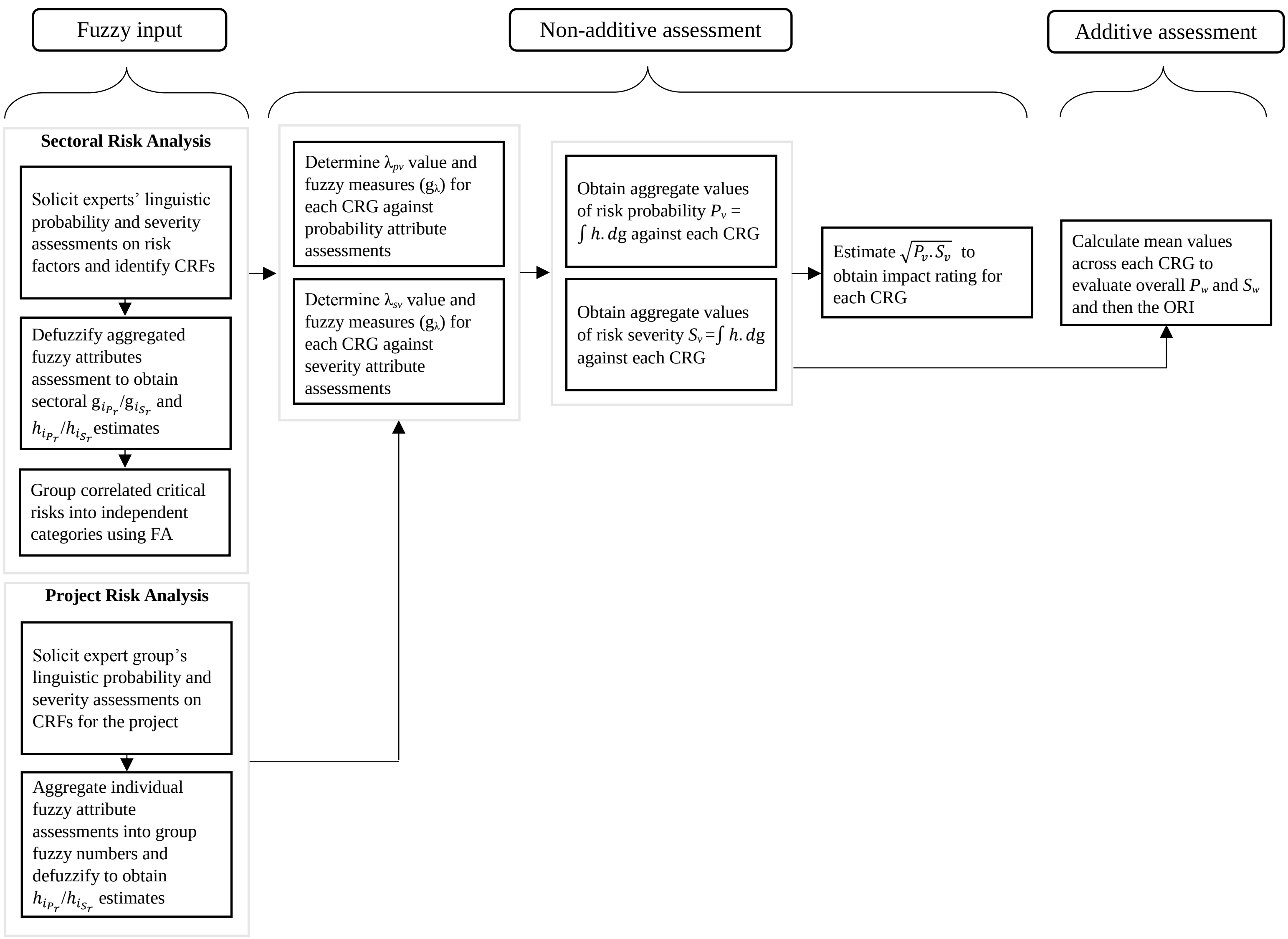

Fig. 8.1. Fuzzy risk assessment model

8.3.3 Step-wise Development and Application of the Model

In order to setup and demonstrate the model application, a stepwise procedure has been delineated in Fig. 8.1. Since assessment of ORI is akin to a multi-attribute decision making problem, as mentioned previously, the idea is to obtain two types of information for each risk factor against each attribute of risk probability and severity. The grades of importance/weightings (g_i) of the factors need to be estimated along with the performance ratings of these factors (h) to assess risk level in the sectoral and/or project specific context. Since four of the CRGs comprise of multiple risk factors, fuzzy measure and Choquet fuzzy Integral analysis were performed for these CRGs to accommodate factor interactions whereas, obviously, no such consideration was necessary for the remaining CRGs. With independence among CRGs, an additive measure was adopted for aggregation to compute ORI (Liou and Tzeng 2007). In this study, both sectoral and project level applications of the model have been presented. The attribute data on each risk for sectoral and case study project analysis (Table 8.5) were processed to determine the risk index of each CRG and the ORI as follows:

i) *Identify critical risk factors* - CRFs for PPP infrastructure projects were identified via questionnaire survey of public and private sector stakeholders in a countrywide data collection effort (Table 8.1).

ii) *Identify CRGs to group correlated factors* – Factor analysis was performed on CRFs to group risk factors that exhibit significant correlation and to obtain uncorrelated CRGs (Table 8.5). In total, seven CRGs were obtained.

iii) Evaluate grade of importance of individual CRFs - The grade of importance/weightings labelled as $g_{i_{P_r}}$/$g_{i_{S_r}}$ were determined via risk attribute assessments of CRFs in the survey. The subscripts were defined to designate fuzzy density values for any CRF *i*, under a CRG *v*, for each of the attributes of probability (P_r) and severity (S_r). The defuzzified aggregated values of both the risk attributes for each individual risk were used for that purpose (Table 8.5) (Ameyaw and Chan 2015c; Wang et al. 2010).

iv) Assess fuzzy measures (g_λ)

a) In order to obtain the aggregate assessment of risk attributes (P_v/S_v), a λ value was calculated for each CRG against each attribute, hence two sets (one for each infrastructure sector) of eight λ values (λ_{p1} - λ_{p4}, $\lambda_{s1} - \lambda_{s4}$) were calculated. The λ values were calculated by inserting fuzzy densities ($g_{i_{P_r}}$/$g_{i_{S_r}}$) in Eq. (8). For example, for transport infrastructure projects, λ_{p4} (-0.7139) for CRG-4 (Project revenue), was assessed as:

$$(1+0.407\lambda_{p4})*(1+0.572\lambda_{p4})*(1+0.446\ \lambda_{p4}) = (1+\lambda_{p4})$$

b) For the general sectoral evaluation (power/transport) of risk level, attribute values $h_{i_{P_r}}/h_{i_{S_r}}$ on component risks were derived from respondents' ratings of probability (P_r) and severity (S_r) (crisp values) in the survey, whereas, for the case study analysis, $h_{i_{P_r}}/h_{i_{S_r}}$ were calculated using crisp values of risk attributes that were specifically assessed by the experts to reflect the perceptions regarding the project only (Table 8.5).

c) The λ values were then utilized to obtain the values of fuzzy measure g_λ for each subset of risk factors under the CRGs, for both risk attributes, separately. Before calculating g_λ, the risk attributes ratings $h_{i_{P_r}}/h_{i_{S_r}}$ are required to be rearranged in-order to enable application of the methodology for the calculation of fuzzy measures and fuzzy integral using Eq. (6) & (7).

d) Since the λ values explain interaction between factors, λ values obtained for transport sector analysis were also used for determining the fuzzy measures for the case study analysis (Table 8.6). Here, only the case study analysis is shown while omitting detailed calculations of the sectoral fuzzy measure evaluations due to limitation of space.

v) *Evaluate risk level/index of CRGs using Choquet fuzzy integral* - For both sectoral and case study analysis, Choquet fuzzy integral was applied to compute the aggregate probability and severity values for each CRG ($P_1 – P_4$ / $S_1 – S_4$), using Eq. (6) (Table 8.7). To demonstrate the calculation procedure, the aggregate probability value for CRG-4 for case study project was assessed as follows:

$P_4 = h(x_{RF\_25}).\ g_{\lambda}(x_{RF\_17}, x_{RF\_18}, x_{RF\_25}) + [h(x_{RF\_18}) - h(x_{RF\_25})].\ g_{\lambda}(x_{RF\_17}, x_{RF\_18}) + [h(x_{RF\_17}) - h(x_{RF\_18})].\ g_{\lambda}(x_{RF\_17})$ = 0.439*1 + (0.439-0.439)*0.813 + (0.561-0.439)*0.572 = 0.509

Risk impact values for each CRG ($I_1 – I_7$) were also computed by computing the product of risk probability and severity and then taking its square root $\sqrt{P_v * S_v}$, at CRG level (Table 8.7).

vi) *Calculate the overall risk attributes value and obtain ORI* - Since the factor groups obtained from FA can be assumed to be independent, arithmetic mean was employed to obtain the requisite overall probability (P_w) and severity (S_w) values. Risk Impact (I_w) or the ORI was calculated via $\sqrt{P_w * S_w}$ (Table 8.7).

Table 8.6. Case study λ and fuzzy measure (g_λ) analysis

Probability				Severity			
ID	$h_{i_{P_r}}$	g_λ		Identifier	$h_{i_{S_r}}$	g_λ	
CRG-1 (λ_{p1} =-0.9955)				CRG-1 (λ_{s1} =-0.9998)			
RF_28	0.678	$g_\lambda(x_{RF\_28})$	0.569	RF_43	0.794	$g_\lambda(x_{RF\_43})$	0.676
RF_37	0.617	$g_\lambda(x_{RF\_28}, x_{RF\_37})$	0.755	RF_28	0.794	$g_\lambda(x_{RF\_43}, x_{RF\_28})$	0.886
RF_23	0.561	$g_\lambda(x_{RF\_28}, x_{RF\_37}, x_{RF\_23})$	0.886	RF_27	0.683	$g_\lambda(x_{RF\_43}, x_{RF\_28}, x_{RF\_27})$	0.974
RF_27	0.500	$g_\lambda(x_{RF\_28}, x_{RF\_37}, x_{RF\_23}, x_{RF\_27})$	0.952	RF_23	0.678	$g_\lambda(x_{RF\_43}, x_{RF\_28}, x_{RF\_27}, x_{RF\_23})$	0.989
RF_20	0.500	$g_\lambda(x_{RF\_28}, x_{RF\_37}, x_{RF\_23}, x_{RF\_27}, x_{RF\_20})$	0.973	RF_20	0.622	$g_\lambda(x_{RF\_43}, x_{RF\_28}, x_{RF\_27}, x_{RF\_23}, x_{RF\_20})$	0.997
RF_39	0.439	$g_\lambda(x_{RF\_28}, x_{RF\_37}, x_{RF\_23}, x_{RF\_27}, x_{RF\_20}, x_{RF\_39})$	0.988	RF_36	0.622	$g_\lambda(x_{RF\_43}, x_{RF\_28}, x_{RF\_27}, x_{RF\_23}, x_{RF\_20}, x_{RF\_36})$	0.999
RF_43	0.439	$g_\lambda(x_{RF\_28}, x_{RF\_37}, x_{RF\_23}, x_{RF\_27}, x_{RF\_20}, x_{RF\_39}, x_{RF\_43})$	0.995	RF_37	0.622	$g_\lambda(x_{RF\_43}, x_{RF\_28}, x_{RF\_27}, x_{RF\_23}, x_{RF\_20}, x_{RF\_36}, x_{RF\_37})$	0.999
RF_36	0.378	$g_\lambda(x_{RF\_28}, x_{RF\_37}, x_{RF\_23}, x_{RF\_27}, x_{RF\_20}, x_{RF\_39}, x_{RF\_43}, x_{RF\_36})$	1.000	RF_39	0.561	$g_\lambda(x_{RF\_43}, x_{RF\_28}, x_{RF\_27}, x_{RF\_23}, x_{RF\_20}, x_{RF\_36}, x_{RF\_37}, x_{RF\_39})$	1.000
CRG-2 (λ_{p2} =-0.8651)				CRG-2 (λ_{s2} =-0.8084)			
RF_05	0.683	$g_\lambda(x_{RF\_05})$	0.619	RF_06	0.561	$g_\lambda(x_{RF\_06})$	0.553
RF_07	0.678	$g_\lambda(x_{RF\_05}, x_{RF\_07})$	0.870	RF_05	0.561	$g_\lambda(x_{RF\_06}, x_{RF\_05})$	0.858
RF_06	0.561	$g_\lambda(x_{RF\_05}, x_{RF\_07}, x_{RF\_06})$	1.000	RF_07	0.561	$g_\lambda(x_{RF\_06}, x_{RF\_05}, x_{RF\_07})$	1.000
CRG-3 (λ_{p3} =-0.9744)				CRG-3 (λ_{s3} =-0.9907)			
RF_09	0.794	$g_\lambda(x_{RF\_09})$	0.597	RF_09	0.739	$g_\lambda(x_{RF\_09})$	0.631
RF_03	0.739	$g_\lambda(x_{RF\_09}, x_{RF\_03})$	0.840	RF_40	0.622	$g_\lambda(x_{RF\_09}, x_{RF\_40})$	0.837
RF_30	0.617	$g_\lambda(x_{RF\_09}, x_{RF\_03}, x_{RF\_30})$	0.933	RF_30	0.561	$g_\lambda(x_{RF\_09}, x_{RF\_40}, x_{RF\_30})$	0.947
RF_40	0.439	$g_\lambda(x_{RF\_09}, x_{RF\_03}, x_{RF\_30}, x_{RF\_40})$	0.978	RF_16	0.561	$g_\lambda(x_{RF\_09}, x_{RF\_40}, x_{RF\_30}, x_{RF\_16})$	0.985
RF_16	0.378	$g_\lambda(x_{RF\_09}, x_{RF\_03}, x_{RF\_30}, x_{RF\_40}, x_{RF\_16})$	1.000	RF_03	0.500	$g_\lambda(x_{RF\_09}, x_{RF\_40}, x_{RF\_30}, x_{RF\_16}, x_{RF\_03})$	1.000
CRG-4 (λ_{p4} =-0.7139)				CRG-4 (λ_{s4} =-0.9556)			
RF_17	0.561	$g_\lambda(x_{RF\_17})$	0.572	RF_25	0.739	$g_\lambda(x_{RF\_25})$	0.750
RF_18	0.439	$g_\lambda(x_{RF\_17}, x_{RF\_18})$	0.813	RF_18	0.733	$g_\lambda(x_{RF\_25}, x_{RF\_18})$	0.913
RF_25	0.439	$g_\lambda(x_{RF\_17}, x_{RF\_18}, x_{RF\_25})$	1.000	RF_17	0.683	$g_\lambda(x_{RF\_25}, x_{RF\_18}, x_{RF\_17})$	1.000

Table 8.7. Sectoral and case study CRG and overall risk ratings

Identifier	Group description	Power sector				Transport sector				Case study			
		P_v	S_v	I_v	Rank	P_v	S_v	I_v	Rank	P_v	S_v	I_v	Rank
CRG-1	Project planning and implementation	0.543	0.648	0.593	4	0.554	0.753	0.646	1	0.629	0.781	0.701	3
CRG-2	Country economy	0.553	0.515	0.534	6	0.587	0.540	0.563	5	0.666	0.561	0.611	5
CRG-3	Public sector maturity	0.647	0.716	0.681	1	0.578	0.638	0.607	4	0.739	0.685	0.712	2
CRG-4	Project revenue	0.487	0.689	0.579	5	0.512	0.728	0.610	3	0.509	0.733	0.611	5
CRG-5	Project finance	0.536	0.707	0.616	2	0.571	0.728	0.645	2	0.739	0.794	0.766	1
CRG-6	Political stability	0.411	0.638	0.512	7	0.398	0.600	0.489	7	0.378	0.561	0.460	7
CRG-7	Government interference	0.548	0.652	0.598	3	0.483	0.633	0.553	6	0.711	0.561	0.632	4
ORI		0.5891				0.5893				0.6459			

8.4 DISCUSSION OF CRGs

The aggregate risk attribute score, obtained via fuzzy measure and Choquet Fuzzy Integral approach for each CRG of sectoral and case study analysis are shown in Table 8.7. The ORI can be converted back into a representative linguistic expression for risk assessment by determining the linguistic term that provides the highest membership at ORI value according to Table 2.2 (Chapter 2). In that sense, both the power and transport infrastructure sectors exhibit *moderate* level of risk (Fig. 8.2) when considering investment in these sectors. Further examining the risk

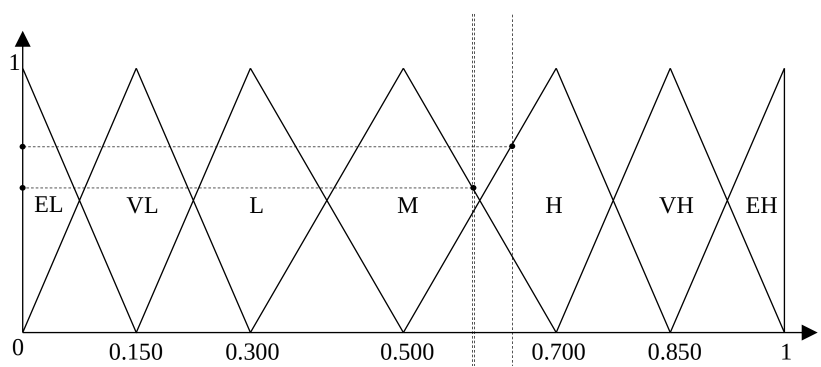

Fig. 8.2. Linguistic interpretation of the ORI

impact indices of factor groups, it is evident that at sectoral level, the situation is quite different. For power infrastructure projects, *public sector maturity* and *project finance* were rated as the only CRGs at *high* risk level, whereas, *project planning and implementation*, *project finance*, *project revenue*, and *public sector maturity*, were all rated as *high* risk CRGs for transport infrastructure projects. One possible explanation to this effect can be the fact that investment in transport infrastructure PPP projects has a young history in Pakistan as opposed to the power sector where the private investment started in the early 90's (Mazher et al. 2017). The remaining CRGs in each sector were rated at a *moderate* risk level thus suggesting that all the CRGs are in fact significant and demand attention by the stakeholders.

8.4.1 CRG-1 Project Planning and Implementation

Factor group one represents risk factors that spread over the project lifecycle including planning and design, construction and operation and maintenance phase. The eight factors in this category capture the uncertainty in ability of the stakeholders, both the public and the private sectors, in terms of not being able to execute their responsibilities properly.

The risk of land acquisition was rated *moderate* (ranking 7th) and *high* (ranking 1st) for power and transport infrastructure projects, respectively. It is the highest ranking risk factor in this group and has different criticality for the power and transport infrastructure sectors as acquiring right of way for a toll road is more difficult than acquiring a parcel of land due to issues of multiple ownership and the complex negotiations (PPIAF 2009a). Land acquisition is responsibility of the government (State Bank of Pakistan 2007). Poor governance (lengthy procedures and late payments to the land owners) usually results in delays and extra costs (Noor 2011; State Bank of Pakistan 2007). Soomro and Zhang (2011) cited conflicts and differences between the central and provincial governments regarding land ownership and privatization, as one of the reasons that led to cancellation of the M9 motorway project concession.

Construction risk, rated *high* for transport infrastructure projects (ranking 5th) and *moderate* for power projects (ranking 6th), is considered significant as construction phase is the most investment intensive phase of the project due to the characteristic large capital costs. Any delays or overruns can be devastating, as delays can disturb project cashflow; thus, resulting in penalties in the form of additional interest payments, increase in project cost due to effects of inflation and may necessitate arrangement of additional finance, should the need arise. Delays during construction leading to extensions in the commercial operations date were reported at the three recently built Re-Gasified Liquefied Natural Gas (RLNG) fired power plants at Bhikki, Baloki and Haveli Bahadur Shah (Jamal 2016, 2018). These were attributed to multiple reasons such as late delivery of gas turbines and various technical commissioning issues. All of these plants are being procured under the latest power policy of 2015. Noor (2011) also reported delays on a thermal power project based on BOO scheme as a result of delays in supply of engines and other equipment from international manufacturer and suppliers and delays due to difficulty in transportation of the equipment from the port to final place of installation. Transport infrastructure projects may face less issues in the domain of commissioning and importation delays due to relatively low technological scope and production based on mostly locally sourced materials and available equipment. However, delays and/or cost overruns due to other issues may remain a problem and may result in loss of revenues in the form of missed toll earnings.

Risk of corruption was marked *moderate*, at a large difference across the sectors while ranking 12th for power and 29th for transport infrastructure projects. Allegations of corruption were leveled against the first set of IPPs by the incoming government, as explained previously (Fraser 2005; Reside 2009). Political pressure in the form of influence to affect the procurement methods and unethical or corrupt practices to influence award of the projects were also reported in the power sector (although no clear linkage with PPP type procurement was established) (Noor 2011). Corrupt practices were also considered to impact the effective implementation of projects in case study of a transport sector organization (ibid.). Corruption was reported as prevailing and in some cases a critical concern in PPP projects in developing countries including China, Ghana, Nigeria and India (Chan et al. 2011; Ibrahim et al. 2006; Meduri and Annamalai 2013; Osei-Kyei and Chan 2017b).

Among the failed PPP cases discussed in Chapter 5, some of the reasons contributing/leading to their failures can be attributed to shortfalls in project development efforts by both the public and private sector stakeholders (including lack of, or poor, feasibility studies; design problems etc.). Planning risk achieved *moderate* impact rating of 0.497 (ranking 20) and 0.567 (ranking 11) for power and transport infrastructure sector respectively. Sometimes there is a tendency to undertake projects via PPPs without comprehensive feasibilities studies. Perhaps, as a result, one of the BOT transport infrastructure project investigated by Noor (2011) suffered community backlash and resistance to paying tolls to use a route that was previously un-tolled. Similarly, another project i.e., the Hyderabad-Mirpurkhas dual carriageway BOT project, also suffered local community opposition to paying tolls as the road was previously free (Tribune 2017). This resulted in a court order to reduce the toll tax and exemption of commuters residing within five km proximity of the road's entry points. An availability based payment mechanism may have suited these projects provided the social status of the project bearing region had been studied comprehensively. The state bank of Pakistan has issued Prudential Regulations (PRs) for infrastructure project financing

(IPF) to facilitate the banks and development finance institutions (DFIs) in evaluating cashflow generating capacity of the projects and to develop relevant expertise (State Bank of Pakistan 2016). Improper due diligence by the lenders (attributed to "*... local financial institutions having no or little prior experience of project financing lack the knowledge of rigorous due diligence practices.*", for studied case study projects) leading to a higher probability of selection of unsuitable concessionaire, was reported as one of the failure drivers for transportation PPP projects (Soomro and Zhang 2011, 2015a; Zhang and Soomro 2015). Planning risk may be ranked lower for power sector probably because of relatively more local experience in executing such projects and involvement of experienced international investors, lenders and consultants in such projects (See Chapter 3).

Design and construction deficiencies risk was ranked 23rd and 13th with a *moderate* impact rating of 0.488 and 0.545 for power and transport infrastructure projects respectively. All design and construction quality risks are usually or preferred to be allocated to the private sector in PPP projects (GI Hub 2016; Ke et al. 2010a; b). Any faults in the design can create major issues during the constriction and commissioning, whereas faults in both design and construction can give rise to operation and maintenance risks. The Habibabad flyover BOT project developed cracks few weeks after its inauguration which were attributed to undue haste in construction while no evidence of substandard materials was found (Ansari 2016).

Both the sectors ranked availability/performance risk closely at 18th and 16th position for power and transport sectors respectively with *moderate* impact. This risk is more critical for the power sector in the sense that payments to power producers are made on availability basis. Additionally, the probability of this risk materializing is very real for thermal power plants due to the issue of circular debts and resulting delayed payments by the power purchasing agency which strains upon the ability of the power producer to purchase fuel (Kiani 2017; State Bank of Pakistan 2013). This ultimately transforms into the IPPs not being able to perform at full capacity or to remain idle. Many other reasons can also contribute to this risk including: design and construction deficiencies; technological risks (such as the commissioning difficulties related to General Electric's new 9HA class turbines at Bhikki, Haveli and Balloki RLNG plants [Jorgic and Gloystein 2017]); and poor management by the private operator. This risk would directly and severely impact the ability of the project to generate revenues and therefore, it was marked with a *high* severity for both the sectors.

The risk of operation cost overrun was ranked 19th and 14th for power and transport infrastructure sectors respectively, with *moderate* outlook for the risk's impact. If there are no planning related risks, this risk would occur as a result of design/construction deficiencies and/or variations in economic risks, such as variation in inflation and interest rates as well as foreign exchange rate risks. Changes in input prices will lead to high operational costs. Real risk transfer from public and private sector should occur in case of main operational expenditure items including hard facility management, lifecycle or other maintenance costs. If the risk of long term maintenance costs is not passed down to the subcontractors, the project company remains exposed to the risk. Long term maintenance costs constitute the largest risk for the lenders and the investors, and these are difficult to predict (Yescombe 2007).

The outlook for procurement risk is different in both the sectors, while ranking 7th and 13th in transport and power infrastructure sectors, respectively, with *moderate* impact. A notable difference lies in the level of participation of both local and international players in PPP projects' tendering. For power infrastructure sector, international interest and investment are relatively higher as apparent from the World Bank's PPI database (World Bank 2018b) and findings reported by Noor (2011). This may be due to a number of factors such as the maturity of policy and procurement framework in the power sector owing to its tested history and express guarantees by the federal government to ensure returns to investors and lenders (ibid.). Furthermore, for the renewable energy sector (wind, solar, biomass etc.) since the projects can be installed for various generation capacities (even in sub-megawatt range i.e., kilowatts), the amount of investment required for setting up a viable project is low as compared to hydropower projects which easily run in to hundreds of millions of dollars and have to be large enough to be viable. This allows more investors to consider entering in to this business (specially the local investors) and thus the risk of low competition is relatively lower in the renewable energy sector. For transport infrastructure sector which has a relatively young history of private sector participation, it was initially hard for the public authorities to generate competition with relatively low interest of local investors (Noor 2011). International investors have also showed little interest in the past. A possible reason for low interest of local investor may be because transport infrastructure projects are usually large horizonal projects which are financially intensive; thus, requiring large upfront investments. This was the case even though almost all the highway/tunnel/bridge projects undertaken thus far were brownfield projects on existing routes with some confidence in traffic flow and forecasts (see Chapter 3). Problems in securing required financing is also a related concern (ADB 2014). Financial, economic and security situation of Pakistan is believed to have increased the overall cost of doing business (Noor 2011). Poor security situation of Pakistan was reported as the most important impediment to project procurement and implementation in the country. According to the author (ibid.), these issues in conjunction with risk of political instability and immaturity of public sector organizations and institutions lead to a lack of investor interest, both domestic and foreign. Now that a number of examples exist of successfully procured projects across the country, local banks and investors are showing more interest in investing on projects in the pipeline that exhibit strong economic/financial/technical viability and are also attracting international interest, such as in the case of Hyderabad-Sukkur motorway (M6), and Hyderabad-Mirpurkhas dual carriageway (Amin 2017; Tribune 2017; Wasif 2016).

8.4.2 CRG-2 Country Economy

Factor group two accommodates risk factors that are directly influenced by the dynamics of the project's host country economy. Inflation, variation in interest and foreign exchange rate directly impact project cost and profitability. Inflation risk was seen as a *moderate* impact risk and ranked lower for power infrastructure projects (ranked 15^{th}) as opposed to transport infrastructure projects (8^{th}). A relatively lower ranking in power as opposed to the transport infrastructure projects sector may be explained by the way it is treated in both the sectors. For power sector projects, the effects of inflation are adjusted periodically on actual basis (i.e., indexed) in the price of the electricity sold to the utilities, which is different from transport infrastructure projects, where effects of inflation must be forecasted and built into the toll tax schedule for the entire concession period as being practiced on some projects. The consequence of inflation rate volatility include difficulty in making realistic financial projections by the private investors and consequent increase in toll charges (or service pricing), which may lead to user agitations and fall in demand for the public facility (Osei-Kyei 2018).

Interest rate fluctuation risk was rated at 25th and 15th position for power and transport infrastructure projects, respectively, with a *moderate* impact rating. For the cases where floating interest rate regime is adopted, local loans may be indexed to changes in benchmark interest rate of Karachi Interbank Offered Rate (KIBOR), etc., whereas foreign loans are indexed similarly to LIBOR, etc. (Ministry of Water and Power 2005). However, the way interest rate variation risk is allocated in contracts varies across sectors. The higher ranking of risk in transport infrastructure projects may be explained by the relatively more volatile situation of local economy and the fact that many of the projects in this sector are locally funded. According to World Bank (2018e), the lending interest rate in Pakistan has varied from 7.258% in 2004 up to 14.419% in 2011 and all the way down to 8.21% in 2017. Also, for some projects witnessed during the research, it was learnt that time based indexation of interest rate was not allowed (for transport sector projects), rather the private sector is completely allocated the risk of variations, which may result in a higher risk perception and thus, the added high premium in the bid.

Variation in foreign exchange rate and convertibility issues risk was rated much higher for power sector (9th position) as compared to transport infrastructure sector (20th position) with a *moderate* impact. This is because majority of the plant equipment and instrumentation is imported in foreign currency, which constitutes a bulk of the total project investment. Furthermore, if the prices are denominated in local currency while financing and other obligations (loan payment commitments and purchase of project resources such as fuel or equipment) must be met in other currencies (UNCITRAL 2001), foreign exchange risk becomes a concern for as long as the obligations are not completely met.

In order to facilitate understanding of the situation of macroeconomic risks, a comparison of the indicators data (inflation, interest rate, foreign exchange rate) over a period of 20 years (1997-2017) was performed, between Pakistan and developed and mature PPP markets. As compared to mature PPP markets such as Australia and the UK, Pakistan's economy is apparently very much variable which is evident from the observation of twenty year official exchange rate (Local Currency Units (LCU) per US$, period average) (Fig. 8.3), inflation, consumer prices (annual %) (Fig. 8.4), and lending interest rate (%) (Fig. 8.5), available from World Bank data (World Bank 2018e).

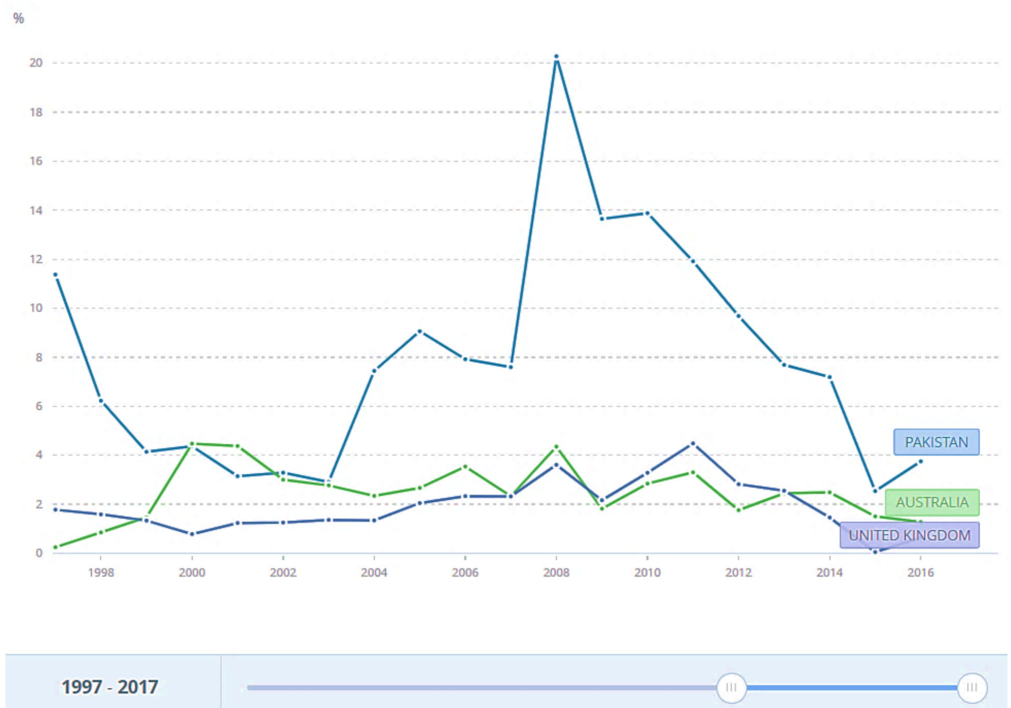

Fig. 8.3. Inflation, consumer prices (annual %) – comparison of Australia, Pakistan and United Kingdom

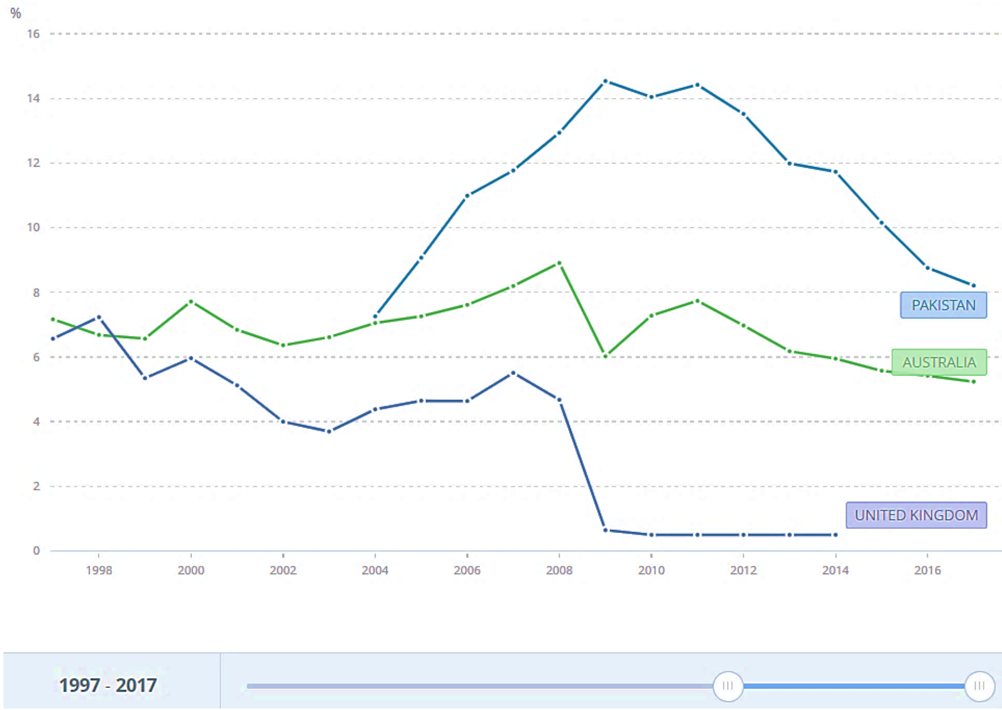

Fig. 8.4. Lending interest rate (%) – comparison of Australia, Pakistan and United Kingdom

Fig. 8.5. Official exchange rate (Local Currency Units (LCU) per US$, period average) – comparison of Australia, Pakistan and United Kingdom

8.4.3 CRG-3 Public Sector Maturity

The third factor group dealing with public sector's capacity and commitment towards procuring and operating PPP projects emphasizes the need to streamline processes and procedures and to adopt best practices. Delay in financial closure, the top-ranking risk factor of this group, is dependent upon a number of factors such as bankability of the project, which is in turn determined by project demand, government support, and timely acquisition of land and the requisite permits/ clearances. These issues are significantly influenced by government's policy and cooperation (Thomas et al. 2003). While these issues are applicable for Pakistan as well, delays can be avoided if the concerned public authorities can reduce uncertainties by conducting project feasibility studies, acquiring project land, obtaining project approvals/permits early and selecting strong private sponsors for the project. Furthermore, projects may simply be costing more because the bidders have to add hefty contingency margins to cover change in component costs, owing to long time duration between bid submission and subsequent financial close and startup of the project.

Change in government and political opposition with a *moderate* impact was ranked at 11^{th} and 19^{th} for power and transport infrastructure sectors, respectively. Although, respondents to the semi-structured interviews and some investigator administered surveys didn't see this as a threat in the post financial close phase of the projects at this time, there is a level of discomfort regarding continued leadership and government support at the project development stage. The risk actually materialized in the late 1990s when the then IPPs were opposed to have colluded with the previous government and forced to renegotiate terms by the new government (Fraser 2005; Reside 2009). Furthermore, power is sort of a political subject (which is subsidized by the government (Lodhi 2014)) potentially making this sector prone to some extent to the influences of the political and social climate. However, once the agreements are signed, there is little threat perceived by the investors. This is indirectly observable by the fact that a huge bulk of investment under the CPEC program is envisaged for the development of energy infrastructure projects, where all the energy projects will be implemented under the IPP mode (see Chapter 3). Lee and Schaufelberger (2013) emphasized the importance of host government's support and active involvement for effective risk management on projects in addition to a need for collaborative working relationships between the public and private sectors to create win-win situations.

The risk of poor public decision making process ranked 8th (*moderate* impact) for power and 6th (*high* impact) for transport sector, which is evident from a low level of PPP operational maturity of Pakistan among Asia-Pacific countries (Economist Intelligence Unit 2015), lack of PPP capacity in provincial governments (ADB 2015a), and as mentioned earlier, long and protracted procedures in acquisition of land, permits and approvals. Noor (2011) reported that poor coordination between government departments (the project procuring authority and higher level project approving bodies) and lack of timely policy decision resulted in a two year delay in procurement of a BOT tunnel project. The same study concluded that the proposal and bid evaluation procedures in public infrastructure procurement in Pakistan were "*... bureaucratic and cumbersome ...*" causing delays in selection of consultants, contractors and private parties. According to ADB (2007) as cited in Noor (2011), the overcentralized governance in Pakistan causes disempowerment of public sector infrastructure procurement institutions which results in delays in project approvals and allows for non-economic considerations in prioritization. The consequences of this risk were reported by Fraser (2005) in terms of government's poor definition of project selection criteria for procurement of power generation projects (IPPs), in the early 90's. More recently, the diagnostic exercises on provincial PPP frameworks (Punjab and Sindh) and the status of PPP projects' implementation identified *inherent bias/risk-aversion in the selection process of development projects* (ADB 2015a). This was attributed to a lack of experience and an inability to plan/appraise projects which instill uncertainty in reaching financial close and project implementation.

This risk of pricing and toll/tariff review uncertainty was ranked at 10th and 17th position for power and transport infrastructure projects, respectively. The higher ranking attributed to the power sector may be attributable to the perceived uncertainty at the pre-financial close stage, where the tariff has to be approved by the regulator, National Electric Power Regulatory Authority (NEPRA). Tariff determination by the regulator at the procurement stage is time consuming task and if the regulator has issues with the IPP, then the IPP has to appeal and reappeal and sometimes this process can take a long time to resolve (Noor 2011). However, according to perceptions of the respondents to the survey in this research, once the entire tariff has been finalized, no problems are foreseen by the investors post financial close. The same perception exists for transport infrastructure sector as well. Two of the road projects facing problems with regards to tolls have been mentioned previously, where for one project, the private sector is not able to recover sufficient revenues due to unforeseen failure of implementation of toll, which is attributable to law and order situation and interference of the civil administration (Noor 2011). For the other project (Hyderabad-Mirpurkhas dual carriageway BOT project), a court order has directed to reduce tolls.

For the public sector, pricing for power supplied to the consumers is a complex task. Power generated from various sources (including IPPs) is purchased by the National Transmission & Dispatch Company (NTDC) through its Central Power Purchasing Agency (CPPA), as per tariff determined by NEPRA (Lodhi 2014). The consumer end tariff is also determined by NEPRA which includes the cost of the entire supply chain (generation, transmission and distribution).

Various adjustments are made to the consumer end tariff at different intervals such as the monthly fuel adjustments due to variation in fuel prices and quarterly adjustments that focus on multiple variables. All the power sold to the market has to be paid for recovering revenues principally from bill payments by the consumers and tariff differential subsidy (TDS) paid by the government. It is contended that the pricing methodology adopted by NEPRA to obtain the sale price of electricity has many issues (insufficient accounting of actual transmission and distribution losses, lack of accounting of late payment surcharges to IPPs, etc.) which ultimately leads to insufficient revenues for the public sector; hence, creating circular debt. This issue of pricing then affects the entire power sector (Lodhi 2014; State Bank of Pakistan 2013).

Delays in project approvals and permits was ranked at 2nd and 9th position for power (*high* impact) and transport (*moderate* impact) infrastructure projects, respectively. Noor (2011) reported that for power projects, a number of consents are needed from various government institutions and public sector stakeholders in setting up IPP projects, which can run in to hundreds. As per policy, obtaining these statuary consents is a private sector responsibility after the signing of the project agreement which was considered as a significant cause of delays and often conflicts.

8.4.4 CRG-4 Project Revenue

Factor group four deals with risk factors that relate to the project's ability to generate sufficient revenue. Payment risk was significantly higher for power sector (ranked 3rd) with *high* impact rating while the transport sector recorded a *moderate* rating (ranked 26th). For the power sector, lack of or delayed payments by the power purchaser (Economist Intelligence Unit 2015) strain the power producers' ability to operate the plant (Lodhi 2014) and also to pay off debt (ranked at 14th

place) (Ghumman 2012). PPP projects in Pakistan follow different payment mechanisms for projects. For power sector, the NTDC makes payments (government pays type arrangements where the state owned utility makes payments as per the signed PPA) to IPPs for the produced electricity whereas, for transport sector projects 'user pays' scheme is more prevalent. The power sector's circular debt crisis, which is a manifestation of operational inefficiencies and mis-governance (higher transmission losses, low recoveries from billed amount, non-payment by public sector entities, high differential between generation cost and notified tariff, delays in determination of fuel price adjustment and recovery, delay in release of tariff differential subsidy, etc.), seriously hampers NTDC's ability to make timely payments to the power producers (i.e., IPPs) (State Bank of Pakistan 2013). This sometimes results in IPPs invoking sovereign guarantees for NTDC's failure of payments (The News 2017a). For transport infrastructure sector, this risk is rather low with some recorded experience of user's hesitating to pay for using the facility except the two projects discussed above (Noor 2011; Tribune 2017). Another important factor that can contribute to this risk is poor local economy which may aggravate the problem due to lowering demand and defaulting consumers; thus, resulting in problems for the power purchaser to make payments. Poor economy may also render the government unable to honor its guarantees (Xenidis and Angelides 2005a). For the transport infrastructure projects, payment risk may not be a big problem as potential consumers may only be able to use the facility upon paying a predetermined toll tax. However, poor economy may significantly influence travel patterns, thus hitting hard on demand and the ability to pay off debts in time. Inability of debt service ranked 14th and 9th with *moderate* impact rating for power and transport infrastructure projects, respectively. The relatively higher perception of this risk for transport infrastructure projects may be explained by examining the stock of currently operational PPP projects most of which are brownfield, perhaps explaining concerns regarding the bankability of potential greenfield projects. Furthermore, unlike power sector, transport sector projects do not carry demand guarantees for most of the projects in operation in the country, therefore, possibly making the inability of debt service a relatively higher perceived risk. The ranking of this risk correlates with assertions of the then director general of Sindh PPP unit who noted that due to the government payment delays to IPPs (for power sector), many banks do not trust the government to pay back loans (ADB 2014). Also, the federal government has poor credit, which makes it difficult for the banks to lend to government (ibid.). Factors that influence international economy such as the global financial crisis also impact local PPP projects by hampering the flow of international financing (Noor 2011), specifically for power sector projects in Pakistan. The risk factor of unfavorable national/international economy received a ranking of 26th (*moderate* impact) and 3rd (*high* impact) and for power and transport infrastructure projects in the country, respectively. According to Lodhi (2014), high power tariff is beyond the capacity of consumers to pay despite the heavy subsidy from the government. In one of the organizational case studies performed by Noor (2011) which covered a provincial public highway organization, respondents asserted that toll capacity of people in Pakistan was very low for projects to be executed on PPP basis. Such depictions are by themselves reflective of the state and influence of local economy.

8.4.5 CRG-5 Project Finance

Factor group five independently accounts for financing risk alone. Financing risk was ranked among the top ten factors for power and transport infrastructure projects in China (Cheung and Chan 2012). Financing risk was ranked at 4th and 2nd position with *high* impact rating for power and transport infrastructure projects, respectively. Raising finance for PPP projects can be a problem as only short to medium term financing is available from commercial banks due to lack of debt market maturity (ADB 2015a). The then director general Sindh PPP unit articulated that the longest term that the banks are willing to finance is 10 years which is not enough for many PPP projects; however, this will get better as market develops (ADB 2014). Realizing the fiscal constraints, the GoP has instituted the Pakistan Development Fund Limited (PDFL) to finance the multi-billion dollar projects on PPP pattern. The company is intended to provide complementary long-term project finance to encourage private sector participation (Haider 2016). Furthermore, the creditworthiness of the potential sponsor is also important for securing loans (Xenidis and Angelides 2005a). Low financial capacity in the local market was also reported as an underlying reason for considering international competitive bidding to satisfy the financial appetite of hydropower power projects (Noor 2011). Another problem reported was the commitment of investors to the project. Net worth of a company may not be a sufficient indicator of a company's future investment intentions. Noor (2011) reported that in one instance a private power sector project suffered later during its lifecycle when the project company which initially had the required finances, reprioritized its investment commitments to other projects in its portfolio. It was also determined that global financial crisis had also impacted financing of power projects in the country. In another instance, accessibility to finance was reported a problem due to the low tariff rates suggested by the power purchaser due to which the private sector couldn't secure finance at first for the first BOOT hydropower project in Pakistan. Stringent rules and regulations of the local and international financial institutions were also determined to be a contributory factor in this case. For transport infrastructure projects, most of the financing is local except in case of some of the latest projects where foreign investment in PPP highway projects has also started (Amin 2017; Tribune 2017; Wasif 2016).

8.4.6 CRG-6 Political Stability

Factor six independently accounts for political violence/government instability risk. Noor (2011) reported unstable political scenario and law and order/security situation among the barriers to implementation of modern project procurement method and systems (PPPs) in Pakistan, which lead to a lack of investor interest, both domestic and foreign. The risk of political violence/government instability ranked higher for power infrastructure projects with a *moderate* impact (ranked 17th) as opposed to the transport infrastructure projects that recorded a perceived *moderate* impact (ranked 23rd). This may be explained by the fact that most of the investment in large power projects is foreign, whereas it is local for the transport sector projects. Two transport sector case studies (including development of service areas on a motorway and a tunnel project on BOT basis) as presented by Noor (2011) suffered directly or indirectly from poor law and order, security or political issues thus influencing the projects in the procurement stage and resulting in implementation delays. According to the then director general of Sindh PPP unit, the provincial government had to insure the Hyderabad Mirpurkhas dual carriageway (executed in 2009) project against a number of possibilities including terrorism, which is expensive in Pakistan due to risks (ADB 2014). However, the situation regarding risk of political violence/government instability and its ensuing effects may be changing given the rapid rise in private investments in both infrastructure sectors.

8.4.7 CRG-7 Government Interference

Factor group seven independently accounts for government intervention risk. Risk of government intervention was ranked among the top ten factors for power and transport infrastructure projects in China (Cheung and Chan 2012). Government intervention was perceived as a fairly important risk ranking at 5th and 12th position with *moderate* impact values for power and transport infrastructure projects, respectively. Government intervention is mostly seen as a pre-financial closure risk for PPP projects in both the sectors (in Pakistan) where intervention in the form of changing policies/project requirements is mainly seen as a problem resulting in delays and potentially extra cost. An example of this occurred when the government banned procurement of privately funded power projects that depended on imported fuel, influencing several projects under development stage (Bhutta 2017). A case study of BOT tunnel project reported by Noor (2011) exhibited toll implementation issues due to problems such as law and order situation and interference of local civil administration, whereby the implemented tolls were lower than those envisaged in the project's financial model; thus, resulting is losses to the project. A high perception of political interference for toll setting was also reported as an issue for securing lending for projects of one of the transport sector public organization which lead to shorter than ideal lending terms and/or higher cost of borrowing (higher interest rates), which also ultimately affects the toll rates.

All in all, the analysis shows that under the existing circumstances, both the public and private sectors need to execute meticulous risk management efforts while considering development and promotion of PPP infrastructure projects in Pakistan.

8.5 PROJECT RISK ASSESSMENT (CASE STUDY)

Looking at the case study project, the experts' assessment of risks conclusively put all the CRGs at *high* risk rating except the *political stability* CRG which is rated as *moderate*, with the ORI at

0.6459 that is interpreted as *high*. A possible explanation for this may be the fact that the case study project is the largest BOT transport infrastructure project investment in the country's history. Also, at the same time, it is reassuring to see that *political stability* CRG obtained moderate rating suggesting a lower level of concern potentially owing to the improvement in political and security arena.

8.6 MODEL TEST PROCESS

Following the procedure adopted to test the developed model in Zayed et al. (2008), this research also employed convergent validation method to establish the robustness of the proposed model. A questionnaire (Appendix E) was developed based on 22 CRFs and sent to highway PPP experts in Pakistan to obtain project specific assessment of the CRFs. The questionnaire also solicited holistic risk evaluation for the project, as a whole, based on the perceptions of the experts and their experience of having worked on the project. The risks were assessed using the linguistic terms (Table 2.2, See Chapter 2)) while the holistic evaluation was also made using the same terms. In total, five projects worth of risk assessment data were received from five highway PPP experts. Each expert evaluated the risks and provided a holistic risk evaluation for a project on which they had recently worked. The procedure adopted for case study analysis (mentioned above) was used to assess the ORI for the five projects. The calculated ORIs, their corresponding linguistic approximations (Table 2.2), and the holistic linguistic risk evaluations are shown in Table 8.8.

It is evident that the proposed model performed satisfactorily in approximating experts' overall evaluation. Furthermore, the ranking obtained for the projects using the proposed methodology is similar to the ranking based on holistic risk evaluation.

Additionally, the model output obtained using the proposed analytical method was also compared with an additive model i.e., FSAW was also used to calculate the risk index for each CRG which were then averaged to obtain the $ORI_{(FSAW)}$ for each project. Firstly, normalized weights (w_i) of risk factors are calculated for evaluation of each CRG's overall probability and severity, the P_v and S_v. Aggregate crisp Probability (P_r) and severity (S_r) assessments of CRFs under each CRG, obtained from transport sector officials (Table 8.5), were used for this purpose. For example, in order to calculate P_1 of CRG-1, normalized weights (w_i) of CRFs were evaluated by normalizing the crisp attribute assessments ($w_i{}'$= risk probability) as follows:

$$w_i = \frac{w_i{}'}{\sum_{i=1}^{8} w_i{}'}$$

The set of all the CRFs normalized weights under the CRG-1 was obtained to constitute the weight vector $W_{P1} = [w_1, w_2, \dots, w_8]$. The weight vector ($Ws_1 = [w_1, w_2, \dots, w_8]$) for obtaining CRG-1 severity evaluation (S_1) is obtained following a similar exercise.

Separate fuzzy rating vectors containing P_r and S_r assessments for each CRG with fuzzy attribute assessments of all CRFs within were developed from validation case study data. Again, taking example of CRG-1, fuzzy attributes rating vectors are:

$$\tilde{C}_{P1} = \begin{bmatrix} \tilde{h}_{1_{P_r}} & \tilde{h}_{2_{P_r}} & \cdots & \tilde{h}_{8_{P_r}} \end{bmatrix}, \qquad \tilde{C}_{S1} = \begin{bmatrix} \tilde{h}_{1_{S_r}} & \tilde{h}_{2_{S_r}} & \cdots & \tilde{h}_{8_{S_r}} \end{bmatrix}$$

The fuzzy score vector representing the aggregated probability and severity for each CRG was then calculated by taking a product of the fuzzy rating vector and the weight vector W.

$$\tilde{P}_1 = \tilde{C}_{P1} \otimes W_{P1}^T, \qquad \tilde{S}_1 = \tilde{C}_{S1} \otimes W_{S1}^T$$

After calculating all the sets of P_v and S_v, as defined above, the fuzzy score vectors were then averaged using Eq. (4) to obtain overall $\tilde{P}_w$ and $\tilde{S}_w$ estimates which were then processed via taking a square root of their product to obtain the $ORI_{(FSAW)}$ and then finally defuzzified for interpretation (Table 8.8) (for detailed instructions on application of FSAW, readers are referred to Chen and Hwang (1993), Chou et al. (2008), Lin et al. (2010) and Tzeng and Huang (2011)).

Table 8.8. Holistic and models' based risk evaluation

Projects	Holistic evaluation	Proposed model		Additive model	
		ORI	Linguistic evaluation	$ORI_{(FSAW)}$	Linguistic evaluation
B	VH	0.762	H	0.573	M
E	VH	0.751	H	0.586	M
D	H	0.738	H	0.619	H
A	H	0.734	H	0.619	H
C	M	0.711	H	0.577	M

It is evident that the proposed model performed better in approximating experts' overall evaluation then the additive model. Furthermore, the ranking obtained for the projects using the proposed methodology is similar to the ranking based on holistic risk evaluation. The ranking obtained from $ORI_{(FSAW)}$ is different from experts' holistic assessments.

8.7 CHAPTER SUMMARY

The research reported in this chapter has delivered on several objectives. Firstly, 22 critical risks were identified, based on input from a wide array of PPP stakeholders from a developing country perspective, in two of the most active infrastructure sectors for private investment, i.e., power and transport sectors. This also addresses the paucity of research studies in the extant literature that explores pertinent risks for multiple infrastructure sectors to provide critical insights on how risks and their significance vary across sectors. The results indicate that the most critical risks in power sector are delay in financial closure, delay in project approvals and permits, payment risk, and financing risk, whereas the highest impact risks in the transport infrastructure sector include land acquisition, financing risk, unfavorable national/international economy, delay in financial closure, and construction risk. The critical risks were further categorized in seven CRGs which provide better understanding of main issues that require immediate stakeholders' attention. These include: project planning and implementation; country economy; public sector maturity; project revenue; project finance; political stability and government interference. Comparison of the review of extant PPP risk assessment literature and the risk assessment results from this research showed that both the developing status of a country and its PPP implementation and operational maturity influence riskiness of projects.

Secondly, this research presents a novel methodology to analyze project risks and obtain assessments of risk level of CRGs and overall sector and project by employing fuzzy measure and Choquet fuzzy integral which can accommodate interactions among risk factors. This research also adopts FST to model human subjective judgement in risk assessment. The results of model application indicate 'public sector maturity' as the most critical risk group for power infrastructure projects while 'project planning and implementation' risk group is determined to be the most significant for transport infrastructure projects with both the sectors determined as *moderately* risky. In addition to sectoral risk evaluation, the methodology was also extended to perform a case study analysis to analyze summary level risk indicators at CRG and project level and to demonstrate its applicability for project risk analysis. Validation results also show the robustness of the model for project risk assessment. Comparison of the proposed methodology with traditional additive model revealed the difference in performance of the models thereby further validating the usefulness of the fuzzy measure and Choquet integral method for project risk assessment.

The presented methodology has multiple practical implications in terms of enabling: identification of most critical risk factors that warrant management attention and further detailed analysis (Ameyaw and Chan 2015c), identification of CRGs for efficient planning and execution of remedial actions, assessment of overall risk level of the project by the stakeholders (Xu et al. 2010b), prioritization of projects based on risk level to decide projects worth promotion by the private sector (Zayed et al. 2008), and assessment of the local country conditions from a risk perspective before setting up the project structure and normal due diligence (Ameyaw and Chan 2015c). Therefore, this research was successful in contributing to existing PPP risk management literature by establishing critical risks for key infrastructure sectors and by demonstrating and validating a risk assessment model to allow assessment of the impact of these risks on stakeholders' value ambitions. Other contributions include comparative analysis of PPP sectoral risks and discussion on the underlying causal factors. The presented methodology can be modified to suit the specific contextual needs by adjusting for critical risks, risk groups, and number of experts for soliciting inputs.

CHAPTER 9 MODELING RISK ALLOCATION CAPABILITY FOR EQUITABLE RISK ALLOCATION AND SHARING[10]

9.1 INTRODUCTION

The chapter presents a methodology to assist experts in risk allocation and sharing decision making for PPP infrastructure projects. The undertaken analysis strives to understand why certain risks (if any) may be allocated differently across projects and reveal how various contexts can justify a variation in risk allocation and sharing practices. The proposed model is based on RMC paradigm (see Chapter 4) and incorporates methods to accommodate subjective uncertainty (fuzziness–ambiguity of semantics) and aspects of criteria interaction (see Chapter 2). The RAC and key risk factors (which lack consensus on allocation and sharing strategy and thus may be difficult to allocate) for risk allocation and sharing decision assessment were selected based on extant literature and experts' opinions. As the decision problem is modeled by MADM method, aggregation approaches that employ additive and non-additive measures were applied to compare and explore how interactions may influence resulting decisions. After evaluating the RAC assessments, the proposed methodology provided an overall RMCI that can be linguistically interpreted from *very low* to *very high*. The final allocation strategy can be interpreted in view of the RMCIs of each party for each risk while considering efficiency. The developed model was demonstrated and further validated using data from two PPP projects in the power and transport infrastructure sectors. They also provided unique insights regarding sectoral practices and

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Parts of this chapter have been included in:

[10] Mazher, K. M., Chan, A.P.C., Zahoor, H., Ameyaw, E.E., Edwards, D.J., & Osei-Kyei, R. (accepted). "Modelling capability based risk allocation in PPP projects using fuzzy integral." Canadian Journal of Civil Engineering.

underlying reasons for differences in the apportionment of some common risks. Hence, a two-pronged validation of the proposed methodology was performed by comparing the results with a traditional additive aggregation approach and actual project data. The model aims to reduce inherent subjectivity and implicitness of the decision-making process and assist experts in negotiating an efficient allocation and sharing of risks on PPP projects rather than specifying general risk apportionment strategies. These strategies, as explained earlier, may not be optimum for all projects and situations due to contextual aspects.

9.2 SELECTION OF RAC AND KEY RISK FACTORS

The research started with a literature review of risk allocation in PPPs along with a brief exploration of existing models and methods to support risk allocation and sharing decision making on projects. Applicable RAC for each party were initially extracted from the literature. A review of the PPP risk allocation literature complemented by discussions with industry experts highlighted several risk factors out of the initial risk register, that exhibit diversity of experts' preferences/opinions, hence creating the lack of a clear consensus on their allocation and sharing strategy. Thus, a standard approach to apportionment of key risks is hard to specify. As stated previously, these differences may arise as a result of contextual aspects (infrastructure sector specific and market related considerations, unique project specific situations) and other factors that may influence risk appetite and attitude of the stakeholders (variations in a party's understanding and perceptions of risks and their ability to control and manage risks) (Ameyaw and Chan 2013; APMG International 2016a; Arndt 1999; Carbonara et al. 2015; GI Hub 2016; Ibrahim et al. 2006; Irwin 2007; Ke et al. 2010a; b; Ng and Loosemore 2007; Nguyen et al. 2018; UNCITRAL 2001; VDTF 2001). Some risks are out of control of both the parties hence their apportionment is particularly more challenging (APMG International 2016a; Arndt 2000; Irwin 2007; VDTF 2001; World Bank 2017). Initially, a total of 22 such risks were identified from academic and institutional literature (GI Hub 2016; Irwin 2007; Ke et al. 2010a; b) which also existed in the developed risk register (see Chapter 6). These risks exhibited variability in suggested or preferred allocation and sharing strategies and include: inflation; variation in foreign exchange rate and convertibility issues; interest rate fluctuation; land acquisition; public opposition; change in law/regulation; change in market demand; supply, input or resource risk; delay in project approvals and permits; insurance risk; unforeseen geotechnical conditions; financing risk; residual asset value on transfer to the government; competition risk; design/construction/operation changes; lack of supporting infrastructure/utilities; unfavorable national/international economy; pricing and toll/tariff review uncertainty; environmental damage risk; technology risk; conflicting or imperfect contract; and operation cost overrun. These risks were presented to experts while conducting semi-structured interviews (Appendix A) to further shortlist and select only those risk factors that may need more thought and systematic consideration regarding their efficient allocation and sharing. This would also reduce the effort required to assess risks for demonstration of proposed model application, since each risk needed to be carefully assessed by the experts across eight to nine RAC for evaluating their RMC. Finally, seven of the 22 risks were considered less significant and hence removed whereas two new risks were added from the main risk register including “payment risk” and “latent defect risk”. This led to identification of 17 pertinent risk factors that were selected and explored for allocation and sharing between the public and private sectors. Also, these include only those risks that are explicitly addressed in concession or project agreements. The approach allowed focus on risk factors that may be harder to allocate rather than focusing on those factors for which allocation regime is more obvious (such as the construction risk which is almost exclusively a private sector concern in PPP projects). Relevant RAC extracted from the literature were also presented to the experts to obtain their feedback on adequacy and relevance to the research objective.

9.3 MODEL DEVELOPMENT

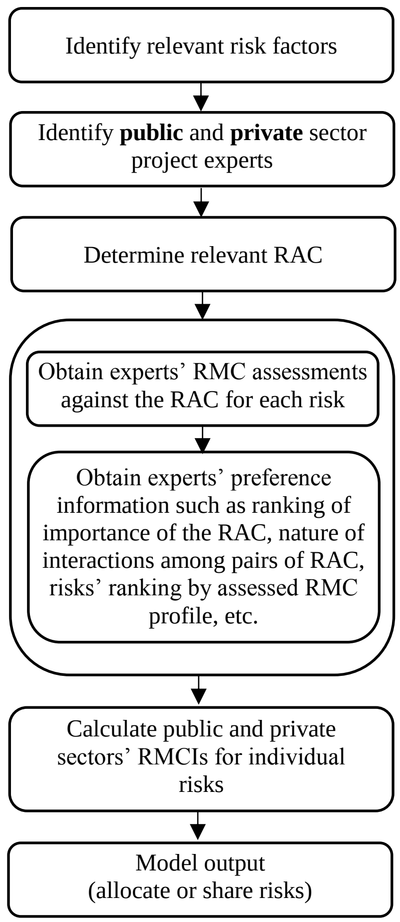

Fig. 9.1. Fuzzy integral based risk allocation and sharing decision model

The literature review helped to determine the constraints of the existing methods and a new methodology was proposed, wherein each party can independently operate the model to evaluate its RMC against each risk (see Chapter 4). It allows assessment of RMCI of a party for individual risks, which can be then used to inform the risk allocation and sharing decision making process. The process of synthesizing the RMCI involves integrating expert RMC assessments against each RAC for each risk, with the weightings of RAC that reflect the relative importance of the criteria. As the research intends to incorporate interaction effects for risk allocation and sharing decision making, fuzzy measure and Choquet integral analysis was performed (Fig. 9.1).

As discussed in Chapter 4, the proposed methodology enables the relevant parties to systematically evaluate their individual RMC for each risk while accommodating their preferences on relevant RAC. Furthermore, in order to observe the differences between aggregation approaches based on non-additive and additive measures, the results from fuzzy measure and Choquet integral analysis were compared with those obtained from FSAW. The principal difference between the two methodologies lies in estimating and treating the importance weights of the RAC. The entire evaluation procedure is composed of three stages namely: preparation; expert elicitation; and analysis. Whereas, RMC evaluations for risks across the RAC were obtained and treated separately for each case-study and stakeholder, the data on importance and ranking of RAC, and interaction among the RAC were collected and aggregated for public and private sectors and used for formulation of RMCI in both case study projects. This treatment of data was undertaken due to the underlying similarity of opinions on importance of, and interactive effects among, the RAC at organizational level (public and private sectors). The fuzzy measure and Choquet integral analysis was implemented using the Kappalab package for the GNU R statistical system whereas the FSAW based analysis was executed on Microsoft Excel 2015.

9.4 DATA COLLECTION

Two case studies were conducted in Pakistan based on the availability and willingness of experts to participate; both focused upon risk allocation but one case study involved a power sector project while the other involved a transport sector project. Investigating risk allocation based on the RMC paradigm across different sectors allows insights into how and why certain common risks are allocated differently. Secondary data was collected in the form of project documents and other related sources (where available). The power sector case study represented one of the early wind power projects in Pakistan (referred to as CS1). The project involved finance, design, construction, commissioning and operation and maintenance of a wind farm in the south. The project was procured on a BOO basis under a standard 20-year term. The second case-study project (referred to as CS2) involved revamp and modification work and operation of a brownfield controlled-access highway project on BOT basis. The project was awarded under a concession period of 25 years. One notable difference between the two sectors is that the power sector is regulated under government policy, which also has implications for the standardization of risk allocation regime, whereas, this is not the case for highway infrastructure sector projects. Both case study projects were already operational at the time of conducting this research. Complying with ethical requirements of confidentiality, names of projects and participating people/organizations involved have not been declared. Experts from public and private sector organizations that were involved in delivering the case study projects participated by providing information on the actual allocation of the selected project risks (Table 9.1). According to the experts, risk allocation and sharing strategies adopted on the two projects represented an efficient profile which was to the satisfaction of both the public and private sector stakeholders. Other inputs were also provided in terms of: individual assessments of importance and ranking of RAC; interactions among the RAC; their perceived RMC on each RAC for risks in relation to the projects under consideration; and preferences on ranking of risks with respect to the overall RMC profile of risks. This was in line with the requirements of the methodologies adopted in this research. Participating experts were selected based upon their experience and their association of having worked on the selected case study projects. This has been discussed in more detail in Chapter 2 on research methodology. For each project, six experts participated to render the needed linguistic assessments (Table 2.3, See Chapter 2) for the selected risk factors, with three representing interests of the private sector (project company/investors) and three representing the public sector authority.

Table 9.1. Selected risk factors and their actual apportionment in case study projects

Identifier	Risk factors	Risk allocation	
		CS1	CS2
RF_01	Inflation	Pu.	Pr.
RF_02	Variation in foreign exchange rate and convertibility issues	Pu.	Pr.
RF_03	Interest rate fluctuation	Pu.	Pr.
RF_04	Land acquisition	Pu.	Pu.
RF_05	Public opposition	Sh.	Sh.
RF_06	Change in law/regulation	Pu.	Pu.
RF_07	Change in market demand	Pu.	Pr.
RF_08	Supply, input or resource risk	Pu.	Pr.
RF_09	Delay in project approvals and permits	Sh.	Sh.
RF_10	Insurance risk	Sh.	Sh.
RF_11	Unforeseen geotechnical conditions	Pr.	Pr.
RF_12	Financing risk	Pr.	Pr.
RF_13	Payment risk	Pu.	Sh.
RF_14	Latent defect risk	-	Pr.
RF_15	Residual asset value on transfer to the government	-	Pr.
RF_16	Competition risk	Pu.	Pu.
RF_17	Design/construction/operation changes	Sh.	Sh.

Risk allocated to public sector (Pu.), Risk allocated to private sector (Pr.), Risk shared (Sh.)

9.5 DATA ANALYSIS AND MODEL IMPLEMENTATION

Stage 1: Preparation

Preparation entails selection of risk factors that need to be allocated as well as the relevant RAC upon which RMC will be assessed and identification of the committee/panel of expert decision makers (public and private sectors). The pertinent risks, relevant RAC with respect to each stakeholder and the panel members that participated have been discussed above. Considering the direct involvement of all the participating experts with the procurement and management of the selected case-study projects in this research, all experts were considered equally important in the risk allocation decision making problem. Hence, for each project, the public and private sector groups were considered homogenous.

Stage 2: Expert Elicitation

Expert elicitation is based upon collection of necessary information in relation to the analysis methodology that will be employed for RMC assessment.

For FSAW based analysis, first the relative importance of individual RAC were assessed by experts using linguistic terms. The linguistic terms and the associated TFNs (Table 2.3) were adopted based on consensus of the experts which allowed them to render necessary assessments. The linguistic assessments were converted into corresponding TFNs and aggregate importance assessments ($\widetilde{w}_i$) were obtained for each RAC using Eq. (4) (Table 9.2). All experts were considered equally important. Experts also evaluated each risk against the RAC using the linguistic terms in order to declare their RMC; Eq. (4) was then adopted to obtain aggregate assessments of

RMC ($\tilde{h}_i$) against all the RAC (i = 1, …, m) for each risk (j = 1, …, n). These inputs formed the key inputs required for a FSAW based analysis.

The application of fuzzy measure and Choquet integral based approach requires additional information which was also provided by the experts and included: RAC rankings (Table 9.2); initial partial weak orders or ranks of risk factors (Table 9.3) in terms of a party's perceived overall RMC (from high to low – this is to obtain the desired ranking of risks based on preferences of the experts in view of the collective RMC evaluations on all the RAC for all risks); and information on interaction effects among RAC (Table 9.4). Crisp values for importance ratings of the RAC were obtained using Eq. (5). Since 2-additive Choquet integral was employed, participating experts considered and provided interaction information on some pairs of RAC that were interpreted as complementary. For all the other pairs, the RAC were considered non-interactive. The experts

Table 9.2. RAC importance ratings (crisp values) and ranking

Identifier	RAC	Public sector		Private sector	
		Crisp aggregate importance rating	rank	Crisp aggregate importance rating	rank
C1	Be able to foresee (predict) the chance/probability of risk occurrence and assess potential risk consequence/severity	0.861	1	0.805	2
C2	Be able to avoid, minimize, monitor and control the chance/probability of risk occurrence	0.777	4	0.666	5
C3	Be able to minimize or control the loss if the risk occurs	0.805	2	0.750	4
C4	Be able to sustain, diversify or absorb the consequences of the risk that materializes	0.583	7	0.416	9
C5	Be able to bear the risk at the lowest cost	0.777	4	0.666	5
C6	Be able to assume and manage the direct loss in case of risk occurrence	0.638	6	0.861	1
C7	Be able to get reasonable and acceptable premium for assuming the risk	-	-	0.805	2
C8	Benefit from enhanced risk undertaker's credibility, reputation and efficiency in risk management	0.805	2	0.500	8
C9	The risk-taking party prefers to assume the risk (Risk attitude)	0.472	8	0.638	7

Table 9.3. Risk prioritization/ranking based on perceived overall RMC (descending order)

Case	Stakeholder	Priority
CS-1	Public sector	RF_04≻13≻9≻7≻8≻16≻3≻1≻2≻17≻5≻6≻10≻11≻12
	Private sector	RF_11≻12≻4≻9≻10≻17≻5≻8≻1≻3≻2≻6≻7≻13≻16
CS-2	Public sector	RF_04≻5≻16≻9≻17≻6≻13≻1≻2≻7≻10≻3≻11≻15≻8≻12≻14
	Private sector	RF_11≻14≻15≻12≻7≻8≻9≻10≻2≻1≻3≻4≻13≻5≻17≻6≻16

Table 9.4. Interactions among RAC

Stakeholder	Pairs of RAC	Complementary / Substitutive
Public sector	(C1,C2), (C1,C3), (C1,C5), (C1,C8), (C1,C9), (C2,C3), (C2,C5), (C2,C8), (C2,C9), (C3,C5), (C3,C8), (C3,C9), (C4,C6), (C4,C8), (C4,C9), (C5,C8), (C5,C9), (C6,C8), (C6,C9), (C8,C9)	Complementary
Private sector	(C1,C2), (C1,C3), (C1,C5), (C1,C6), (C1,C7), (C1,C9), (C2,C3), (C2,C5), (C2,C6), (C2,C7), (C2,C9), (C3,C5), (C3,C6), (C3,C7), (C3,C9), (C4,C6), (C4,C7), (C5,C6), (C5,C7), (C6,C7), (C6,C9), (C7,C9)	Complementary

collectively agreed that none of the RAC pairs should exhibit a substitutive relationship.

Stage 3: Analysis

Analysis includes assessment of RMCIs of the stakeholders for each risk.

The FSAW based RMCI was computed using a simplified version of Eq. (1). Firstly, normalized weights (w_i) for each RAC were computed from the crisp importance ratings of the RAC ($w_1', \ldots, w_m'$) (Table 9.2) and the corresponding weight vector ($W = [w_1, \ldots, w_m]$) developed for each party, which represents the crisp normalized weights for all the RAC. The crisp values ${w_i}'$ as obtained from application of Eq. (3) are further normalized as:

$$w_i = \frac{{w_i}'}{\sum_{i=1}^{m} {w_i}'}$$

The weight vector $W = [w_1, w_2, \dots, w_m]$ is thus obtained.

Separate fuzzy rating matrices representing public and private sector project stakeholders and containing the RMC assessments ($\tilde{h}_i$) on the relevant RAC in each row, for all risk factors, were established. Hence, for each project, matrices of order *n* x *m*, i.e., 17x8 and 17x9 were formed containing all the fuzzy aggregated RMC assessments for public and the private party, respectively. The fuzzy rating matrix containing the RMC assessments for all risk factors against each applicable RAC was developed as:

$$\tilde{C} = \begin{bmatrix} \tilde{h}_1^1 & \tilde{h}_2^1 & \cdots & \tilde{h}_m^1 \\ \tilde{h}_1^2 & \tilde{h}_2^2 & \cdots & \tilde{h}_m^2 \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{h}_1^n & \tilde{h}_2^n & \cdots & \tilde{h}_m^n \end{bmatrix}$$

The fuzzy score vector representing the RMC for each risk was then calculated by taking a product of the fuzzy rating matrix and transpose of the weight vector *W*.

$$\begin{bmatrix} \tilde{M}_1 \\ \tilde{M}_2 \\ \vdots \\ \tilde{M}_n \end{bmatrix} = \tilde{C} \otimes W^T = \begin{bmatrix} \tilde{h}_1^1 & \tilde{h}_2^1 & \cdots & \tilde{h}_m^1 \\ \tilde{h}_1^2 & \tilde{h}_2^2 & \cdots & \tilde{h}_m^2 \\ \vdots & \vdots & \cdots & \vdots \\ \tilde{h}_1^n & \tilde{h}_2^n & \cdots & \tilde{h}_m^n \end{bmatrix} \otimes \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_m \end{bmatrix}$$

The fuzzy values (from fuzzy score vector) were then defuzzified using Eq. (5) to obtain the RMCI of each risk factor and to aid interpretation and risk allocation and sharing decision making (Table 9.5) (for detailed instructions on application of FSAW, readers are referred to Chen and Hwang (1993), Chou et al. (2008), Lin et al. (2010) and Tzeng and Huang (2011)).

For fuzzy measure and Choquet integral analysis, the aggregated experts' RMC assessments were defuzzified (Eq. 5) to obtain crisp values of the same. The defuzzified RMC values ($h'_1, \dots, h'_m$)

for all risk factors along with information on RAC rankings obtained from Table 9.2, initial partial weak orders or ranks of risk factors derived from experts' preferences (Table 9.3) and information on defined complementary interactions among some pairs of RAC (Table 9.4), were programmed in to the Kappalab package (for instructions on usage of the application software, readers are referred to Grabisch et al. (2008)). The analysis was performed separately on data from public and private parties for each project. The application was used to calculate the importance indices (Shapley values) and interaction indices for the RAC and for evaluation of fuzzy measures and corresponding Choquet integral to obtain RMCI of each risk factor using the MV approach (Table 9.5). Shapley values (representing the relative importance of each criterion in the RAC set) and interaction indices obtained based on the MV approach and initial preferences of the decision makers were complemented with additional constraints on both the indices to make sure that the preferences of public sector experts were adequately modeled. Afterwards, for each case study, the Shapley values and interaction indices of fuzzy measures obtained were in accordance with the importance rankings of the RAC and specified interactions among the RAC. For private sector expert inputs, additional constraints only on the interaction indices were considered over the initial preferences to ensure desired interactions among the RAC are achieved.

The proposed methodology after evaluating the RAC assessments provides an overall RMCI that can be linguistically interpreted from *very low* to *very high*. The final allocation strategy can be interpreted in view of the RMCIs' of each party for each risk, while considering efficiency. Using the same linguistic terms to represent the RMCI (RMC, Table 2.3), the calculated RMCIs can be translated employing the methodology adopted by Yang et al. (2003) and Zhao et al. (2013).

Table 9.5. Risk allocation analysis results

ID	CS1											CS2										
	$FSAW_{Public}$		$FSAW_{Private}$		Model based decision	CI_{Public}		$CI_{Private}$		Model based decision	Actual risk treatment	$FSAW_{Public}$		$FSAW_{Private}$		Model based decision	CI_{Pulic}		$CI_{Private}$		Model based decision	Actual risk treatment
RF_01	0.648	H	0.432	M	Pu.	0.618	M	0.404	M	Sh.	Pu.	0.562	M	0.569	M	Sh.	0.491	M	0.527	M	Sh.	Pr.
RF_02	0.638	H	0.315	L	Pu.	0.608	M	0.288	L	Pu.	Pu.	0.576	M	0.599	M	Sh.	0.481	M	0.557	M	Sh.	Pr.
RF_03	0.702	H	0.322	L	Pu.	0.655	H	0.298	L	Pu.	Pu.	0.525	M	0.485	M	Sh.	0.417	M	0.547	M	Sh.	Pr.
RF_04	0.786	H	0.583	M	Pu.	0.769	H	0.566	M	Pu.	Pu.	0.805	H	0.489	M	Pu.	0.776	H	0.501	M	Pu.	Pu.
RF_05	0.626	H	0.463	M	Pu.	0.588	M	0.447	M	Sh.	Sh.	0.772	H	0.478	M	Pu.	0.749	H	0.481	M	Pu.	Sh.
RF_06	0.595	M	0.283	L	Pu.	0.574	M	0.267	L	Pu.	Pu.	0.603	M	0.258	L	Pu.	0.569	M	0.265	L	Pu.	Pu.
RF_07	0.699	H	0.250	L	Pu.	0.685	H	0.231	L	Pu.	Pu.	0.487	M	0.643	H	Pr.	0.437	M	0.630	H	Pr.	Pr.
RF_08	0.711	H	0.433	M	Pu.	0.675	H	0.414	M	Pu.	Pu.	0.514	M	0.624	M	Sh.	0.329	L	0.620	M	Pr.	Pr.
RF_09	0.682	H	0.544	M	Pu.	0.695	H	0.526	M	Pu.	Sh.	0.680	H	0.550	M	Pu.	0.636	H	0.567	M	Pu.	Sh.
RF_10	0.583	M	0.530	M	Sh.	0.564	M	0.508	M	Sh.	Sh.	0.518	M	0.610	M	Sh.	0.427	M	0.537	M	Sh.	Sh.
RF_11	0.480	M	0.750	H	Pr.	0.479	M	0.730	H	Pr.	Pr.	0.436	M	0.754	H	Pr.	0.354	L	0.746	H	Pr.	Pr.
RF_12	0.525	M	0.659	H	Pr.	0.469	M	0.643	H	Pr.	Pr.	0.457	M	0.666	H	Pr.	0.319	L	0.640	H	Pr.	Pr.
RF_13	0.752	H	0.245	L	Pu.	0.738	H	0.221	L	Pu.	Pu.	0.644	H	0.520	M	Pu.	0.559	M	0.491	M	Sh.	Sh.
RF_14	-	-	-	-	-	-	-	-	-	-	-	0.349	L	0.666	H	Pr.	0.267	L	0.650	H	Pr.	Pr.
RF_15	-	-	-	-	-	-	-	-	-	-	-	0.421	M	0.636	H	Pr.	0.339	L	0.601	M	Pr.	Pr.
RF_16	0.713	H	0.238	L	Pu.	0.665	H	0.211	L	Pu.	Pu.	0.729	H	0.194	L	Pu.	0.689	H	0.189	L	Pu.	Pu.
RF_17	0.631	H	0.477	M	Pu.	0.598	M	0.457	M	Sh.	Sh.	0.653	H	0.497	M	Pu.	0.600	M	0.471	M	Sh.	Sh.

Choquet Integral (CI), Risk allocated to public sector (Pu.), Risk allocated to private sector (Pr.), Risk shared (Sh.), Low (L), Moderate (M), High (H)

9.6 COMPARISON OF MODELS' OUTCOMES AND ACTUAL RISK ALLOCATIONS

Theoretically, if both parties possess *moderate* RMCI ratings, risks could be shared. Risks can be allocated to a party that possesses a higher RMCI. Alternatively, if the capability ratings reside on the same side of *moderate* RMCI (either lower or higher), risks could also be shared (Ameyaw and Chan 2015; ADB 2000; Irwin 2007). This would ensure that parties retain the incentive to influence the risks or reduce project's exposure to risks and also that the party responsible is the most suitable carrier of risk based on its RMC.

Comparing the outcomes of fuzzy measure and Choquet integral analysis with FSAW (Table 9.5), it is evident that the former methodology modelled experts' preferences more closely. For most risk factors, it is apparent that the linguistic RMCI assessments obtained from both the methodologies are the same and agree with the actual allocation of risks, however, the underlying numerical indices vary for both methods. Actual allocation of risk factors: public opposition (RF_05) and design/construction/operation changes (RF_17) for CS1 and payment risk (RF_13) and RF_17 for CS2 were more accurately represented by the non-additive method. These risks were shared as both the stakeholders obtained moderate RMCIs. The risk allocation for supply, input or resource risk (RF_08) for CS2 was also more accurately modelled by the non-additive method which was allocated to the private sector as apparent from its relatively higher RMCI. Also, for most of the risk factors studied, actual risk apportionments seem to agree with obtained RMCIs' as parties with relatively higher indices carry risks, with a few exceptions. For instance, both the parties exhibited moderate RMCIs for macroeconomic risks (inflation (RF_01), variation in foreign exchange rate and convertibility issues (RF_02), interest rate fluctuation (RF_03)) for CS2, the risks were still allocated to the private sector rather than sharing the risks. This, although justifiable by the relatively higher numerical RMCIs of private sector, indicates that the decision to share or allocate a risk to one party may require further consideration beyond the RMCI alone. The same can be said for RF_01 for CS1. On the other hand, for some risk factors, including delay in project approvals and permits (RF_09) for CS1 and CS2 and RF_05 for CS2, the preference was to share the risks rather than transferring to the party with a higher RMCI. However, the output from both methodologies do not refute the actual allocation as both parties possess moderate to high RMCIs, thus indicating some ability to contribute to management of these risks. Several reasons might explain these observations. It is recognized by APMG International (2016a) that on certain occasions, a risk may be tolerable by the private partner at a reasonable price however, the public party may be better positioned to handle the risk and therefore may consider taking it back or sharing it to some extent so as to realize increased VfM by taking it back. Similarly, some risks may be shared with the private party even if it cannot fully or accurately assess the risk, as it may be able to act by limiting risks' occurrence or limiting or mitigating risks' consequences. Yet in other cases, it may be reasonable to compromise on optimal risk allocation and VfM prospects to some extent in emerging or in less mature PPP markets to ensure project's bankability and commercial feasibility by applying de-risking strategies (cf. APMG International 2016a; Arndt 2000; VDTF 2001; World Bank 2017). Risks may be shared or transferred to the private sector only where this brings efficiency. This is important because size of the risk premium will depend to a large extent on the degree of uncertainty surrounding the risk and degree of risk aversion of the service provider (Arndt 1999). Quantitative assessment may be employed for better insights however, for a number of risks, reliance on common practice and precedents as well as exercising judgment will be important since innovation and risk management capability are difficult to evaluate and some risks are unquantifiable hence suggesting caution in quantitative assessment of

VfM (APMG International 2016b). The model therefore aims to assist experts to negotiate an efficient allocation of risks on PPP projects rather than specifying general allocation strategies of risks which, as explained earlier, may not be optimum for all the projects and situations due to contextual aspects (APMG International 2016b, GI Hub 2016). Overall and for most risk factors, the consideration of interactions in RAC seems to provide more conservative estimates of RMCI.

It can be observed that relatively large values of interaction exist between C8, C9 and other RAC from C1-C6 for the public sector stakeholders in each case study project (Tables 9.6 and 9.8). This is not the case for private sector stakeholders (Tables 9.7 and 9.9). Hence, RAC C8 and C9 which deal with the *ability to obtain intangible benefits* and *risk preferences* of the public sector stakeholders appear to assume an important role in risk apportionment considerations in combination with other RAC. Further discussion on risks allocation on case study projects is made in relation to the results obtained from fuzzy measure and Choquet integral analysis.

Table 9.6. Shapley values and interaction indices for the RAC (CS1 - public sector)

CS1 Public sector	Shapley values	Interaction indices							
		C1	C2	C3	C4	C5	C6	C8	C9
C1	0.157	-	0.010	0.010	0.049	0.010	0.000	0.018	0.010
C2	0.126	-	-	0.026	0.000	0.010	0.014	0.010	0.010
C3	0.136	-	-	-	0.000	0.010	0.032	0.019	0.018
C4	0.106	-	-	-	-	0.000	0.010	0.010	0.010
C5	0.126	-	-	-	-	-	0.000	0.010	0.010
C6	0.116	-	-	-	-	-	-	0.035	0.046
C8	0.136	-	-	-	-	-	-	-	0.010
C9	0.096	-	-	-	-	-	-	-	-

Table 9.7. Shapley values and interaction indices for the RAC (CS1 - private sector)

CS1 Private sector	Shapley values	Interaction indices								
		C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0.129	-	0.010	0.010	0.000	0.010	0.010	0.010	0.000	0.010
C2	0.109	-	-	0.071	0.000	0.010	0.010	0.010	0.006	0.010
C3	0.119	-	-	-	0.000	0.011	0.010	0.010	0.005	0.014
C4	0.079	-	-	-	-	0.000	0.010	0.010	0.000	0.002
C5	0.106	-	-	-	-	-	0.010	0.010	0.000	0.000
C6	0.139	-	-	-	-	-	-	0.010	0.000	0.014
C7	0.133	-	-	-	-	-	-	-	0.017	0.010
C8	0.089	-	-	-	-	-	-	-	-	0.005
C9	0.099	-	-	-	-	-	-	-	-	-

Table 9.8. Shapley values and interaction indices for the RAC (CS2 - public sector)

CS2 Public sector	Shapley values	Interaction indices							
		C1	C2	C3	C4	C5	C6	C8	C9
C1	0.148	-	0.049	0.010	0.047	0.010	0.005	0.010	0.037
C2	0.128	-	-	0.028	0.000	0.021	0.000	0.064	0.091
C3	0.138	-	-	-	0.029	0.046	0.000	0.042	0.057
C4	0.108	-	-	-	-	0.018	0.012	0.041	0.076
C5	0.128	-	-	-	-	-	0.003	0.022	0.019
C6	0.118	-	-	-	-	-	-	0.042	0.057
C8	0.138	-	-	-	-	-	-	-	0.010
C9	0.098	-	-	-	-	-	-	-	-

Table 9.9. Shapley values and interaction indices for the RAC (CS2 - private sector)

CS2 Private sector	Shapley values	Interaction indices								
		C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0.129	-	0.010	0.010	0.022	0.010	0.010	0.010	0.000	0.010
C2	0.109	-	-	0.010	0.065	0.023	0.010	0.010	0.000	0.010
C3	0.119	-	-	-	0.017	0.010	0.010	0.010	0.000	0.010
C4	0.079	-	-	-	-	0.033	0.074	0.015	0.000	0.069
C5	0.099	-	-	-	-	-	0.010	0.010	0.000	0.018
C6	0.139	-	-	-	-	-	-	0.010	0.000	0.010
C7	0.139	-	-	-	-	-	-	-	0.051	0.010
C8	0.089	-	-	-	-	-	-	-	-	0.000
C9	0.099	-	-	-	-	-	-	-	-	-

9.6.1 Macroeconomic Risks (RF_01, RF_02, & RF_03)

Starting with the macroeconomic risks, almost all the stakeholders in both the case studies exhibited a low-moderate ability to manage the risks. This is consistent with contemporary discourse (Arndt 1999; Irwin 2007). Whereas, governments are the primary decision makers on macroeconomic policy and by that virtue hold a higher capability to influence these risks, there is an argument that governments should not be required to shape policies on such matters while constrained by project specific situations. Conversely, the private sector also holds a measure of control by being responsible to potentially finance, design, construct and operate and maintain the infrastructure assets. Thus, the extent of project exposure to macroeconomic risks can be potentially reduced by incorporating business acumen and various strategies that can partially hedge against the potential impacts. In addition, the quantum of risk itself can be an influential factor. Power infrastructure projects in Pakistan are more exposed to foreign exchange risks as opposed to transport infrastructure due to the large and expensive equipment imports involved. Unpredictable variances in foreign exchange rate can be excessive for any private sponsor to manage, not to mention the potential difficulties in convincing investors to accept such a risk exposure. Hence, the observed difference of macroeconomic risks allocation practice across the sectors can be best explained by difference in stakeholders’ risk attitude/preferences, which is influenced by country and project specific contextual aspects. Apparently, macroeconomic risks rest best with the government, given the investment climate and current risk preferences of both the public and private, power sector stakeholders in Pakistan. However, as the investment climate improves, and the investors show greater interest in establishing projects in the country, reassessment of the situation may dictate gradual transfer of macroeconomic risks to the private sector. For the transport infrastructure sector, the allocation of macroeconomic risks to the private sector falls in line with the recommendations discussed above and because of relatively higher preference of the private sector to bear these risks. This could be the case due to strong viability of the brownfield case study project where strong existing and forecasted demand projections may have encouraged the private sector towards a risk seeker attitude.

9.6.1.1 Inflation (RF_01)

Inflation and interest rate risks are macroeconomic in nature, and public and private sectors have little influence on these risks (Dunn 2017). The risk of eroding the value of payments to be received by a private partner should be shared with the authority. The latter can provide protection to the private partner in form of indexation (to an extent) of payments to a price benchmark (such as consumer price index or some other) (APMG International 2016a). The cost of inflation may be higher than expected and it may not be effectively captured by the established indexation mechanism; a risk which will be assumed by the private partner. The private partner can exercise several venues to mitigate the risk, including allocating the risk to contractors, fixing or limiting the price of O&M tasks, or linking the cost of inflation risk to the index defined in the PPP contract by specifying a correlated inflation index. Given the possibility to revise prices, the risk of inflation may be transferred to users in user-pays projects up to the limits defined for indexation, beyond which the risk is borne by the private partner. In government-pays projects, inflation is a concern to the authority if it is linked to the payment and extent of its linkage (ibid.). Indexation incorporated with the pricing mechanism is preferred; otherwise, the private party tends to cover the inflation risk by building contingencies in the bid (VDTF 2001). Given the uncertainty associated with the future forecasting of inflation rates, this approach generally leads to government losing VfM (ibid.).

Depending on the payment mechanism adopted, the risk of inflation was handled in different ways in the highway PPP projects explored by Nguyen (2017). For projects based on availability payment scheme, the risk was shared, whereas in tolled and lease projects, the resulting compensation was integrated into a fixed schedule of toll rate increases, which may or may not cover the entire impact. The allocation preferences for this risk vary in the literature (Dunn 2017; GI Hub 2016). According to a report by the Global Infrastructure Hub (GI Hub), which provides guidance for risk allocation (GI Hub 2016), the risk of inflation should be shared in toll road (DBFO) projects in developed and emerging markets. The same risk is recommended to be allocated to private and public sectors for solar PV (BOO) and hydropower (BOOT) projects in both types of markets. The risk of inflation rate volatility was preferred to be allocated to the private sector in the UK, whereas experts from China, Hong Kong and Greece preferred more for the risk to be shared. However, a large proportion of respondents in China and Hong Kong also favored risk allocation to the private sector (Ke et al. 2010a).

9.6.1.2 Variation in Foreign Exchange Rate and Convertibility Issues (RF_02)

The main currency risk in countries with floating exchange rates is the exchange rate risk, whereas restrictions on the conversion of local and foreign currencies transferred out of the country may be restricted in countries with fixed exchange rates (Irwin 2007). Convertibility and transferability risks may be allocated to the government as it alone controls these matters. However, it does not enjoy the same control over exchange rate itself. Thus, there is comparably no strong argument for them bearing it (Irwin et al. 1997). Risk of change in exchange rates is beyond the control of public and private sectors; hence, it should be addressed explicitly in contracts (VDTF 2001). Governments have the most influence (relatively) on exchange rate, which leads some to believe that risks should be allocated to the government (Irwin 2007). In the opinion of others, it should be allocated to customers, whereas others consider allocating it to firms as they can influence a project's sensitivity to the risk factor. An infrastructure firm may be exposed to exchange rate risk because it uses tradable inputs (e.g., fuel used by power generation plants) and produces tradable services (power transmission to neighboring markets: less likely) or financing arrangements are in foreign currency. From the perspective of tradable inputs, the author suggests allocation between customers and a firm or allocation just to the firm depending upon their RMC. For borrowing of foreign currency, it should be allocated in proportion to the delegation of rights to make such a decision (ibid.).

The procurement authority is generally not expected to bear the risk or assist a project company with its mitigation. However, in some countries with underdeveloped financial markets, it may not be possible for the firm to hedge against risks (Croce et al. 2017). The procurement authority may need to retain the risk of local currency devaluation to the extent of protecting the economic viability of the project (ibid.).

For exchange rate risk, in emerging markets, a GI Hub report proposes sharing the risk for the transport sector (highway) and allocation to public or private sector or sharing the risk for power sector projects (solar/hydropower) (GI Hub 2016). The risk of foreign currency exchange also recorded contentious allocation preferences in a review conducted by Ke et al. (2010b).

9.6.1.3 Interest Rate Fluctuation (RF_03)

Similar with exchange rate risk, the procurement authority generally does not consider assuming the interest rate risk, and the project company can find suitable hedging instruments to mitigate this risk (Croce et al. 2017). However, as previously explained, hedging instruments may not be available in certain countries. The authority may retain the risk in case this strategy proves to be relatively efficient (to secure VfM) or share the risk (ibid.). Change of interest rate between making a bid and financial close may be shared between the parties as both are in a position to influence the timing of financial close (VDTF 2001). According to Dunn (2017), in instances where the interest rate is charged at a fixed rate, significant government support should not be required. However, the opposite may be true for the case of floating interest rates.

The GI Hub report proposes sharing of the interest rate risk in emerging markets for the transport sector (highway) and allocation to the private sector for power sector projects (solar/hydropower) (GI Hub 2016). Ke et al. (2010a) determined that, for interest rate volatility risk, China, Hong Kong, and the UK favor more the allocation to the private sector, whereas respondents from Greece exhibited a greater support for sharing the risk.

9.6.2 Land Acquisition (RF_04)

Owing to the potential of delays and costs involved in negotiations with multiple owners (possibly large in number) and the need to undertake complex efforts to establish the regularity of the title of individual owners (as may be required in some jurisdictions), the concessionaire is not the most suitable authority to assume the responsibility for the acquisition of lands for a project (when the land is not already owned by the contracting authority and needs to be purchased from its owners) (UNCITRAL 2001). The contracting authority therefore typically assumes this responsibility to avoid unnecessary delays or cost overruns. For the construction of a new infrastructure facility where the contracting authority or any other public authority holds the ownership of the land or in the case of the modernization and rehabilitation of an existing facility, the owner of the land or facility is normally responsible to make the land available to the concessionaire (ibid.). According to VDTF (2001), for a preferred site that is in a third-party ownership or includes third-party owned sites, the risks for site acquisition generally fall to the private party. However, the government authority may coordinate in the acquisition and even take over the process if necessary. The guide (ibid.) suggests that it may be more cost effective for the government to take charge of the process and utilize its statutory powers of compulsory acquisition (if necessary) in the event that voluntary acquisition may prove to be difficult and costly and where the government is to become the land owner. In the case of linear infrastructure and when the precise route definition is dependent on an environmental assessment, the government may need or wish to assume a coordinating role even when it does not act for the acquisition of land (ibid.).

According to GI Hub, the contracting authority bears the principal risk for transport (highway) sector projects, and its allocation strategy varies with the type of project for power infrastructure (generation [solar/hydropower], transmission) (GI Hub 2016). This risk also recorded contentious allocation preferences in the literature review and empirical study conducted by Ke et al. (2010a, b).

9.6.3 Public Opposition (RF_05)

While studying risk perceptions of Australian stakeholder groups in PPP toll road projects, Chung et al. (2010) argued that the risk of public misperception manifests itself as the lack of public support, causing project approval delays and contract variations. Differences between public perception regarding road pricing and private ownership of toll roads need to be carefully distinguished to investigate this risk. Both factors could be significant precursors to problems on projects. Divestment of public treasures either through privatization or PPPs is usually not taken kindly by citizens (Nwangwu 2016). As suggested, most misconceptions arise from the lack of understanding of benefits that tollways generate (Chung et al. 2010). Another highlighted deficiency pointed out to the lack of understanding of tollway operating companies on market segments (and their characteristics). As governments have a vested interest in reducing public aversion, the authors referred to Australian government efforts to manage public perception and minimize public resistance by community engagement via VfM and environmental impact assessment statements. The private sector can also take responsibility by allocating resources to promote benefits of tollways and making the project a part of the community (ibid.). The parties to a project must identify the possible risks of public opposition to a project and evaluate and allocate them appropriately (Nwangwu 2016). Afterward, the public and private sector parties must commence a risk mitigation process by designing a stakeholder inclusion and consultation program. This problem is a risk that is better shared and mitigated jointly by both parties (ibid.).

The guide to community engagement for power projects in Kenya (Power Africa 2018) lays out details for developers to adequately inform the community on the various aspects of projects, including its impacts and benefits for the community, and stresses community engagement (to obtain community consent for the project) throughout the project lifecycle. Insufficient engagement with communities and other stakeholders is termed as the contributory factor leading to some energy generation and other development projects being stalled or halted.

The risk of *level of public opposition to project* was greatly preferred to be allocated to the public sector in China and the UK. However, experts from Hong Kong and Greece favored sharing the risk (Ke et al. 2010a). While studying risk allocation on highway PPP projects in the US, Nguyen (2017) found that the risk of *socio-political opposition and protesters* was predominantly shared in the studied highway contracts.

For the case study projects, in the event that the risk materializes, the level/intensity of opposition determines who takes the responsibility as small local issues fall within the management domain of the project sponsor. By contrast, politically influenced/social unrest at a large scale becomes an issue out of its control. Hence, the public sector must manage it. The risk consequences were subsequently shared for both the case study projects.

9.6.4 Change in Law/Regulation (RF_06)

Laws and regulations defining the rights and obligations of public and private agents have been employed by governments to manage social and economic activities (Irwin et al. 1997). The exercised powers may be used to generate tax-based revenues, manage perceived market failures and achieve specific social or political goals. Laws and regulations can be characterized as those that are economy-wide in their scope and application and a set that is specific to an industry or a project (ibid.).

Economy-wide laws and regulations that can influence the profitable operation of an investment include those governing (Irwin et al. 1997) foreign investments, labor, immigration, antitrust, environmental protection, securities and other matters. Such rules are in a constant state of evolution in response to meeting the variations in the perceptions of public interest. Modernization of environmental regulations is an example that may benefit enterprises/society while concurrently adding to the operating costs of other firms. Competitive market firms can absorb costs induced by changes to such laws/regulations via investment decisions and charging more from the consumers. However, the same situation is difficult for infrastructure industries as decisions to invest in a particular location or technology are difficult to modify because of limitations induced by price regulation. Taxes, environmental laws and import/export restrictions are of high concern to investors. Control of prices and service standards (quality) in the regulation of monopolistic activities and control of other parameters to manage environmental, safety and public health concerns may constitute the objectives of detailed industry- or project-specific regulations pertaining to infrastructure activities. The risk arises from uncertainty over how the government may exercise its regulatory authority to control various parameters, either opportunistically or in good faith, which is unfavorable for investors (ibid.). A comprehensive evaluation of related risks requires consideration of three main issues, namely, social and political climate affecting an infrastructure investment (which varies across countries, activities and over time), pressure for adaptation (such as industry- or project-specific regulatory frameworks to changing technology or economic thinking, problems in long-term planning, etc.) during the entirety of the arrangement, and design characteristics of the specific framework (ibid.).

According to Irwin (2007), the most direct result of many unexpected changes in policy (whether project specific or economy-wide) is the redistribution of project value (changes in the proportion of the total project value accrued to each stakeholder). In addition, given that project-specific policy risk (such as the government lowering a controlled price in a manner that could not have been anticipated – a project-specific distributional risk) is controlled by the government, the government itself should bear it (ibid.).

Investments in infrastructure projects are sunk. Thus, a firm is as vulnerable to economy-wide policy risks as it is to project-specific policy risks, and large benefits may be involved in protecting the firm from risks (Irwin 2007). Although the government may influence or even control such a risk, it should not determine economy-wide policy by reference to any particular project (ibid.). Iossa et al. (2007) viewed that while private sector party cannot control the risk of changes in law, the public sector party has little influence over national legislation. The private sector party can minimize the impacts of risk materializing on service provision, whereby, an argument to share the risk between the two parties exists. However, governments do not protect all firms from all policy risks (Irwin 2007). Problems related to providing protection to all infrastructure enterprises from all law or policy changes over the long period include (Irwin et al. 1997) reduced effectiveness of policy adjustment in large and important economic sectors, distortion of investment and operation decisions and resulting claims from other firms on grounds of inequitable treatment that are not protected from policy changes.

Infrastructure firms entering into contracts with governments in many countries, as per the contract, are protected against most adverse project-specific policy changes and some adverse economy-wide policy changes (Irwin 2007).

The World Bank guide on PPP contractual provisions (World Bank 2017) provides further details in support of providing protection to private partners against change in law (general/discriminatory and/or specific) risk in PPP procurement due to the following reasons: lack of pricing flexibility, bankability concerns and potentially excessive cost to the contracting authority (in the form of contingency/premium). The guide also recognizes the need for different approaches toward the optimum risk allocation in the context of legislative or regulatory volatility risk in the jurisdiction and sector concerned and the maturity of the market (emerging/developed). One of the approaches defined for the risk allocation in some emerging markets requires the contracting authority to take all the risks and provide complete relief to the private partner. This process may be necessary to obtain private financing (and provide optimum balance among affordability, bankability and risk transfer concerns) and may also enable the private partner to offer a competitive price.

For emerging markets, the risk allocation reference guide by GI Hub (2016) suggests public sector allocation and sharing of this risk for transport (highway) and power infrastructure sector (solar/hydropower) projects in emerging markets.

Changes in law/regulation risk was exclusively recorded in the domain of the public sector across the two case study projects in this research. However, an existing argument prevails that the private sector may retain some levels of risk responsibility to influence a project's sensitivity, as much as possible, and be less vulnerable to the effects of such changes (Arndt 1999; Irwin 2007). However, the government covers this risk possibly due to the emerging status of the market in renewable energy and highway infrastructure sectors and associated high risk averseness of the private sector. This finding is in line with Ke et al.'s study (2010a) where respondents from Greece, Hong Kong and China (with relatively less experience in PPPs) exhibited a higher preference for the public sector to share or undertake legal risks as opposed to the UK, where few respondents indicated their preference to allocate legal risks to the public sector.

9.6.5 Change in Market Demand (RF_07)

This risk is also difficult to allocate. In the case of toll road, tunnel, or bridge projects, public and private sectors can influence and control risks within specific confines (Irwin et al. 1997). For example, the government can influence some of the underlying factors that affect demand, including the quality of policies, which in turn affect average income and therefore demand by deciding to build other roads (some of which may act as feeders while others may compete). Similarly, a toll road operator may have little control over demand as any effort to enhance the quality of service delivery beyond a certain minimum standards may have insignificant influence on demand. Provision of demand guarantees by the government may create incentive problems by reducing investors' interest in carefully screening a project for demand risk (ibid.). Events that may influence market demand include general economic downturn, changes in government policy, introduction of competitors, competitive pricing of alternate services, changes in market composition or demographics, changing technology and changes in industrial activity/focus (VDTF 2001). Demand risk is difficult to accurately predict and is high in many sectors (Iossa et al. 2007). Often, this is more applicable for the construction of new infrastructure projects, such as road, bridge or tunnel projects, where the expected revenue calculations are based on service demand forecasts and complete risk transfer may substantially increase capital cost (high risk premium) (ibid.).

Changes in market demand risk should be allocated while considering the circumstances of the project, related infrastructure sector, and host market. According to GI Hub (2016), for power infrastructure projects (solar/hydropower), demand risk should be allocated with the contracting authority owing to the market structure (vertically integrated utilities) in emerging markets. For a toll road project, risk is recommended to be shared. In a study of 21 highway PPP contracts in the US, Nguyen (2017) determined that usage/demand risk was allocated to public and private sectors for different projects and was shared on one of the projects. The risk of *market demand change* recorded a contentious allocation regime in a review conducted by Ke et al. (2010b).

The demand risk was parked with the public sector because CS1 project's applicable policy and energy purchase agreement provide for the mandatory purchase of electricity. Given that CS2 is a brownfield project with sufficient data on demand and confidence in strong forecasts, the private sector was willing to bear the risk.

9.6.6 Supply, Input or Resource Risk (RF_08)

The government can assume this risk to the extent that it can control the availability and quality of inputs that will be utilized by the private party in delivering contracted services (VDTF 2001). The government may agree to take or share this risk in public interest or enhance VfM even if it cannot entirely control the availability and quality of input but is relatively better at it as compared with the private party. For example, Blomfield and Plummer (2014) presented various approaches to the management of hydrological risk (*"… hydrological risk is generally seen as the risk of having insufficient water in the source river or dam to support the expected levels of electricity generation."*), a key input risk in hydropower projects, and the underlying reasons justifying each scenario of risk allocation.

According to GI Hub, this risk should be transferred to the private party for transport (highway) sector projects, whereas its allocation strategy varies with the type of project for power infrastructure (generation [solar/hydropower], transmission) (GI Hub 2016).

With regard to CS1, only the first batch of wind power projects in Pakistan was specifically given coverage for wind resource risk. This arrangement was necessary as the existing data on wind resource assessment were inadequate and not in accordance with the acceptable standards. Projects under the revised policy do not enjoy this coverage. For the CS2, supply, input or resource risk is a private sector concern.

9.6.7 Delay in Project Approvals/Permits (RF_09)

A range of approvals, permits, licenses and consents are required to support various aspects (planning, design, construction, operation and maintenance) of a PPP project over its lifecycle (Department of Infrastructure and Regional Development 2016; UNIDO 1996). Approvals, permits or licenses may also be required in relation to land zoning, town planning, environmental and building standards, health and safety regulations (Rothballer and Gerbert 2015) and others related to project design, construction and operations, such as development/work approvals (VDTF 2001), import licenses for equipment and supplies, registration and stamp duties for the use or ownership of land, authorizations for the employment of foreigners, licenses for the incorporation of the concessionaire, licenses under foreign exchange regulations, etc. (UNCITRAL 2001). VDTF (2001) recommends that the required government and agency approvals and any potential problem in acquiring them should be investigated at the pretender stage. While some of the approvals are best left to the private party to acquire, other approvals can be facilitated by the government. Unnecessary and costly delays in obtaining the approvals, permits, and licenses by the private sponsors may be avoided if the host government can coordinate the policies and responsibilities of the concerned entities (ministries, agencies and local authorities) in advance (UNIDO 1996). Legislation may facilitate the issuance of licenses and permits, which may fall under the jurisdiction of various organs at different levels of the administration whereas the time required to obtain them may be significant in particular situations (UNCITRAL 2001). Project development agreements can be used to obtain a measure of pre-contractual certainty with regard to the approval process where the private party can agree to seek the relevant approvals for a given risk profile and the government agrees to absorb the additional costs above a specified level, arising out of the process (VDTF 2001). Regulatory approvals can be obtained by either the public or private sector, depending upon the stage in the project development process, entity best suited for obtaining the approvals, and the statutory requirements of the approvals/clearances (Department of Economic Affairs 2016).

In the comparison of allocation preferences of this risk by Ke et al. (2010a), experts from the UK were mostly divided with somewhat equal preferences for allocation to public and private sectors and for sharing of this risk. Experts from China, Hong Kong and Greece exhibited a great preference for the risk allocation to the public sector.

The risk on both case study projects was shared and the estimated RMCIs for the risk agreed well with the actual risk allocations where the public sector exhibited *high* RMC and the private sector exhibited a *moderate* RMC.

9.6.8 Insurance Risk (RF_10)

Given that almost all design, construction and operational risks in connection to a project are taken by the private party (except those retained by the government), the private party and sub-contractors mainly maintain the required insurances (VDTF 2001). For force majeure risks, contextual aspects (a force majeure risk that is non-insurable or insurable at an unreasonable cost) may dictate risk sharing to achieve better VfM. A private party can mitigate the effects of the force majeure event if it can acquire insurance for it so that the financial impacts will be capped. In another instance, a particular risk that is within the ambit of the private party to get insured may become uninsurable over the life of a project or the insurance may no longer be available on commercially acceptable terms. In such a situation, the contract can be drafted to relieve the private party of its obligation to maintain insurance where it becomes unavailable with suitable substitute arrangements determined in the contract to ensure that the private party manages the risk. However, if this is not possible, then the parties will be required to renegotiate an appropriate allocation for uninsurable risks (ibid.). In some countries, difficulties may arise as the type of coverage offered may be limited as compared with international market coverage and the limitations on the ability of local insurers to reinsure the risks on international insurance and reinsurance markets (UNCITRAL 2001). Yescombe (2007) argued that if the addition of large contingencies to bids is the only option available to bidders to offset the cost risk of large (above inflation) increases in operation phase insurance, then better VfM may be achieved by sharing the risks with the public sector.

According to GI Hub, this risk should be shared for the transport (highway) and power infrastructure (generation [solar/hydropower], transmission) sectors for emerging markets, whereas in some instances, it can be allocated to the private sector in developed markets (GI Hub 2016).

Insurance risk was shared for CS1 with a cap defined at one percent of project cost. Any deviation over the cap would be absorbed by the project sponsor. However, according to experts, such a cap is not usually breached. For the CS2, it was mostly carried by the project sponsor. In either case, if a risk becomes uninsurable, then the project sponsors are not responsible to maintain insurance.

9.6.9 Unforeseen Geotechnical Conditions (RF_11)

According to Yescombe (2007), allocating the risk of unexpected site geology is difficult. Preferably, risk should be transferred to the private party and then to construction subcontractors. One possibility to reduce the exposure to risk is by conducting site survey; however, this does not guarantee mitigation of the risk and conducting a detailed site investigation for liner projects may be impossible. For brownfield projects, issues may arise as surveys may be difficult due to existing buildings on site. In such cases, taking this risk in some projects rather than paying for costly surveys may mean more VfM for the public authority. Furthermore, any information provided by the public authority on ground conditions will make it liable for any losses in the event the information is incorrect (ibid.).

The risk also recorded contentious allocation preferences in reviews conducted by Dunn (2017) and the study by Ke et al. (2010a).

Risks related to geotechnical conditions in both case study projects were seen as fairly predictable due to the nature and scope of work in CS1, whereas the risk was perceived as predictable and low as CS2 was a brownfield project. In each case, the risk was allocated to the private sector.

9.6.10 Financing Risk (RF_12)

Financing is generally the responsibility of the private party or concessionaire who is required to fund and operate the facility (APMG International 2016a; UNCITRAL 2001). The financial obligations of the contracting authority or other public authorities are restricted to those that are made explicit in the project agreement or to forms of direct support that the government extends to the project (UNCITRAL 2001). In some cases, government support in the form of public loans and loan guarantees or direct or indirect equity participation in the project company may be possible to lower financing costs, enhance financial terms by complementing senior commercial loans, obtain a favorable debt to equity ratio, and/or satisfy legal requirements with regard to the composition of local establishment of companies (ibid.). The risk of financing (especially third-party financing, i.e., debt arrangements), either not being available (at commercial close or before construction) or being available on prohibitive terms, can be shared with the private partner (for some projects in countries classified as emerging markets and developing economies (EMDE)) by putting in place public institutional finance (APMG International 2016a). Options for potential public party participation include equity or debt contributions, provision of certain explicit guarantees and credit enhancement measures. Possible forms of government support have also been discussed in detail in UNCITRAL (2001) and World Bank (2005).

Risks of poor financial market and availability of finance were determined to exhibit contentious risk allocation preferences by Ke et al. (2010a).

Risks related to financing were assumed by the project sponsors in both cases as they were required to finance the projects. In the case of CS1, the government's provision of guaranteed purchase of electricity and return on equity and, in the case of CS2, strong project viability had enabled project sponsors to easily secure the required financing.

9.6.11 Payment Risk (RF_13)

Payment risk relates to the credit risk aspect of payments, i.e., whether the project company can expect to be paid the revenues (Yescombe 2007). Under concessions, it is a matter of "willingness to pay" on the part of the users, whereas for PFI model projects (payment by public authority – usage based or availability type payment mechanisms), it relates to the public authority's "ability to pay" (ibid.). In the case of user-pays PPPs, the APMG guide (APMG International 2016a) further specifies fraud (to willingly avoid payment) and collection risks ("… nonpayment when the payment may be or become unaffordable for the user."). Fraud risk is very relevant with public transportation projects and should be borne to some extent by the private party in transport PPP projects that involve transit operations because the private party is best positioned to manage it as it can mitigate the risk via access and ticket controls. The guide suggests that the private partner should be explicitly incentivized to control fraud in both payment systems (user pays and availability type). In toll road projects, fraudulent use is rare. However, in electronic tolling technologies where payments are made ex post, it has recently become an issue (ibid.).

For road PPP projects, revenue risk is a function of traffic volumes/toll rates risk and collection/enforcement risk (World Bank 2018f). Real tolled payment structures are considered to be capable of transferring both types of risk. According to Yescombe (2007), for road projects where a concession is considered a viable option, the public authority evaluates the suitability of tolling the road by considering, among other factors, users' willingness to pay and users' perceptions on the reasonableness of the actual toll level. For government-pays schemes, the public authority should check for "affordability" to evaluate whether it can actually afford to pay for the services (Yescombe 2007), which is determined before tendering (APMG International 2016a).

Under offtake purchase agreements (such as in power generation sector), credit risk associated with the offtake purchaser is significant to the project company and lenders (Delmon 2009).

Escrow accounts, revolving bank guarantees, or state/federal guarantees may be required from the offtake purchaser as credit enhancements (ibid.).

For sub-sovereign PPPs, especially those of a government-pays type in emerging markets and developing economy regions, a good practice is to provide credit enhancement in the form of support from the central government to ensure access to investors market (APMG International 2016a). The private partner may also contract political risk guarantees and partial risk guarantees to cover the debt to be raised (ibid.).

For CS1, delays in payments by the power purchaser are compensated by adjusting the payable amount in proportion to a predefined interest rate as per provisions of the contractual agreement. For CS2, the concessionaire is responsible for toll collection; however, the enforcement of the toll is the government's responsibility.

9.6.12 Latent Defect Risk (RF_14)

The public authority should retain some of the exposure to latent defect risk if the facility under consideration has been in public authority's ownership for many years and performing an assessment of its condition is difficult (Yescombe 2007). Defects in this case should be treated as compensation events over a specified limit to allow the project company (hence, the construction subcontractor) to have the opportunity to first manage the risks. The risk should be allocated to the private sector only when meaningful information is available for the bidders to perform asset condition assessment before submission of the bid (APMG International 2016a).

While studying the risk allocation on highway PPP projects in the US, Nguyen (2017) found that the *latent defect risk* was shared on some projects and allocated to the private party on others.

The latent defect risk did not apply to CS1 because it is a greenfield project. For the CS2, the risk was allocated to the project sponsor. Project sponsor was considered in the best position to assess the situation before taking over the project and building suitable strategies and their costs in the estimates.

9.6.13 Residual Asset Value on Transfer to the Government (RF_15)

In case the facility is required for ongoing use after the end of the contract term, adherence of the asset to various performance standards is required by the government to ensure a reasonable condition and fitness for purpose (VDTF 2001). For such assets, the government should be protected against inheriting significant costs or liabilities associated with the rehabilitation or removal from the project land (ibid.). To incentivize the private sector party to maintain the facility during the contract life and particularly toward its end, contractual clauses should be set in place to provide the final compensation payment to the private partner conditional upon the state of the facility once the contract expires (Iossa et al. 2007). General maintenance obligations can also be imposed with agreed maintenance and refurbishment schedules and a right to inspect the asset to enforce such obligations (VDTF 2001). The contracting authority may require the concessionaire to provide special guarantees to ensure satisfactory handover of the facilities (UNCITRAL 2001).

This risk also recorded contentious allocation preferences in a comparative study of Ke et al. (2010a) on risk allocation preferences across different countries.

The residual value risk did not apply to CS1 as it was set up on a BOO basis. For the CS2, the risk was allocated to the project sponsor. For residual risk, the sponsor is contractually required to bring the project in a pre-specified state, as per handback requirements, before transferring it back to the government.

9.6.14 Competition Risk (RF_16)

Legal, political or social grounds sometimes justify monopolies (monopoly means market with only one supplier), but they may have negative economic effects (UNCITRAL 2001). Notwithstanding the negative effects, in the absence of natural monopoly conditions, monopolistic conditions and other regulatory barriers to competition have sometimes been maintained due to the benefit of promoting certain policy objectives, such as providing services at low prices or below cost in certain regions or to certain categories of consumers. Legal monopolies are also retained in the absence of natural monopolistic conditions to make the sector attractive to private investors. The exclusivity rights may be granted upon the requirement of the private operators to reduce the commercial risks to their investments. However, where needed, such incentives of restricted competition should only be provided temporarily (ibid.). Offtake contracts, which are common in power and output generating infrastructures, are allowed for limiting the monopoly power of certain projects and locking in a pre-agreed price to sell the generated output, thus lowering revenue uncertainties. Limiting market exposure lowers cash flow volatility and can provide an improved credit rating (providing that leverage is not too high) (Croce et al. 2017). Several countries and states (Canada, Mexico, Victoria (Australia), California, Thailand, Portugal and Northern Ireland) have undergone or are planning to undergo power sector restructuring to implement competitive electricity markets for the benefit of consumers. Under this system, merchant plants carry full market risk (Woolf and Halpern 2001). However, privatization to this stage is considered outside the scope of PPPs (PPIAF 2016).

Various studies have reviewed the different recorded perceptions on this risk's allocation with all options on board, including sharing, transfer to the private sector and risk retention by the public sector (Dunn 2017; Ke et al. 2010b). Nguyen (2017) recorded variations in practice in the allocation of *network* risk where it is mostly shared across the highway PPP projects studied by the author and the risk is allocated to the public sector on few projects. Very few projects have recorded risk allocation to the private sector.

In both case study projects, the risk of competing facilities is retained by the public sector. For CS1, the mandatory purchase provision underpins the arrangement, whereas for CS2, the government will reimburse the project sponsor for potential losses in case any competing facilities are introduced in the future.

9.6.15 Design/Construction/Operation Changes (RF_17)

According to VDTF (2001), changes in service specifications may be required during the entirety of the contract due to changes in technology or industry practices, demand for contracted services, and law and government policies. The proposed changes may require work modifications prior to completion and post-completion modifications i.e., variations in service specifications (VDTF 2001). Compensation events and force majeure can also lead to contract changes (APMG International 2016a). The party initiating or proposing the pre-completion modifications of work should endure the consequences (except for certain limited exceptions for the government) (VDTF

2001). However, the government should be wary not to take back design risk unintentionally. Except under special circumstances, only the government shall have the right to modify service specifications during the operating phase and should bear the consequences for such modifications. The private party should have the necessary flexibility to make changes to the way it delivers its services in lieu of innovation and technological advancements (ibid.). According to the guide, the Victorian Government's preferred position is to incentivize the private party to keep cost of the changes to a minimum by compensating only where the costs of government-initiated modifications exceed a pre-specified minimum monetary amount (VDTF 2001). Arndt (1999) presented an example and suggested that the risk of changes in environmental legislation will be better off being allocated to the private provider as designers are in the best position to factor cost impacts of potential future changes in relation to the current design of a plant. Thus, the ability to influence the consequences of the risk eventuating in the future is demonstrated.

The risk of construction/design changes was found to be a contentious risk in terms of allocation preferences obtained from the literature reviewed by Dunn (2017).

For both case study projects, the party initiating any changes was considered responsible for bearing the impact. Thus, this risk was also shared.

9.7 CHAPTER SUMMARY

It is well established in literature that risks should be allocated or shared in accordance with the risk management capabilities of contractual parties. While this is easier to understand for some risks (such as design, construction and performance risks), contextual aspects (RMC, country/market, sector, and project) make it difficult to define a standard for other risks. A list of

17 such risk factors was developed from experts' inputs and extant literature. A fuzzy measure and Choquet integral based multiple attribute risk allocation decision making model was proposed that employs explicit and accepted risk allocation principles. Two case study projects, one from power and another from transport infrastructure sector, were investigated for actual allocation of the key risks and to demonstrate and validate the risk allocation and sharing model. The results show that a risk allocation model capable of considering interactions among the qualitative RAC can assist stakeholders as a decision support tool and provide more representative results vis-à-vis models that rely on aggregation operators based on additive measures. Additionally, the discussion on differences in allocation and sharing strategies of specific risks across sectors provided insights towards the underlying reasons and showed that for given risks, it may be viable (to secure VfM) and in some cases absolutely necessary to determine a custom risk allocation practice over any standard approach. This is particularly important when the public sector has to adjust and make room for accommodating risk preferences of the private sector for the sake of building private sector confidence and for growth of the market. Apparently, the allocation and sharing of key risks are significantly influenced by market, infrastructure sector and project contexts. The methodology presented herein aims to reduce the inherent subjectivity and implicitness of the process and provides an explicit, structured and a comprehensive framework to assist experts to negotiate an efficient allocation and sharing of risks on PPP projects. Specifying general risk apportionment strategies, as explained earlier, may not be optimum for all the projects and situations due to contextual aspects (APMG International 2016a; GI Hub 2016).

While the case studies discussed in this paper did not originally apply the proposed model for risk allocation and sharing decision analysis, the value of application of such quantitative analysis is to facilitate learning and appreciation of RMC differences among the parties with a view to enhance judgement in decision making. This can potentially save time and resources in risk allocation related contract negotiations and may even positively influence RMC perceptions of the parties as well as their risk attitudes. The model's application can assist relevant decision makers in achieving an efficient risk apportionment profile on projects to be undertaken in the future. This is particularly important as the issue of inappropriate allocation of risks on projects has been reported in literature (Arndt 2000, Zou et al. 2008, Marques and Berg 2011, HM Treasury 2012, Vassallo et al. 2012). Explicit and systematic deliberation over the identified RAC for each risk and the calculated RMCIs can highlight strengths and weaknesses of the involved parties, thus adequately informing decision making regarding risk allocation and sharing. This signifies the proposed method's potential to assist as a risk allocation and sharing decision support tool for PPP projects.

The discussion of allocation and sharing practices of the key risks in light of the existing literature provides important directions on when to consider transferring more risks to the private sector. It may be prudent to look out for changes in infrastructure sector market structure or characteristics, relevant indicators of regional economic growth, and PPP implementation and operational maturity, as well as the risk perceptions and preferences of the stakeholders, to continually reassess and exploit opportunities for more efficient risk transfer from public to the private sector.

While the fuzzy measure and Choquet integral model adequately predicted the actual risk allocation based on the RMC paradigm, the decision regarding when to share a risk between public and private sectors is often unclear and requires consideration of specifics contexts (such as in allocation of macroeconomic risks, public opposition, delay in project approvals and permits) to determine the actual apportionment strategy. As apparent from the discussions on allocation and sharing of risks in the case study projects, decision between sharing or retaining risks and sharing or transferring risks, where both the parties exhibit closely similar RMCI's- such as both public and private sectors demonstrating *low* to *moderate*, *moderate*, or *moderate* to *high* RMCIs, may require further considerations for efficiency. More work is required in future to develop methodologies to incorporate such specific considerations in risk allocation and sharing strategy analysis.

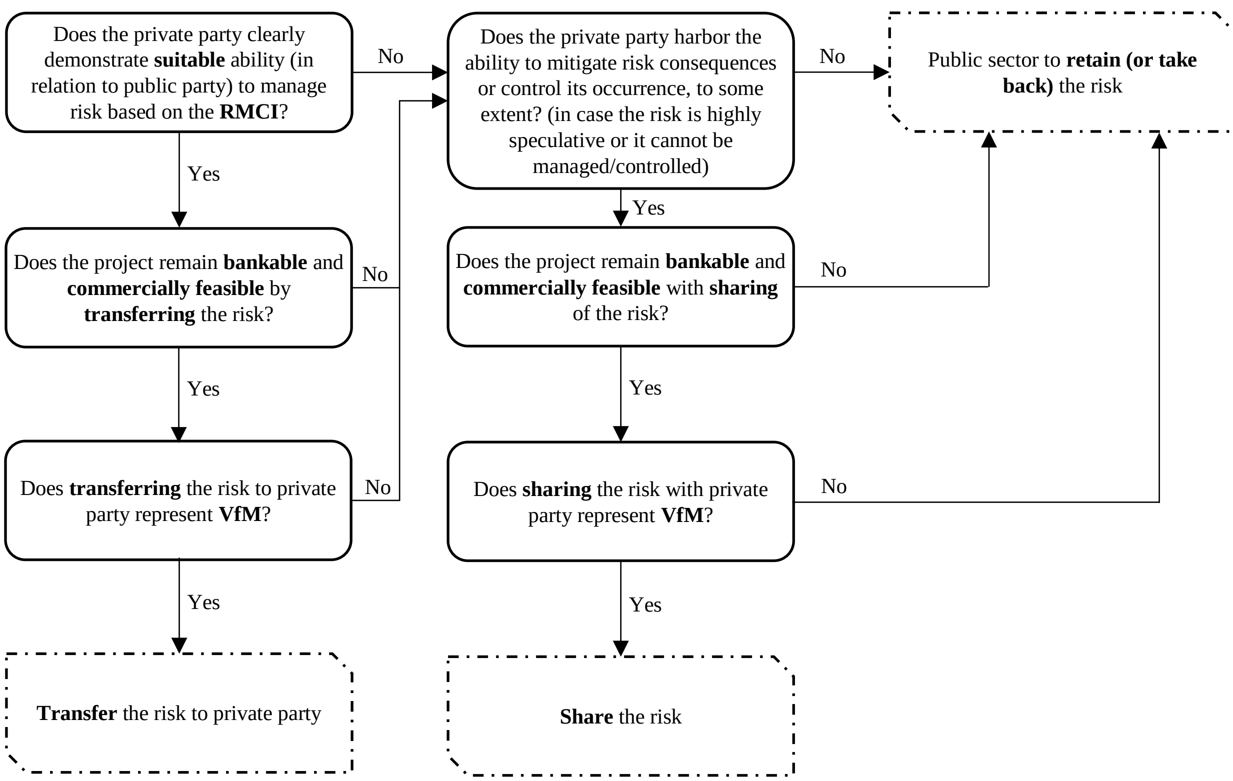

Fig. 9.2. Risk allocation and sharing general decision framework

A quantitative analysis of VfM for different risk allocation strategies (such as taking back the respective risk, sharing the impact, or capping the risk transferred) may also be performed for making final decision (APMG International 2016a), especially where RMCI indices alone are insufficient or of limited value. For a number of risks, reliance on common practice and precedents as well as exercising judgment will be important since innovation and risk management capability are difficult to evaluate and some risks are unquantifiable hence suggesting caution in quantitative assessment of VfM (APMG International 2016a). The final decision framework as provided in Fig. 9.2 (based on lessons from the case studies and guidelines by APMG International (2016a), Arndt (2000), VDTF (2001) and World Bank (2017)) may facilitate with the allocation and sharing of risks and provide assistance on how to translate the obtained RMCIs to final risk allocation and sharing strategies.

CHAPTER 10 CONCLUSIONS AND RECOMMENDATIONS

10.1 INTRODUCTION

Abundant research and other literature exist on PPPs and on risk management in PPPs; however, several broad dimensions continue to induce further critical investigations. First, contextual aspects render the generalization of certain research outcomes difficult, thereby making it necessary to study the subject in its unique contextual setting. Second, as highlighted in previous chapters, limitations of the existing models, which are less related to contextual aspects and pertain more to the methodology adopted therein, must be addressed. Finally, some areas demand special attention and contribution due to a lack of research in the extant literature. Hence, this study addresses the identified knowledge gaps in prior research and further elaborates and builds on contextual and methodological aspects. This chapter concludes the study by summarizing the work conducted under each objective, presents the results and relevant implications, addresses its significance and makes the inherent limitations explicit. The chapter ends with recommendations for further research in the domain of risk management in PPPs. The overall aim of this study was to conduct empirical investigations for risk management in the context of PPP infrastructure projects in Pakistan. This aim was achieved with emphasis on the identification of risks and development of ERM measures to ensure project success. The study also developed, demonstrated and validated risk assessment and allocation models to assist stakeholders in risk management decision making on projects. Specific objectives formulated for such ends include:

1. To investigate the project delivery trends in infrastructure procurement in the Pakistani construction industry and evaluate the scope of applicability and issues related to the PPP model for infrastructure procurement;
2. To develop and evaluate the ERM measures for PPP infrastructure projects to enhance and complement the efficiency of risk management efforts on projects;
3. To identify risks, assess stakeholders' perceptions on risks and develop a risk assessment model for PPP infrastructure projects;
4. To determine the optimal RAC for PPPs; and
5. To develop a risk allocation model to assist in the efficient and equitable allocation and sharing of risks on PPP infrastructure projects.

10.2 REVIEW OF RESEARCH OBJECTIVES AND CONCLUSIONS

Objective 1: To investigate the project delivery trends in infrastructure procurement in the Pakistani construction industry and evaluate the scope of applicability and issues related to the PPP model for infrastructure procurement

This objective had a broad focus on infrastructure and its procurement in the Pakistani construction industry to provide the necessary background for readers and set a firm foundation for the research in the local context. Extant academic and institutional literature related to infrastructure development in Pakistan was recovered from publicly accessible data repositories and then carefully analyzed and summarized.

Pakistan was found to be facing an acute shortage of infrastructure in virtually all sectors, and its public resources cannot sufficiently meet the demands. Moreover, project delivery by traditional methods of procurement was reported to be inefficient. PPP for infrastructure provision had been applied for infrastructure procurement in Pakistan; however, its utilization was limited to the procurement of power generation plants, port infrastructure, and more recently, road and highway infrastructure projects. Thus far, other infrastructure sectors failed to initiate any recent considerable venture. Concession-type contracts were also the norm for PPP-based infrastructure procurement, where BOOT, BOT and BOO were the common modalities used for power generation projects, whereas BOT and DBFOT were prevalent for road/highway infrastructure projects. BOO, BOT, ROT and BROT have been utilized for port sector and airport projects.

Further review of the literature revealed that budgetary constraints, desire for efficient infrastructure delivery and promotion of economic growth in the country could be considered the main categories of drivers or promoters of PPPs for public infrastructure procurement in Pakistan. Several barriers that hinder the implementation of the PPPs in Pakistan were identified, and they include the broad categories of constraints in raising private debt financing, poor economy, institutional immaturity, the country's environmental issues (e.g., political, legal and security issues) and lack of investor interest. The literature review also provided multiple references that indicated the risks prevalent on PPP infrastructure projects; however, no single comprehensive study was found in this regard. A summary from the review showed that risks in virtually all domains potentially threatened projects. Finally, the literature was also sifted for evidence on the status of risk management practice in the construction industry and PPPs, whereby all the main industry stakeholders were revealed to lack risk management maturity. Adherence to any established standards and best practices in risk management were not reported.

Government efforts toward the promotion of PPPs for public infrastructure delivery in the country were found to be ongoing with public sector organizations, at the federal and provincial levels, with the aim of enhancing institutional capacity. Many new PPP projects were initiated during the conduct of this research.

Objective 2: To develop and evaluate the ERM measures for PPP infrastructure projects to enhance and complement the efficiency of risk management efforts on projects

Reports in the existing literature of poor risk management on PPP projects leading to distress and ultimate failure provided the call for investigations into ERM measures. Hence, through literature review, semi-structured interviews, expert review and an industry-wide questionnaire survey, 30 ERM measures for PPPs were identified and validated. The measures that were rated as at least *very important* included the following: (1) quality of the project's financial model, (2) adequate administration/management of the contract between the public and private sectors (concession agreement), (3) comprehensive project risk management plan, (4) identification of project's and key stakeholders' objectives and requirements, (5) careful bid evaluation by the public sector and (6) efficient contract negotiations. Clearly, the top-ranking measures focus on the project planning, procurement and implementation phases of a PPP project lifecycle, thereby bearing a complete lifecycle perspective. As public and private sector stakeholders must exert mutual efforts to implement the measures properly, the measures are also multiorganizational. The characteristics defined for the top-ranking measures also extend to the remaining measures. All factors were rated as at least of *moderate* importance.

Application of factor analysis to obtain principal factors (underlying variables) representing the observed variables led to a six-factor solution, including the following: (1) well-documented structured management approach, (2) comprehensive requirements and risks evaluation, (3) post-contract risk management, (4) knowledge-driven risk management, (5) risk assessment quality and (6) public sector risk management, in order of the ranking obtained from mean ratings of the measures in each group. The review of obtained factor groups enables better comprehension of the facets that principally influence the quality and outcomes of risk management efforts. It also provides a guide to industry practitioners for effectively deploying the existing risk management knowledge base (i.e., guidelines, processes, tools and techniques) for successful PPP projects.

Objective 3: To identify risks, assess stakeholders' perceptions on risks and to develop a risk assessment model for PPP infrastructure projects

Adequate assessment of risk is essential to assist stakeholders in planning for efficient risk allocation and mitigation and ensure success in business and projects. Relevant risks were identified for power and transport PPP infrastructure projects following a systematic approach. A 45-factor risk register was established based on the literature review and the PPP experts' semi-structured interviews. The identified risks were initially categorized into two main groups of *systematic/country risk group* and *specific project risk group*, with several sub-groups under each category. Application of FST for risk analysis revealed 22 CRFs that were later categorized into seven independent CRGs of correlated factors using factor analysis. Risk factors that achieved a linguistic assessment of *high* impact reflect issues related to institutional capacity and local economy. Comparison of top-ranking risks from this work and from previously published PPP risk assessment research on developing and developed countries or regions showed that developing countries or regions possessed higher prevalence of systematic/country risks compared with developed countries or regions.

Research work under this objective further proposed, demonstrated and validated a novel multi-attribute risk assessment model that supports sectoral and project risk analysis to assist stakeholders in risk management decision making. Analysis based on fuzzy measure and non-additive fuzzy integral combined with arithmetic mean helped to obtain an ORI that indicated a moderate risk outlook for power and transport infrastructure sectors. Conversely, 'public sector maturity' and 'project finance' were assessed as *high*-impact CRGs in the power sector. 'Project planning and implementation' and 'project revenue' were additionally rated as *high*-impact CRGs in the transport infrastructure sector. Demonstration of the developed methodology for a BOT motorway case study project showed that the private sector stakeholders viewed the project as high risk with all the CRGs evaluated as *high*-impact CRGs, except for the political situation CRG, which was assessed as moderately risky. Test results showed that the methodology performed satisfactorily in approximating experts' holistic project risk assessments. The developed framework could be used to assess a country's condition or overall project risk at the initial project stage with minimal input of time and resources, thereby facilitating an efficient and robust risk assessment.

Objective 4: To determine the optimal RAC for PPPs

Stakeholders' value ambitions are directly threatened by potential unchecked and unmanaged materialization of risks in PPP projects. To ensure that all stakeholders achieve success in terms of fulfilling these objectives and ambitions from the PPP project, risks are proportioned among them in a way that best suits their capabilities to manage the risks and thus bring efficiency by lowering costs. Accordingly, risks must be allocated and shared based on representative RAC. A review of academic and institutional literature assisted in collecting and summarizing various elaborations and interpretations of the optimum RAC for PPPs. Nine RAC were identified, and all were applicable in determining the RMC of private sector stakeholders, but only eight were applicable for assessing RMC of public sector stakeholders. A review of the identified RAC by experts in the local industry verified their relevance and usefulness. Hence, all of them were employed for RMC assessment in the last objective of this research.

Objective 5: To develop a risk allocation model to assist in the efficient and equitable allocation and sharing of risks on PPP infrastructure projects

PPPs for infrastructure development are characterized by a radical approach to the management of risks wherein appropriate risk allocation and sharing is a critical success factor. However, evidence suggests poor risk allocation practices prevail on projects, thus signifying the need to develop a robust model to assist stakeholders (namely, public and private sector partners) in capability-based risk allocation decision making. Discussions with industry experts and review of the literature revealed 17 risk factors from the risk register developed for this study that exhibit lack of consensus among experts regarding their allocation and sharing strategy. These risks may be allocated differently based on contextual factors, as evident from the literature. Hence, these factors were considered worthy of further investigation for their appropriate allocation and sharing while using the RAC from Objective 4. Case studies of operational projects from power and transport infrastructure sectors were conducted wherein public and private sectors experts that had participated in setting up these projects were invited to provide assessments on RMC for each of the 17 risk factors against each RAC. Data were also collected on the actual allocation of these risks on the case study projects along with other information needed for the demonstration and validation of the risk allocation model. A non-additive fuzzy integral-based multiple attribute risk allocation decision approach was proposed to effectively aggregate each stakeholder's RMC assessments on the accepted risk allocation principles derived from qualitative judgements and experience-based knowledge of experts. The model's output in the form of RMCI value for each risk and for each party can then be compared to determine the party that exhibits greater RMC and thus qualifies for allocation of the risk based on higher RMC. All the RMCIs obtained for the 17 risks for each case study project could be easily interpreted to obtain the actual risk allocations on the projects. This outcome indicated that the results from the model converged with the actual allocation and sharing of risks, thereby validating the model. However, for a few risks, the decision was unclear, and contextual factors clarified the disparity between the predicted allocation and sharing strategy interpreted from the RMCI and the actual strategy adopted for those risks on the projects. A companion decision-making framework for the risk allocation model was proposed on the basis of the literature review and the observed contextual aspects that could aid in explaining the disparity between the model results and the actual strategy adopted for these risks on the projects. The companion framework provides a useful guide to arrive at a suitable risk treatment strategy (allocation or sharing) based on the steps provided therein.

Furthermore, comparison of results with an additive aggregation approach revealed the suitability of the adopted methodology as it performed well in modeling the risk allocation preferences of experts due to its capability to handle interdependencies or interactions in the RAC.

10.3 RESEARCH VALUE AND CONTRIBUTIONS

This research has made valuable contributions, which will have implications for local and international PPP infrastructure industry.

First, this study identified ERM measures on PPP projects and established their significance. This outcome corresponds to the findings in extant literature that deduced failures on PPP projects as a result of poor risk management. The identified measures indicate important environmental, organizational and project parameters, which, if given due attention, could potentially improve risk management outcomes on projects. Although only six top-ranking measures achieved an importance rating of *high,* none of the identified measures rated below *moderate* importance, thereby implying considerable importance of the entire set. Understandably, every stakeholder in the project will manage its own set of risks; however, failure at any level may have implications for the interests and objectives of other stakeholders as well. The conceptual framework in Chapter 5 clearly shows that almost all the identified measures are aspects related to public and private sector stakeholders; hence, joint efforts will be necessary for their adequate implementation. For example, risk management maturity and risk management commitment are traits required for all stakeholders on the projects. Similarly, hiring of experienced and skilled consultants and external advisors for project procurement and management is important for all stakeholders to ensure that they can make informed decisions that are supported by sound advice from relevant experts. Xiong et al. (2017) categorized risk management efforts in to ex-ante and ex-post efforts for PPP projects, and emphasized ex-post risk management for ERM due to the characteristic long duration of the projects and its resulting challenges (and many other reasons, including complexity and incomplete nature of contracts, project finance and increased risk transfer to private sector etc.). The framework indicates that 20 of the identified measures can potentially improve risk management outcomes at the project implementation phase, which focuses on project construction operation and maintenance. Hence, the implementation of the identified measures will be most important to ex-post risk management. Nevertheless, this finding does not suggest that risk management efforts in project planning (project identification and detailed preparation) and procurement phases will not benefit. Out of the 30 identified measures, 28 can potentially affect ex-ante risk management by enabling effective risk identification, analysis, response planning and/or control by the involved stakeholders. Most importantly, the identified measures indicate that risk management is not an isolated function but an integral part of project management, where risks are managed while conducting project appraisals and feasibility studies, tendering/bidding, negotiating and drafting contracts, administering and managing contracts and coordinating/collaborating with stakeholders, etc. Thus, efforts for improving risk management outcomes on projects should be given focus and consistent efforts by all stakeholders are required throughout the project lifecycle to make the project a success. Given that RMC is based on organizational risk management experience and learning capabilities (Jin and Doloi 2008) and on risk management maturity (Wibowo and Taufik 2017; Zhao et al. 2013; Zou et al. 2009), among other possible factors, stakeholders involved in PPP projects in developing countries and/or those that have recently started with the PPP paradigm must be vigilant because such organizational parameters have also been identified as important ERM measures on projects.

Second, this study developed a 45-factor risk register that is comprehensive and representative of the local PPP industry and the dominant infrastructure sectors with high project activity. Twenty-two critical risks were also identified and discussed in detail in the local context. The risk register may be used by practitioners as a starting point to evaluate projects and may modify it as per contextual requirements. The difference in the top-ranking factors across power and transport infrastructure sectors provides useful insights on where the policy makers, project execution authorities and the private sector may focus first to alleviate individual sectoral issues. Indicatively, a need exists to focus on risks and issues related to the local economy and the maturity of public procurement organizations. Government guarantees and other forms of public financial support appear to continue to be of significance and play a substantial role in the development of PPP infrastructure projects due to the poor economic conditions in the country. In summary, a review of the top-ranking risks reveals that efforts by public and private sector stakeholders are required at the policy, market, infrastructure sector and project levels to increase the attractiveness of the infrastructure to private investment and secure public interest.

This study also presents a methodology that provides an effective approach for multiple attribute project risk assessment using fuzzy measures and fuzzy integral. The proposed method was demonstrated and validated and could be applied for assessing riskiness at the sectoral level (overall) and for an individual project. This feature can be useful for informing stakeholders while considering entering into business transactions in particular sectors and projects. Moreover, the ranked CRGs can further indicate areas that require further attention at the sectoral and/or project level from the concerned public and private sector stakeholders for risk response planning and mitigation. The sectoral evaluation rated both the sectors as moderately risky for investments overall; however, different CRGs were indicated as highly risky, thereby highlighting risks related to ‘public sector maturity’ and ‘project finance’ CRGs as a priority for the management and mitigation efforts of the power infrastructure projects in the country. Similarly, CRGs, including ‘project planning and implementation’, ‘project finance’, ‘project revenue’ and ‘public sector maturity’, were all rated at *high* impact, thereby providing a priority for the management and mitigation efforts of the transport infrastructure projects in the country. Public and private sector stakeholders can utilize this information to better manage and control risks at the sectoral level. The results on top-ranking risks confirmed a slightly similar trend for developing countries, wherein risks from systematic/country risk group are more prevalent. Thus, the local government must play a larger role to address the issues.

Finally, this study presented a risk allocation and sharing model to assist stakeholders in negotiating an efficient solution for individual projects. The methodology applied could model decision makers' preferences more closely than the traditionally applied methods because it could cater for interactions among the identified RAC. Case studies conducted on projects from the power and transport infrastructure sectors showed that the proposed model could assist in arriving at suitable recommendations while accommodating contextual factors. The usefulness of the model lies in introducing structure to the decision-making process where all the relevant RAC are considered along with contextual aspects in arriving at a final decision. Efficient risk allocation and sharing can provide dividends to all stakeholders in terms of increased VfM for the public sector, sufficient profitability for the sponsors and timely settlement of debts to the lenders. These outcomes could be achieved by allocating and sharing of risks according to the RMC of the respective parties to a contract.

10.4 LIMITATIONS OF THE STUDY AND RECOMMENDATIONS FOR FUTURE WORK

Similar to other research, this study also exhibits limitations, which are primarily related to the methodology and generalizability of results in this case.

With regard to the ERM measures, the findings reflect perceptions of respondents from a developing country with low maturity in PPP project implementation. Hence, the findings may not be generalizable to other geographical locations. The ERM measures may be further explored in mature PPP markets to determine any similarities and/or differences. Efforts in this direction may involve a more rigorous research regime that utilizes a larger panel of experts and/or case studies to explore the level of implementation of these measures on actual projects to further validate the findings. A case study approach may provide specific insights on the measures that are absolutely critical for ERM. Such an approach will also overcome the limitations of a questionnaire-based data collection methodology, in which any potential differences in the respondents' understanding of the measures/statements in the questionnaire may distort the ratings.

The established risk register represents information from existing literature and inputs of local PPP experts. Most of the risk factors are generally applicable for any developing country context; however, certain market-, sector and project-specific situations might indicate otherwise. Hence, any generalizations must be considered cautiously, specifically regarding the criticality of risks. Moreover, several methodologies are available for evaluating the fuzzy measure for Choquet fuzzy integral analysis. Although, λ fuzzy measures for risk assessment are easy to operationalize, there are associated limitations in terms of employing a single index to represent the interactions between all risk factors within each CRG. Other methods can be employed and compared with the applied methodology to determine which methods provide more practical and representative solutions. Furthermore, the results obtained by the application of the proposed methodology need to be validated with a larger set of project data and compared to other available MADM methods in the existing literature to establish concretely the relative advantages and disadvantages in the context of project risk assessment.

Given that the model output is a number or linguistic assessment (the RMCI), the comparison of public and private sector indices and the selection of a final allocation or sharing strategy again relies on the subjective assessment of the decision makers. The model can only help in introducing structure to the decision-making process rather than concretely identifying a strategy because of the difficulty of adequately capturing and modeling all the decision parameters. Although the fuzzy measure and Choquet integral model adequately predicted the actual risk allocation based on the RMC paradigm, the decision regarding when to share a risk between public and private sectors is often unclear and requires consideration of specifics to determine the actual strategy. Furthermore, the proportion of risk sharing cannot be determined from the model output. For each of the risk factors, the proportion of responsibility that is attributed to a party is strongly related to the nature of the risk and different underlying scenarios, which must be investigated individually. This situation creates avenues for further research to develop mechanisms that guide the risk-sharing proportion based on the RMC of the parties. More case studies may also be conducted in the future to further validate the applicability of the methodology for practical use. In addition, the method utilized to estimate the values of fuzzy measures can be improved to model the decision makers' preferences more accurately. It may also be useful to investigate the indicators of risk management attitude for public and private sector PPP stakeholders because it forms an important aspect in determining the RMC of a party and directly affects the risk allocation and sharing regime.

Research is also required on the manner in which risk allocation and sharing strategies are translated and structured in contracts. Identifying various relevant approaches, understanding their pros and cons and providing a decision-making framework to suit stakeholders' interests are needed.

APPENDIX A – SEMI-STRUCTURED INTERVIEWS

<u>Study title</u>: Risk assessment and allocation model for Public-Private Partnership (PPP) Infrastructure Projects in Pakistan

Semi-Structured Interviews Summary

Conducted between 5th September to 30th September 2016

The purpose of the semi-structured face-to-face interviews was to collect most current and necessary information from practitioners with direct hands-on experience so that any mismatch between theoretical and contextual aspects could be ratified. An important purpose of conducting the interviews was to determine whether the risk factors for assessment and allocation, RAC and measures of ERM identified from the literature review were appropriate, clear, sufficient and representative. The interviews also enabled the researcher to learn more about actual practices and issues related to PPP projects in Pakistan.

All of the interviewees were contacted by telephone/email before the actual meeting, whereby the time, date, and venue for the interview was set. The interviewees were appraised of the interview agenda and the initial set of questions was shared with them. The interviews were conducted on weekdays and at the offices of the respective interviewees. On average, the interviews spanned from 80 to 90 minutes in duration. Voice recording was not allowed however, notes were made during (where the situation allowed) and immediately after the interviews. Open ended questions were asked to allow the interviewees to express their thoughts freely and present examples/actual scenarios, where applicable. The information recorded has been summarized under the questions below. Some other information regarding current projects, difficulties/barriers to foreign investment, internal working of organizations, risk allocation and the intricacies (for some specific risks), and examples of issues on some specific projects relevant to the context of the discussion were also shared by the interviewees but only that information is presented below which fits well under the nature of the questions asked.

Data on Interviewees

Interviewee	Sector	Organization	Designation	Experience
A	Power	Public authority	Deputy Director Hydropower	-
B	Power	Public authority	Director Hydropower	13 Years
C	Power	Public authority	Director Renewable Energy Projects	12 Years
D	Power	Project company	Chief Operating Officer (COO)	15 Years
E	Transport	Public authority	Director PPP	6 Years
F	Transport	Project company	-	-
G	Transport	Project company	Financial Analyst	6 Years
H	General	Public office	Infrastructure Specialist	5 Years

Interview Questions

1. What are the lifecycle risks facing PPP infrastructure projects in Pakistan?

This question was asked to solicit information based on the interviewee's general experience on the relevant risks that have been experienced on previous and/or current PPP projects. The results have been summarized in the table below.

Interviewee A	▪ Concerns about the security situation of Pakistan and its negative impact on foreign investment ▪ Hydrological risk ▪ Delays in payments to the project company by the public authority ▪ Fuel supply risk (possible situations may include political violence/public unrest) ▪ Poor local economy ▪ Fuel cost volatility ▪ Government interference in the functioning of the regulator ▪ Local investors' credibility ▪ Long and protracted public decision making process ▪ Significant delays in financial closure ▪ Small gaps in legal and regulatory framework ▪ Development risk (changes in government project procurement requirements/policies – resulting loss of project development costs) ▪ Poor global economy (escape or lack of interest of western investors)

Interviewee B	▪ Land acquisition (multiple ownership issues leading to significant delays. This risk is more pronounced in hydropower projects as compared to thermal or alternate energy projects due to vast land requirement and the relative inflexibility in potential relocation of the proposed facility.) ▪ Availability and supply of fuel (input risk - thermal projects) ▪ Hydrological risk ▪ Change in government and the resulting changes in PPP policy disturb the projects in the pipeline ▪ Technology risks (quality of generation plant and manufacturer (OEM) related issues) ▪ Turnover of public sector officials (loss of corporate knowledge) ▪ Cost escalation ▪ Geological risks ▪ Power evacuation risks (no transmission line/lack of access to the grid) ▪ Delays in project approvals/permits ▪ Changes in design/construction requirements
Interviewee C	▪ Land acquisition/allocation (multiple legitimate/illegal ownership issues resulting in delays) ▪ Resource assessment (wind/solar resource assessment data does not exist for Pakistan except for a few places/regions) ▪ Power evacuation problems (lack of and/or inefficient grid infrastructure) ▪ Inflation and Forex risks (most equipment imported) ▪ Institutional capacity issues (technical and commercial aspects of distributed generation/net metering not understood) ▪ Poor risk perception (results in high interest rate financing even though Pakistan has improved on the country risk and the domestic unrest front)
Interviewee D	▪ Geo-political situation and country political stability risks (important consideration for foreign investor) ▪ Economic stability ▪ Geological risks (hydropower) ▪ Environmental risk (loss of or damage to biodiversity in rivers) (hydropower) ▪ Flood risk (hydropower) ▪ Hydrological risk (hydropower) ▪ Resource data availability/reliability (renewable energy) ▪ Fuel price volatility (thermal) ▪ Relatively higher operations and maintenance risk (thermal) ▪ Corruption ▪ Lack of capability to raise finance (local market)
Interviewee E	▪ Construction risk (Quality) ▪ High internal resistance to PPP (within govt./public institutions/authorities – lack of ownership) ▪ Public opposition (opposition against high tolls on one project) ▪ Corruption ▪ Lack of competition ▪ Lack of international participation in bidding ▪ Land acquisition issues (multiple ownership/encroachments) ▪ Coordination issues between government departments ▪ Political risks

Interviewee F	▪ Land acquisition (Project usually started with only partially allocated/acquired land. For the remaining land, acquisition problems arise during the currency of the project and puts the project in delays.) ▪ Lack of skilled experts (legal, finance and technical experts for BOT projects) ▪ Ownership and understanding of the public PPP Acts is lacking in public sector officials
Interviewee G	▪ Demand risk ▪ Competition risk ▪ Toll escalation ▪ Construction risk ▪ Operation and Maintenance (O&M) risk ▪ Construction equipment risk (breakdown, repair and maintenance) ▪ Availability/performance risk ▪ Political risk ▪ Force majeure ▪ Land acquisition ▪ Government intervention ▪ Lack of ownership of the concept of PPP by the public officials ▪ Lack of skilled manpower (legal, finance and technical experts) ▪ Credit risk
Interviewee H	▪ Just reviewed and commented on the list of risks obtained from the literature review

2. How are the risks allocated among the public and private project parties? Are any standard risk allocation criteria considered for allocation of risks on projects?

<u>**Interviewee B:**</u> Standard contract documents have been prepared with the assistance of an international consultant. Risks have been clearly defined and parked/allocated in these documents to each stakeholder (public/private). No negotiations are accepted at the government level that can potentially re-allocate risks and change the contract structure. Negotiations may be focused on changing the contract language where ambiguity exists but that too in a way that does not increases government's liability or exposure. Interviewee A is from the same organization and reported similarly with regards to the issue.

<u>**Interviewee C:**</u> Standard documents exist for all types of projects (wind / solar / small hydro / bioenergy projects) that define risk allocation in detail.

<u>Interviewee D:</u> Also agreed with the interviewees A and B in that no major renegotiations take place for projects and that the standard documents that also included consultation with the private sector while drafting the documents, are acceptable.

<u>Interviewee E</u> form the transport/highway sector contended that standard contract documents have been prepared that contain pre-defined risk allocation for federal government projects procured by the authority as mandated to it by the federal government. Provincial procuring authorities have their own procurement mechanisms which may be different.

<u>Interviewee G</u> from the transport/highway sector agreed with the notion that for federal projects, it is desirable to maintain the pre-defined risk allocation, as provided the standard documents however, some risks might become irrelevant on certain projects, for example, land acquisition was not a relevant risk on some brownfield highway projects where the respondent was currently working while representing the SPV on these projects.

Upon inquiring the interviewees (B, D, E, G, & H) regarding the risk allocation criteria identified from research, the interviewees generally agreed to the adequacy of it. Regarding the criterion on premium added for risk in the project, interviewee D contended that it was not necessary that only risks in each project were evaluated individually and premiums added in the cost rather the business as a whole was also an important additional consideration. The interviewee gave an example by explaining the fact that if their parent group was sponsoring more than one project on PPP basis, then overall return on equity from previous projects will also be considered when adjusting bids for risks on potential future projects. Interviewee G speaking with reference to transport sector argued that all the identified risk allocation criteria were very important and that they should be used in evaluating optimum risk allocation on projects but also noted at the same time that this was not always done. The interviewee further stated that for some risks e.g., land acquisition, all these criteria were actually considered while negotiating the risk on one of the projects being sponsored by their organization. However, not all the risks were evaluated similarly for the purpose of allocation.

3. What is the status of risk management on PPP projects and what can be done to improve it?

Interviewees, in general, contended that most of the issues faced on PPP projects were during the project development phase and therefore post financial close issues were not significant. Both the public and private sector agreed on this assertion except in a few cases. Interviewee B stressed on proper planning and joint risk management to solve issues on projects. Interviewee C and D specifically pointed out the lack of institutional capacity at both ends, i.e., the public and private sectors, which was a major cause of problems at the pre-financial close stage of the projects. Interviewee D held the opinion that projects that bring foreign investment had seen good risk management efforts due to foreign experience and expertise of the lenders/multilaterals. Local lenders were also maturing over time; however, the local lenders may be forced to act outside principles, at times, under political influence (ibid.). The interviewee also held that public sector lacked understanding of risks and exhibited weak contract administration skills in privately financed power projects. Another point raised by the interviewee was that sponsor characteristics (foreign/local, experience, risk attitude, capacity to absorb risks, etc.) also matter when it comes to risk management on projects.

For the transport/highway sector, interviewee E suggested dissatisfaction with the pre-tender risk management efforts on projects on behalf of the public authority. Interviewee G argued that government was particularly weak in understanding risks and contract administration efforts. In addition, the interviewee also expressed dis-satisfaction with the quality of pre-feasibility and feasibility studies conducted by the government for the privately financed transport/highway projects based on his previous experience in working for an apex federal government organization that is responsible for PPP project appraisals. It was also stressed that there was a lack of availability of risk mitigation instruments (hedges/swaps) for mitigating certain risks in Pakistan and a lack of historical data over which to assess risks for upcoming projects (ibid.). Interviewees E and H expressed that risk management plans are neither made nor managed by the public sector and that risks are only discussed within the framework of contract agreements. Interviewee H expressed a great desire to develop detailed and specific risk management plans for PPP projects. On one project, the organization of interviewee H did procure services of an independent consultant for the development of a risk management plan but the experience of the interviewee was not good and thus unsatisfactory.

4. Which of the identified risk factors are important and relevant in the local context?

Interviewees A, B, E, G & H were consulted to discuss in detail the risk factors identified via literature review. In addition to suggesting some risk factors in Question 1 of the interview, the interviewees were content with the comprehensiveness of the risk factors identified. Some factors although relevant, were regarded as of relatively low importance based on experience of interviewees on previous projects, hence these were removed. These risks included: default and termination (of the project company); insufficient financial audit (of the project company);

political discontent and early termination; and third-party delay/violation/default. It was also suggested to club a few factors due similar underlying meaning. Change in law/regulation was retained to cover broadly all policy and regulatory risks thus ‘change in tax regulation’ and ‘environment risk (change/amendment in regulations) were removed. Similarly, Design/construction/operation risk was retained as one risk factor only whereas initially it was defined separately for public and private sector stakeholders. Another risk factor ‘resettlement and rehabilitation risk’ was removed considering the related ‘land acquisition’ risk, which was retained in the final risk register. Some interviewees (interviewees E and H) further considered ‘expropriation/nationalization of assets’, ‘insurance risk’, ‘conflicting or imperfect contract’, and ‘latent defect risk’ as not too significant however, these risks were retained in the final register due to a lack of consensus.

5. Which of the identified measures of Effective Risk Management (ERM) are important to ensure successful risk management efforts on PPP projects?

Interviewees B, D, E, G, & H were consulted to discuss and solicit their views on the relevancy and adequacy of the ERM factors. Some interviewees expressed reservations on certain factors (well-established project management scheme, increased confidence, trust, and cooperation among partners, existence of independent risk management unit with the government) in terms of their significance, while no new factors were identified by the interviewees that can provide guidance towards enhancing the effectiveness of the risk management efforts on PPP infrastructure projects. In general, the interviewees considered that risk management should be an intrinsic responsibility of all those who are involved and that the function demands seriousness and commitment from the stakeholders. The interviewees expressed general satisfaction with the rest of the measures of ERM.

6. Specify any project from your experience which may be suitable for a detailed case-study on risk allocation and management from your concerned infrastructure sector.

Based on the inputs of the interviewees, six projects were identified that represent the active infrastructure sectors and for which contacts may be available to solicit project information and conduct risk allocation and sharing studies.

The identified case studies could be considered landmark deals with respect to Pakistani PPP infrastructure projects industry. Two of the identified projects by interviewee C belonged to wind power generation, each bearing nearly 50 MW of generation capacity. Both the projects were operational at the time of this research and procured under 20-year terms on BOO basis. On average, each project costed nearly USD 130 million. Both of these projects belong to one of the earliest wind power deals in the country.

Interviewees A, B and D suggested another particular case study project which is Pakistan's first BOOT hydropower project. The project was operational at that time and has a rated output of 84 MW. It was procured under a 25-year contract and costed around USD 215 million.

Interviewees E and F suggested three highway projects for case-study where one was under construction and two were operational. All the projects had been procured under BOT contracts for a concession term of 25 years and were brownfield in nature. One of the projects was too small which costed close to USD 10 million while the other two were budgeted at over USD 350 million.

It was decided to select two projects for this research, one from each infrastructure sector, based on availability of experts from both the public and private sectors, that were involved in delivering the projects.

7. **Decisions regarding risk transfer, retention and sharing have to be made on projects to structure PPP contracts. Generally, which risk factors have the most significant variation in interpreting efficient risk allocation and sharing strategy among the experts? Also, risk factors may be identified for which the allocation and sharing strategy on projects is most sensitive to contextual aspects.**

The list of 22 key risks derived from literature (Chapter 9) was presented to five experts (B, D, E, G, & H) to consider modifications based on their experience. Collectively, seven risk factors were considered less significant from the perspective of ease of identification of an optimal risk allocation and sharing strategy. These risks included: lack of supporting infrastructure/utilities; unfavorable national/international economy; pricing and toll/tariff review uncertainty; environmental damage risk; technology risk; conflicting or imperfect contract; and operation cost overrun.

Two risk factors were added based on suggestions from the interviewees (E & G) which include latent defect risk and payment risk. Brownfield facilities are susceptible to latent defect risks which are hard to assess and may become a significant concern. Whether a transportation project follows an *availability based*, *usage*, or *user pays* payment mechanism is strictly dependent on viability of the project which in turn is dependent on many aspects including the socio-economic makeup of the project bearing region. These considerations have implications for determining efficient risks' allocation and sharing strategy.

In the end, 17 risks were finalized for studying risk allocation and sharing on case study projects and also to demonstrate and validate the proposed risk allocation model.

APPENDIX B – SURVEY QUESTIONNAIRE

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

DEPARTMENT OF
BUILDING & REAL ESTATE
建築及房地產學系
INTERNATIONAL • COLLABORATIVE • CONSTRUCTION
FACULTY OF CONSTRUCTION AND ENVIRONMENT
建設及環境學院

Invitation to participate in PhD research study on risk management in infrastructure public-private partnerships

Dear Sir/Madam,

I am writing to request your participation and assistance in filling the **attached questionnaire**, as a practitioner with knowledge in Public-Private partnership (PPP) infrastructure projects in Pakistan. The questionnaire identifies various risks factors in the Pakistani context and measures to promote effective risk management efforts on PPP projects and forms a part of an ongoing PhD research, being conducted at, and funded by, The Hong Kong Polytechnic University, under the supervision of Ir Professor Albert P. C. Chan. The study aims to **identify critical risks**, understand **risk allocation** (as practiced), and develop risk assessment and allocation **models**, which may prove useful in informing decision making for future PPP projects.

The study adopts a two part approach where part one attempts to identify critical risks and important measures for effective risk management on PPP projects and part two investigates the key risks for efficient risk allocation on PPP projects. The attached questionnaire constitutes part one and requires **15-20 minutes** to complete. For stage two, case study projects will be selected to study risk allocation practice and determine the most efficient risk allocation strategy for the projects. All responses to the surveys will be treated in strict confidence and utilized solely for academic purposes.

I would be grateful if you could forward the questionnaire to potential expert(s) who you consider to be relevant and willing to participate in this research. Should you have any queries, please do not hesitate to contact either Khawaja Mateen Mazher (primary researcher – *mateen.mazher@ XXXXXXXXX/ Mobile: XXXXXXXXX*) or Professor Albert P.C. Chan (*albert.chan@ XXXXXXXXX*).

Your response will make a significant contribution towards this research and in potentially informing research, decision making, and management of PPP infrastructure projects in Pakistan, in the future.

I would be grateful if you can provide your response by *DD* **of** *MM* **2017**. The completed questionnaire may be emailed to the researcher or it can be collected in person, based on your convenience.

Thanking you in anticipation.

Yours truly,

Khwaja Mateen Mazher, PhD Candidate
Ir Professor Albert P.C. Chan, HoD, Department of Building and Real Estate
The Hong Kong Polytechnic University, Hong Kong.

<u>Study Title</u>: ***Risk assessment and allocation model for Public-Private Partnership (PPP) Infrastructure Projects in Pakistan***

<u>Introduction</u>

Pakistan, similar to other developing countries, is facing a severe shortage of infrastructure that hampers economic growth and development of the country. In order to meet the infrastructure requirements, private investment seems to offer a promising solution to partially mitigate the above-mentioned issue. PPP projects are known to be riskier than the projects delivered through traditional procurement methods. Research has determined that equitable risk allocation is one of the most important driver for achieving success and Value for Money (VfM) in such projects. Failure of projects procured under various modalities of PPP, world over, has indicated a shortfall in effective risk management efforts by the stakeholders involved. To better understand risks and their management on PPP infrastructure projects in the Pakistani context, this research endeavors to identify critical risks and factors that determine effective risk management (ERM) efforts on projects delivered through PPPs. The relevant risk factors and measures of ERM, have been determined through an extensive review of the international research, published literature, and information obtained from interviews with PPP experts in Pakistan, both in the power and transport infrastructure sectors. This questionnaire constitutes part one of the research and solicits information on risks and measures of ERM. ***<u>Risk</u>*** *<u>in this research, has been defined as an occurring event or existing condition that can cause actual project circumstances to differ from those assumed and hence negatively influence project cost/benefits.</u>*

<u>Structure of the Questionnaire:</u>

The questionnaire is divided into three (3) sections. **<u>Section A</u>** solicits background information on respondent and the organization (*All fields are not mandatory*). **<u>Section B</u>** identifies several PPP specific risks in an attempt to analyze risks by determining their probability and severity. **<u>Section C</u>** attempts to understand the significance of measures of ERM on PPP projects therefore, the respondents are requested to assess the importance of each factor towards the mentioned goal of ERM. All the answers are solicited on specified scales which will be used for various statistical analysis. The appendix to the questionnaire provides definitions of all the factors to ensure uniformity in understanding and interpretation of the factor meanings among the respondents, when answering the questionnaire.

<u>Section A: General Background Information on the Respondent Expert</u>

1. Name of the respondent: ____
2. Name of the organization (Mandatory): ____
3. Email address for correspondence (Mandatory): ____
4. Contact number (Office/Mobile phone): ____
5. Which sector(s) best applies to your current role/occupation:

   - Public sector [ ]
   - Private sector: Project company [ ]; Consultant [ ]; Contractor [ ]; Operator [ ]; Investor [ ]; Financial institution [ ]; Other (Please specify:_________)
   - Academic sector [ ]
6. PPP specific experience in the industry/research (Number of years – Number of projects): ______-_______
7. Name of the most recent PPP project you have worked on: _______________________
8. Area/Sector of expertise: Power [ ]; Water supply and sanitation [ ];
   Transportation (Highway/Tunnel/Bridge; Rail; Ports/Harbors; Airports): [ ]
   Other (Please specify: _________)
9. Current designation in your organization: ______________________
10. Type of most recent PPP project that you have been involved in: Concession (BOT, BOO, BOOT etc.) [ ]; Management contract [ ]; Other (Please specify: ____________)

Section B: Risk Assessment for PPP projects

Based on your general working experience/knowledge, please evaluate the significance of each risk factor provided below, in terms of the **probability (*likelihood*) of occurrence** and **severity (*impact on objectives*)** of risk on the following scale: Extremely Low **(EL)**; Very Low **(VL)**; Low **(L)**; Moderate **(M)**; High **(H)**; Very High **(VH)**; Extremely High **(EH)**.

ID	Risk factor	Probability of occurrence	Severity of risk
1	Government intervention	EL VL L M H VH EH	EL VL L M H VH EH
2	Quasi-commercial risk	EL VL L M H VH EH	EL VL L M H VH EH
3	Poor public decision-making process	EL VL L M H VH EH	EL VL L M H VH EH
4	Expropriation/nationalization of assets	EL VL L M H VH EH	EL VL L M H VH EH
5	Inflation	EL VL L M H VH EH	EL VL L M H VH EH
6	Interest rate fluctuation	EL VL L M H VH EH	EL VL L M H VH EH
7	Variation in foreign exchange rate and convertibility issues	EL VL L M H VH EH	EL VL L M H VH EH
8	Financing risk	EL VL L M H VH EH	EL VL L M H VH EH
9	Delay in financial closure	EL VL L M H VH EH	EL VL L M H VH EH
10	Insurance risk	EL VL L M H VH EH	EL VL L M H VH EH
11	Change in law/regulation	EL VL L M H VH EH	EL VL L M H VH EH
12	Conflicting or imperfect contract	EL VL L M H VH EH	EL VL L M H VH EH
13	Imperfect law and supervision system	EL VL L M H VH EH	EL VL L M H VH EH
14	Competition risk	EL VL L M H VH EH	EL VL L M H VH EH
15	Change in market demand	EL VL L M H VH EH	EL VL L M H VH EH
16	Pricing and Toll/Tariff review uncertainty	EL VL L M H VH EH	EL VL L M H VH EH
17	Unfavorable national/international economy	EL VL L M H VH EH	EL VL L M H VH EH
18	Payment risk	EL VL L M H VH EH	EL VL L M H VH EH
19	Public opposition	EL VL L M H VH EH	EL VL L M H VH EH
20	Availability/performance risk	EL VL L M H VH EH	EL VL L M H VH EH
21	Residual asset value on transfer to the government	EL VL L M H VH EH	EL VL L M H VH EH
22	Technology risk	EL VL L M H VH EH	EL VL L M H VH EH
23	Operation cost overrun	EL VL L M H VH EH	EL VL L M H VH EH
24	Archaeological discovery/Cultural heritage	EL VL L M H VH EH	EL VL L M H VH EH

ID	Risk factor	Probability of occurrence	Severity of risk
25	Inability of debt service	EL VL L M H VH EH	EL VL L M H VH EH
26	Environmental damage risk	EL VL L M H VH EH	EL VL L M H VH EH
27	Land acquisition	EL VL L M H VH EH	EL VL L M H VH EH
28	Construction risks	EL VL L M H VH EH	EL VL L M H VH EH
29	Material/labor shortage or non-availability	EL VL L M H VH EH	EL VL L M H VH EH
30	Delay in project approvals and permits	EL VL L M H VH EH	EL VL L M H VH EH
31	Design/Construction/Operation changes	EL VL L M H VH EH	EL VL L M H VH EH
32	Unforeseen weather/geotechnical conditions	EL VL L M H VH EH	EL VL L M H VH EH
33	Lack of supporting infrastructure/utilities	EL VL L M H VH EH	EL VL L M H VH EH
34	Organization and coordination risk	EL VL L M H VH EH	EL VL L M H VH EH
35	Force majeure	EL VL L M H VH EH	EL VL L M H VH EH
36	Procurement risk	EL VL L M H VH EH	EL VL L M H VH EH
37	Development risk	EL VL L M H VH EH	EL VL L M H VH EH
38	Corruption	EL VL L M H VH EH	EL VL L M H VH EH
39	Latent defect risk	EL VL L M H VH EH	EL VL L M H VH EH
40	Planning risk	EL VL L M H VH EH	EL VL L M H VH EH
41	Change in government and political opposition	EL VL L M H VH EH	EL VL L M H VH EH
42	Political violence/government instability	EL VL L M H VH EH	EL VL L M H VH EH
43	Lack of skilled experts	EL VL L M H VH EH	EL VL L M H VH EH
44	Supply, input or resource risk	EL VL L M H VH EH	EL VL L M H VH EH
45	Design and construction deficiencies	EL VL L M H VH EH	EL VL L M H VH EH
	Others (if any):		

Note: Factors have been developed based on a review of multiple sources from academic and institutional literature as well as expert interviews.

Section C: Measures of Effective Risk Management for PPP projects

Based on your experience/knowledge, please indicate the importance of the factors given below in ensuring ***effective risk management*** on PPP projects on the following scale: **1 = Not Important (NI); 2 = Very Low Importance (VLI); 3 = Low Importance (LI); 4 = Moderate (M); 5 = Important (I); 6 = Very Important (VI); 7 = Extremely Important (EI).** ERM as considered in this research (Chapman and Ward 2003) involves "*… doing the right things with respect to the risk management process (RMP) so that the project is risk efficient in the corporate sense and all other project objectives are achieved*." Here, as per guidelines of the Project Management Institute (2009, 2013), RMP refers to the component processes of: risk management planning; risk identification; risk analysis; risk response planning; and risk control.

ID	Measures of Effective Risk Management	Level of importance
1	Identification of projects' and key stakeholders' objectives and requirements	① ② ③ ④ ⑤ ⑥ ⑦
2	A well-established project management scheme	① ② ③ ④ ⑤ ⑥ ⑦
3	Comprehensive project risk management plan	① ② ③ ④ ⑤ ⑥ ⑦
4	Comprehensive lifecycle based risk identification and assessment	① ② ③ ④ ⑤ ⑥ ⑦
5	Explicit risks allocation in the contract	① ② ③ ④ ⑤ ⑥ ⑦
6	Efficient contract negotiations	① ② ③ ④ ⑤ ⑥ ⑦
7	Adequate administration/management of the contract between the public and private sectors (concession agreement)	① ② ③ ④ ⑤ ⑥ ⑦
8	Quality of project's pre-feasibility/feasibility study	① ② ③ ④ ⑤ ⑥ ⑦
9	Quality of project's financial model	① ② ③ ④ ⑤ ⑥ ⑦
10	Risk communication and reporting	① ② ③ ④ ⑤ ⑥ ⑦
11	Collaborative risk management	① ② ③ ④ ⑤ ⑥ ⑦
12	Risk management maturity of project stakeholders	① ② ③ ④ ⑤ ⑥ ⑦
13	Third-party review	① ② ③ ④ ⑤ ⑥ ⑦
14	Experience, skills and maturity of financial institutions (debt/equity providers, insurance companies)	① ② ③ ④ ⑤ ⑥ ⑦
15	Availability of reliable risk mitigation tools/instruments (guarantees, insurances, hedges/swaps, etc.)	① ② ③ ④ ⑤ ⑥ ⑦
16	Experience of the public sector in managing PPP projects	① ② ③ ④ ⑤ ⑥ ⑦
17	Experience of the private partner in conducting similar projects	① ② ③ ④ ⑤ ⑥ ⑦
18	Risk management personnel training and development	① ② ③ ④ ⑤ ⑥ ⑦
19	Application of appropriate risk analysis tools and techniques (RATT's)	① ② ③ ④ ⑤ ⑥ ⑦
20	Availability of historical data on previous projects	① ② ③ ④ ⑤ ⑥ ⑦
21	Consideration of interrelation between risks	① ② ③ ④ ⑤ ⑥ ⑦
22	Flexible and collaboration supportive contract	① ② ③ ④ ⑤ ⑥ ⑦
23	Effectiveness of dispute resolution	① ② ③ ④ ⑤ ⑥ ⑦
24	Increased confidence, trust, and cooperation among parties	① ② ③ ④ ⑤ ⑥ ⑦
25	Availability of reliable specialist consultants/external advisors	① ② ③ ④ ⑤ ⑥ ⑦
26	Careful bid evaluation by the public sector	① ② ③ ④ ⑤ ⑥ ⑦
27	Explicit risk pricing in the bid	① ② ③ ④ ⑤ ⑥ ⑦

ID	Measures of Effective Risk Management	Level of importance
28	Retaining the contract negotiation team for contract administration	① ② ③ ④ ⑤ ⑥ ⑦
29	Learning from risks (*knowledge management*)	① ② ③ ④ ⑤ ⑥ ⑦
30	Stakeholder's risk management commitment	① ② ③ ④ ⑤ ⑥ ⑦
	Others (if any):	

Note: Measures have been developed based on a review of multiple sources from academic and institutional literature as well as expert interviews.

The End. Thank you for your participation.

Note: *Please contact the author should you require information on the source or references of the content provided above.*

Appendix

Risk factors and their description:

ID	Risk factor	Description
1	Government intervention	Negative influence on the autonomy of the regulator or private sector operations due to direct and unreasonable intervention by the government officials in the activities of the regulator or the project operators.
2	Quasi-commercial risk	Risk of decentralized governments/public authority not fulfilling their contractual obligations as suppliers or purchasers of the privatized service, due to willingness and/or capacity issues.
3	Poor public decision-making process	Inexperienced public sector agencies/officials, lack of standard procedures, insufficient project preparation, information asymmetry, bureaucracy, poor inter-departmental relationships and self-interests amounting to poor decision making.
4	Expropriation/nationalization of assets	Government takes over the project or facility due to political, social, or economic reasons, without giving the private sector a reasonable compensation.
5	Inflation	Poor local economic conditions and other factors leading to inflation thus impacting project costs and revenues.
6	Interest rate fluctuation	Poor local economic conditions and other factors leading to variation in interest rates thus resulting in additional financing costs.
7	Variation in foreign exchange rate and convertibility issues	Risk of exchange rate fluctuation and/or convertibility issues.
8	Financing risk	Risks related to poor financial market, unavailability of finance or irrational financing structure of the project.
9	Delay in financial closure	Delay in negotiations to achieve financial close and the consequent start of the project.
10	Insurance risk	Possibility of substantial increase in insurance premium and/or changes in the availability of certain insurance over time.
11	Change in law/regulation	Changes in legislation/regulation (environmental, tax laws, tariff setting/approval etc.) and policies thus impacting project costs/revenues.
12	Conflicting or imperfect contract	Contractual risk arising as a result of inequitable risk sharing, inaccurate, vague, incomplete, or inconsistent contract language etc.
13	Imperfect law and supervision system	Lack of supporting legal and regulatory frameworks to enable smooth implementation and effective regulation of PPP projects.
14	Competition risk	Competition impacting revenues that results from a new project or an existing project in the same business region.
15	Change in market demand	Factors other than competition such as changes in laws, population, macroeconomics, and social factors leading to a change in demand.
16	Pricing and Toll/Tariff review uncertainty	Inadequate pricing (too high/low) or uncertainty in adjustment of toll/tariff due to inflexible framework, delays, or restrictions thus impacting revenues.
17	Unfavorable national/international economy	Unfavorable local/global economic conditions leading to problems of public sector's ability to meet its obligations, financing issues and/or the change in service demand, among other possible outcomes.
18	Payment risk	Problems in payment (toll/tariff) for services to the project company, by the government or the consumer, due to social or other issues.
19	Public opposition	Risks to project construction/operation resulting from lack of protection of or damage to public interests which may lead to public/political opposition.

ID	Risk factor	Description
20	Availability/performance risk	Inability of the project company to make services available or satisfy the performance criteria/service standards (quantity/quality) in service delivery/asset operation, according to the client's output specifications.
21	Residual asset value on transfer to the government	Uncertainty related to the condition of the asset on transfer, at the end of the concession period, with respect to its continued functionality and usability.
22	Technology risk	Risk related to immature or low applicability technology which is unable to deliver service requirements.
23	Operation cost overrun	Increase in operational costs due to errors in estimates, loss in operational efficiency, higher than expected maintenance, or other reasons.
24	Archaeological discovery/Cultural heritage	Delays or extra costs that occur as a result of archaeological or cultural heritage discoveries on the project site.
25	Inability of debt service	Financial crisis that result in constraining the project company's ability to satisfy its debt service obligations in time.
26	Environmental damage risk	Risk of damage to the environment caused as a result of project construction/operation activities.
27	Land acquisition	Land acquisition cost and/or required time are more than what was budgeted and its consequential impact on the project's cost and schedule.
28	Construction risks	Risk of not achieving the budgeted standards for construction cost and time.
29	Material/labor shortage or non-availability	Loss resulting from delay in supply of key project resources either due to unavailability or failure of the subcontractors or suppliers to oblige their agreements.
30	Delay in project approvals and permits	Delays in obtaining requisite approvals/permits from the relevant government authorities/departments. This also includes refusal to provide permit or cancellation of previously provided permits.
31	Design/Construction/Operation changes	Statutory/policy changes affecting project design and/or owner's variation leading to construction and/or operation changes. Changes to the means by which the output specifications are achieved. It may be initiated due to improper design or poor investigation.
32	Unforeseen weather/geotechnical conditions	Unexpected weather and/or geotechnical conditions.
33	Lack of supporting infrastructure/utilities	Availability and reliability of necessary infrastructure/utilities such as electricity, water, gas, road/rail transport network, distribution networks etc., timely and at a fair cost, to support project construction and operations.
34	Organization and coordination risk	Delays, increased transaction costs and/or conflicts due to improper coordination and poor communication at inter- and intra-organizational levels.
35	Force majeure	Natural and man-made events that cannot be influenced by any party such as worker strikes, war, riots, natural calamities, fire, embargo etc.
36	Procurement risk	Issues such as lack of competition, lowest bid exceeding affordability limits, procurement award successfully challenged, or non-responsive or low quality bids that may be attributed to unclear bidding requirements, excessive financial commitment requirements, fear of protection of design and proprietary information, bidding transparency concerns, etc.
37	Development risk	Loss of project development costs and efforts due to change of central/local government policies related to PPP project procurement.
38	Corruption	Bribes or unjust rewards demanded/offered between public and private sector officials either for winning PPP contracts or inter-party

ID	Risk factor	Description
		relationship management. This may become costly and it also instills a fear of contract termination.
39	Latent defect risk	Possibility of loss or damage arising from latent defects in the facilities included in the project (*brownfield projects*).
40	Planning risk	Refers to the risk that the pre-development studies (technical, legal, financial and others) conducted are inadequate or not robust enough resulting in potential variations in outcomes from that which were planned or expected in the PPP project development.
41	Change in government and political opposition	Risk that succeeding government(s) oppose and/or abandon PPP scheme(s), resists honoring contractual commitments, or puts previous projects under review with the intent to renegotiate original agreements.
42	Political violence/government instability	This includes frequent changes in government, acts of civil strife, declared war, terrorism, insurrection, public disturbances, sabotage, and revolution; potentially impacting project implementation and revenues/profitability of PPP projects.
43	Lack of skilled experts	Lack of skilled experts in technical, legal, financial and other relevant domains leading to a risk of poor project analysis, decision making and/or project management.
44	Supply, input or resource risk	Deficient quality of project inputs (water/energy) and/or delays or failure in supplying the inputs that disrupts project operations.
45	Design and construction deficiencies	The designed/constructed facility fails to satisfy required specifications, resulting in construction problems and/or poor service delivery.

Measures of Effective Risk Management and their description:

ID	Measures of Effective Risk Management	Description
1	Identification of project's and key stakeholders' objectives and requirements	The client, private consortium, lenders, and debt providers have specific needs/requirements that form the objectives of their involvement in the business venture. The general public has legitimate needs/requirements as it indirectly funds the project and is influenced by it. Lack of identification of these objectives/requirements and that of the project may lead to poor risk identification and management.
2	A well-established project management scheme	Application of best practice project management principles to assist risk management efforts on PPP projects.
3	Comprehensive project risk management plan	Project risk management plan that specifies identified risks, their allocation, planned risk response strategies and the risks monitoring scheme.
4	Comprehensive lifecycle based risk identification and assessment	Lifecycle based identification of risks to ensure that all possible uncertainties are accounted and mitigated.
5	Explicit risks allocation in the contract	Use of contractual terms and conditions to expressly allocate risks and responsibility to the public and the private sector stakeholders.
6	Efficient contract negotiations	The spirit and structure of negotiations encouraging communication, information exchange and positive development of perspectives thus leading to an efficient and justifiable allocation of risks to the contractual parties.
7	Adequate administration/management of the contract between the public and private sectors (concession agreement)	The enforcement of contractual terms and conditions to: ensure fulfillment of obligations by the partners; manage relationship; monitor performance; and maintain the integrity of the contract. This also includes regular monitoring of project's risk profile to identify and manage new risks and executing the risk response actions to negate or minimize the potential

ID	Measures of Effective Risk Management	Description
8		consequences of retained and allocated risks within the contractual framework.
8	Quality of project’s pre-feasibility/feasibility study	Reliability and comprehensiveness of the feasibility study in identifying and evaluating risks of procuring through the PPP channel and to evaluate the bids and project risk allocation to assess potential for Value for Money (VfM).
9	Quality of project's financial model	Reliability and comprehensiveness of the project's financial model in simulating future cash flows and risks for assistance in making important decisions by the stakeholders such as the decision to bid, negotiations, project funding, and project monitoring etc.
10	Risk communication and reporting	Exchange of information (feedback and interaction) between project team members and the stakeholders to ensure risk accountability, better understanding of risks and requirements of other stakeholders and that of the project and to monitor and report projects performance.
11	Collaborative risk management	Joint effort of project stakeholders to identify and assess risks, prepare risk response strategies in consultation with each other for complex project risks, and to jointly manage unforeseen/new project risks ex-post.
12	Risk management maturity of project stakeholders	Risk management maturity of an organization measured as managerial capacity in relation to risk, organizational risk culture, ability to identify and analyze risks and standardized risk management processes.
13	Third-party review	Use of external consultants to conduct due diligence before financial close including review of legal, technical, and financial aspects of the project and the financial model; independent gateway reviews by public sector organizations over the lifecycle of the PPP project to ensure transparency, effective execution of risk allocation and risk management in conducting PPP transactions, in addition to other comprehensive audit criteria.
14	Experience, skills and maturity of financial institutions (debt/equity providers, insurance companies)	The ability and skills of the financial institutions to advise the public and private sector clients and to monitor risks on PPP projects where they become a party to the contract.
15	Availability of reliable risk mitigation tools/instruments (guarantees, insurances, hedges/swaps, etc.)	Availability and reliability of insurance, guarantees, hedging or other financial products and other forms of support to the public and private sector stakeholders to better manage risks.
16	Experience of the public sector in managing PPP projects	Past experience of the public sector agencies in developing, managing, and delivering PPP projects.
17	Experience of the private partner in conducting similar projects	Past experience of the project company's management in delivering similar PPP projects and knowledge of geography, local codes, business practices, and other cultural and operational issues relevant to the host region/country.
18	Risk management personnel training and development	Formal education and training of risk management personnel to equip them with enhanced skills for risk assessment and management.
19	Application of appropriate risk analysis tools and techniques (RATT's)	Appropriate use of quantitative/qualitative risk analysis techniques and the methods to quantify risks in consideration of the objectives of risk assessment and amount and quality of the information available.
20	Availability of historical data on previous projects	Cost and risk data on previously completed/similar PPP projects to aid in risk assessment and response planning of future project(s).

ID	Measures of Effective Risk Management	Description
21	Consideration of interrelation between risks	Incorporation of potential interrelationships between risks to analyze/assess risks holistically in terms of their influence on each other, where applicable.
22	Flexible and collaboration supportive contract	Contracts with built-in mechanisms to accommodate adjustments for events such as variations, changes in law, market demand or other factors without requiring any or substantial renegotiation. This may include effective design of concession terms (toll/tariff and concession duration) and pre-specification of explicit events/situations and methods to trigger and manage re-negotiations, respectively.
23	Effectiveness of dispute resolution	A mature legal, regulatory and policy framework for PPPs in combination with specification of effective dispute resolution mechanisms in the contract to provide certainty to how potential future conflicts will be handled. Speedy and efficient solutions to potential conflicts are desirable to provide immediate or interim relief.
24	Increased confidence, trust, and cooperation among parties	Promotion of confidence building and trust among partners to enhance inter-party relationships and to avoid opportunism and conflicts.
25	Availability of reliable specialist consultants/external advisors	Use of expert services provided by third party consultants for assistance in preparation of feasibility studies, drafting contracts, conducting negotiations, and other functions for which in-house skills are not available.
26	Careful bid evaluation by the public sector	Evaluation of the bidding consortia and the individual proposals submitted to ensure technical and financial capability of the consortium and its members and to establish adequacy of the proposal.
27	Explicit risk pricing in the bid	Separate contractor pricing of risks in project bids to assist efficient and quick proposed risk allocation strategy analysis by the public sector agencies.
28	Retaining the contract negotiation team for contract administration	To ensure that the contract administration team has the knowledge of details of contract negotiations to enable efficient contract management.
29	Learning from risks	Knowledge driven risk management process and focus on lessons learned to enable the development of corporate risk memory, embodying information on effectiveness of response strategies and factors that affect the risk consequences.
30	Stakeholder's risk management commitment	Partner's willingness/commitment to manage risks; measured as risk attitude (neutral, seeking or averse), perceived own capability to manage risk, and perceived reward for handling the risk.

APPENDIX C – INVESTIGATOR ADMINISTERED RISK ALLOCATION AND SHARING CASE STUDY SURVEY QUESTIONNAIRE

<u>Study title</u>: *Risk assessment and allocation model for Public-Private Partnership (PPP) Infrastructure Projects in Pakistan*

Project Risk Allocation based on Assessment of Risk Management Capability

Introduction

One of the objectives of this PhD research is to develop a model to assist practitioners in efficiently allocating and sharing risks on PPP projects. Published literature in the domain of infrastructure PPPs suggests that risks should be allocated to the party (public/private) that has the ability to manage the assigned risks most efficiently (or at lowest cost). In order to meet this objective, case-studies will be conducted and based on discussions with public and private sector experts in the PPP *XXX* infrastructure sector in Pakistan, it was decided to select Project *A/B* for the stated purpose. The questionnaire attempts to solicit information on:

a) actual allocation of risks (as per contract) for the identified key risks given below,
b) importance and interactions of various aspects/criteria that determine risk management capability, and
c) risk management capability of the project stakeholders against key risks, based on the perceptions and determination of the experts.

Structure of the Questionnaire:

This questionnaire is divided into three (3) sections. **<u>Section A</u>** solicits background information on respondent, organization and the project. **<u>Section B</u>** inquiries about information on actual allocation of project risks which have been identified as the most dynamic risks from allocation and sharing perspective and are addressed in the project contracts. **<u>Section C</u>** asks the respondents to rank the importance of risk allocation criteria, provide information on potential importance and interactions of pairs of criteria, and other information on decision preferences. **<u>Section D</u>** is designed to evaluate the risk management capability (RMC) of the parties by asking the respondents to evaluate the RMC for each critical risk against the risk allocation criteria (RAC). All the answers are solicited on a scale of linguistic terms which will be used for fuzzy analysis and modeling.

Section A: General Background Information (*Mandatory)

1. Name of the respondent: ____
2. Name of the Organization: ____
3. Name of the PPP project*:____
4. Email address for correspondence*: ______________________________________
5. Contact number (Office/Mobile phone): ___________________________________
6. PPP specific experience in the industry/research (Number of years – Number of projects)*: _____-_____
7. Current designation in your organization*:________________________________

Section B: Allocation of Project Risks

Based on your project's contractual knowledge and experience, please indicate the allocation and sharing of given key risks on the following scale: **1 = public sector takes sole responsibility; 2 = public sector takes major responsibility; 3 = both parties take equal responsibility; 4 = private sector takes major responsibility; 5 = private sector takes sole responsibility**. For risks that do not apply to the case-study project, please indicate as NOT APPLICABLE. Other significant risks may be added based on respondent's experience (if necessary).

Sr. No.	Risk factor	Risk allocation
1	Inflation	① ② ③ ④ ⑤
2	Variation in foreign exchange rate and convertibility issues	① ② ③ ④ ⑤
3	Interest rate fluctuation	① ② ③ ④ ⑤
4	Land acquisition	① ② ③ ④ ⑤
5	Public opposition	① ② ③ ④ ⑤
6	Change in law/regulation	① ② ③ ④ ⑤
7	Change in market demand	① ② ③ ④ ⑤
8	Supply, input or resource risk	① ② ③ ④ ⑤
9	Delay in project approvals and permit	① ② ③ ④ ⑤
10	Insurance risk	① ② ③ ④ ⑤
11	Unforeseen geotechnical conditions	① ② ③ ④ ⑤
12	Financing risk	① ② ③ ④ ⑤
13	Payment risk	① ② ③ ④ ⑤
14	Latent defect risk	① ② ③ ④ ⑤
15	Residual asset value on transfer to the government	① ② ③ ④ ⑤
16	Competition risk	① ② ③ ④ ⑤
17	Design/construction/operation changes	
18	**Others**	
19		
20		
21		
22		

Section C: Risk Allocation Criteria for Efficient Risk Allocation

Risks should be allocated to the party that has the best capability to manage the assigned risks. The table below provides multiple dimensions that determine the risk management capability of a party (public/private). Based on your experience, please rate the importance of risk allocation criteria on the following scale: **Very Low Importance (VLI); Low Importance (LI); Moderate (M); Important (I); Very Important (VI)**.

Sr. No.	Risk Allocation Criteria	Importance of the Criteria
1	Be able to foresee (predict) the chance/probability of risk occurrence and assess potential risk consequence/severity	**VLI LI M I VI**
2	Be able to avoid, minimize, monitor and control the chance/probability of risk occurrence	**VLI LI M I VI**
3	Be able to minimize or control the loss if the risk occurs	**VLI LI M I VI**
4	Be able to sustain, diversify or absorb the consequences of the risk that materializes	**VLI LI M I VI**
5	Be able to bear the risk at the lowest cost	**VLI LI M I VI**
6	Be able to assume and manage the direct loss in case of risk occurrence	**VLI LI M I VI**
7	Be able to get reasonable and acceptable premium for assuming the risk	**VLI LI M I VI**
8	Benefit from enhanced risk undertaker's credibility, reputation and efficiency in risk management	**VLI LI M I VI**
9	The risk-taking party prefers to assume the risk (Risk attitude)	**VLI LI M I VI**

Source: Xu et al. 2010

Using the serial number of the RAC indicated in the table above, please provide information on potential interactions among pairs of criteria (pairs of 2), preferences on ranking of interactions and any quantitative information on these aspects (if applicable)?

Interactions pairs of criteria e.g., C2-C3 (Complementary/Substitutive), etc. (if any)	**Rankings of interaction indices** e.g., I(C2,C3) > I(C8,C9), etc. (if any)	**Quantitative information on RAC importance and interaction** (if any)

Section D: Risk Management Capability (RMC) Rating

Based on your experience, please indicate the ability of your organization by expressing the strength of agreement with each risk allocation criteria for each risk on the following scale: **Very Low (VL); Low (L); Moderate (M); High (H); Very High (VH)**

Sr. No.	Risk Allocation Criteria	Inflation	Variation in foreign exchange rate and convertibility issues	Interest rate fluctuation	Land acquisition	Public opposition	Change in law/regulation	Change in market demand	Supply, input or resource risk	Delay in project approvals and permits	Insurance risk	Unforeseen weather/geotechnical conditions	Financing risk	Payment risk	Latent defect risk	Residual value risk	Competition risk	Design/construction/operation changes						
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
1	Be able to foresee (predict) the chance/probability of risk occurrence and assess potential risk consequence/severity																							
2	Be able to avoid, minimize, monitor and control the chance/probability of risk occurrence																							
3	Be able to minimize or control the loss if the risk occurs																							
4	Be able to sustain, diversify or absorb the consequences of the risk that materializes																							
5	Be able to bear the risk at the lowest cost																							
6	Be able to assume and manage the direct loss in case of risk occurrence																							
7	Be able to get reasonable and acceptable premium for assuming the risk																							
8	Benefit from enhanced risk undertaker's credibility, reputation and efficiency in risk management																							
9	The risk-taking party prefers to assume the risk (Risk attitude)																							

The End. Thank you for your participation.

Appendix

Risk factors and their descriptions (Refer to survey questionnaire – Appendix A)

APPENDIX D – VALIDATION SURVEY (MEASURES OF EFFECTIVE RISK MANAGEMENT)

Validation Survey

Measures of Effective Risk Management for PPP infrastructure projects

Dear Expert,

Introduction of private investment in public infrastructure development is gaining momentum in many developing countries, where public-private partnerships are being sought as a preferred alternative to traditional public infrastructure procurement. Given the complexity of such long-term relationships, multiple sources in the existing literature point out to *inadequate risk management efforts* on such projects, leading to stressed, or worse, failed PPP initiatives. Looking primarily from the perspective of grantors (public authorities), sponsors/investors (consortiums and equity investors) and lenders (debt financiers), inadequate risk management efforts can directly influence each primary stakeholder and potentially amount to problems in satisfying budgeted indicators of, for instance, value for money, rate of return, and debt cover ratio's, etc.

A research effort was launched at The Hong Kong Polytechnic University to identify significant factors, that may influence risk management effectiveness on PPP projects (henceforth, the measures of effective risk management (ERM)), and enable the stakeholders to identify, analyze, plan for risk responses, and monitor and control risks, adequately. In total 30 measures were identified from an extensive literature review and thereafter validated by experts from Pakistan, Hong Kong and Australia. A survey was launched to obtain the perceptions of the stakeholders (grantors, sponsors, investors, lenders, and transaction advisors) to determine the importance and ranking of measures, in being able to promote effective risk management on PPP projects. The 30 measures were initially identified from a review of extant literature, verified via reviews by experts in all the three countries and then a survey was conducted in Pakistan.

A list of the measures of ERM has been attached along with the established importance and ranking of each measure. Some conclusions drawn from the survey have also been provided for your consideration. You, as a PPP expert, are requested to comment on rankings obtained for the principal dimensions/groups (shown below) and the conclusions derived from the research. You may accept, reject, modify and/or comment on the importance, rankings and conclusions, based on your experience. Your input is being solicited to perform a post-assessment validation of the research findings and conclusions. This will greatly help by enhancing confidence in the research outcomes. Overall, the research is expected to complement the existing risk management body of knowledge. Additionally, it aims to assist the stakeholders in enhancing risk management outcomes on PPP projects, by inviting their attention to the identified measures of ERM.

Should you have any queries, please do not hesitate to contact Khawaja Mateen Mazher (primary researcher – *mateen.mazher@ XXXXXXXXX/ Mobile: XXXXXXXXX*).

All responses to this survey will be treated in strict confidence and utilized solely for academic purposes.

I shall be grateful if you can provide your response via email by *DD* **of** *MM* **2018**.

Thanking you in anticipation.

Yours truly,

Khwaja Mateen Mazher
PhD Candidate

Basic information

Your designation:-

Organization name (***optional***):-

Organization type (public authority/project sponsor/bank/investor/consultant or advisor etc.):-

Working experience in construction sector (Years):-

Working experience on PPP projects (Years – Number of projects):- XX - YY

Measures of ERM

The table below enlists the measures of effective risk management with *importance index* and *rankings*, as established by the questionnaire survey. The respondents to the survey rated the measures of ERM on a 7 point Likert type scale (of 1 to 7) with 1 being "not important" and 7 being "E\extremely important", that indicated their importance towards ensuring ERM on PPP projects. The research analysis includes ***factor analysis*** (a statistical method) that allows for grouping of correlated variables, which resulted in six principal factors/dimensions of ERM. This is helpful in a way that it provides a lesser number of dimensions (six in this case) to understand the ***main/underlying issues***, rather than focusing on 30 individual factors. Interpretation of the dimensions/groups is based on judgements of the researchers. ***You are requested to comment based on the ranking and appropriateness of labeling of the six principal dimensions/groups, extracted from the analysis, with a view of enhancing risk management effectiveness on PPP projects***. Additional space for comments is also provided at the end of the table, in case you wish to comment on individual factors, conclusions or any other aspect based on your general experience. Furthermore, a table containing the definition of each measure of ERM has also been appended (at the end) to facilitate a unified and consistent understanding of the identified measures.

Well Documented Structured Management Approach (Mean: 5.998 - Rank: 1)

This factor group accommodates four factors that include 'a well-established project management scheme', 'adequate administration/management of the contract between the public and private sectors (concession agreement)', 'comprehensive project risk management plan' and 'efficient contract negotiations'. Risk management does not function alone as a separate process rather, it is one of the several project management processes in operation on any project, that interact with each other. Additionally, since the contract document provides the protocol for responsibility and risk sharing between the partners, sufficient execution of these protocols is essential to ERM from the perspective of both public and private sector partners.

Measures of ERM	Mean	Rank	Comments (if any)
Adequate administration/management of the contract between the public and private sectors (concession agreement)	6.07	2	
Comprehensive project risk management plan	6.04	3	
Efficient contract negotiations	6.01	6	
A well-established project management scheme	5.87	8	

Comprehensive Requirements and Risks Evaluation (Mean: 5.918 - Rank: 2)

This factor group is comprised of four factors which are ‘careful bid evaluation by the public sector’, ‘quality of project's financial model’, ‘identification of project’s and key stakeholders’ objectives and requirements’, and ‘risk management maturity of project stakeholders’. ERM demands that the needs and requirements of the project and its stakeholders are identified early in order to plan for their optimum fulfillment while identifying and countering any potential variations in project parameters that lead to a departure from the planned outcomes. Organizations with high level of risk management maturity can be in a better position to identify and assess the requirements and their associated risks effectively owing to existence of risk management culture and a mature framework of policies and processes in place. The bids evaluation phase also provides an important opportunity to assess risks posed to the project in terms of assumptions made by each bidder and thereby a proper evaluation at this stage may help in ensuring high value for money (VfM) contracts by selecting suitable project sponsors. For PPP projects, an important tool in analyzing the impact of risks on stakeholder objectives is the project’s financial model, therefore a comprehensive and reliable model can go a long way in assisting risk evaluations throughout the project life-cycle.

Measures of ERM	Mean	Rank	Comments (if any)
Quality of project's financial model	6.18	1	
Identification of project’s and key stakeholders’ objectives and requirements	6.04	4	
Careful bid evaluation by the public sector	6.02	5	
Risk management maturity of project stakeholders	5.43	19	

Post-Contract Risk Management (Mean: 5.464 - Rank: 3)

This factor group is composed of five factors. ‘flexible and collaboration supportive contract’, ‘effectiveness of dispute resolution’, ‘increased confidence, trust, and cooperation among parties’, ‘availability of reliable risk mitigation tools/instruments (guarantees, insurances, hedges/swaps, etc.)’ and ‘collaborative risk management’. Since the contractual relationship between the public and the private sectors is managed over a long period of time, risk management at the post-contract stage is absolutely critical for all the stakeholders. Contracts that define this relationship need to cater for possibility of changes and specify how to handle those events without breaking down the relationships. Collaboration in risk management and inter-party trust and cooperation are essential to manage any differences, that may arise, amicably. For some risks, mitigation might be possible by transferring them to other parties via insurance, derivatives and government guarantees, if available. In case of failure to settle any potential differences that might arise, effective dispute management protocols need to be in place to provide a timely relief to the parties.

Measures of ERM	Mean	Rank	Comments (if any)
Effectiveness of dispute resolution	5.74	11	
Increased confidence, trust, and cooperation among parties	5.72	13	
Availability of reliable of risk mitigation tools/instruments (guarantees, insurances, hedges/swaps, etc.)	5.56	16	
Collaborative risk management	5.43	20	
Flexible and collaboration supportive contract	4.87	30	

Knowledge Driven Risk Management (Mean: 5.435 - Rank: 4)

This factor group consists of four factors including ‘retaining the contract negotiation team for contract administration’, ‘stakeholders’ risk management commitment’, ‘learning from risks’, and ‘availability of reliable specialist consultants/external advisors’. Knowledge on various aspects of risk management is the key to achieve effective outcomes. Risk management knowledge may be either tacit or explicit in nature and it may be leveraged from different sources. From an organizational perspective, retaining key individuals that are involved in project procurement phase, for project implementation may be important when focusing on the tacit knowledge aspect of the project. From a long-term and explicit knowledge perspective, organizations must enable systematic learning from projects, to capture and learn from experiences and become effective for future actions on projects. A more superior source of knowledge that may be leveraged for ERM is by hiring reliable external consultants/advisors for the project. Additionally, continued commitment by all the stakeholders to diligently exert energies on risk management function, throughout the life-cycle of the project, is essential.

Measures of ERM	Mean	Rank	Comments (if any)
Availability of reliable specialist consultants/external advisors	5.70	14	
Learning from risks	5.50	17	
Stakeholder's risk management commitment	5.30	23	
Retaining the contract negotiation team for contract administration	5.24	24	

Risk Assessment Quality (Mean: 5.304 - Rank: 5)

This factor group includes five factors, namely ‘risk management personnel training and development’, ‘availability of historical data on previous projects’, ‘risk communication and reporting’, ‘quality of project’s pre-feasibility/feasibility study’, and ‘application of appropriate risk analysis tools and techniques (RATT's)’. The quality of risk assessments will depend on the quality of the input data and information, nature of assumptions made in the analysis, the tools employed, and the availability of knowledge and skills to make best use of the available resources and methods. A focus on all these aspects is therefore extremely important to ensure ERM.

Measures of ERM	Mean	Rank	Comments (if any)
Quality of project’s pre-feasibility/feasibility study	5.83	9	
Risk communication and reporting	5.41	21	
Risk management personnel training and development	5.23	25	
Application of appropriate risk analysis tools and techniques (RATT's)	5.03	27	
Availability of historical data on previous projects	5.02	28	

Public Sector Risk Management (Mean: 5.26 - Rank: 6)

This factor group comprises of ‘Explicit risk pricing in the bid’, ‘experience of the public sector in managing PPP projects’, and ‘third-party review’. The primary responsibility of the government is to protect public interest and provide services to its people while ensuring that all of this is done with the best VfM. Achieving VfM is one of the main drivers for promoting public infrastructure development via PPPs. The three measures in this group correspond to enhancing public sector prospects of initially achieving and then maintaining the VfM throughout the project lifecycle. Since achieving and maintaining VfM is a stakeholder requirement, any variation in achieving or maintaining it may be out of failure of public executing entities to manage the underlying risks.

Measures of ERM	Mean	Rank	Comments (if any)
Explicit risk pricing in the bid	5.44	18	
Experience of the public sector in managing PPP projects	5.36	22	
Third-party review	4.98	29	

General comments (if any):

Appendix

Measures of ERM and their descriptions (Refer to survey questionnaire – Appendix A)

APPENDIX E – CASE BASED SURVEY FOR RISK ASSESSMENT MODEL

<u>Case Based Survey</u>

Risks Assessment Model for PPP Infrastructure Projects in Pakistan

Dear Expert,

Introduction of private investment in public infrastructure development is gaining momentum in many developing countries, where public-private partnerships are being sought as a preferred alternative to traditional public infrastructure procurement. Given the complexity of such long-term relationships, multiple sources in the existing literature point out to *inadequate risk management efforts* on such projects, leading to stressed, or worse, failed PPP initiatives. Looking primarily from the perspective of grantors (public authorities), sponsors/investors (consortiums and equity investors) and lenders (debt financiers), inadequate risk management efforts can directly influence each primary stakeholder and potentially amount to problems in satisfying budgeted indicators of, for instance, value for money, rate of return, and debt cover ratio's, etc.

A research effort was launched at The Hong Kong Polytechnic University to identify significant risk factors, that may influence primary stakeholders in achieving their objectives on PPP projects in Pakistan. Below, a list of **<u>22</u>** risk factors is presented which were determined to be the most critical in the Pakistani context. A **<u>model was developed to estimate the overall project risk index</u>** based on the inputs on project risks' probability and severity, as determined by the experts.

You, as a PPP practitioner and expert, are requested to select one project on which you possess working experience and provide your opinion on the magnitude of ***<u>probability</u>*** and ***<u>severity</u>*** for the risks provided below. This assessment should be based on your opinions and judgement on how these identified risks impact the success of the project. You are also requested to provide an overall assessment of project risk on a scale (as provide below). Your input will be fed in to the developed risk assessment model and project's overall risk index will be calculated. This will be compared with your overall assessment on the scale to determine the reliability of the model in evaluating overall project riskiness. Your input as an expert and a PPP practitioner will greatly help by enhancing confidence in the research outcomes.

Should you have any queries, please do not hesitate to contact Khwaja Mateen Mazher (primary researcher – *mateen.mazher@ XXXXXXXXX/ Mobile: XXXXXXXXX*).

All responses to this survey will be treated in strict confidence and utilized solely for academic purposes.

I would be grateful if you can provide your response by *DD* **of** *MM* **2018**.

Thanking you in anticipation.

Yours truly,

Khwaja Mateen Mazher
PhD Candidate

Background information

Your designation:-

Organization name (***optional***):-

Organization type (public authority/project sponsor/bank/investor/consultant or advisor etc.):-

Working experience in construction sector (Years):-

Working experience on PPP projects (Years – Number of projects):- XX - YY

Area/Sector of expertise: Power [ ]; Water supply and sanitation [ ]; Transportation (Highway/Tunnel/Bridge; Rail; Ports/Harbors; Airports) Other (Please specify: _________)

Project selected for risk analysis:- ____
Project name (***Optional***): ____
Project type: Power [ ]; Water supply and sanitation [ ]; Transportation: Highway [ ] / Tunnel [ ]/ Bridge [ ]; Rail [ ]; Ports/Harbors [ ]; Airports [ ];

Project's overall risk rating: Extremely Low (EL); Very Low (VL); Low (L); Moderate (M); High (H); Very High (VH); Extremely High (EH)

The following table enlists the most critical risk factors in the context of public-private infrastructure projects in Pakistan. Based on your experience and knowledge of the project selected above, *please evaluate/assess the* ***probability (likelihood) of occurrence and severity (impact on project objectives)*** *of the risk factors based on your believes of their influence on the project*. The assessment has to be made according to the following scale: **Extremely Low (EL); Very Low (VL); Low (L); Moderate (M); High (H); Very High (VH); Extremely High (EH)**.

ID	Risk factors	Risk assessment	
		Probability (P_r)	**Severity (S_r)**
1	Delay in financial closure	EL VL L M H VH EH	EL VL L M H VH EH
2	Land acquisition	EL VL L M H VH EH	EL VL L M H VH EH
3	Financing risk	EL VL L M H VH EH	EL VL L M H VH EH
4	Delay in obtaining project approvals/permits/consents	EL VL L M H VH EH	EL VL L M H VH EH
5	Poor public decision-making process	EL VL L M H VH EH	EL VL L M H VH EH
6	Construction risk	EL VL L M H VH EH	EL VL L M H VH EH
7	Government intervention	EL VL L M H VH EH	EL VL L M H VH EH
8	Procurement risk	EL VL L M H VH EH	EL VL L M H VH EH
9	Inability of debt service	EL VL L M H VH EH	EL VL L M H VH EH

ID	Risk factors	Risk assessment													
		Probability (P_r)							Severity (S_r)						
10	Inflation	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
11	Payment risk	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
12	Planning risk	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
13	Pricing and Toll/Tariff review uncertainty	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
14	Change in government and political opposition	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
15	Unfavorable national/international economy	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
16	Design and construction deficiencies	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
17	Availability/performance risk	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
18	Variation in foreign exchange rate and convertibility issues	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
19	Operation cost overrun	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
20	Political violence/government instability	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
21	Interest rate fluctuation	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH
22	Corruption	EL	VL	L	M	H	VH	EH	EL	VL	L	M	H	VH	EH

General comments (if any):

The end.

Thank you for your participation.

Appendix

Risk factors and their descriptions (Refer to survey questionnaire – Appendix A)

REFERENCES

Abdul-Aziz, A.-R. (2001). "Unraveling of BOT scheme: Malaysia's Indah water konsortium." *Journal of Construction Engineering and Management*, 127(6), 457–460.

Abrahamson, M. (1973). "Contractual risks in tunnelling: how they should be shared." *Tunnels and Tunnelling*, 587–598.

Asian Development Bank (ADB). (2000). *Developing best practices for promoting private sector investment in infrastructure: water supply*. Asian Development Bank, Manila, Philippines.

Asian Development Bank (ADB). (2008). *Public-private partnership handbook*. Asian Development Bank, Metro Manila, Philippines.

Asian Development Bank (ADB). (2010). *Guidance note: Urban water supply sector risk assessment*. Asian Development Bank, Mandaluyong City, Metro Manila, Philippines.

Asian Development Bank (ADB). (2012). *Assessment of Public–Private Partnerships in Cambodia: Constraints and Opportunities*. Asian Development Bank, Philippines.

Asian Development Bank (ADB). (2014). *6th People's Republic of China-ADB knowledge-sharing platform: Workshop on deepening public-private partnerships in Asia and the Pacific*. Asian Development Bank, Philippines.

Asian Development Bank (ADB). (2015a). "Public-private partnership in Pakistan." *Country Partnership Strategy: Pakistan, 2015–2019*, Asian Development Bank, <https://www.adb.org/sites/default/files/linked-documents/cps-pak-2015-2019-sd-06.pdf> (Nov. 22, 2016).

Asian Development Bank (ADB). (2015b). *Country partnership strategy: Pakistan (2015-2019)*. Asian Development Bank.

Asian Development Bank (ADB). (2016). "Private Sector Assessment (Summary)." *Country partnership strategy: Pakistan, 2015–2019*, Asian Development Bank, <https://www.adb.org/sites/default/files/linked-documents/cps-pak-2015-2019-psa.pdf> (Nov. 26, 2016).

Afshari, A. R., Yusuff, R. M., and Derayatifar, A. R. (2013). "Linguistic extension of fuzzy integral for group personnel selection problem." *Arabian Journal for Science and Engineering*, 38(10), 2901–2910.

Ahadzie, D. K., Proverbs, D. G., and Olomolaiye, P. O. (2008). "Critical success criteria for mass house building projects in developing countries." *International Journal of Project Management*, 26(6), 675–687.

Ahire, S. L., Golhar, D. Y., and Waller, M. A. (1996). "Development and Validation of TQM Implementation Constructs." *Decision sciences journal*, 27(1), 2004.

Ahmed, V., Abbas, A., and Ahmed, S. (2013). "Public infrastructure and economic growth in Pakistan: A dynamic CGE-Microsimulation analysis." *Infrastructure and Economic Growth* *in Asia*, Springer International Publishing, Cham, 117–143.

Ahsan, K., and Gunawan, I. (2010). "Analysis of cost and schedule performance of international development projects." *International Journal of Project Management*, 28(1), 68–78.

Akintoye, A., Beck, M., and Hardcastle, C. (Eds.). (2003a). *Public-private partnerships: Managing risks and opportunities*. Blackwell Science, Oxford Malden, MA.

Akintoye, A., Beck, M., Hardcastle, C., Chinyio, E., and Asenova, D. (2003b). "A framework for the risk management of private finance initiative projects." *Public-private partnerships: Managing risks and opportunities*, A. Akintoye, M. Beck, and C. Hardcastle, eds., Blackwell Science Ltd., Oxford, UK, 385–414.

Akintoye, A., Hardcastle, C., Beck, M., Chinyio, E., and Assenova, D. (2001). *Framework for risk assessment and management of private finance initiative projects*. Glasgow Caledonian University Press, Glasgow, Scotland, UK.

Akintoye, A., Taylor, C., and Fitzgerald, E. (1998). "Risk analysis and management of Private Finance Initiative projects." *Engineering Construction and Architectural Management*, 5(1), 9–21.

Al-Sharif, F., and Kaka, A. (2004). "PFI/PPP topic coverage in construction journals." *20th Annual ARCOM Conference*, F. Khosrowshahi, ed., Heriot Watt University, Edinburgh, Scotland, U.K, 711–719.

Alfonso, L. (2016). "Technical note: An approach to derive breeding goals from the preferences of decision makers." *Journal of Animal Science*, 94(11), 4498–4506.

Ali, T. H., Stewart, R., and Qureshi, S. (2007). "Evaluating risk management practices in the Pakistani construction industry: The current state of play." *Proceedings of the Fourth International Conference on Construction in the 21st Century : Accelerating Innovation in Engineering, Management and Technology*, Gold Coast, Australia.

Alireza, V., Mohammadreza, Y., Zin, R. M., Yahaya, N., and Noor, N. M. (2014). "An enhanced multi-objective optimization approach for risk allocation in public-private partnership projects: A case study of Malaysia." *Canadian Journal of Civil Engineering*, 41(2), 164–177.

Allen & Overy. (2010). *Global guide to public-private partnerships*. Allen & Overy LLP, London, UK.

African Legal Support Facility (ALSF), and Commercial Law Development Program (CLDP). (2014). *Understanding Power Purchase Agreements – Version 1.3*. Power Africa, Washington D.C.

Ameyaw, E., and Chan, A. (2016a). "A Fuzzy Approach for the Allocation of Risks in Public–Private Partnership Water-Infrastructure Projects in Developing Countries." *Journal of Infrastructure Systems*, American Society of Civil Engineers, 22(3), 4016016.

Ameyaw, E. E. (2015). "Risk allocation model for public-private partnership water supply projects in Ghana." PhD Thesis, The Hong Kong Polytechnic University, Hong Kong.

Ameyaw, E. E., and Chan, A. P. C. (2013). "Identifying public-private partnership (PPP) risks in managing water supply projects in Ghana." *Journal of Facilities Management*, 11(2), 152–182.

Ameyaw, E. E., and Chan, A. P. C. (2015a). "Risk allocation in public-private partnership water supply projects in Ghana." *Construction Management and Economics*, 33(3), 187–208.

Ameyaw, E. E., and Chan, A. P. C. (2015b). "Evaluating key risk factors for PPP water projects in Ghana: a Delphi study." *Journal of Facilities Management*, 13(2), 133–155.

Ameyaw, E. E., and Chan, A. P. C. (2015c). "Evaluation and ranking of risk factors in public-private partnership water supply projects in developing countries using fuzzy synthetic evaluation approach." *Expert Systems with Applications*, 42(12), 5102–5116.

Ameyaw, E. E., and Chan, A. P. C. (2016b). "Critical success factors for public-private partnership in water supply projects." *Facilities*, 34(3/4), 124–160.

Ameyaw, E. E., Chan, A. P. C., Owusu-Manu, D.-G., Edwards, D. J., and Dartey, F. (2017). "A fuzzy-based evaluation of financial risks in build–own–operate–transfer water supply projects." *Journal of Infrastructure Systems*, 23(4), 4017033.

Ameyaw Effah, E., Chan, A. P. C., and Owusu-Manu, D.-G. (2015). "Domestic Private Sector Participation in Small-Town Water Supply Services in Ghana: Reflections on Experience and Policy Implications." *Public Organization Review*, 15(2), 175–192.

Amin, T. (2017). "Hyderabad-Sukkur motorway: NHA to issue LoI to China state construction engineering corporation." *Business Recorder*, Islamabad.

Amos, P. (2004). *Public and private sector roles in the supply of transport infrastructure and services: Operational guidance for World Bank staff*. The International Bank for Reconstruction and Development/The World Bank, Washington DC.

Andrew, D. P. S., Pedersen, P. M., and McEvoy, C. D. (2011). *Research methods and design in sport management*. Human Kinetics, Illinois, US.

Ansari, A. (2016). "Habibabad flyover – a story of undue haste." *Dawn*, Kasur, <https://www.dawn.com/news/1237273> (Mar. 15, 2018).

AON. (2015). "Operational Insurance Benchmarking and its Role in Public-Private Partnerships." *Aon Infrastructure Solutions*, <http://www.aon.com/attachments/risk-services/Operational-Insurance-Benchmarking.pdf> (Jul. 26, 2016).

APMG International. (2016a). "Structuring and drafting the tender and contract." *The APMG PPP Certification Program Guide*, APMG International, UK.

APMG International. (2016b). "Appraising PPP projects." *The APMG PPP Certification Program Guide*, APMG International, UK.

APMG International. (2016c). "Managing the contract – strategy, delivery and commissioning." *The APMG PPP Certification Program Guide*, APMG International, UK.

APMG International. (2016d). "Managing the contract – Operations and hand-back." *The APMG PPP Certification Program Guide*, APMG International, UK.

Associated Press of Pakistan (APP). (2016). “CPEC attracting more investment in infrastructure development: Dar.” *Associated Press of Pakistan*, Islamabad, <https://www.app.com.pk/cpec-attracting-more-investment-in-infrastructure-development-dar/> (Sep. 25, 2016).

Arndt, R. (1999). “Optimum risk transfer in build-own-operatetransfer projects: The challenge for governments.” *Transactions of Multi-disciplinary Engineering*, Australia, 1–8.

Arndt, R. H. (2000). “Getting a fair deal: Efficient risk allocation in the private provision of infrastructure.” PhD Thesis, The University of Melbourne, Melbourne, Australia.

Asenova, D. (2010). *Risk management in private finance initiative projects: The role of financial services providers*. LAP Lambert Academic Publishing, Saarbrücken, Germany.

Asenova, D., and Beck, M. (2003). “A financial perspective on risk management in public-private partnership.” *Public-private partnerships: Managing risks and opportunities*, A. Akintoye, M. Beck, and C. Hardcastle, eds., Blackwell Science Ltd, Oxford, 127–151.

Ashuri, B., Kashani, H., Molenaar, K., Lee, S., and Lu, J. (2011). “Risk-Neutral Pricing Approach for Evaluating BOT Highway Projects with Government Minimum Revenue Guarantee Options.” *Journal of Construction Engineering and Management*, 138(4), 545–557.

Asian Business. (1996). “Race to keep up with growth.” *Asian Business*, 32(3), 4.

Atmo, G., and Duffield, C. (2014). “Improving investment sustainability for PPP power projects in emerging economies: Value for money framework.” *Built Environment Project and Asset Management*, Emerald, 4(4), 335–351.

Baccarini, D. (1999). “The logical framework method for defining project success.” *Project Management Journal*, 30(4), 25–32.

Baloi, D., and Price, A. D. F. (2003). “Modelling global risk factors affecting construction cost performance.” *International Journal of Project Management*, 21(4), 261–269.

Banihashemi, S., Hosseini, M. R., Golizadeh, H., and Sankaran, S. (2017). “Critical success factors (CSFs) for integration of sustainability into construction project management practices in developing countries.” *International Journal of Project Management*, 35(6), 1103–1119.

Bansal, A. (2012). “Comparison of public private partnership with traditional delivery methods in highway construction industry.” MS Thesis, Arizona State University, Arizona.

Beckers, F., Chiara, N., Flesch, A., Maly, J., Silva, E., and Stegemann, U. (2013). *A risk-management approach to a successful infrastructure project: Initiation, financing, and execution. McKinsey Working Papers on Risk, Number 52*.

Beckett, M., Drazin, S., Finlay, D., Kingsley-Smith, H., Martin, N., Neathey, R., and Robertson, J. (2009). *Performance of PFI Construction: A review by the private finance practice*. National Audit Office, Victoria, London.

Bel, G., Bel-Piñana, P., and Rosell, J. (2017). “Myopic PPPs: Risk allocation and hidden liabilities for taxpayers and users.” *Utilities Policy*, 48, 147–156.

Bellman, R. E., and Zadeh, L. A. (1970). “Decision-making in a fuzzy environment.” *Management*

Science, 17(4), B-141-B-164.

Bhatti, R. (2015). “To close infrastructure gap: country needs to invest 10 percent of GDP until 2020: SBP.” Business Recorder, <http://fp.brecorder.com/2015/03/201503271165421/> (Feb. 12, 2017).

Bhutta, Z. (2017). “Govt to lift ban on imported fuel-based power plants.” *Tribune*, <https://tribune.com.pk/story/1408481/govt-lift-ban-imported-fuel-based-power-plants/> (Oct. 23, 2017).

Bing, L., Akintoye, A., Edwards, P. J., and Hardcastle, C. (2005). “The allocation of risk in PPP/PFI construction projects in the UK.” *International Journal of Project Management*, 23(1), 25–35.

Black, S. A., and Porter, L. J. (1996). “Identification of the critical factors of TQM.” *Decision Sciences*, 27(1), 1–21.

Blomfield, A., and Plummer, J. (2014). “The allocation and documentation of hydrological risk.” *The International Journal of Hydropower & Dams*, 21(5), 94–108.

Boote, D. N., and Beile, P. (2005). “Scholars Before Researchers: On the Centrality of the Dissertation Literature Review in Research Preparation.” *Educational Researcher*, 34(6), 3–15.

Boussabaine, A. (2013). *Cost planning of PFI and PPP building projects*. Routledge, New York.

Brandao, L. E. T., and Saraiva, E. (2008). “The option value of government guarantees in infrastructure projects.” *Construction Management and Economics*, 26(11), 1171–1180.

Brosig, J., Traulsen, I., and Krieter, J. (2014). “Multicriteria Evaluation of Classical Swine Fever Control Strategies Using the Choquet Integral.” *Transboundary and Emerging Diseases*, 63, 1–11.

Brown, J. W., Pieplow, R., Driskell, R. L., Gaj, S. J., Garvin, M. J., Holbombe, D. L., Saunders, M. T., Seiders Jr, J. J., and Smith, A. L. (2009). *Public-private partnerships for highway infrastructure: Capitalizing on international experience*. Report FHWA-PL-09-010. FHWA, U.S. Department of Transportation.

Brown, T. A. (2015). *Confirmatory factor analysis for applied reaearch*. The Guilford Press, New York.

Bruzelius, N., Flyvbjerg, B., and Rothengatter, W. (2002). “Big decisions, big risks. Improving accountability in mega projects.” *Transport Policy*, 9(2), 143–154.

Buckley, J. J. (1985). “Ranking alternatives using fuzzy numbers.” *Fuzzy Sets and Systems*, 15(1), 21–31.

Burger, P., Tyson, J., Karpowicz, I., and Coelho, M. D. (2009). *The Effects of the Financial Crisis on Public-Private Partnerships: IMF working paper*. WP/09/144. Fiscal Affairs Department , International Monetary Fund.

Butt, N., and Saeed, A. (2017). “NA passes ‘Public Private Partnership Authority Bill 2017.’” *Business Recorder*, Islamabad, <https://fp.brecorder.com/2017/03/20170323157192/> (Jun.

15, 2018).

Calderón, C., Moral-Benito, E., and Servén, L. (2015). "Is infrastructure capital productive? A dynamic heterogeneous approach." *Journal of Applied Econometrics*, 30(2), 177–198.

Carbonara, N., Costantino, N., Gunnigan, L., and Pellegrino, R. (2015). "Risk management in motorway PPP projects: Empirical-based guidelines." *Transport Reviews*, 35(2), 162–182.

Carbonara, N., Costantino, N., and Pellegrino, R. (2014). "Revenue guarantee in public-private partnerships: a fair risk allocation model." *Construction Management and Economics*, 32(4), 403–415.

Carr, V., and Tah, J. H. . (2001). "A fuzzy approach to construction project risk assessment and analysis: Construction project risk management system." *Advances in Engineering Software*, 32(10), 847–857.

Carrillo, P. M., Robinson, H. S., Anumba, C. J., and Bouchlaghem, N. M. (2006). "A Knowledge Transfer Framework: the PFI context." *Construction Management and Economics*, 24(10), 1045–1056.

Carrillo, P., Robinson, H., Foale, P., Anumba, C., and Bouchlaghem, D. (2008). "Participation, Barriers, and Opportunities in PFI: The United Kingdom Experience." *Journal of Management in Engineering*, 24(3), 138–145.

Castalia Limtited. (2010). *Pakistan: Contingent liabilities from public private partnerships*. Castalia Strategic Advisors.

Castro-Nova, I. G. (2016). "Geotechnical risk decision tools for alternative project delivery method selection." MS Thesis, Iowa State University, Iowa.

Chan, A. P. C., Lam, P. T. I., Chan, D. W. M., Cheung, E., and Ke, Y. (2009). "Drivers for Adopting Public Private Partnerships—Empirical Comparison between China and Hong Kong Special Administrative Region." *Journal of Construction Engineering and Management*, 135(11), 1115–1124.

Chan, A. P. C., Lam, P. T. I., Wen, Y., Ameyaw, E. E., Wang, S., and Ke, Y. (2014). "Cross-sectional analysis of critical risk factors for PPP water projects in China." *Journal of Infrastructure Systems*, 21(1).

Chan, A. P. C., Yeung, J. F. Y., Yu, C. C. P., Wang, S. Q., and Ke, Y. (2011). "Empirical study of risk assessment and allocation of public-private partnership projects in China." *Journal of Management in Engineering*, 27(3), 136–148.

Chan, H. lun J. (2011). "Developing a fuzzy risk assessment model for target cost and guaranteed maximum price contracts in the construction industry of Hong Kong." PhD Thesis. The Hong Kong Polytechnic University, Hong Kong.

Chapman, C., and Ward, S. (2003). *Project risk management: processes, techniques and insights*. Wiley, England.

Chen, C.-T., and Cheng, H.-L. (2009). "A comprehensive model for selecting information system project under fuzzy environment." *International Journal of Project Management*, 27(4), 389–

399.

Chen, S.-J., and Hwang, C.-L. (1993). *Fuzzy multiple attribute decision making: Methods and applications*. *Lecture Notes in Economics and Mathematical Systems,* Springer, New York.

Cheung, E., and Chan, A. P. C. (2012). "Risk factors of public-private partnership projects in China: Comparison between the water, power, and transportation sectors." *Journal of Urban Planning and Development*, 137(4), 409–415.

Cheung, E., Chan, A. P. C., Lam, P. T. I., Chan, D. W. M., and Ke, Y. (2012). "A comparative study of critical success factors for public private partnerships (PPP) between Mainland China and the Hong Kong Special Administrative Region." *Facilities*, 30(13), 647–666.

Chiang, J.-H. (1999). "Choquet fuzzy integral-based hierarchical networks for decision analysis." *IEEE Transactions on Fuzzy Systems*, 7(1), 63–71.

Chileshe, N., and Kikwasi, G. J. (2013). "Perception of barriers to implementing risk assessment and management practices by construction professionals in Tanzania." *Proceedings of 29th Annual ARCOM Conference,* S. D. Smith and D. D. Ahiaga-Dagbui, eds., Association of Researchers in Construction Management, Reading, UK, 1137–1146.

Chileshe, N., and Kikwasi, G. J. (2014). "Critical success factors for implementation of risk assessment and management practices within the Tanzanian construction industry." *Engineering, Construction and Architectural Management,* Emerald, 21(3), 291–319.

Chinyio, E., and Fergusson, A. (2003). "A construction perspective on risk management in public-private partnership." *Public-private partnerships: Managing risks and opportunities*, A. Akintoye, M. Beck, and C. Hardcastle, eds., Blackwell Science Ltd., Oxford, UK, 93–126.

Chiou, H. K., Tzeng, G. H., and Cheng, D. C. (2005). "Evaluating sustainable fishing development strategies using fuzzy MCDM approach." *Omega*, 33(3), 223–234.

Chohan, U. W. (2017). "What is One Belt One Road? A surplus recycling mechanism approach." *SSRN Electronic Journal, Discussion Paper Series: Notes on the 21 st Century*.

Choi, J. H., Chung, J., and Lee, D. J. (2010). "Risk perception analysis: Participation in China's water PPP market." *International Journal of Project Management,* 28(6), 580–592.

Choquet, G. (1953). "Theory of capacities." *Annales de l'institut Fourier*, 5, 131–295.

Chou, J.-S., and Leatemia, G. T. (2016). "Critical Process and Factors for Ex-Post Evaluation of Public-Private Partnership Infrastructure Projects in Indonesia." *Journal of Management in Engineering*, 32(5), 5016011.

Chou, J. S., and Pramudawardhani, D. (2015). "Cross-country comparisons of key drivers, critical success factors and risk allocation for public-private partnership projects." *International Journal of Project Management*, 33(5), 1136–1150.

Chou, S.-Y., Chang, Y.-H., and Shen, C.-Y. (2008). "A fuzzy simple additive weighting system under group decision-making for facility location selection with objective/subjective attributes." *European Journal of Operational Research,* North-Holland, 189(1), 132–145.

Chou, S. Y., and Chang, Y. H. (2008). "A decision support system for supplier selection based on a strategy-aligned fuzzy SMART approach." *Expert Systems with Applications*, 34(4), 2241–2253.

Choudhry, R., and Iqbal, K. (2012). "Identification of Risk Management System in Construction Industry in Pakistan." *Journal of Management in Engineering*, American Society of Civil Engineers, 29(1), 42–49.

Chow, L. (2005). "Incorporating fuzzy membership functions and gap analysis concept into performance evaluation of engineering consultants: Hong Kong study." PhD Thesis, The University of Hong Kong, Hong Kong.

Chowdhury, A. N., and Charoenngam, C. (2009). "Factors influencing finance on IPP projects in Asia: A legal framework to reach the goal." *International Journal of Project Management*, 27(1), 51–58.

Chowdhury, A. N., Chen, P. H., and Tiong, R. L. K. (2015). "Credit enhancement factors for the financing of independent power producer (IPP) projects in Asia." *International Journal of Project Management*, 33(7), 1576–1587.

Chung, D., Hensher, D. A., and Rose, J. M. (2010). "Toward the betterment of risk allocation: Investigating risk perceptions of Australian stakeholder groups to public-private-partnership tollroad projects." *Research in Transportation Economics*, 30(1), 43–58.

Clayton UTZ. (2006). "Successfully allocating risk and negotiating a PPP Contract." *6th Annual National Private Public Partnerships Summit*, Clayton Utz, <https://www.claytonutz.com/docs/PPP_Summit_Paper_May06.pdf> (Jun. 18, 2016).

Clifton, C., and Duffield, C. F. (2006). "Improved PFI/PPP service outcomes through the integration of Alliance principles." *International Journal of Project Management*, 24(7), 573–586.

Cobârzan, B., and Hamlin, R. E. (2005). "Corruption and ethical issues regarding public-private partnership." *Revista Transilvană de Ştiinţe Administrative*, 3(15), 28–37.

Cooper, D., Grey, S., Raymond, G., and Walker, P. (2005). *Project risk management guidelines: Managing risk in large projects and complex procurements.* John Wiley & Sons Ltd, Chichester, West Sussex, England.

Corner, D. (2005). "The United Kingdom private finance initiative: The challenge of allocating risk." *The Challenge of Public-Private Private Partnerships. Cheltenham, UK: Edward Elgar*, 44–61.

Costello, A. B., and Osborne, J. W. (2005). "Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis." *Practical Assessment, Research & Evaluation*, 10(7), 1–9.

Crampes, C., and Estache, A. (1998). "Regulatory trade-offs in the design of concession contracts." *Utilities Policy*, 7(1), 1–13.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches*. Sage Publications Inc., US.

Creswell, J. W., Plano-Clark, V. L., Gutmann, M. L., and Hanson, W. E. (2003). “Advanced mixed methods research designs.” *Handbook of Mixed Methods in Social and Behavioral Research*, A. Tashakkori and C. Teddlie, eds., Sage, Thousand Oaks, CA., 209–240.

Croce, R. D., Paula, J., and Assab, A. (2017). *Selected good practices for risk allocation and mitigation in infrastructure in APEC economies*. Organization for Economic Co-operation and Development.

Cruz, N., and Marques, R. (2012). “Delivering Local Infrastructure through PPPs: Evidence from the School Sector.” *Journal of Construction Engineering and Management*, American Society of Civil Engineers, 138(12), 1433–1443.

Cuttaree, V. (2008). “Successes and Failures of PPP Projects.” The World Bank, Warsaw, <http://goo.gl/sshR8D> (Oct. 19, 2016).

Darvish, H., Zou, P. X. W., Loosemore, M., and Zhang, G. M. K. (2006). “Risk management, public interests and value for money in PPP projects: Literature review and case studies.” *Proceedings of CRIOCM 2006 International Research Symposium on Advancement of Construction Management and Real Estate*, 546–557.

David, M., and Sutton, C. D. (2004). *Social research: The basics*. SAGE Publications, London.

Dawson, J. (2016). *Analysing quantitative survey data for business and management students*. SAGE, Croydon, London.

Delhi, V. S. K., Mahalingam, A., and Palukuri, S. (2012). “Governance issues in BOT based PPP infrastructure projects in India.” *Built Environment Project and Asset Management*, 2(2), 234–249.

Delmon, J. (2009). *Private sector investment in infrastructure: Project finance, PPP projects and risks*. Kluwer Law International, The Netherlands.

Delmon, J., and Delmon, V. rigby. (2010). *International project finance and PPPs: A legal guide to key growth markets*. Kluwer Law International, The Netherlands.

Dentons. (2016). “One Belt One Road: PPP Alchemy – is the Silk Road paved in Gold?” *Dentons*, <https://beltandroad.hktdc.com/sites/default/files/common/Business Guides/One_Belt_One_Road_Guide__December_2016_screen_version187033851 (1).pdf> (Jan. 9, 2018).

Department of Economic Affairs. (2016). *PPP Guide for Practitioners*. PPP Cell, Department of Economic Affairs, Ministry of Finance, Government of India.

Department of Finance and Administration. (2005). *Public Private Partnerships Risk Management Guideline: Commonwealth Policy Principles for the Use of Private Financing*. *(Rep. No. Financial Management Guidance No.18)*, Department of Finance and Administration, Australia.

Department of Infrastructure and Regional Development. (2016). *National Public Private Partnership Guidelines Volume 7: Commercial Principles for Economic Infrastructure*. Commonwealth of Australia, Canberra.

Deptartment of Economic Affairs. (2010). "Risk – a critical focus of PPP design, PPP TOOLKIT for improving PPP decision-making processes." Deptartment of Economic Affairs, Ministry of Finance, Government of India, India, <https://www.pppinindia.gov.in/toolkit/ports/module1-racfopd-mriip.php?links=risk1a> (Nov. 16, 2016).

Dey, P. K., and Ogunlana, S. O. (2004). "Selection and application of risk management tools and techniques for build-operate-transfer projects." *Industrial Management and Data Systems*, 104(3), 334–346.

Dikmen, I., Birgonul, M. T., Anac, C., Tah, J. H. M., and Aouad, G. (2008). "Learning from risks: A tool for post-project risk assessment." *Automation in Construction*, 18(1), 42–50.

DLA Piper. (2009). *European PPP report 2009*. DLA Piper & European PPP Expertise Center, London.

Doloi, H. (2009). "Relational partnerships: the importance of communication, trust and confidence and joint risk management in achieving project success." *Construction Management and Economics*, Routledge, 27(11), 1099–1109.

Dunn, J. (2017). "Project risk management in public-private partnerships: An equitable risk allocation decision model based on psychometrics." MS Thesis, University of Windsor, Canada.

Dursun, M., Karsak, E. E., and Karadayi, M. A. (2011). "A fuzzy multi-criteria group decision making framework for evaluating health-care waste disposal alternatives." *Expert Systems with Applications*, 38(9), 11453–11462.

East Asia Analytical Unit. (1998). *Asia's infrastructure in the crisis: harnessing private enterprise*. Department of Foreign Affairs and Trade, Canberra.

Ebrahimnejad, S., Mousavi, S. M., and Seyrafianpour, H. (2010). "Risk identification and assessment for build–operate–transfer projects: A fuzzy multi attribute decision making model." *Expert Systems with Applications*, 37(1), 575–586.

Economist Intelligence Unit. (2015). *Evaluating the environment for public-private partnerships in Asia-Pacific: The 2014 Infrascope*. The Economist Intelligence Unit Ltd., and Asian Development Bank, London.

Efficiency Unit. (2008). *An Introductory Guide to Public Private Partnerships (PPPs)*. Efficiency Unit, Hong Kong.

Ehrlich, M., and Tiong, R. L. K. (2012). "Improving the Assessment of Economic Foreign Exchange Exposure in Public-Private Partnership Infrastructure Projects." *Journal of Infrastructure Systems*, 18(2), 57–67.

El-Amm, L. A. (2003). "Risk Management in Toll Road Concessions." MS Thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States.

El-Gohary, N. M., Osman, H., and El-Diraby, T. E. (2006). "Stakeholder management for public private partnerships." *International Journal of Project Management*, 24(7), 595–604.

Estache, A., Goicoechea, A., and Trujillo, L. (2009). "Utilities reforms and corruption in developing countries." *Utilities Policy*, 17(2), 191–202.

European Commission. (2003). *Guidelines for successful public-private partnerships*. Directorate-General Regional Policy, Brussels.

European Commission. (2004a). *Resource book on PPP case studies*. Directorate-General Regional Policy, Brussels.

European Commission. (2004b). *Green paper on public-private partnerships and community law on public contracts and concessions. COM (2004) 327 Final*, European Commission, Brussels, Belgium.

European Investment Bank. (2015). "Dispute resolution." European Investment Bank, <http://www.eib.org/epec/g2g/iv-project-implementation/41/415/index.htm> (Oct. 19, 2016).

European PPP Expertise Centre. (2012). *The guide to guidance: How to prepare, procure and deliver PPP projects*. European PPP Expertise Centre, Luxembourg.

Federal Highway Administration. (2012). *Risk Assessment for Public-Private Partnerships: A Primer*. Federal Highway Administration, US Department of Transportation, US.

Federal Highway Administration. (2013). *Guidebook for risk assessment in public private partnerships*. Federal Highway Administration, US Department of Transportation, US.

Fellows, R. F., and Liu, A. M. M. (2015). *Research methods for construction, 4th Ed.* John Wiley & Sons Ltd., Oxford, UK.

Feng, C. M., Wu, P. J., and Chia, K. C. (2010). "A hybrid fuzzy integral decision-making model for locating manufacturing centers in China: A case study." *European Journal of Operational Research*, 200(1), 63–73.

Field, A. (2005). *Discovering Statistics Using SPSS, 2nd Ed.* SAGE Publications Ltd., London.

Fischer, K., Leidel, K., Riemann, A., and Alfen, H. W. (2010). "An integrated risk management system (IRMS) for PPP projects." *Journal of Financial Management of Property and Construction*, 15(3), 260–282.

Flyvbjerg, B. (2013). "Quality control and due diligence in project management: Getting decisions right by taking the outside view." *International Journal of Project Management*, 31(5), 760–774.

Flyvbjerg, B., Holm, M. S., and Buhl, S. (2002). "Underestimating costs in public works projects: Error or lie?" *Journal of the American Planning Association*, Routledge, 68(3), 279–295.

Flyvbjerg, B., Skamris Holm, M. K., and Buhl, S. L. (2005). "How (in)accurate are demand forecasts in public works projects?: The case of transportation." *Journal of the American Planning Association,* Routledge, 71(2), 131–146.

Fraser, J. M. (2005). *Lessons from the independent private power experience in Pakistan, Energy and mining sector discussion paper, No. 14*. World Bank Group, Washington D.C.

Gannon, M. J., and Smith, N. J. (2011). “An effective outline business case to facilitate successful decision-making.” *Construction Management and Economics*, 29(2), 185–197.

Garvin, M. J. (2010). “Enabling development of the transportation public-private partnership market in the United States.” *Journal of Construction Engineering and Management,* 136(4), 402–411.

Ghumman, M. (2012). “Debt repayment to banks: nine IPPs default.” *Business Recorder*.

GI Hub. (2016). *Allocating risks in public-private partnership contracts*. Global Infrastructure Hub Ltd., Sydney.

GI Hub. (2018). *Managing PPP contracts after financial close: Practical guidance for governments managing PPP contracts, informed by real-life project data*. Global Infrastructure Hub Ltd., Sydney.

GoKp. (2014). “The Khyber Pakhtunkhwa Public Private Partnership Act, 2014.” *Government of Khyber Pakhtunkhwa,* <http://www.pakp.gov.pk/2013/acts/the-khyber-pakhtunkhwa-public-private-partnership-act2014/> (Mar. 25, 2018).

GoKp. (2017). “The Khyber Pakhtunkhwa Public Private Partnership (Amendment) Act, 2017.” *Government of Khyber Pakhtunkhwa*, <http://cmkp.gov.pk/legislation/The-KP-Public-Private-Partnership-Amend-Act-2017_1530787186.pdf> (Mar. 25, 2018).

Gomm, R., Hammersley, M., and Foster, P. (2000). *Case study method: Key issues, key texts*. Sage Publications, London.

GoP. (2006). *Policy for Development of Renewable Energy for Power Generation: Employing Small Hydro, Wind, and Solar Technologies*. Government of Pakistan, Pakistan.

GoP. (2010). *Pakistan policy on public private partnerships: Private participation in infrastructure for better public services*. Government of Pakistan, Pakistan.

GoP. (2015). *Power generation policy 2015*. Government of Pakistan, Pakistan.

GoPb. (2011). *Risk management manual for public-private partnerships in infrastructure*. Government of Punjab, Pakistan.

Government of the Netherlands. (2002). *Public Private Comparator*. PPP Knowledge Centre, The Hague, The Netherlands.

Grabisch, M. (1996). “The application of fuzzy integrals in multicriteria decision making.” *European Journal of Operational Research*, 89(3), 445–456.

Grabisch, M. (1997). “K-Order Additive Discrete Fuzzy Measures and Their Representation.” *Fuzzy Sets and Systems*, 92(2), 167–189.

Grabisch, M., Kojadinovic, I., and Meyer, P. (2008). “A review of methods for capacity identification in Choquet integral based multi-attribute utility theory.” *European Journal of Operational Research*, 186(2), 766–785.

Grabisch, M., Kojadinovic, I., and Meyer, P. (2015). “kappalab: Non additive measure and integral manipulation functions.” <https://cran.r-project.org/web/packages/kappalab/index.html>

(Feb. 4, 2018).

Grabisch, M., Murofushi, T., and Sugeno, M. (Eds.). (2000). *Fuzzy measures and integrals: Theory and applications*. Physica-Verlag Heidelberg, Germany.

Grimsey, D., and Lewis, M. (2007). *Public private partnerships: The worldwide revolution in infrastructure provision and project finance*. Edward Elgar Publishing, Cheltenham, U.K.

Grimsey, D., and Lewis, M. K. (2002). “Evaluating the risks of public private partnerships for infrastructure projects.” *International Journal of Project Management*, 20(2), 107–118.

Grimsey, D., and Lewis, M. K. (2004). “The governance of contractual relationships in public-private partnerships.” *The Journal of Corporate Citizenship*, (15), 91.

Guasch, J. L. (2004). *Granting and renegotiating infrastructure concessions: Doing it right*. The World Bank, Washington, DC.

Guasch, J. L., Laffont, J.-J., and Straub, S. (2008). “Renegotiation of concession contracts in Latin America: Evidence from the water and transport sectors.” *International Journal of Industrial Organization*, 26(2), 421–442.

Gurbuz, T. (2010). “Multiple Criteria Human Performance Evaluation Using Choquet Integral.” *International Journal of Computational Intelligence Systems*, 3(3), 290–300.

Hahs-Vaughn, D. L. (2016). *Applied multivariate statistical concepts*. Routledge, New York.

Haider, M. (2016). “Govt establishes fund for mega projects.” *The News*, <https://www.thenews.com.pk/print/119799-Govt-establishes-fund-for-mega-projects#> (Feb. 12, 2017).

Hair, J. F. (2010). *Multivariate data analysis: A global perspective, 7th Ed.* Pearson Education, London.

Hardcastle, C., and Boothroyd, K. (2003). “Risks Overview in Public-Private Partnership.” *Public-Private Partnerships: Managing Risks and Opportunities*, A. Akintoye, M. Beck, and C. Hardcastle, eds., Blackwell Science Ltd, Oxford, UK, 31–57.

Hayford, O. (2013). *Improving the Outcomes of Public Private Partnerships*. Clayton UTZ, Sydney, Australia.

HM Treasury. (2004). *Managing risks with delivery partners: A guide for those working together to deliver better public services*. Office of Government Commerce, HM Treasury, London, UK.

HM Treasury. (2007). *Standardisation of PFI contracts*. The Stationery Office, London, United Kingdom.

HM Treasury. (2012). *A new approach to public private partnerships*. HM Treasury, London, UK.

Hodge, G. A. (2004). “The risky business of public-private partnerships.” *Australian Journal of Public Administration*, 63(4), 37–49.

Hodge, G. A., and Greve, C. (2007). “Public-private partnerships: An international performance review.” *Public Administration Review*, 67(3), 545–558.

Hong, Y., Chan, D. W. M., Chan, A. P. C., and Yeung, J. F. Y. (2011). "Critical analysis of partnering research trend in construction journals." *Journal of Management in Engineering*, 28(2), 82–95.

Hong Kong Institute of Surveyors. (2009). *Practical Guide to Public Private Partnership (PPP) Projects*. Hong Kong Institute of Surveyors (HKIS), Hong Kong SAR, China.

Hsieh, T. Y., Lu, S. T., and Tzeng, G. H. (2004). "Fuzzy MCDM approach for planning and design tenders selection in public office buildings." *International Journal of Project Management*, 22(7), 573–584.

Hu, Y., Chan, A. P. C., and Le, Y. (2015). "Understanding the Determinants of Program Organization for Construction Megaproject Success: Case Study of the Shanghai Expo Construction." *Journal of Management in Engineering*, 31(5), 5014019.

Hu, Y., Chan, A. P. C., Le, Y., Xu, Y., and Shan, M. (2016). "Developing a Program Organization Performance Index for Delivering Construction Megaprojects in China: Fuzzy Synthetic Evaluation Analysis." *Journal of Management in Engineering*, 32(4), 5016007.

Hussain, K. (2017). "German companies express interest in CPEC projects." *The Express Tribune*, <https://tribune.com.pk/story/1407615/german-companies-express-interest-cpec-projects/> (Jun. 15, 2018).

Hwang, B., Zhao, X., and Gay, M. J. S. (2013). "Public private partnership projects in Singapore: Factors, critical risks and preferred risk allocation from the perspective of contractors." *International Journal of Project Management*, 31(3), 424–433.

Ibrahim, A. D., Price, A. D. F., and Dainty, A. R. J. (2006). "The analysis and allocation of risks in public private partnerships in infrastructure projects in Nigeria." *Journal of Financial Management of Property and Construction*, 11(3), 149–164.

Indonesia Infrastructure Guarantee Fund. (2017). *Risk allocation guideline: Public-private partnership (PPP) in Indonesia*. *Indonesia Infrastructure Guarantee Fund*, Indonesia Infrastructure Guarantee Fund, Jakarta.

Iossa, E., and Martimort, D. (2014). *Corruption in PPPs, Incentives and Contract Incompleteness (Working Paper n. 67)*. Working Paper Series - ISSN 1973-0381, IEFE - The Center for Research on Energy and Environmental Economics and Policy, Bocconi University, Milano.

Iossa, E., Spagnolo, G., and Vellez, M. (2007). "Best Practices on Contract Design in Public-Private Partnerships." <https://www.researchgate.net/publication/237579814_Best_Practices_on_Contract_Design_in_Public-Private_Partnerships> (Jun. 15, 2018).

Iqbal, T., and Badshah, M. (2016). *Rating report: Deokjae connecting roads (private) limited*. JCR-VIS Credit Rating Company Limited, Karachi.

Irshad, M. S. (2015). "One Belt and One Road: Dose China-Pakistan Economic Corridor Benefit for Pakistan's Economy?" *Journal of Economics and Sustainable Development*, 6(24).

Irwin, T. (2007). *Government guarantees: Allocating and valuing risk in privately financed infrastructure projects*. The International Bank for Reconstruction and Development/The

World Bank, Washington, DC.

Irwin, T., Klein, M., Perry, G. E., and Thobani, M. (Eds.). (1997). *Dealing with public risk in private infrastructure*. The International Bank for Reconstruction and Development/The World Bank, Washington D.C.

Ishii, K., and Sugeno, M. (1985). "A model of human evaluation process using fuzzy measure." *International Journal of Man-Machine Studies*, 22(1), 19–38.

Iyer, K. C., and Sagheer, M. (2010). "Hierarchical structuring of PPP risks using interpretative structural modeling." *Journal of Construction Engineering and Management*, 136(2), 151–159.

Iyer, K. C., and Sagheer, M. (2011). "A real options based traffic risk mitigation model for build-operate-transfer highway projects in India." *Construction Management and Economics*, 29(8), 771–779.

Jamal, N. (2016). "Commissioning of two power plants likely to be delayed by five months." *Dawn*, <https://www.dawn.com/news/1281967> (Jun. 15, 2018).

Jamal, N. (2018). "After snags, new gas power plants may start by March." *Dawn*, <https://www.dawn.com/news/1386149> (Jun. 15, 2018).

Jang, G. W. (2010). "The Bids-Evaluation Decision Model Development and Application for PPP Transport Projects: A Project Risks Modeling Framework." PhD Thesis, Colorado State University, Fort Collins, Colorado.

Jin, X. H. (2010). "Determinants of efficient risk allocation in privately financed public infrastructure projects in Australia." *Journal of Construction Engineering and Management*, 136(2), 138–150.

Jin, X. H., and Doloi, H. (2008). "Interpreting risk allocation mechanism in public-private partnership projects: An empirical study in a transaction cost economics perspective." *Construction Management and Economics*, 26(7), 707–721.

Jin, X. H., Lee, C. L., and Zhang, G. (2011). "Critical uncertainty factors for efficient allocation of demand risk in privately financed public infrastructure projects in Australia." *International Journal of Project Organisation and Management*, 3(3–4), 243–257.

Jin, X. H., and Zhang, G. (2011). "Modelling optimal risk allocation in PPP projects using artificial neural networks." *International Journal of Project Management*, 29(5), 591–603.

Jin, X. H., Zhang, G., and Yang, R. J. (2012). "Factor analysis of partners' commitment to risk management in public-private partnership projects." *Construction Innovation*, 12(3), 297–316.

Jin, X. H., and Zuo, J. (2011). "Critical uncertainty factors for efficient risk allocation in privately financed public infrastructure projects in Australia." *International Journal of Construction Management*, 11(3), 19–34.

Jorgic, D., and Gloystein, H. (2017). "In Pakistan, questions raised over GE's flagship power turbines." *Reuters*, <https://www.reuters.com/article/us-generalelectric-pakistan-insight/in-

pakistan-questions-raised-over-ges-flagship-power-turbines-idUSKBN1EL0VN> (Jun. 15, 2018).

Jover, J., Bombardier, V., and Thomas, A. (2013). "Wood piece quality evaluation using choquet integral and fuzzy merging." *IJCCI 2013 - Proceedings of the 5th International Joint Conference on Computational Intelligence*, 249–256.

Kachwaha, S., and Rautray, D. (2016). "PPP problems." Indian Business Law Journal, <https://www.vantageasia.com/ppp-problems/> (May 13, 2017).

Kahkonen, K., and Artto, K. A. (1997). *Managing Risks in Projects*. *Proceedings of the IPMA Symposium on Project Management 1997*, Taylor & Francis Group, Helsinki, Finland.

Kahn, R., and Cannell, C. (1957). *The Dynamics of Interviewing*. Wiley, New York and Chichester.

Karim, N. A. A. (2011). "Risk allocation in public private partnership (PPP) project: a review on risk factors." *International Journal of Sustainable Construction Engineering and Technology*, 2(2).

Karsak, E. E., Khosla, R., Howlett, R., and Jain, L. (2005). "Choquet Integral-Based Decision Making Approach for Robot Selection." *Knowledge-Based Intelligent Information and Engineering Systems*, 3682, 162.

Ke, Y. J., Wang, S. Q., and Chan, A. P. C. (2009a). "Public-Private Partnerships in China's infrastructure development: lessons learnt." *Proceedings of International Conference on Changing Roles: New Roles and New Challenges*, H. Wamelink, M. Prins, and R. Geraedlts, eds., TU Delft, Netherlands, 177–188.

Ke, Y., Liu, X., and Wang, S. (2008). "Equitable Financial Evaluation Method for Public-Private Partnership Projects." *Tsinghua Science & Technology*, 13(5), 702–707.

Ke, Y., Wang, S., and Chan, A. P. C. (2010a). "Risk allocation in public-private partnership infrastructure projects: Comparative study." *Journal of Infrastructure Systems*, 16(4), 343–351.

Ke, Y., Wang, S., and Chan, A. P. C. (2012). "Risk management practice in China's Public-Private Partnership projects." *Journal of Civil Engineering and Management*, 18(5), 675–684.

Ke, Y., Wang, S., Chan, A. P. C., and Cheung, E. (2009b). "Research trend of public-private partnership in construction journals." *Journal of Construction Engineering and Management*, 135(10), 1076–1086.

Ke, Y., Wang, S., Chan, A. P. C., and Cheung, E. (2011). "Understanding the risks in China's PPP projects: Ranking of their probability and consequence." *Engineering, Construction and Architectural Management*, 18(5), 481–496.

Ke, Y., Wang, S., Chan, A. P. C., and Lam, P. T. I. (2010b). "Preferred risk allocation in China's public-private partnership (PPP) projects." *International Journal of Project Management*, 28(5), 482–492.

Keci, J., and Mustafaraj, E. (2013). "Practices, barriers and challenges of risk management implementation in Albanian construction industry." *ATINER's conference paper series CIV2013-0639*, Athens Institute for Education and Research, Athens, Greece.

Khan, A. H., Jamil, M., and Sattar, M. (2008). "The trend of build operate and transfer (BOT) projects in Pakistan." *First International Conference on Construction In Developing Countries (ICCIDC–I): Advancing and Integrating Construction Education, Research & Practice*, S. M. Ahmed, ed., Department of Civil Engineering, NED University of Engineering & Technology, 88–97.

Khazaeni, G., Khanzadi, M., and Afshar, A. (2012). "Optimum risk allocation model for construction contracts: fuzzy TOPSIS approach." *Canadian Journal of Civil Engineering*, NRC Research Press, 39(7), 789–800.

Kiani, K. (2017). "Pakistan told to pay Rs14 billion to nine power producers." *Dawn*, Islamabad, <https://www.dawn.com/news/1367589> (Jun. 15, 2018).

Kim, S. D. (2012). "Characterizing unknown unknowns." *PMI® Global Congress 2012—North America, Vancouver, British Columbia, Canada*, Project Management Institute, Newtown Square, PA.

Kline, P. (1994). "An easy guide to factor analysis." *Personality and Individual Differences*, 17(2), 302.

Kojadinovic, I. (2004). "Unsupervised aggregation by the choquet integral based on entropy functionals: Application to the evaluation of students." *Modeling Decisions for Artificial Intelligence, Proceedings*, 3131, 163–174.

Kojadinovic, I. (2007). "Minimum variance capacity identification." *European Journal of Operational Research*, 177(1), 498–514.

Kokkaew, N., and Chiara, N. (2010). "Modelling completion risk using stochastic critical path-envelope method: A BOT highway project application." *Construction Management and Economics*, 28(12), 1239–1254.

Krishnan, A. R., Kasim, M. M., and Bakar, E. M. N. E. A. (2015). "A Short Survey on the Usage of Choquet Integral and its Associated Fuzzy Measure in Multiple Attribute Analysis." *Procedia Computer Science*, 427–434.

Kumaraswamy, M. M., and Morris, D. A. (2002). "Build-operate-transfer-type procurement in Asian megaprojects." *Journal of Construction Engineering and Management*, 128(2), 93–102.

Kurniawan, F. (2013). "An integrated project evaluation tool for public-private partnership projects." PhD Thesis, Heriot-Watt University, Edinburgh, Scotland.

Kwak, Y. H. (2002). "Analyzing asian infrastructure development privatization market." *Journal of Construction Engineering and Management*, 128(2), 110–116.

van Laarhoven, P. J. M., and Pedrycz, W. (1983). "A fuzzy extension of Saaty's priority theory." *Fuzzy Sets and Systems*, 11(1–3), 199–227.

Laishram, B. S., and Kalidindi, S. N. (2009). "Desirability rating analysis for debt financing of public-private partnership road projects." *Construction Management and Economics*, 27(9), 823–837.

Lam, K. C., Wang, D., Lee, P. T. K., and Tsang, Y. T. (2007). "Modelling risk allocation decision in construction contracts." *International Journal of Project Management*, 25(5), 485–493.

Lam, W. H. K., and Tam, M. L. (1998). "Risk analysis of traffic and revenue forecasts for road investment projects." *Journal of Infrastructure Systems*, 4(1), 19–27.

Lee, N., and Schaufelberger, J. (2013). "Risk Management Strategies for Privatized Infrastructure Projects: Study of the Build–Operate–Transfer Approach in East Asia and the Pacific." *Journal of Management in Engineering*, American Society of Civil Engineers, 30(3).

Lehtiranta, L., and Junnonen, J. M. (2014). "Stretching risk management standards: Multi-organizational perspectives." *Built Environment Project and Asset Management*, 4(2), 128–145.

Li, B. (2003). "Risk management of construction public-private partnership projects." PhD Thesis, Glasgow Caledonian University, Glasgow, Scotland.

Li, J., and Zou, P. X. W. (2011). "Fuzzy AHP-based risk assessment methodology for PPP projects." *Journal of Construction Engineering and Management*, 137(12), 1205–1209.

Li, J., Zou, P. X. W., Cheng, H., and Dai, Z. H. (2007). "Contract conditions of BOT projects in China." *Proceedings of CRIOCM 2007 International research symposium on advancement of construction management and real estate*, Sydney, Australia, 966–979.

Li, Y., and Wang, X. (2016). "Risk assessment for public–private partnership projects: Using a fuzzy analytic hierarchical process method and expert opinion in China." *Journal of Risk Research*, 1–22.

Li, Y., Wang, X., and Wang, Y. (2017). "Using Bargaining Game Theory for Risk Allocation of Public-Private Partnership Projects: Insights from Different Alternating Offer Sequences of Participants." *Journal of Construction Engineering and Management*, 143(3), 4016102.

Liang, G.-S., and Wang, M.-J. J. (1991). "A fuzzy multi-criteria decision-making method for facility site selection." *International Journal of Production Research*, Taylor & Francis, 29(11), 2313–2330.

Lin, H. Y., Liao, C. J., and Chang, Y. H. (2010). "Applying fuzzy simple additive weighting system to health examination institution location selection." *Proceedings - 2010 IEEE 17th International Conference on Industrial Engineering and Engineering Management, IE and EM2010*, 646–650.

Lindsay, J. M. (2012). "Compulsory acquisition of land and compensation in infrastructure projects." *PPP Insights*, PPP in Infrastructure Resource Center for Contracts, Laws and Regulation (PPPIRC), Washington, D.C., 1(3), 1–10.

Liou, J. J. H., and Tzeng, G. H. (2007). "A non-additive model for evaluating airline service quality." *Journal of Air Transport Management*, 13(3), 131–138.

Liu, J., Li, B., Lin, B., and Nguyen, V. (2007). "Key issues and challenges of risk management and insurance in China's construction industry: an empirical study." *Industrial Management & Data Systems*, 107(3), 382–396.

Liu, J., Li, Q., and Wang, Y. (2013). "Risk analysis in ultra deep scientific drilling project - A fuzzy synthetic evaluation approach." *International Journal of Project Management*, 31(3), 449–458.

Liu, J., Love, P. E. D., Davis, P. R., Smith, J., and Regan, M. (2015a). "Conceptual framework for the performance measurement of public-private partnerships." *Journal of Infrastructure Systems*, 21(1).

Liu, J., Love, P. E. D., Smith, J., Regan, M., and Davis, P. R. (2015b). "Life cycle critical success factors for public-private partnership infrastructure projects." *Journal of Management in Engineering*, 31(5), 4014073(7).

Liu, T. T., and Wang, Y. C. (2018). "Examining Critical Factors Affecting Knowledge Transfer in Public-Private Partnership (PPP) Projects." *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*, K. W. Chau, I. Y. S. Chan, W. Lu, and C. Webster, eds., Springer Singapore, Singapore.

Lodhi, A. L. (2014). *Costing and Tariff setting in power sector of Pakistan*. Institute of Cost and Management Accountants of Pakistan (ICMAP), Pakistan.

Loosemore, M., and Cheung, E. (2015). "Implementing systems thinking to manage risk in public private partnership projects." *International Journal of Project Management*, 33(6), 1325–1334.

Loosemore, M., and McCarthy, C. (2008). "Perceptions of Contractual Risk Allocation in Construction Supply Chains." *Journal of Professional Issues in Engineering Education and Practice*, 134(1), 95–105.

Loosemore, M., Raftery, J., and Reilly, C. (2006). *Risk management in projects, 2nd Ed.* Taylor and Francis, Abingdon, England.

Macdonald, R. (1997). *Chinese BOT risks*. unpublished Research Report, Tokyo University, Tokyo, Japan.

Malik, A. R. (2015). "A miracle on the Indus river." The Diplomat, <http://thediplomat.com/2015/12/a-miracle-on-the-indus-river/> (Jan. 4, 2017).

Mandri-Perrott, C., and Menzies, I. (2010). *Private sector participation in light rail-light metro transit initiatives*. World Bank, Washington D.C.

Mangione, T. W. (1995). *Mail surveys: Improving the quality*. Sage Publications, California, USA.

De Marco, A., and Mangano, G. (2013). "Risk and value in privately financed health care projects." *Journal of Construction Engineering and Management*, 139(8), 918–926.

Marichal, J.-L. (2000a). "An axiomatic approach of the discrete Choquet integral as a tool to aggregate interacting criteria." *IEEE Transactions on Fuzzy Systems*, 8(6), 800–807.

Marichal, J.-L. (2000b). "Behavioral analysis of aggregation in multicriteria decision aid." *Preferences and Decisions under Incomplete Knowledge*, J. Fodor, B. De Baets, and P. Perny, eds., Physica-Verlag, 153–178.

Marichal, J.-L. (2004). “Tolerant or intolerant character of interacting criteria in aggregation by the Choquet integral.” *European Journal of Operational Research*, 155(3), 771–791.

Marichal, J. L., and Roubens, M. (2000). “Determination of weights of interacting criteria from a reference set.” *European Journal of Operational Research*, 124(3), 641–650.

Marle, F., and Vidal, L. A. (2011). “Project risk management processes: Improving coordination using a clustering approach.” *Research in Engineering Design*, 22(3), 189–206.

Marques, R., and Berg, S. (2010). “Revisiting the Strengths and Limitations of Regulatory Contracts in Infrastructure Industries.” *Journal of Infrastructure Systems*, American Society of Civil Engineers, 16(4), 334–342.

Marques, R., and Berg, S. (2011). “Risks, Contracts, and Private-Sector Participation in Infrastructure.” *Journal of Construction Engineering and Management*, 137(11), 925–932.

Martini, C. A., and Lee, D. Q. (1996). “Difficulties in infrastructure financing.” *Journal of Applied Finance and Investment*, 1(1), 24–27.

Matsukawa, T., and Habeck, O. (2007). *Review of Risk Mitigation Instruments for Infrastructure*. The World Bank, Washington DC.

Matsumoto, T. (2012). “Risk Management and Governance for PFI Project: Technology Policy Lessons from the Case of Japan.” MS Thesis, Massachusetts Institute of Technology, Cambridge, Massachusetts, United States.

Mazher, K. M., Chan, A. P. C., and Zahoor, H. (2017). “A research framework for effective risk management in public-private partnership (ppp) infrastructure projects in Pakistan.” *13th International Postgraduate Research Conference (IPGRC 2017)*, C. Pathirage, U. Kulatunga, Y. Ji, R. Gameson, C. Udeaja, C. Trillo, M. Takhtravanchi, and B. Allali, eds., University of Salford, Salford.

McDowall, E. (2003). “Applications of risk management strategies in public-private partnership procurement.” *Public-private partnerships: Managing risks and opportunities*, A. Akintoye, M. Beck, and C. Hardcastle, eds., Blackwell Science Ltd, Oxford, U.K, 183–204.

Medda, F. (2007). “A game theory approach for the allocation of risks in transport public private partnerships.” *International Journal of Project Management*, 25(3), 213–218.

Meduri, S. S., and Annamalai, T. R. (2013). “Unit Costs of Public and PPP Road Projects: Evidence from India.” *Journal of Construction Engineering and Management*, 139(1), 35–43.

Meng, X., Zhao, Q., and Shen, Q. (2011). “Critical success factors for transfer-operate-transfer urban water supply projects in china.” *Journal of Management in Engineering*, 27(4), 243–251.

Multilateral Investment Guarantee Agency (MIGA). (2009). *World investment and political risk*. Multilateral Investment Guarantee Agency (MIGA), The International Bank for Reconstruction and Development / The World Bank, Washington, DC.

Miller, G. A. (1956). "The magical number seven, plus or minus two: some limits on our capacity for processing information." *Psychological Review*, 63(2), 81–97.

Ministry of Planning Development & Reform. (2016). "FAQs." CPEC Secretariat, Ministry of Planning, Development & Reform, Pakistan, <http://www.cpec.gov.pk/faqs> (Nov. 26, 2016).

Ministry of Water and Power. (2005). *Guidelines for determination of Tariff for Independent Power Producers (IPPs)*. Government of Pakistan, Pakistan.

Mirza, J. (2017). "Japan wants Pakistan to open CPEC for other countries." *The News*, Karachi.

Mitchell, M. L., and Jolley, J. M. (2012). *Research Design Explained*. *Cengage Learning*.

Monteiro, R. S. (2008). "Public-Private Partnerships in the Czech Republic: Setting up a proper risk management system at the project level (Twinning Project CZ/2005/IB/FI/04)." Ministerstvo financí, Prague, Parpública SA, Portugal, <http://www.mfcr.cz/assets/cs/media/Twinning_2008-09_Setting-up-a-proper-risk-management-system-at-the-project-level-2008-09.ppt> (Oct. 19, 2016).

Moro Visconti, R. (2011). "Inflation Risk and Project Finance." *SSRN Electronic Journal*, 21.

Moro Visconti, R. (2014). "Multidimensional principal–agent value for money in healthcare project financing." *Public Money & Management*, Routledge, 34(4), 259–264.

Morse, A. (2009). *Commercial skills for complex government projects*. *National Audit Office*, UK.

Motiar Rahman, M., and Kumaraswamy, M. M. (2005). "Assembling integrated project teams for joint risk management." *Construction Management and Economics*, Routledge, 23(4), 365–375.

Mubin, S., and Ghaffar, A. (2008). "BOT contracts: Applicability in Pakistan for infrastructure development." *Pakistan Journal of Engineering and Applied Sciences*, 3, 33–46.

National Audit Office. (2006). *A Framework for evaluating the implementation of Private Finance Initiative projects: Volume 1*. National Audit Office, London.

National Treasury. (2004). *PPP manual Module 4: PPP feasibility study*. PPP Unit, National Treasury, Johannesburg, South Africa.

Nelms, C. (2012). "A risk identification framework and tool for large infrastructure public private partnership delivery." PhD Thesis, University of British Columbia, Vancouver, Canada.

Ng, A., and Loosemore, M. (2007). "Risk allocation in the private provision of public infrastructure." *International Journal of Project Management*, 25(1), 66–76.

Ng, S. T., and Skitmore, R. M. (2002). "Contractors' risks in Design, Novate and Construct contracts." *International Journal of Project Management*, 20(2), 119–126.

Ng, S. T., Wong, Y. M. W., and Wong, J. M. W. (2012). "Factors influencing the success of PPP at feasibility stage - A tripartite comparison study in Hong Kong." *Habitat International*, 36(4), 423–432.

Nguyen, D. A. (2017). "Improving public-private partnership contracts through risk characterization, contract mechanisms, and flexibility." PhD Thesis, Virginia Polytechnic Institute and State University, Virginia, US.

Nguyen, D. A., Garvin, M. J., and Gonzalez, E. E. (2018). "Risk Allocation in U.S. Public-Private Partnership Highway Project Contracts." *Journal of Construction Engineering and Management*, 144(5), 4018017.

Nieto-Morote, A., and Ruz-Vila, F. (2011). "A fuzzy approach to construction project risk assessment." *International Journal of Project Management*, 29(2), 220–231.

Noor, M. A. (2011). "Investigating the role of procurement practices in effective implementation of infrastructure projects in a developing country: A case of Pakistan." PhD Thesis, RMIT University, Melbourne.

Noor, M. A., Khalfan, M. M. A., and Maqsood, T. (2012). "Methods used to procure infrastructure projects in Pakistan: An overview." *International Journal of Procurement Management*, 5(6), 733–752.

Norusis, M. J. (2003). *SPSS 12.0 Statistical Procedures Companion*. Prentice Hall PTR, Chicago.

NPWC/NBCC Joint working Party. (1990). "'No Dispute' Paper 1 - Risk Allocation." *Australian Construction Law Newsletter*, (14), 8–15.

Nwangwu, G. (2016). *Public private partnerships in Nigeria: Managing risks and identifying opportunities*. Palgrave Macmillan, London.

Ogunlana, S. (1997). "Build Operate Transfer procurement traps: examples from transportation projects in Thailand." *Proceedings of CIB W92 symposium on procurement*, CIB, Montreal, Canada, 585–594.

Olanipekun, A. O., Chan, A. P. C., Xia, B., and Ameyaw, E. E. (2017). "Indicators of owner commitment for successful delivery of green building projects." *Ecological Indicators*, 72, 268–277.

Onisawa, T., Sugeno, M., Nishiwaki, Y., Kawai, H., and Harima, Y. (1986). "Fuzzy measure analysis of public attitude towards the use of nuclear energy." *Fuzzy Sets and Systems*, 20(3), 259–289.

Oranization for Economic Co-operation and Development. (2008). *Public-private partnerships: In pursuit of risk sharing and value for money*. OECD Publicatoins, Paris, France.

Organization for Economic Cooperation and Development. (2009). *Private sector participation in water infrastructure: OECD checklist for public action*. OECD publications, Paris, France.

Osei-Kyei, R. (2018). *A best practice framework for public-private partnership implementation for infrastructure development in Ghana*. PhD Thesis, The Hong Kong Polytechnic University, Hong Kong.

Osei-Kyei, R., and Chan, A. P. C. (2015). "Review of studies on the Critical Success Factors for Public–Private Partnership (PPP) projects from 1990 to 2013." *International Journal of Project Management*, 33(6), 1335–1346.

Osei-Kyei, R., and Chan, A. P. C. (2017a). "Developing a Project Success Index for Public–Private

Partnership Projects in Developing Countries." *Journal of Infrastructure Systems*, 23(4), 4017028.

Osei-Kyei, R., and Chan, A. P. C. (2017b). "Risk assessment in public-private partnership infrastructure projects: Empirical comparison between Ghana and Hong Kong." *Construction Innovation*, 17(2), 204–223.

Osipova, E. (2008). "Risk management in construction projects: A comparative study of the different procurement options in Sweden." PhD Thesis, Luleå University of Technology, Sweden.

Özdoganm, I. D., and Talat Birgönül, M. (2000). "A decision support framework for project sponsors in the planning stage of build-operate-transfer (BOT) projects." *Construction Management and Economics*, 18(3), 343–353.

Ozorhon, B., and Cinar, E. (2015). "Critical Success Factors of Enterprise Resource Planning Implementation in Construction: Case of Turkey." *Journal of Management in Engineering*, 31(6), 4015014.

Panko, R. R. (1998). "What we know about spreadsheet errors." *Journal of Organizational and End User Computing (JOEUC)*, 10(2), 15–21.

Pantelias, A., and Zhang, Z. (2010). "Methodological framework for evaluation of financial viability of public-private partnerships: Investment risk approach." *Journal of Infrastructure Systems*, 16(4), 241–250.

Park, T., Kim, B., and Kim, H. (2013). "Real option approach to sharing privatization risk in underground infrastructures." *Journal of Construction Engineering and Management*, 139(6), 685–693.

Partnerships Victoria. (2003). *Contract management guide*. Department of Treasury and Finance, Melbourne, Australia.

Partnerships Victoria. (2005). *Managing interest rate risk*. Victorian Department of Treasury and Finance, Melbourne, Victoria, Australia.

Patel, D. A., and Jha, K. N. (2017). "Developing a process to evaluate construction project safety hazard index using the possibility approach in India." *Journal of Construction Engineering and Management*, 143(1), 4016081.

Pellegrino, R., Ranieri, L., Costantino, N., and Mummolo, G. (2011). "A real options-based model to supporting risk allocation in price cap regulation approach for public utilities." *Construction Management and Economics*, 29(12), 1197–1207.

Phillips, R. (2008). "Matrix of Risks Distribution - Roads." PPP in Infrastructure Resource Center for Contracts, Laws and Regulations (PPPIRC), World Bank, <http://ppp.worldbank.org/public-private-partnership/sites/ppp.worldbank.org/files/documents/roadriskmatrix_1.pdf> (Oct. 19, 2016).

Pipattanapiwong, J., Ogunlana, S., and Watanabe, T. (2003). "Multi-Party Risk Management Process for a Public-Private Partnership Construction Project in Asia." *Public-Private Partnerships: Managing Risks and Opportunities*, A. Akintoye, M. Beck, and C. Hardcastle, eds., Blackwell Science Ltd, Oxford, UK, 351–368.

Posner, R. A., and Rosenfield, A. M. (1977). "Impossibility and Related Doctrines in Contract Law: An Economic Analysis." *The Journal of Legal Studies*, The University of Chicago PressThe University of Chicago Law School, 6(1), 83–118.

Power Africa. (2018). *Guide to Community Engagement for Power Projects in Kenya*. Power Africa, Nairobi, Kenya.

Public-Private Infrastructure Advisory Facility (PPIAF). (2009a). "Risk management: Tool kit for public-private partnerships in roads & highways." Public-Private Infrastructure Advisory Facility, <https://ppiaf.org/sites/ppiaf.org/files/documents/toolkits/highwaystoolkit/6/pdf-version/5-37.pdf> (Oct. 23, 2017).

Public-Private Infrastructure Advisory Facility (PPIAF). (2009b). "Dispute Resolution." Public-Private Infrastructure Advisory Facility, <https://ppiaf.org/sites/ppiaf.org/files/documents/toolkits/highwaystoolkit/5/5-72.html> (Oct. 19, 2016).

Public-Private Infrastructure Advisory Facility (PPIAF). (2016). *The State of PPPs: Infrastructure public-private partnerships in emerging markets & developing economies 1991-2015*. Public-Private Infrastructure Advisory Facility / World Bank, Washington D.C.

PPP Knowledge Lab. (2018a). "Power." *PPP Knowledge Lab*, <https://pppknowledgelab.org/sectors/power> (Jul. 4, 2018).

PPP Knowledge Lab. (2018b). "Transport." *PPP Knowledge Lab*, <https://pppknowledgelab.org/sectors/transport>.

Project Management Institute. (2009). *Practice standard for project risk management*. Project Management Institute, Newtown Square, Pa.

Project Management Institute. (2013). *A guide to the Project Management Body of Knowledge (PMBOK guide)*. Project Management Institute, Newtown Square, Pa.

Public Private Partnerships Programme. (2007). *4Ps - A Guide to contract management for PFI and PPP projects*. 4Ps, UK.

Queensland Treasury. (2013). *Gateway review guidebook for project owners and review teams*. Queensland Government, Department of Infrastructure and Planning, Queensland.

Quiggin, J. (2005). "Public-private partnerships: Options for improved risk allocation." *Australian Economic Review*, 38(4), 445–450.

Qureshi, F., and Akintug, B. (2014). "Hydropower Potential in Pakistan." *11th International Congress in Advances in Civil Engineering-ACE 2014*, Istanbul Technical University, Istanbul, Turkey.

R Development Core Team. (2005). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing.

Rahman, M., and Kumaraswamy, M. (2004). "Potential for Implementing Relational Contracting and Joint Risk Management." *Journal of Management in Engineering*, American Society of

Civil Engineers, 20(4), 178–189.

Rai, V. (2009). *Public private partnerships (PPP) in infrastructure projects: Public auditing guidelines*. Comptroller and Auditor General of India.

Raisbeck, P., Duffield, C., and Xu, M. (2010). "Comparative performance of PPPs and traditional procurement in australia." *Construction Management and Economics*, 28(4), 345–359.

Rall, J., Reed, J. B., and Farber, N. J. (2010). *Public-Private Partnerships for Transportation: A Toolkit for Legislators / NCSL Partners Project on Public-Private Partnerships (PPPs) for Transportation*. National Conference of State Legislatures (NCSL), Colorado and Washington.

Rana, S. (2015). "UK to partner in CPEC, provide $121.6 million grant." *The Express Tribune*, <https://tribune.com.pk/story/948870/uk-to-partner-in-cpec-provide-121-6-million-grant/> (Jul. 16, 2016).

Ray, K. S. (2015). *Soft computing and its Applications, Volume I: A unified engineering concept*. Apple Academic Press, Oakville, Canada.

Raymond, J. (2008). "Benchmarking in public procurement." *Benchmarking: An International Journal*, 15(6), 782–793.

Rebeiz, K. S. (2012). "Public-private partnership risk factors in emerging countries: BOOT illustrative case study." *Journal of Management in Engineering*, 28(4), 421–428.

Reijniers, J. J. A. M. (1994). "Organization of public-private partnership projects. The timely prevention of pitfalls." *International Journal of Project Management*, 12(3), 137–142.

Reside, J. R. E. (2009). *Global determinants of stress and risk in public-private partnerships (PPP) in infrastructure*. ADBI Working Paper Series 133, Asian Development Bank Institute, Tokyo.

Rizzolo, L., Abichou, B., Voisin, A., and Kosayyer, N. (2011). "Aggregation of health assessment indicators of industrial systems." *The 7th conference of the European Society for Fuzzy Logic and Technology, EUSFLAT-2011, Jul 2011*, Aix-Les-Bains, France.

Robinson, H., Carrillo, P., Anumba, C. J., and Patel, M. (2010). *Governance and knowledge management for public-private partnerships*. Wiley-Blackwell, Chichester, West Sussex.

Robson, C. (2002). *Real world research: A resource for social scientists and practitioner-researchers, 2nd Ed.* Blackwell Publishers, Oxford, England.

Rockart, J. F. (1981). "The changing role of the information system executive: a critical success factor perspective." *Sloan Management Review*, 15–25.

Rothballer, C., and Gerbert, P. (2015). "Preparing and structuring bankable PPP projects." *Public private partnerships for infrastructure and business development*, S. Caselli, G. Corbetta, and V. Vecchi, eds., Palgrave Macmillan US, New York.

Roumboutsos, A., and Anagnostopoulos, K. P. (2008). "Public private partnership projects in Greece: Risk ranking and preferred risk allocation." *Construction Management and Economics*, 26(7), 751–763.

Rowley, H. V., Geschke, A., and Lenzen, M. (2015). "A practical approach for estimating weights of interacting criteria from profile sets." *Fuzzy Sets and Systems*, 272(1), 70–88.

Roy, D., Kalidindi, S., and Soundararajan, A. (2014). "Risk allocation in concession agreements for PPP road projects in India." *Urbanization in Asia: Governance Infrastructure and the Environment*, 119–136.

Sachs, T., Tiong, R., and Wang, S. Q. (2007). "Analysis of political risks and opportunities in public private partnerships (PPP) in China and selected Asian countries: Survey results." *Chinese Management Studies*, Emerald, 1(2), 126–148.

Santos, J. R. A. (1999). "Cronbach's alpha: A tool for assessing the reliability of scales." *Journal of extension*, 37(2), 1–5.

Saunders, M., Lewis, P., and Thornhill, A. (2012). *Research methods for business students*. Pearson, Harlow, England.

Schaufelberger, J. E., and Wipadapisut, I. (2003). "Alternate financing strategies for build-operate-transfer projects." *Journal of Construction Engineering and Management*, 129(2), 205–213.

Schieg, M. (2006). "Risk management in construction project management." *Journal of Business Economics and Management*, Taylor & Francis, 7(2), 77–83.

Schindler, M., and Eppler, M. J. (2003). "Harvesting project knowledge: A review of project learning methods and success factors." *International Journal of Project Management*, 21(3), 219–228.

Schwab, K. (2016). *The Global Competitiveness Report 2016–2017*. *World Economic Forum Reports 2016*, World Economic Forum, Geneva.

Schwartz, G., Corbacho, A., and Funke, K. (Eds.). (2008). *Public investment and public-private partnerships: Addressing infrastructure challenges and managing fiscal risks*. International Monetary Fund.

Shahneel, M. (2012). "Public private partnership - Case Study: Project structure & risk matrix." State Bank of Pakistan, Karachi, <http://www.sbp.org.pk/departments/ihfdfin.htm> (May 10, 2018).

Shan, L., Garvin, M. J., and Kumar, R. (2010). "Collar options to manage revenue risks in real toll public-private partnership transportation projects." *Construction Management and Economics*, 28(10), 1057–1069.

Shaoul, J., Stafford, A., and Stapleton, P. (2006). "Highway Robbery? A Financial Analysis of Design, Build, Finance and Operate (DBFO) in UK Roads." *Transport Reviews*, Routledge, 26(3), 257–274.

Shaukat, A., Choudhry, R. M., and Gabriel, H. F. (2011). "Comparison of Project Delivery Methods Used in Building Construction Projects." *Sixth International Conference on Construction in the 21st Century (CITC-VI), Construction Challenges in the New Decade*, Kuala Lumpur, Malaysia.

Shen, L. Y., Platten, A., and Deng, X. P. (2006). "Role of public private partnerships to manage risks in public sector projects in Hong Kong." *International Journal of Project Management*, 24(7), 587–594.

Shen, L. Y., and Wu, Y. Z. (2005). "Risk concession model for build/operate/transfer contract projects." *Journal of Construction Engineering and Management*, 131(2), 211–220.

Siegel, S., and Castellan, N. J. (1988). *Nonparametric statistics for the behavioral sciences*. McGraw-Hill, Maidenhead.

Soomro, M. A., and Zhang, X. (2011). "Analytical review on transportation public private partnerships failures." *International Journal of Sustainable Construction Engineering and Technology*, 2(2).

Soomro, M., and Zhang, X. (2015a). "Roles of Private-Sector Partners in Transportation Public-Private Partnership Failures." *Journal of Management in Engineering*, American Society of Civil Engineers, 31(4), 4014056.

Soomro, M., and Zhang, X. (2015b). "Evaluation of the Functions of Public Sector Partners in Transportation Public-Private Partnerships Failures." *Journal of Management in Engineering*, 32(1), 4015027.

SPSS Inc. (2010). *SPSS Statistcs Base User's Guide 17.0*. Statistical Package for Social Sciences, Inc., Chicago, IL.

State Bank of Pakistan. (2007). *The Pakistan infrastructure report*. State Bank of Pakistan, Islamabad.

State Bank of Pakistan. (2013). *The state of Pakistan's economy: Annual report 2011-2012*. State Bank of Pakistan, Islamabad.

State Bank of Pakistan. (2016). *Prudential regulations for infrastructure project financing (IPF)*. State Bank of Pakistan, Isalamabad.

Stemmer, E. (2008). *Contractual structures and risk allocation and mitigation in the context of public private partnerships in the health sector*. World Bank, Washington, DC.

Sugeno, M. (1974). *Theory of fuzzy integrals and its applications*. PhD Thesis, Tokyo Institute of Technology, Tokyo, Japan.

Tah, J. H. M., and Carr, V. (2000). "A proposal for construction project risk assessment using fuzzy logic." *Construction Management and Economics*, 18(4), 491–500.

Tam, C. M. (1999). "Build-operate-transfer model for infrastructure developments in Asia: reasons for successes and failures." *International Journal of Project Management*, 17(6), 377–382.

Tan, C., Wu, D. D., and Ma, B. (2011). "Group decision making with linguistic preference relations with application to supplier selection." *Expert Systems with Applications*, 38(12), 14382–14389.

Tang, L., Shen, Q., and Cheng, E. W. L. (2010a). "A review of studies on Public-Private Partnership projects in the construction industry." *International Journal of Project Management*, 28(7), 683–694.

Tang, L., Shen, Q., and Cheng, E. W. L. (2010b). “A review of studies on Public–Private Partnership projects in the construction industry.” *International Journal of Project Management*, 28(7), 683–694.

Taus-Bolstad, S. (2003). *Pakistan in Pictures*. Lerners Publications Company, Minneapolis.

Tavakoli, H. (2013). *A dictionary of research methodology and statistics in applied linguistics*. Rahnama Press.

The News. (2017a). “IPPs invoke sovereign guarantee for Rs48bln dues.” *The News*, <https://www.thenews.com.pk/print/189984-IPPs-invoke-sovereign-guarantee-for-Rs48bln-dues> (Jun. 15, 2018).

The News. (2017b). “France eyes business opportunities offered under CPEC.” *The News*, <https://www.thenews.com.pk/print/196490-France-eyes-business-opportunities-offered-under-CPEC> (Jun. 15, 2018).

Thomas, A. V, Kalidindi, S. N., and Ananthanarayanan, K. (2003). “Risk perception analysis of BOT road project participants in India.” *Construction Management and Economics*, 21(4), 393–407.

Thomas, A. V, Kalidindi, S. N., and Ganesh, L. S. (2006). “Modelling and assessment of critical risks in BOT road projects.” *Construction Management and Economics*, 24(4), 407–424.

Tiong, R. L. K. (1995). “Risks and guarantees in BOT tender.” *Journal of Construction Engineering and Management*, 121(2), 183–188.

Tiwari, S., and Ashish, A. (2013). “A review on cancellation of PPP projects in India.” *International Journal of Advanced and Innovative Research*, 2(6), 202–213.

Tribune. (2017). “On Hyderabad-Mirpurkhas Road: SHC orders reduction in toll tax.” *The Express Tribune*, <https://tribune.com.pk/story/1299666/hyderabad-mirpurkhas-road-shc-orders-reduction-toll-tax/> (Jun. 15, 2018).

Trivedi, A., and Singh, A. (2017). “A hybrid multi-objective decision model for emergency shelter location-relocation projects using fuzzy analytic hierarchy process and goal programming approach.” *International Journal of Project Management*, 35(5), 827–840.

Tzeng, G. H., and Huang, J.-J. (2011). *Multiple attribute decision making : methods and applications*. CRC Press, Boca Raton, FL.

United Nations Commission on International Trade Law (UNCITRAL). (2001). *Legislative guide on privately financed infrastructure projects*. United Nations Commission on International Trade Law, United Nations Publications, New York.

United Nations Environment Programme (UNEP). (2006). *Financing water: Risks and opportunities*. Issue Paper, United Nations Environment Programme - Finance Initiative.

United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). (2008). *Public-private partnerships in infrastructure development: A Primer*. Transport Division, United Nations Economic and Social Commission for Asia and the Pacific, Bangkok, Thailand.

United Nations Industrial Development Organization (UNIDO). (1996). *Guidelines for infrastructure development through BOT Projects*. United Nations Industrial Development Organization (UNIDO) Publication, Vienna, Austria.

United Nations Economic Commission for Europe (UNECE). (2000). "Negotiation platform for public-private partnerships in infrastructure projects." New York, <http://www.unece.org/fileadmin/DAM/ie/ppp/documents/negotiation.pdf> (May 7, 2016).

United Nations Economic Commission for Europe (UNECE). (2008). *Guidebook on promoting good governance in public-private partnership*. United Nations Economic Commission for Europe, United Nations Publications, New York and Geneva.

Vagliasindi, M. (2013). *Revisiting public-private partnerships in the power sector*. International Bank for Reconstruction and Development / The World Bank, Washington D.C.

Valipour, A., Yahaya, N., Md Noor, N., Kildiene, S., Sarvari, H., and Mardani, A. (2015). "A fuzzy analytic network process method for risk prioritization in freeway PPP projects: An Iranian case study." *Journal of Civil Engineering and Management*, 21(7), 933–947.

Valipour, A., Yahaya, N., Md Noor, N., Mardani, A., and Antuchevičienė, J. (2016). "A new hybrid fuzzy cybernetic analytic network process model to identify shared risks in PPP projects." *International Journal of Strategic Property Management*, 20(4), 409–426.

Victoria Department of Treasury and Finance (VDTF). (2001). "Risk allocation and contractual issues." *Department of Treasury and Finance*, <http://www.dtf.vic.gov.au/files/c9f5ed58-1da2-417e-9081-a1cb01133eab/Risk-Allocation-and-Contractual-Issues1-Entire.pdf> (Dec. 22, 2016).

Virginia Public-Private Partnerships. (2015). *P3 Risk Management Guidelines*. Commonwealth of Virginia.

Wang, C. H., Lu, I. Y., and Chen, C. B. (2010). "Integrating hierarchical balanced scorecard with non-additive fuzzy integral for evaluating high technology firm performance." *International Journal of Production Economics*, 413–426.

Wang, J., and Yuan, H. (2011). "Factors affecting contractors' risk attitudes in construction projects: Case study from China." *International Journal of Project Management*, 29(2), 209–219.

Wang, S. Q., and Tiong, L. K. (2000). "Case study of government initiatives for PRC's BOT power plant project." *International Journal of Project Management*, 18(1), 69–78.

Wang, S. Q., Tiong, R. L. K., Ting, S. K., and Ashley, D. (2000a). "Evaluation and management of foreign exchange and revenue risks in China's BOT projects." *Construction Management and Economics*, 18(2), 197–207.

Wang, S. Q., Tiong, R. L. K., Ting, S. K., and Ashley, D. (2000b). "Foreign exchange and revenue risks: Analysis of key contract clauses in China's BOT project." *Construction Management and Economics*, 18(3), 311–320.

Wang, S. Q., Tiong, R. L. K., Ting, S. K., and Ashley, D. (2000c). "Evaluation and management of political risks in China's BOT projects." *Journal of Construction Engineering and*

Management, 126(3), 242–250.

Wang, Y.-M., and Elhag, T. M. S. (2007). “A fuzzy group decision making approach for bridge risk assessment.” *Computers & Industrial Engineering*, 53(1), 137–148.

Wasif, S. (2016). “Hyderabad-Sukkur section: China, S Korea lobbying for M-6 motorway.” *The Express Tribune*, <https://tribune.com.pk/story/1150871/hyderabad-sukkur-section-china-s-korea-lobbying-m-9-motorway/> (Jun. 15, 2018).

Wen, X., Yan, M., Xian, J., Yue, R., and Peng, A. (2016). “Supplier selection in supplier chain management using Choquet integral-based linguistic operators under fuzzy heterogeneous environment.” *Fuzzy Optimization and Decision Making*, 15(3), 307–330.

Wibowo, A., and Mohamed, S. (2010). “Risk criticality and allocation in privatised water supply projects in Indonesia.” *International Journal of Project Management*, 28(5), 504–513.

Wibowo, A., and Taufik, J. (2017). “Developing a self-assessment model of risk management maturity for client organizations of public construction projects: Indonesian context.” *Procedia Engineering*, 274–281.

Wong, K. Y., and Aspinwall, E. (2005). “An empirical study of the important factors for knowledge-management adoption in the SME sector.” *Journal of Knowledge Management*, 9(3), 64–82.

Woolf, F., and Halpern, J. (2001). *Integrating independent power producers into emerging wholesale power markets*. Policy Research Working Paper No. 2703, World Bank, Washington D.C.

World Bank. (1994). *World development report 1994: Infrastructure for development*. Oxford University Press Inc., Madison Avenue, New York.

World Bank. (2005). *Approaches to private participation in water services*. The International Bank for Reconstruction and Development / The World Bank, Washington DC.

World Bank. (2010). *Pakistan - Operational design for the project development fund and for the viability gap fund*. World Bank, Washington, DC.

World Bank. (2015). “World Development Indicators (GDP ranking 2015).” The World Bank, <http://data.worldbank.org/data-catalog/GDP-ranking-table> (Feb. 12, 2017).

World Bank. (2016a). “World development indicators (Population, Total).” World Bank, <http://data.worldbank.org/indicator/SP.POP.TOTL?order=wbapi_data_value_2014+wbapi_data_value+wbapi_data_value-last&sort=desc> (Feb. 12, 2017).

World Bank. (2016b). “Government objectives: Benefits and risks of PPPs.” World Bank, <http://ppp.worldbank.org/public-private-partnership/overview/ppp-objectives> (Oct. 19, 2016).

World Bank. (2016c). “Public-Private Partnerships Laws / Concession Laws.” World Bank, <http://ppp.worldbank.org/public-private-partnership/legislation-regulation/laws/ppp-and-concession-laws> (Oct. 19, 2016).

World Bank. (2016d). “Regulation of sectors and regulatory issues impacting PPPs.” World Bank,

<http://ppp.worldbank.org/public-private-partnership/legislation-regulation/regulatory> (Oct. 19, 2016).

World Bank. (2016e). “Force majeure clauses - Checklist and sample wording.” World Bank, <http://ppp.worldbank.org/public-private-partnership/ppp-overview/practical-tools/checklists-and-risk-matrices/force-majeure-checklist> (Oct. 19, 2016).

World Bank. (2016f). *The World Bank Group A to Z 2016*. The World Bank, Washington, DC.

World Bank. (2017). *Guidance on PPP contractual provisions*. Washington DC.

World Bank. (2018a). “Grantor | PPP Knowledge Lab.” *PPP Knowledge Lab*, <https://pppknowledgelab.org/glossary/grantor> (Jun. 29, 2018).

World Bank. (2018b). “Private participation in infrastructure database.” The World Bank, <http://ppi.worldbank.org/> (Jun. 15, 2018).

World Bank. (2018c). “Legal Issues on Energy and Power PPPs.” *World Bank*, <https://ppp.worldbank.org/public-private-partnership/sector/energy> (Jul. 4, 2018).

World Bank. (2018d). “Environmental Standards and Engineering Standards.” *PPPLRC Public-Private-Partnership Legal Resource Center*, <https://ppp.worldbank.org/public-private-partnership/legislation-regulation/framework-assessment/legal-environment/standards-public-liability> (Jul. 22, 2018).

World Bank. (2018e). “World Bank Open Data.” *World Bank*, <https://data.worldbank.org/> (Jun. 6, 2018).

World Bank. (2018f). “Public-Private Partnerships in Roads.” <https://ppp.worldbank.org/public-private-partnership/sector/transportation/roads-tolls-bridges/road-concessions> (Jun. 3, 2018).

World Bank, Asian Development Bank, and Inter-American Development Bank. (2014). *Public Private Partnerships Reference Guide Version 2.0*. World Bank Publications, The World Bank Group, Washington, DC.

World Economic Forum. (2010). *Paving the way: Maximising the value of private finance in infrastructure*. World Economic Forum, New York, USA.

Wu, J., Zhang, Q., Du, Q., and Dong, Z. (2014). “Compromise principle based methods of identifying capacities in the framework of multicriteria decision analysis.” *Fuzzy Sets and Systems*, North-Holland, 246, 91–106.

Xenidis, Y., and Angelides, D. (2005a). “The financial risks in build-operate-transfer projects.” *Construction Management and Economics*, 23(4), 431–441.

Xenidis, Y., and Angelides, D. (2005b). “The legal risks in build-operate-transfer projects.” *Journal of Construction Research*, 6(2), 273–292.

Xiong, W., Zhao, X., Yuan, J.-F., and Luo, S. (2017). “Ex Post Risk Management in Public-Private Partnership Infrastructure Projects.” *Project Management Journal*, 48(3), 76–89.

Xu, Y., Chan, A. P. C., Xia, B., Qian, Q. K., Liu, Y., and Peng, Y. (2015). “Critical risk factors affecting the implementation of PPP waste-to-energy projects in China." *Applied Energy*, 158, 403–411.

Xu, Y., Chan, A. P. C., and Yeung, J. F. Y. (2010a). "Developing a fuzzy risk allocation model for PPP projects in China." *Journal of Construction Engineering and Management*, 136(8), 894–903.

Xu, Y., Yeung, J. F. Y., Chan, A. P. C., Chan, D. W. M., Wang, S. Q., and Ke, Y. (2010b). "Developing a risk assessment model for PPP projects in China-A fuzzy synthetic evaluation approach." *Automation in Construction*, 19(7), 929–943.

Yang, J. L., Chiu, H. N., Tzeng, G. H., and Yeh, R. H. (2008). "Vendor selection by integrated fuzzy MCDM techniques with independent and interdependent relationships." *Information Sciences*, 178(21), 4166–4183.

Yang, J., Shen, G. Q., Ho, M., Drew, D. S., and Chan, A. P. C. (2009). "Exploring critical success factors for stakeholder management in construction projects." *Journal of Civil Engineering and Management*, Taylor & Francis, 15(4), 337–348.

Yang, W. h., and Dai, D. s. (2006). "Concession decision model of BOT projects based on a real options approach." *Proceedings of International conference on management science and engineering (ICMSE '06)*, IEEE, Lille, 307–312.

Yang, Y. Q., Wang, S. Q., Dulaimi, M., and Low, S. P. (2003). "A fuzzy quality function deployment system for buildable design decision-makings." *Automation in Construction*, 12(4), 381–393.

Ye, S., and Tiong, R. (2000a). "NPV-at-Risk Method in Infrastructure Project Investment Evaluation." *Journal of Construction Engineering and Management*, American Society of Civil Engineers, 126(3), 227–233.

Ye, S., and Tiong, R. K. L. (2000b). "Government support and risk-return trade-off in China's BOT power projects." *Engineering Construction and Architectural Management*, 7(4), 412–422.

Ye, S., and Tiong, R. L. K. (2003). "Effects of tariff design in risk management of privately financed infrastructure projects." *Journal of Construction Engineering and Management*, 129(6), 610–618.

Yeo, K. T., and Tiong, R. L. K. (2000). "Positive management of differences for risk reduction in BOT projects." *International Journal of Project Management*, 18(4), 257–265.

Yescombe, E. R. (2007). *Public-private partnerships : principles of policy and finance*. Elsevier, Amsterdam.

Yeung, J. F. Y. (2007). "Developing a partnering performance index for construction projects – a fuzzy set theory approach." The Hong Kong Polytechnic University, Hong Kong.

Yin, R. K. (2009). *Case study research: Design and methods, 4th Ed.* SAGE Publications, Inc., California, USA.

Yu, J., Jeon, M., and Kim, T. W. (2015). "Fuzzy-based composite indicator development methodology for evaluating overall project performance." *Journal of Civil Engineering and Management*, 21(3), 343–355.

Yuan, J. f., Deng, X. p., and Li, Q. m. (2008a). "The relationship of critical risk factors in Chinese PPP projects: Modeling perspective." *2008 International Conference on Information Management, Innovation Management and Industrial Engineering*, IEEE, Taipei, 151–154.

Yuan, J., Skibniewski, M. J., and Li, Q. (2008b). "Managing the performance of public private partnership projects to achieve value for money: Key performance indicators selection." *CIB W112 International conference on multi-natoinal construction projects: Securing high performance through cultural awareness and dispute avoidance*, International Council for Research and Innovation in Building and Construction, Rotterdam, Netherlands.

Zadeh, L. A. (1965). "Fuzzy sets." *Information and Control*, 8(3), 338–353.

Zadeh, L. A. (1975a). "The concept of a linguistic variable and its application to approximate reasoning-I." *Information Sciences*, 8(3), 199–249.

Zadeh, L. A. (1975b). "The concept of a linguistic variable and its application to approximate reasoning—II." *Information Sciences*, Elsevier, 8(4), 301–357.

Zahoor, H., Chan, A. P. C., Utama, W. P., Gao, R., and Memon, S. A. (2017). "Determinants of Safety Climate for Building Projects: SEM-Based Cross-Validation Study." *Journal of Construction Engineering and Management*, 143(6), 5017005.

Zatar, M. (2014). "Pitfalls of public private partnership in toll roads." MS Thesis, The University of Texas at Arlington, Texas.

Zayed, T., Amer, M., and Pan, J. (2008). "Assessing risk and uncertainty inherent in Chinese highway projects using AHP." *International Journal of Project Management*, 26(4), 408–419.

Zayed, T. M., and Chang, L. M. (2002). "Prototype model for build-operate-transfer risk assessment." *Journal of Management in Engineering*, 18(1), 7–16.

Zegordi, S. H., Rezaee Nik, E., and Nazari, A. (2012). "Power plant project risk assessment using a fuzzy-ANP and fuzzy-TOPSIS method." *International Journal of Engineering Transactions B: Applications*, 25(2), 107–120.

Zerah, M.-H., and Graham-Harrison, K. P. (2000). *The cancellation of the Pune Water Supply and Sewerage Project - challenges in private sector participation (English)*. Water and Sanitation Program case study. South Asia, World Bank Group, Washington, D.C.

Zhang, S., Chan, A. P. C., Feng, Y., Duan, H., and Ke, Y. (2016). "Critical review on PPP Research – A search from the Chinese and International Journals." *International Journal of Project Management*, 34(4), 597–612.

Zhang, X. (2005a). "Critical success factors for public-private partnerships in infrastructure development." *Journal of Construction Engineering and Management*, 131(1), 3–14.

Zhang, X. (2005b). "Financial viability analysis and capital structure optimization in privatized public infrastructure projects." *Journal of Construction Engineering and Management*, 131(6), 656–668.

Zhang, X. (2005c). “Criteria for selecting the private-sector partner in public-private partnerships.” *Journal of Construction Engineering and Management*, 131(6), 631–644.

Zhang, X. (2005d). “Concessionaire’s financial capability in developing build-operate-transfer type infrastructure projects.” *Journal of Construction Engineering and Management*, 131(10), 1054–1064.

Zhang, X. Q., Kumaraswamy, M. M., Zheng, W., and Palaneeswaran, E. (2002). “Concessionaire selection for build-operate-transfer tunnel projects in Hong Kong.” *Journal of Construction Engineering and Management*, 128(2), 155–163.

Zhang, X., and Soomro, M. A. (2015). “Failure Path Analysis with Respect to Private Sector Partners in Transportation Public-Private Partnerships.” *Journal of Management in Engineering*, 32(1), 4015031.

Zhao, X., Hwang, B., and Low, S. (2013). “Developing fuzzy enterprise risk management maturity model for construction firms.” *Journal of Construction Engineering and Management*, 139(9), 1179–1189.

Zitron, J. (2006). “Public-private partnership projects: Towards a model of contractor bidding decision-making.” *Journal of Purchasing and Supply Management*, 12(2), 53–62.

Zou, P., Chen, Y., and Chan, T. (2009). “Understanding and Improving Your Risk Management Capability: Assessment Model for Construction Organizations.” *Journal of Construction Engineering and Management*, 136(8), 854–863.

Zou, P. X. W., Wang, S., and Fang, D. (2008). “A life-cycle risk management framework for PPP infrastructure projects.” *Journal of Financial Management of Property and Construction*, Emerald, 13(2), 123–142.

Zou, W. (2012). “Relationship management in public private partnership infrastructure projects.” *PhD Thesis*, The University of Hong Kong, Pokfulam Road, Hong Kong SAR.