Incorporation of sustainability considerations in PPP projects; an exploratory study of risk

Thesis of

Master of Science

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has been accepted towards the partial fulfillment
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Dedication

I dedicate my work to my father for being my inspiration, to my mother for believing in my abilities, to my sisters for their undeterred emotional support and to my brother for encouraging me to solve my own problems

Acknowledgement

First and foremost, I want to thank my Creator for giving me the resilience and perseverance to complete all my tasks. Words fall short to express my gratitude towards my family for their continuous patience, encouragement, prayers and sacrifices throughout this time.

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Beenish

Abstract

Public private partnership (PPP) has been recognized as a potential model for delivery of sustainable infrastructure. The long-duration and risk-sharing mechanisms of PPP provide a unique opportunity for fostering innovation and driving sustainable development. However, efficiency gains from these features can be materialized only through effective implementation. In PPP projects, sole reliance on the traditional project management procedures and processes limits scope of decision making to the contract duration and the contracting parties. For more informed decision-making, it is useful to align the management of large infrastructure projects with the core values of sustainability assessment focusing both short- and long-term impacts of the project and the changing project environment during its life cycle. In particular, such limitations in approach result in a rigid treatment of risk during the risk assessment of PPP projects. Therefore, the study focuses on analyzing PPP infrastructure risks in terms of their possible deterrent effect on sustainability impacts and proposing possible mitigation strategies. A triple bottom line hierarchy of sustainability indicators has been employed over which the impact of various risks is traced both quantitatively and qualitatively. The probability-impact assessment for risk has been carried out through an international survey for highway sector projects procured under PPP. Furthermore, sensitivity analysis has been carried out for measuring probabilistic risk scores of the various risk impacts over the three groups of sustainability; financial, environmental, and social. Additionally, mitigation strategies for the most sensitive risk relationships are devised with the help of experts. Human health damages indicator of environmental sustainability has the highest range of risk score. However, life cycle cost indicator of financial sustainability has the most amount of risks acting on it. For social sustainability, the socio-economic repercussions indicator has the highest value of risk score range as compared to other impact categories. Overall, the study will help decision makers to gain deeper insight into the chain of effects the risks may cause over the life cycle of the project, enabling them to develop a more inclusive risk management framework for PPP projects.

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Chapter 1

INTRODUCTION

1.1 Background:

Sound infrastructure development plays a key role in fostering economic growth. When guided by the principles of sustainable development, it has the potential to fight poverty, promote social welfare, protect environment, improve quality of life and human well-being. Sustainable infrastructure development is one of the most important policy objectives of this era regarding global commitment in the form of Agenda 21 and UN sustainable development goals. It is envisioned in the sustainable development goals (SDGs) to *"develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all."*

For emerging markets and developing economies (EMDE) countries, the booming infrastructure demand has given rise to a staggering infrastructure deficit. According to Asian Development Bank, between 2010 and 2020, Asia alone needs to spend approximately US$8.2 trillion in order to maintain current levels of economic growth (Bhattacharyay, 2010). In addition, approximately US$320 billion on some 1202 regional infrastructure projects in transport, energy and telecommunications is required during the period (Bank, 2009; Bhattacharyay et al., 2012). However, governments do not have the financial capabilities required for public infrastructure delivery. Thus, it has become popular to partner with the private sector for infrastructure and service delivery through public-private-partnerships (PPPs). PPPs are long-term contracts for infrastructure delivery or service provision in which the private sectors bear risks and management responsibility, substantially (Grimsey and Lewis, 2007). When implemented properly, PPPs can be used as tool for overcoming the infrastructure gap effectively with fostering sustainable growth (Olusola, 2016; Udechukwu, 2012).

EMDE countries are capitalizing on the private investment for initiating ambitious large infrastructure projects. According to PPI annual report, PPI investment of US$93.3 billion was recorded across 304 projects, in 2017. The countries with the highest level of private investment as per the report are China, Indonesia, Mexico, Brazil and Pakistan. However, as PPPs are complex, high-budget, and high-risk projects, decision-makers are still struggling to develop best practice solutions for establishing PPP as an effective model for resilient, affordable and sustainable infrastructure delivery. Although, some inherent features of the PPP contract like the long contract duration and risk-revenue sharing mechanism, are in line with the sustainability agenda (Hu and Zhu, 2014; UN, 2013), yet integrating sustainability in PPP projects requires a holistic, life cycle based approach (Patil and Laishram, 2016b). This is necessary because the long project duration of the projects makes them more sensitive to the changing project environment (Alasad and Motawa, 2015).

In this regard, strenuous efforts are required to achieve sustainability in PPP infrastructure projects. Additionally, relying on only the traditional project management procedures and processes limits scope of decision making to the contract duration and the contracting parties. For more informed decision-making, it is more useful to align the management of large infrastructure projects with the core values of sustainability assessment focusing both on short-term and long-term impacts of the project and the changing project environment during the life cycle (Liu et al., 2016; Liu et al., 2015). In particular, such limitations in approach result in a rigid treatment of risk during the risk assessment of PPP projects (Zou, 2008). Over the lifecycle of the project, the probability of occurrence will vary with the changing dynamics of the project boundaries. In the same way, the impact of one risk may create long-lasting impacts creating a chain of impacts forming a risk chain over time affecting multiple project objectives (Nasirzadeh, 2014). For example, inflation changes with the changing market conditions. It not only effects the project initial cost but unpredictable market variations can have significant impact over the life cycle cost as well. Additionally, inflation risk not only impacts the contracting parties but also effect the users of the facility and the overall social benefits being created by the project in the long run. Traditional approach to risk assessment in PPP projects, though useful is unable to capture this effect, substantially (Kang et al., 2005).

Overall, from a decision making perspective, the operationalization of sustainability beyond an ideological level to a practical level requires careful interpretation of its multi-objective nature, difficult conceptualization and complicated implementation (Bagheri and Hjorth, 2007). For an inclusive understanding, the triple-bottom line approach covering the social, environment and financial approach is particularly useful in PPP projects. These projects are multi-stakeholder setups, in which the goals of the parties are essentially conflicting. The private party seek greater revenue opportunities for achieving attractive rate of return on the investment (Patil and Laishram, 2016a) while the government seeks to maximize the social welfare (Zhu, 2015). As the government is dependent on the private party for finance, financial gains become the primary objective of the project, giving less emphasis to the provision of environmental and social objectives in the procurement process (Rouhani et al., 2016). Therefore, envisioning the performance of PPPs as a three-tier sustainability hierarchy is efficient. Thus, it is imperative to explore the effect of project risks over indicators used to determine the sustainability performance of PPP projects.

1.2 Problem Statement:

Risk assessment in PPP projects are either context-oriented or methodology-oriented. The context-oriented studies focus on exploring the effect of risk through varying contextual dynamics (Yuan et al., 2018; Zeng et al., 2008; Zou et al., 2008). The country of project execution, type of project being delivered, characteristics, procurement method and life cycle phases (Zou et al., 2008), are some of the relevant variables explored in these studies. Additionally, exploring the effect and perception of risk on various other contract design constraints, for example, concession period, NPV (Ye and Tiong, 2000), and contract timing is an important area of study in PPP literature. On the other hand, the methodology-oriented studies focus on improving the ranking of risks through application of modelling and simulation techniques (Jin, 2008; Medda, 2007; Xu, 2010). These studies are focused on improvement in precision of the risk analysis process i-e achieving greater precision in risk measurement. However, the outlook of analyzing risks with respect to their impact on desired long-term project sustainability deliverables in has not been yet sufficiently explored (Fernández-Sánchez and Rodríguez-López, 2010).

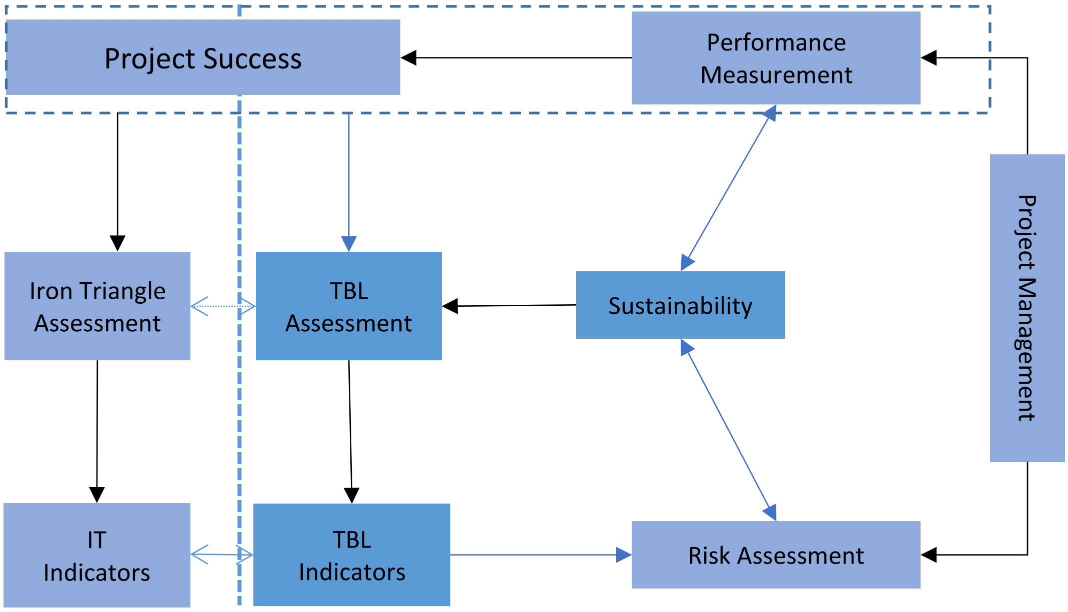

Figure 1.1 Conceptual framework of the study

Envisioning such an assessment requires integration of sustainability assessment with project success (Martens and Carvalho, 2016). For construction projects based on long term contracts, measurement of success demands the extension of concepts of project success beyond the iron-triangle definition (Liu et al., 2016). This is useful because the positive and negative impacts of these projects are much higher, extending much beyond the project boundary. This demands interpretation of sustainability under the umbrella of project management (Silvius and Schipper, 2014). This will allow decision makers to use the different sustainability assessment frameworks for performance measurement both during feasibility stage and later on during project execution phase. For the sake of holistic assessment of sustainability, triple-bottom assessment is desired (Elkington and Rowlands, 1999). The triple-bottom line framework can be used to assess the project performance against criteria belonging to social, environmental and financial areas, under project management (Singh et al., 2009). At the level of feasibility and project evaluation, risk assessment of project is done to assess the level of uncertainty in the project and their possible impact on the project success. When the success of project is extended to include sustainability assessment, sustainability becomes an opportunity during the mitigation of risks (Martens and Carvalho, 2016). Expanding this concept, the present study focuses on analyzing PPP infrastructure risks in terms of their possible deterrent effect on sustainability impacts and proposing possible mitigation strategies. Such an assessment will help decision makers to focus their attention towards developing a risk management framework for assessing the project performance in terms of its holistic impacts in and outside the project boundaries. Risk is interpreted as threats to the overall project sustainability impacts. In this way, understanding risk manifestation in project impacts will help understand the threats to sustainability realization ultimately contributing in facilitating the development of sustainable projects.

1.3 Context of Study

This study is being conducted in context of PPP based highway infrastructure projects. Highways are selected for the study because of the key role it plays in economic development of any country. This can be observed by a simple fact that developed countries have dramatically better transportation infrastructure than poorer nations (Banerjee et al., 2012). Kalra et al. (2016) are of the view that improving foreign direct investment, boosting private sector participation and strengthening transport infrastructure vitalize economic development in the long run. Additionally, increase in travel demands require massive development of transportation infrastructure. In recent years, involving the private sector for infrastructure delivery has become a popular method for overcoming infrastructure deficits. Governments are now in favor of having the private investors play an increased role in the investment and operation of transportation infrastructure projects (Chen and Subprasom, 2007a). According to 2015 global PPI update (WorldBank, 2016) , transport investment stood at US$69.9 billion, 29 percent above the previous year (US$54.3 billion), largely because of major airport projects. This investment is also 53 percent above the five-year average (US$45.6 billion per year) and

86 percent above the 10-year average (US$37.6 billion). However, to deliver sustainable infrastructure projects, it is important that sustainability be introduced as a goal during project development and stakeholders offer commitment for development of sustainable projects. This is important because complex projects have multi-faceted impacts on society. These impacts are positive and negative in nature. During the project development process, such factors should be included in the value for money analysis which are related to the social and environmental aspects of the project to ensure sustainability (Kumaraswamy et al., 2005). This means that the stakeholders should not only focus on fiscal sustainability but also on the environmental and social context of sustainability to ensure overall wellbeing. One efficient way to put sustainability in perspective is to assess the risks which are critical to sustainability of the project (Foerstl et al., 2010). Such a risk assessment will not only cover the financial stressors but help to assess the impacts on the wider environmental, cultural and social layer surrounding the project. Such a risk assessment will provide a more holistic view of the project effects and give an early chance of proposing mitigating strategies for such risks resulting in a more sustainable system (Yilmaz and Flouris, 2010).

1.4 Research Significance

In Pakistan, limited fiscal space, combined with substantial infrastructure needs are drivers favoring private participation in the infrastructure. Like other emerging economies, Pakistan is also seeking PPPs as a viable tool to fill huge infrastructure gaps owing to the economic expansion of the country and growth prospects (WorldBank, 2010). Although, there are visible improvements after success of counter-terrorism operations in the country, regional and local geo-political and geo-economic challenges still plague the investment climate of the country (ADB, 2015). Construction industry in Pakistan has long suffered from lack of public spending and limited private interest. Other issues at hand have been widespread corruption and lack of protection for property owners. According to the latest PPI update, Pakistan is the 5th highest country in terms of private investment. Regional financing, under CEPEC, is proving beneficial to the country with Asian Development Bank (ADB) providing USD800mn of loans to strengthen the country's power sector infrastructure as well as co-funding the USD327mn Hassanabdal-Havelian Expressway (E-35) project. Still, however, the country is struggling to sustain its PPP projects given the huge financing requirements of about 866 projects including the pressing needs of the China Pakistan Economic Corridor (CPEC) (PlanningCommission, 2016). For such pressing needs, private sector needs to be mobilized for removing infrastructure bottlenecks. In the past, the private sector has been constrained from playing an active role in the country's development due to a variety of factors such as the energy deficit, red tapes, lack of security, poor policies and the lack of an enabling environment. In addition to these problems, low skilled labor, slow and costly judicial procedures (contract enforcement), factor market (land, labor and capital) rigidities, intrusive regulations and inadequacies in the system of land purchase and registration have reduced private sector effectiveness. In vision 2025, government has expressed commitment to reach its infrastructure goals (PlanningCommission, 2015). However, for improved planning and development of more sustainable projects, it is important to work on developing workable solutions in managing the PPP projects across the entire life cycle. Risk assessment from the angle of sustainability offering stakeholders a deeper insight into the long-term positive and negative impacts of their projects and timely proposition of mitigating strategies to capitalize the opportunity of a sustainable outcome. This study will thus provide useful guidance to stakeholders interested in developing and procuring sustainable road infrastructure through PPP delivery mechanism.

1.5 Research Objectives

i. To identify and categorize risk factors in highway infrastructure PPP projects in relevance to sustainability.

ii. To map and measure the effect of critical risks on sustainability indicators.

iii. To propose strategies for mitigation of these critical risks

Chapter 2

LITERATURE REVIEW

2.1 Sustainable Infrastructure Development

Infrastructure development is a driver for economic growth and positive social outcomes. But construction activities consume large amount of natural resources (Krajangsri and Pongpeng, 2016). Moreover, ill-planned infrastructure projects can create imbalance in the socio-economic landscape of any country creating financial burdens on local community, loss in livelihood and an overall decrease in quality of life (Sahoo and Dash, 2012). Thus, sustainable infrastructure development is originated out of human necessity. Aspiring for sustainability, in 1987, the United Nations (UN) World Commission on Environment and Development published the famous Brundtland Report, which recognized and defined the Sustainable development as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (Brundtland, 1987). Brundtland Report expanded the concept of sustainable development beyond the initial framework towards the goal of socially and environmentally sustainable economic growth (Sachs, 2015). In lines with global sustainability outlook, sustainable infrastructure development is envisioned by UN with special reference to Goal 9 of the 2030 Agenda for Sustainable Development, encouraging decision makers to look for sustainable development of projects through inclusive planning for environmental and social stressors (Griggs et al., 2013).

Integration of sustainability in infrastructure development not only enables sound economic development, job creation and the purchase of local goods and services, it also enhances quality of life for citizens, increases positive impacts (benefits), helps protect the vital natural resources and environment, and promotes a more effective and efficient use of financial resources (Diaz-Sarachaga et al., 2017). Investors can use sustainable approaches as opportunities for greater profit margin as well (Luke, 2005). Financial and economic benefits can result from reduced use of materials, improved pollution prevention, reduced carbon emissions, payment for environmental services, and better labor and community relations (Lenferink et al., 2013). Environmental sustainability can also improve the prospects for project financing (Grasman, 2014). However, higher upfront costs for environmental intervention may create public apprehension (Kumaraswamy, 2005). Experiences in many countries demonstrate that it is possible to plan, design, construct and maintain infrastructure in a fashion that properly manages any potentially negative environmental, social, and health and safety impacts and risks, while enhancing directly and indirectly related benefits (Redwood, 2012, 2014). For example, Mato Grosso do Sul State Road Transport Project in Brazil was highlighted in a recent World Bank report on improving environmental sustainability in road projects (Montgomery et al., 2015). In this project, the identification and implementation of more sustainable approaches to erosion control saved about US$46 million. Another example is the case of a road in a valuable natural dry forest land, identified as an extremely valuable biodiversity corridor in the Gran Chaco region in Argentina. The challenge of paving a 60km road through such a precious and vulnerable area was transformed into a sustainability opportunity. Sustainability measures included awareness signs and speed reduction measures in critical habitat areas, and special wildlife crossing/connectivity points were established with eight underground and three canopy wildlife crossings.

2.2 Sustainability in PPP Infrastructure Projects

Public private partnership is a complex yet effective approach to procurement and service delivery of public infrastructure projects (Hans Voordijk, 2016). Concession decision-making includes several financial and non-financial criteria. However, the focus of the decision makers is mostly on the financial criteria because of which projects fail ensure the overall wellbeing of the community inclusive of environment (Chen et al., 2017). The private party tends to invest in projects which are more financially beneficial for them (Hu and Zhu, 2015). In such a scenario, the risk of realization of social welfare and wider social/environmental wellbeing of the community is shifted on the government (Rouhani, 2015). Keeping such issues in perspective, there is a recognized need for using PPP as a tool for sustainable development (Grimsey, 2007) and incorporating sustainable considerations in PPP projects (Hueskes, 2017). The PPP delivery system has been acknowledged several times for having strong potential for delivering sustainable projects. It has several features which complement the strategic goals of sustainable development. For example, the long-term infrastructure contracts (LTIC) employed in PPP projects allow for incorporation of life cycle thinking during project's financial appraisal (Hueskes, 2017).

The content analysis of literature reveals that sustainability research in PPP is an emerging area of research, having two major lines of research, presently. Sustainable practices & processes (=17) covers the governance level considerations for sustainable infrastructure development through PPPs. In this regard, sustainable procurement mechanisms have been explored for inclusion of sustainability considerations in the PPP contractual arrangement. For example, (Kumaraswamy, 2005) explored the use of relational contracts for better management of PPP contracts for improving the sustainability in terms of better governance and effective partnership. (Hueskes, 2017) highlighted the role of government in this regard and concluded that government holds a key position in orienting infrastructure development towards sustainability. Patil (2016) highlighted that value for money (VFM) analysis lacks the incorporation of social and environmental externalities and thus needs to be improved. Furthermore, the bid evaluation criteria are deficient in terms of social and environmental issues which can lead to adverse socio-economic effects.

The other main aspect is sustainability assessment for measuring the sustainability performance of PPP projects (=6). Since, sustainability is a subjective concept, identifying suitable qualitative and quantitative indicators for measurement makes an integral part of sustainability assessment in PPP. Extending the same efforts, the present research explores the possibility of introducing sustainability considerations in the planning stage of the project development and particularly towards improvement of the risk assessment methodology through introduction of sustainability concerning performance indicators for a more informed assessment of project success.

2.3 Sustainability Indicators

Following the review of PPP studies incorporating sustainability, it is noted that different kinds of sustainability hierarchies have been established in literature. However, such hierarchies of sustainability indicators are focused according to their goal, scope and boundaries, which are more towards the procurement (Kumaraswamy, 2005) , planning (Dahl, 2005) or design (Koppenjan, 2015). For measuring the impacts of infrastructure projects on the surrounding social and environmental envelope requires clearly defined sustainability goals, criteria and indicators for assessment suitable to the contextual relevance. For example, Shen (2010b) proposed traditional triple bottom line (TBL) breakdown of key sustainability assessment indicators for road infrastructure projects. Also, an infrastructure rating system for developing countries was developed which is based on the Agenda 21 and the Millennium and Sustainable Development Goals (Diaz-Sarachaga et al., 2017). Management has been introduced in the framework as a requirement contributing as a link between the three TBL requirements for sustainability assessment. For introducing sustainability in general and overall perspectives, the traditional TBL seems to incorporate all other sort of aspects in its hierarchy of impact categories and tend to encompass more holistic version of issues and aspects (Hacking and Guthrie, 2008).This study, therefore, adopts the traditional TBL of the sustainability.

Owing to the large variety of indicators at sub-level of sustainability hierarchy, which is context specific and varies from project to project, the standardized, generic and holistic decision-making indicators are considered for this study. For environmental area of sustainability, (Goedkoop et al., 2009) has proposed human health damage, ecosystem damage and resource damage, as general environmental indicators, which further contain a detail variety of impacts (Menoufi et al., 2012). For social assessment, UNEP/SETAC guidelines and methodological sheets published a detail list of social assessment indicators, grouped into six stakeholder-based categories (Benoît-Norris et al., 2011). Based on the relevant stakeholder for PPP, five impact categories are selected for this study, as shown in Table 2-1. For financial area of sustainability, literature establishes the initial capital and lifecycle costs as two main indicators, accompanied by project investment schedule and internal rate of return (IRR) (Shen, 2010a). However, in a broader perspective, indicators like investment schedule and internal return rate are linked with the capital and lifecycle costs and can be considered at further low level of hierarchy. Also, the established functions for assessment of financial sustainability such as Net Present Value (NPV) or IRR inherently incorporate the impact of investment schedule and internal rate of return (Shen, 2002; Ye and Tiong, 2000). Therefore, this study used the initial cost and lifecycle cost as the sub indicators of financial area of sustainability.

Table 2-1 Selected Sustainability Indicators

Sustainability Area	**Indicator**
Financial Sustainability	Initial Cost (I1)
	Life Cycle Cost (I2)
Social Sustainability	Socio Economic Repercussions (I3)
	Health & Safety (I4)
	Cultural Heritage (I5)
	Governance (I6)
	Human Rights (I7)
Environmental Sustainability	Resource damage (I8)
	Ecosystem damage (I9)
	Human health (I10)

2.4 Risk Management in PPP projects

The complex nature of PPP system makes the interpretation and measurement of risk highly contextual (Bing, 2005; Carpintero, 2015; Heravi, 2012; Thomas, 2003). Risks can only be analyzed effectively if their manifestation in a certain context is fully understood by the decision makers. One of the most important aspects of PPP decision-making is effective and timely identification and assessment of risks. (Grimsey, 2002) were of the view that public and private collaboration is tricky and confusing because of the difference in cultural and institutional setups of different parties involved, creating a diverse risk perception. Both these studies pointed to the complexity of PPP delivery method and the additional risks originating from the complexity. Due to the increased level of complexity in PPP projects, numerous studies have been devoted to the identification, allocation and mitigation of risks (Li and Zou, 2011; Roumboutsos, 2013; Xu et al., 2010). In fact, risk management is one of the most specialized themes of PPP research. The research on management of risk in PPP infrastructure project encompasses multiple facets. Majorly, risk studies are focused on effective risk allocation of risks which is considered as the most critical issue in PPP context. Taxonomies of risks in various contexts have been developed for risk assessment and evaluation. From literature, it can be stated that risk assessment in PPP projects are either context-oriented or methodology-oriented. The context-oriented studies focus on exploring the effect of risk through varying contextual dynamics. The country of project execution, type of project being delivered, characteristics, procurement method and life cycle phases (Zou et al., 2008), are some of the relevant variables explored in these studies. Additionally, exploring the effect and perception of risk on various other contract design constraints, for example, concession period, NPV (Ye and Tiong, 2000), and contract timing is an important area of study in PPP literature. On the other hand, the methodology-oriented studies focus on improving the ranking of risks through application of modelling and simulation techniques. These include but are not limited to fuzzy-logic modelling (Jin, 2008; Xu, 2010) game theory (Medda, 2007), artificial neural networks (Jin and Zhang, 2011), neuro-fuzzy techniques (Jin, 2010, 2011), IRMS (Li et al., 2011) and fuzzy-AHP (Li and Zou, 2011). However, these studies are focused on improvement in precision of the risk analysis process; i.e. achieving greater precision in risk measurement. There is a limited research related to PPP risk management focused on analyzing risk for developing sustainable PPP projects. However, the need and importance of such an assessment has been highlighted in literature in recent studies. For example, (Diaz-Sarachaga et al., 2017) developed a rating system for sustainable road infrastructure projects. In the framework, a sustainable risk management (SRM) plan has been identified as one of the important criteria for assessing managerial requirements for sustainable assessment of road infrastructure projects. Such a framework is developed for aligning project development and implementation with the sustainability goals and criteria (Heravi, 2012). In some studies, instead of orienting the risk identification from the sustainability angle, sustainability has been attempted to be built into the traditional PRAM framework interpreting or associating it with project success (Silvius and Schipper, 2014). For this, risk assessment was identified as the sustainability assessment counterpart for the identification of threats and opportunities (Martens and Carvalho, 2016).

Following this research gap, in this study, research articles published between years 2000-2017 are analyzed to synthesize various risk factors in PPP infrastructure projects. 143 risk dimensions were identified and categorized into the following 21 groups: Economic, Financial, Policy & Regulatory, Political, Project development, Negotiation, Moral hazards, Relationships, Legal/Regulatory, Construction, Design, Technical, Technology, Health and safety, Corruption, Credit, Natural, Social, Site risks, Operation and Environmental. The risk breakdown structure (RBS) for these risks can be seen in Table 2-2.

Table 2-2 Taxonomy of risk classification for PPP infrastructure projects

Level 0	**Level 1**	**Level 1a**	**Level 2**	**Level2a**	**Level 3**						
PPP risks	Country risks		Economic		Influential economic events	Foreign exchange risk	Poor financial market	Interest rate volatility	Fluctuating inflation		
			Financial risks		Demand risk/Project usage risk	Financial attraction of project to investors	Credit risk	Delay in financial closure	High finance cost	Competing projects	ROI risk
			Legislative and regulatory risks		Change in government officials	Inadequate legal and regulatory framework	Legislative & regulatory restrictions				
			Political		Unstable political environment	Expropriation/nationalization of assets	Lack of support from government				
	Project Risks	Project development risks	Planning		Permitting risk	Availability of resources (Labor, material & finance)	Planning deficiency/ poor feasibility study				
			Procurement		High bidding cost	Competition risk	Conflict of corporate and social goals of project	Uncompetitive tender	Inadequate distribution of authority responsibility and risk in partnership	Complicated negotiation process	
			Design		Design flaws	Technology risk					
		Life cycle risks	Site		Land use and acquisition / resettlement and rehabilitation risk	H&S and security issues	Unpredicted site conditions and preparation				
			Construction	Time	Delay in completion (completion risk)	Excessive contract variation	Delayed construction initiation				
				Cost	Lack of supporting infrastructure	Cost overruns	Waste of material	Market variation			
				Quality	Changes in construction methods	Quality risk	Unproven engineering techniques				
			Operation		Availability risk	O&M risk	Low residual value (after concession period)	Operator default	Supporting facilities risk		
			Natural		Force majeure	Weather	Off-take risk				
			Social		Corruption	Generation of employment	Public opposition to the project				
			Environmental		Environmental degradation						
	Partnership		Relationship		Liabilities and disputes	Inadequate experience in PPPs	Different working methods	Mutual credibility			
			Contract		Consortium inability	Guarantees and warranties	Insolvency/ default risk				

The risks on level 3 were further ranked on the basis of their frequency and qualitative analysis scoring as shown in Table 2-3. On the basis of Literature Score (LS) and Relative Importance Index (RII), 20 risk factors were shortlisted for further analysis.

Table 2-3 Shortlisted risks from literature

Identified PPP risks	RII	LS	Rank
Demand risk/Project usage risk	0.50	0.05	1
Land use and acquisition / resettlement and rehabilitation risk	0.39	0.10	2
Fluctuating inflation	0.36	0.14	3
Legislative & regulatory changes/ restrictions	0.29	0.17	4
Design risk	0.27	0.20	5
Completion risk	0.26	0.22	6
Excessive contract variation	0.25	0.25	7
O&M risk	0.23	0.28	8
Public opposition to the project	0.23	0.30	9
Corruption	0.23	0.33	10
Interest rate volatility	0.20	0.35	11
Inadequate legal and regulatory framework	0.20	0.37	12
Inadequate distribution of authority responsibility and risk in partnership	0.20	0.39	13
Low residual value (after concession period)	0.20	0.41	14
Environmental degradation	0.20	0.44	15
Foreign exchange risk	0.19	0.46	16
Lack of support from government	0.19	0.48	17
Availability of resources (Labor, material & finance)	0.19	0.50	18
Force Majeure	0.19	0.51	19
Credit Risk	0.19	0.52	20

Chapter 3

RESEARCH METHODOLOGY

The study is divided into a 4-stage process for attaining the three pre-defined objectives as shown in Figure 3.1. In the first stage, a preliminary background research is done to define the problem statement and develop research objectives based on the problem statement. An initial literature search has been carried out to increase the know-how of the topic.

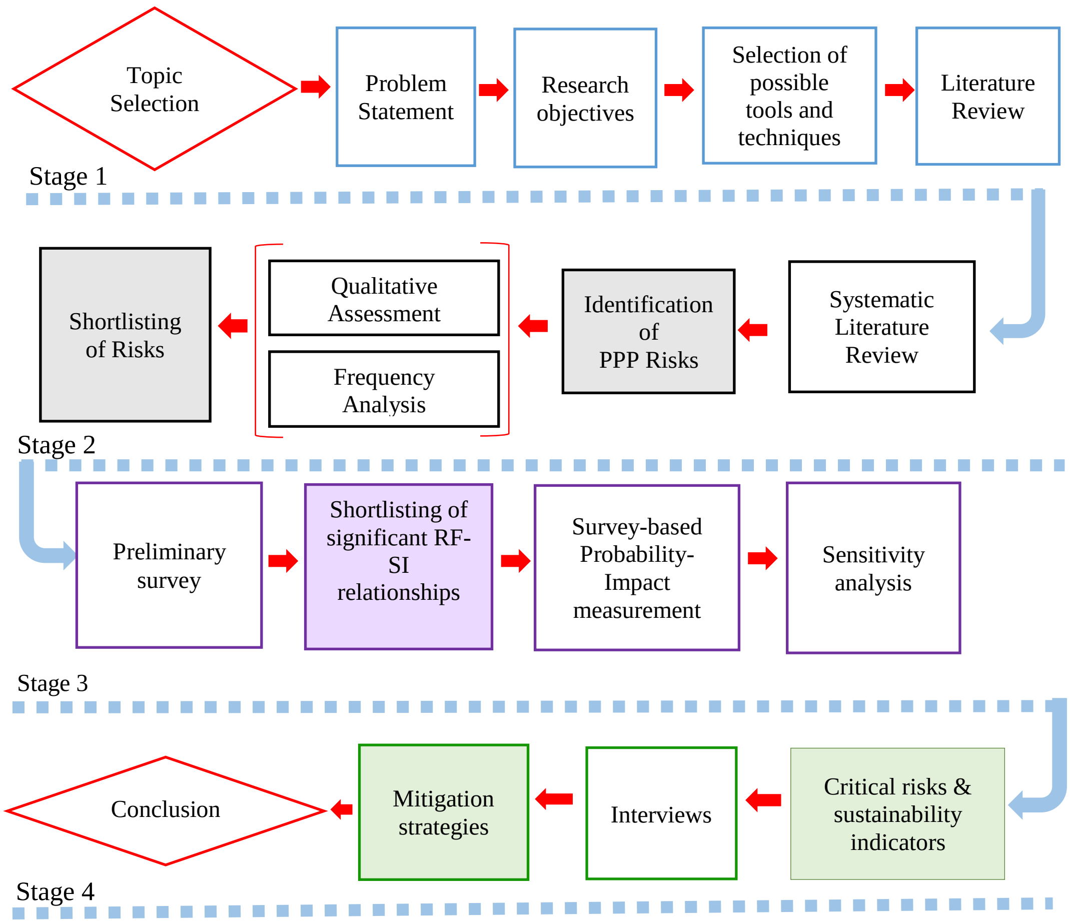

Figure 3.1 Methodological Framework of the Study

3.1 Systematic Literature Review

Furthermore, a systematic literature review for identification and shortlisting of risk factors and relevant sustainability indicators for assessment from the global infrastructure perspective. These sustainability indicators were categorized into three popular dimensions of sustainability i-e financial, environmental and social which are based on the triple bottom line ideology of sustainability categorization. Specifically, research articles ranging from 2000-2017 were analyzed to synthesize various risk factors in PPP infrastructure projects. A risk breakdown structure was developed comprising 143 risk dimensions, overall 21 risk groups categorized into three main categories. Out of these 143 risks, 20 factors were shortlisted based on frequency analysis and qualitative assessment based on frequency analysis and qualitative assessment. Furthermore, these 20 risk factors were categorized according to their relevancy to specific sustainability dimensions based on literature to act as a basis for further analysis.

3.2 Data Collection:

3.2.1 Structured Interview

A qualitative impact matrix was developed to explore the significant relationships between individual impact categories and risk factors irrespective of their parent groups. A preliminary structured interview session was conducted based on responses from a group comprising of 5 respondents belonging to academia. These respondents were selected on based on their relevant background to the study. The significance of relationships was decided based on the impact a certain risk factor has on a particular sustainability indicator. On a 1-5 Likert scale, if the impact was recorded greater than 2, the relationship was considered to be significant. These relationships were mapped out in the form a conceptual diagram for brevity in representation and increasing the understanding of the model logic during sensitivity analysis establishing the links between the risk factors and the relevant sustainability indicators.

3.2.2 International survey

After a qualitative assessment, a detailed international survey was carried out in context of highway infrastructure PPP projects for a quantitative risk assessment of the identified risk factor-sustainability indicator relations. The survey was conducted online through google forms and was dispersed to a global audience of field practitioners and academia via emails, social and professional websites. The experts were identified based on a snowballing technique. Out of the 1500 professionals contacted, 150 responses were obtained giving the response rate of the survey to be 10%.

The sample size was calculated according to (Dillman, 2000) methodology for conducting online surveys. The sample size for the detailed questionnaire was selected to be 96 for a population size of 40,000+ with a sampling error of ±10%. The sample size was calculated for a 95% confidence interval. Respondents were asked to rate the probability of occurrence of each risk-indicator relationship on a 9-point Likert scale for probability of occurrence and a 5-point Likert scale for assessing the impact each risk has on the relevant sustainability indicator. The range of the probability scale varied from 0.01 (0-1%- No chance) to 0.09 (99%- Certain). The range of impact was from 1-incidental to 5-Catastrophic.

3.3 Risk Analysis

Based on the results of the detailed questionnaire survey, risks were analyzed on the basis of their effect on the sustainability indicator system. Risk scores for each relationship was obtained using the formula given in Equation 3.1 where P is the probability and I is the impact of the RF-SI relationship. Both P and I are the commonly used criteria for measurement of risk (Ebrahimnejad, 2010).

$$R = P \times I \qquad \text{Equation 3.1}$$

The obtained risk scores were further normalized on a 0-1 scale using ‘divide by maximum’ method. These normalized risk scores were used for further analysis. A sensitivity analysis was conducted using @Risk software 5.5 for risk analysis and subsequent risk ranking. Based on the sensitivity analysis results, risk prioritization for each sustainability indicator and overall sustainability was obtained.

3.4 Semi-structured interviews:

To devise possible strategies for mitigation, face to face semi-structured interviews were conducted with industry experts. The interviews were interpretative in nature allowing the participants to trace the effect of a particular risk on a relevant sustainability indicator as per their experience and propose possible mitigations for the same. In this situation, semi-structured approach of interviews provided flexibility of framing the questions differently for the interviewees for ease of understanding, and the flow of discussion. The instrument design facilitated identifying potential areas of discussion, clarification in case of misinterpretation of terminologies, and additional probing questions for maintaining the focus of discussion on the desired outcomes.

The interviewees identified were all part of project team of PPP either from the public side or private side involved in delivery of PPP projects from planning to execution phase. All the respondents had relevant working experience of more than one PPP project. All the interviews were ranging from 45 mins-2hrs. Due to the richness of data collected, and conceptual saturation, six interviews were conducted in total (Francis et al., 2010; Longhurst, 2003; Morse, 2000).

Chapter 4

RESULTS AND DISCUSSION

4.1 Identification of Risks Significantly Impacting Sustainability

After systematic review and content analysis, a preliminary survey was carried out in order to shortlist significant sustainability impacting risky situations. For the purpose, an impact matrix of 20x20, consisting of 200 possible relationships was formulated with sustainability indicators on the horizontal axis and high frequency PPP risks on the vertical axis. A focus group of 5 respondents from academia were identified which were asked to rate the impact each risk has on individual sustainability indicators on a 1-5 Likert scale ranging from 1-Very Low to 5-Very High.

Table 4-1 Impact matrix for identification of significant RF-SI relationships

SI / **RF**	Initial Cost	Life Cycle Cost	SER	Health & Safety	Cultural Heritage	Governance	Human Rights	Resource Damage	Ecosystem Damage	Human Health
Interest rate volatility (R1)	4	3								
Foreign exchange risk (R2)	3	4								
Fluctuating inflation (R3)	4	4	4							
Demand risk (R4)		4	3							
Credit risk (R5)		3	3							
Land use & acquisition/resettlement & rehabilitation (R6)	3	3	4		4					3
Legislative & regulatory restrictions (R7)		3	4							3
Inadequate legal and regulatory framework (R8)		4	3			4				3
Design flaws (R9)		4		3						3
Completion risk (R10)		4	4							3
Excessive contract variation (R11)		4								
O&M risk (R12)		4	3	3		3				3
Low residual value (R13)		3								
Force Majeure (R14)		3	3							
Public opposition to the project (R15)	3	3	3	3		3	3			
Corruption (R16)	4	4	4			3	5			
Inadequate distribution of responsibility and risk (R17)	3	3	4			3	4			
Environmental degradation (R18)		4	3	3				3	3	5
Lack of support from government (R19)	4	4	4			3				
Availability of resources (R20)	3	4	3			3				
Frequency	9	20	15	4	1	7	3	1	1	7

Results were analyzed by qualitative assessment of responses on the basis of mode of the responses. Wherever there was lack of consensus on the rating of a certain relationship, the respondent was asked to review their rating to gain consensus over the rating on any relationship. Any relationship rated above 2 was considered to be significant. On the basis of this rating, 68 significant relationships were identified as shown in the Table 4 1. Life cycle cost was found to have a significant relationship with all the risk factors whereas, both resource damage, cultural heritage and ecosystem damage were found to have 1 risk-significant relationship as per the respondents' ratings. However, the number of risk-indicator relationships only provides an overall insight into the consideration of relationships in the later stage of the analysis. For example, resettlement and rehabilitation risk is the only risk significantly impacting cultural heritage but it has a significant relationship with 5 out of 10 sustainability indicators. The risks and their corresponding sustainability indicators have been mapped into a conceptual diagram delineating the inputs and outputs for the risk analysis model. The color coding of red, blue and green have been used for financial, social and environmental sustainability indicators, respectively. It is to be noted that the risk density for financial sustainability is the greatest as compared to others. This can indicate two things. All the risks seem to have a cost impact. Furthermore, the understanding of environmental and social impacts of the PPP projects is limited. So, it is difficult to translate or trace the impact of a certain risk to its relevant indicator. Furthermore, even with ample knowledge, respondents can tend to prioritize financial sustainability over others. Thus, a detailed analysis of these relationships is required to get a deeper insight into the complex risk system for sustainability.

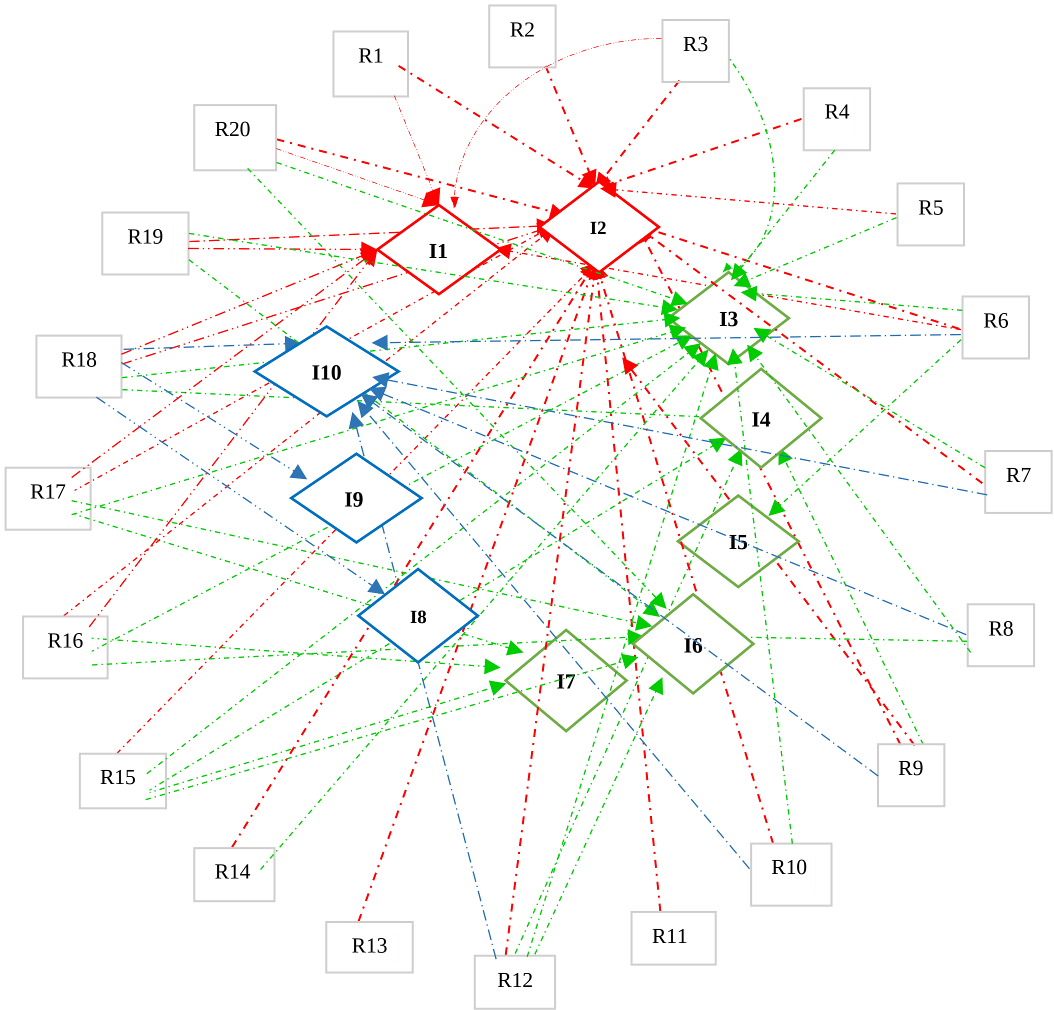

Figure 4.1 Risk map for sustainability

4.2 Risk Assessment

Risk may be objective or subjective. When a risky situation occurs repeatedly or is too complex to interpret, it is useful to obtain expert opinion to assess the situation. Moreover, subjective risk assessment provides useful construct for interpretation and measurement of risk surrounding any decision scenario. In light of the above argument, a detailed international survey was carried out for quantification of risks in a sustainability oriented-system of PPP highway projects. The questionnaire consisted of two parts; the first part focused on the demographical information of the respondents. In the second part of the survey, a probability-impact assessment was designed for the 68 significant risk factor-sustainability indicator relationships

4.3 Demographics

The demographics of the international survey are presented. As shown in Figure 4.2, 51% of the respondents were MS qualified and over 20 % of the respondents were PhDs.

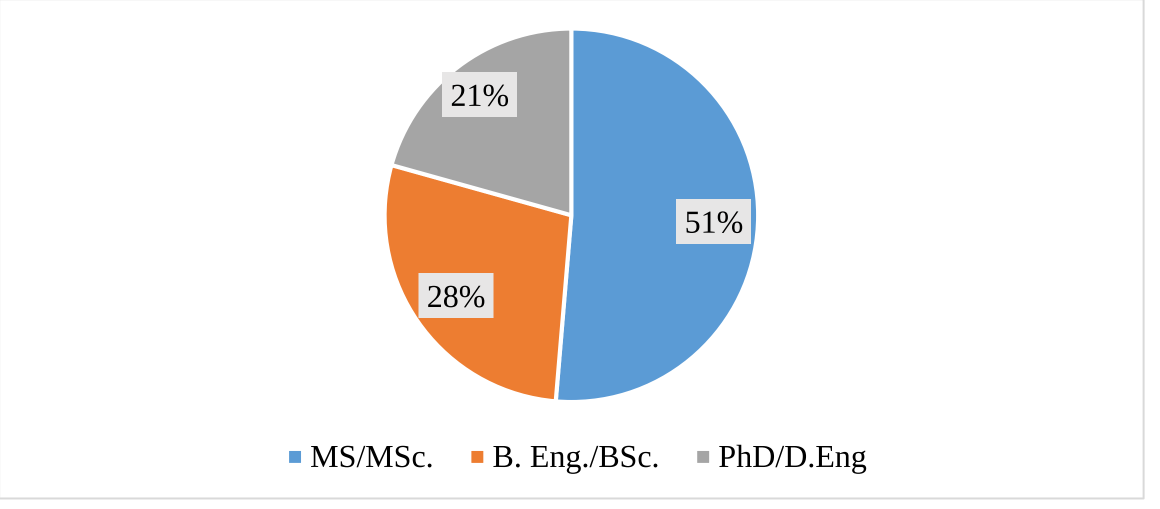

Figure 4.2 Respondents' qualifications

Overall, 54% of the respondents had more than 5 years of experience in managing highway sector PPP projects in Pakistan and abroad with 10 % of the respondents having more than 25 years of relevant experience.

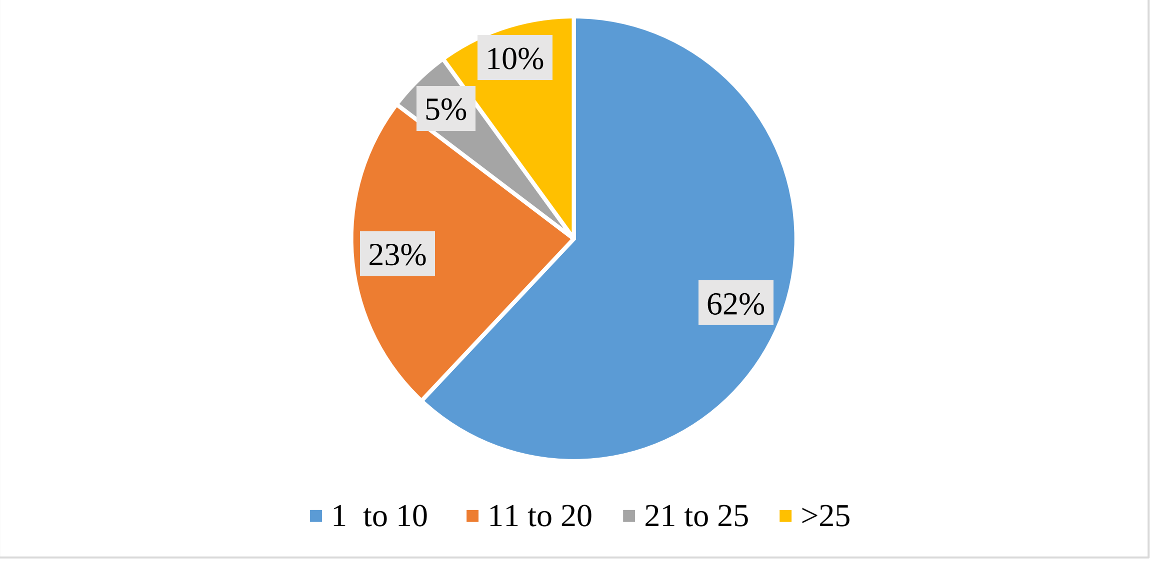

Figure 4.3 Respondents' experience

Moreover, it can be seen in the Figure 4.4, that more than 70% of the respondents belonged to lower-middle-income economies especially Pakistan.

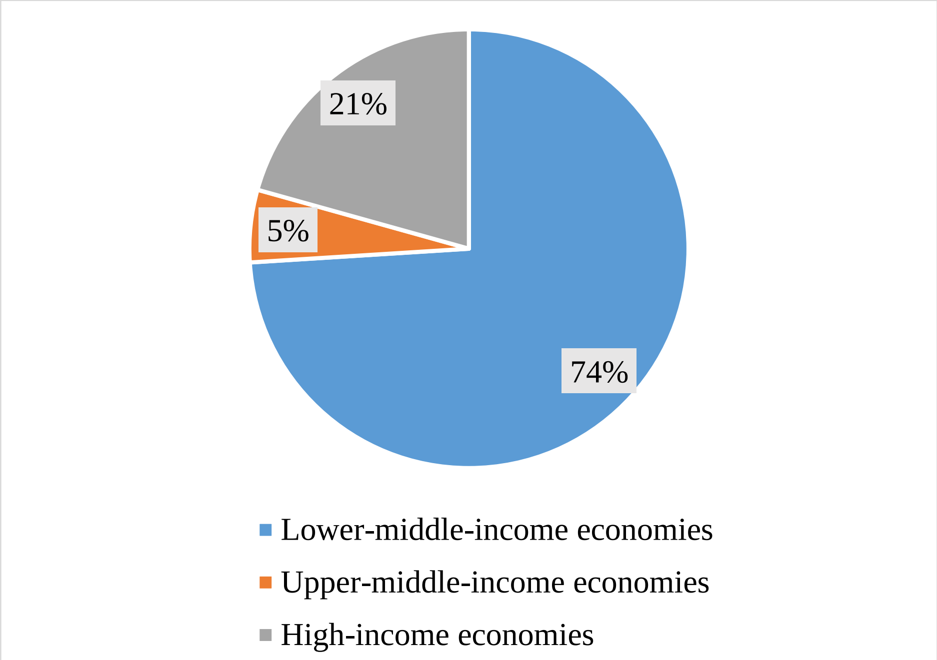

Figure 4.4 Respondents' geographical background

4.4 Risk Analysis

Based on the responses of the detailed questionnaire survey, risks were analyzed to measure their effect on the sustainability indicator system. Risk scores for each relationship was obtained using Equation 3.1. During the questionnaire survey, probability and impact were calculated using a 9-point and 5-point Likert scale. To make the scale uniform allowing for a realistic interpretation of results, the resulting risk scores were normalized to a 0-1 scale. To select the normalization technique, three different transformations were applied to the data as shown in Figure 4.5.

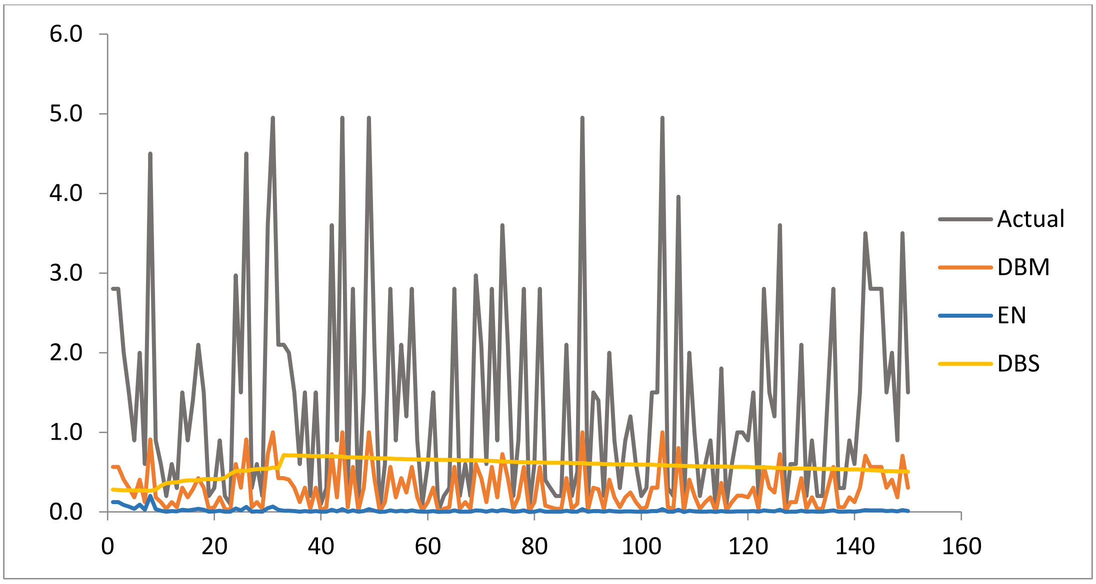

Figure 4.5 Normalization curves

After careful analysis of results, it was found that normalization through DBM (Divide by Max) method perfectly replicated the distribution of the un-normalized risk scores distribution in comparison to EN (Euclidean Normalization) and DBS (Divide by Sum) method. In the DBS method, all the values of risk scores are divided by the maximum value in the data set to scale them down. In this case, the maximum value was 4.95 resulting in a completely linear transformation. Furthermore, to assess the uncertainty involved in the situation of sustainability incorporation in PPPs, high-ranking PPP risk factors were ranked in order of their overall contribution towards triple-bottom-line sustainability indicators. In the model of risk assessment for sustainability, the inputs were the risk scores of the individual risk-sustainability indicator relationships while the outputs of the model were the overall risk scores on the 10 individual indicators of sustainability and overall risk score for sustainability. The inputs were considered as independent in their impact on the outputs. For each risk factor-sustainability indicator relationship, there existed 150 values. In order to find the best fit curve for each of the 68 relationships assessed, distribution fitting was applied using @Risk. The software provides distribution fit options for both discrete and continuous data. In the case of the present study, the type of data was selected on the basis of nature of variable being assessed. In the case of probability, the scale of the probability ranged from 0-1, which is the true scale of probability. In the case of risk impact, the interpretation of risk is usually taken in the form of cost, which follows a continuous scale. Additionally, the relationships being assessed are subjective. Therefore, the data of the risk scores being assessed is taken to be continuous. To find the best-fit curve, chi-squared statistic is used which is the best-known goodness-of-fit statistic. For further assessment, mean values were taken of each resulting distribution fit. Monte Carlo simulation using Latin hypercube sampling was used for sensitivity analysis. The analysis was run for 1 simulation and 5000 iterations for the individual sustainability indicators and 500 iterations for assessing the overall risk score for sustainability. Sensitivity analysis is a useful technique for analyzing complex problems. In this particular study, it is intended to analyze the level of detrimental effect of various risk factors on sustainability criteria while developing sustainable PPP projects. The particular sector targeted in the study is highways but the results can be generally used for any type of PPP infrastructure project.

4.4.1 **Risk Ranking for Financial Sustainability:**

For initial cost, the mean value for risk score came out to be 3.0493 with a 47.2% probability that the value of risk score will be above this mean value. The minimum value of risk score for Initial cost is 0.6821 and the maximum value of 7.22. Overall, there is a 90% probability for the risk score to be in a range of 1.67-4.65 i-e for the risk score to be 4.65, the probability is 95% as shown in Figure 4.6.

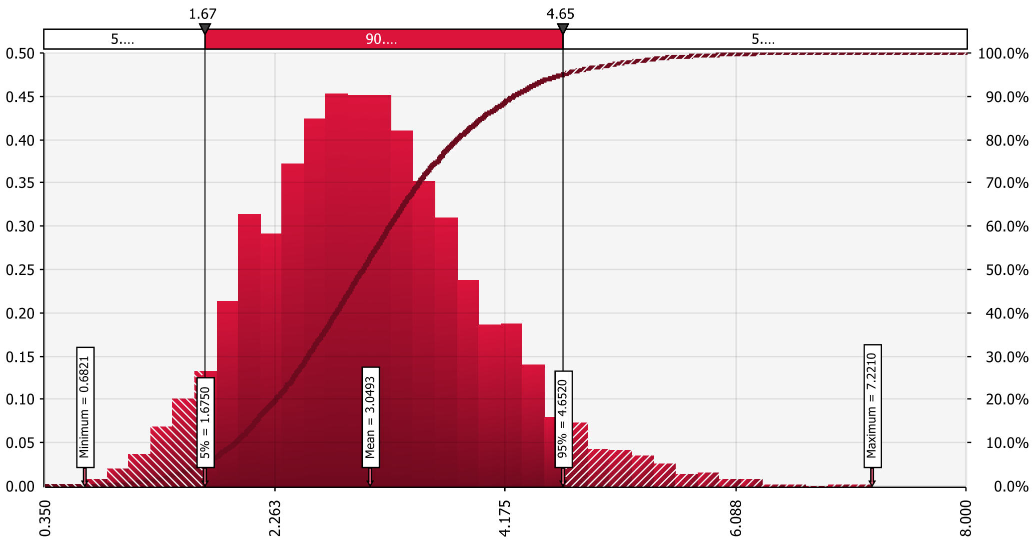

Figure 4.6 Probabilistic risk score for Initial Cost

To assess the most critical risks for the initial cost indicator, we use the tornado graphs option in @Risk. While generating a tornado graph, @RISK runs a regression where each iteration represents an observation. The dependent variable is the output cell, which in this case is the 'Risk score for Initial Cost" and the independent variables are each "random" of the input. Over here, the comparative effect of 9 risk inputs has been explored. According to the ranking based on regression coefficients, availability of resources is the most critical risk, followed by risk of corruption in the initial phases of the project planning as shown in Figure 4.7.

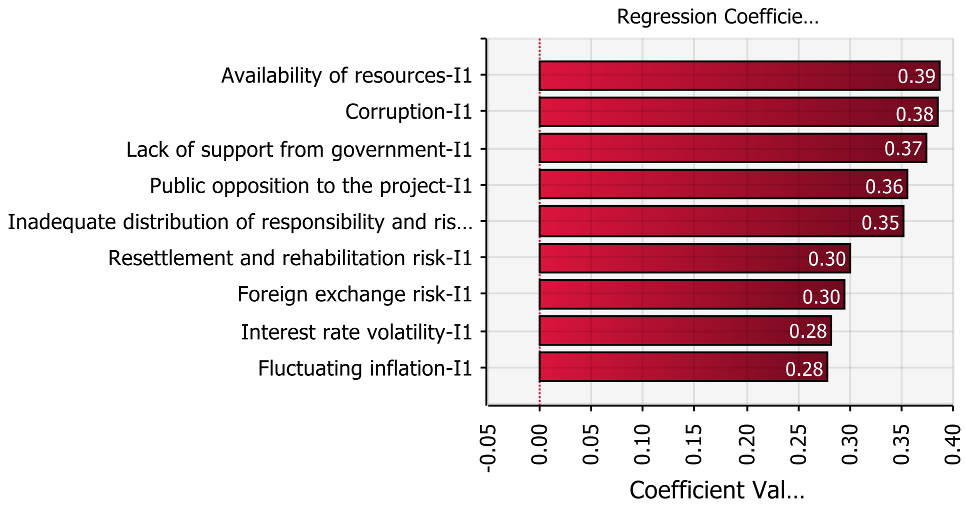

Figure 4.7 Risk ranking for Initial Cost

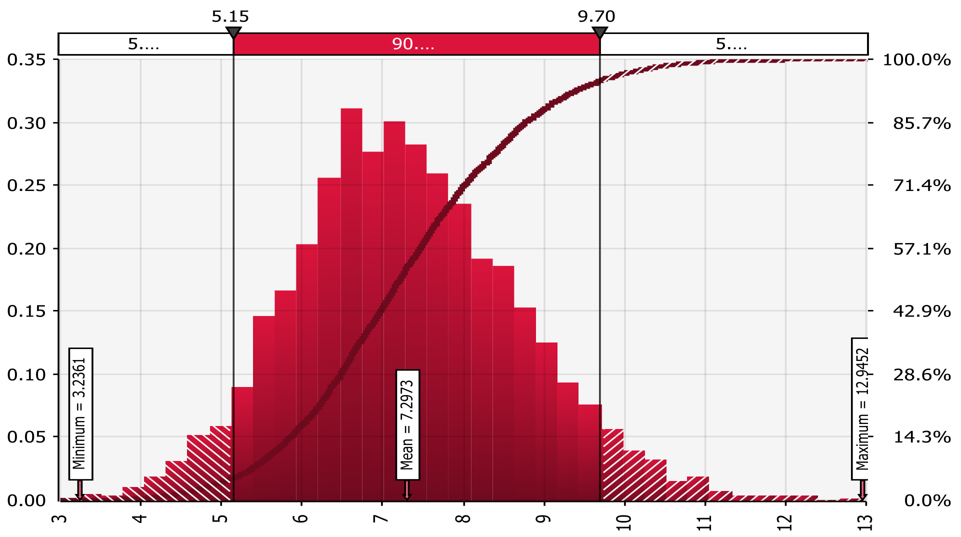

Figure 4.8 Probabilistic risk score for Life cycle cost

For Life cycle cost, the mean value for risk score came out to be 7.2973 with a 47.3% probability that the value of risk score will be above this mean value. The minimum value of risk score for Life cycle cost is 3.2361 and the maximum value of 12.9452. Overall, there is a 90% probability for the risk score to be in a range of 5.15-9.70 i-e for the risk score to be 9.70, the probability is 95% as shown in Figure 4.8.

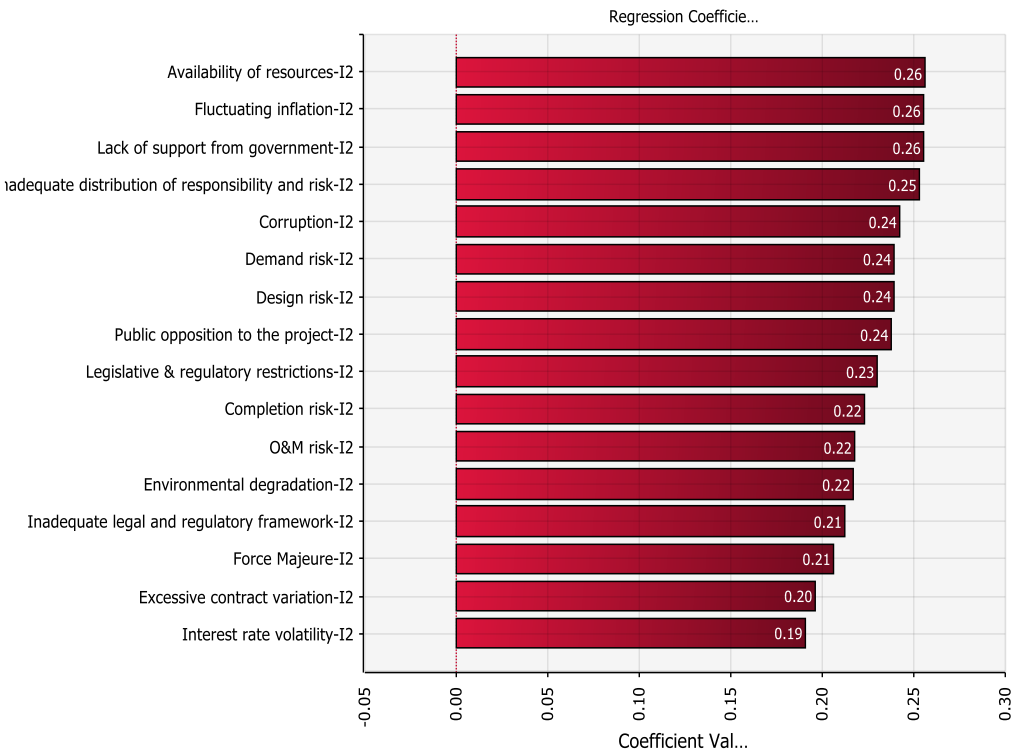

Figure 4.9 Risk Ranking for Life cycle cost

It is pertinent to note that, out of the 20 risk factors influencing life cycle cost, availability of resources is the most critical risk, similar to initial cost. However, market risk of fluctuating inflation, also seems to highly critical for causing cost overruns over the life cycle of the project as shown in Figure 4.9.From

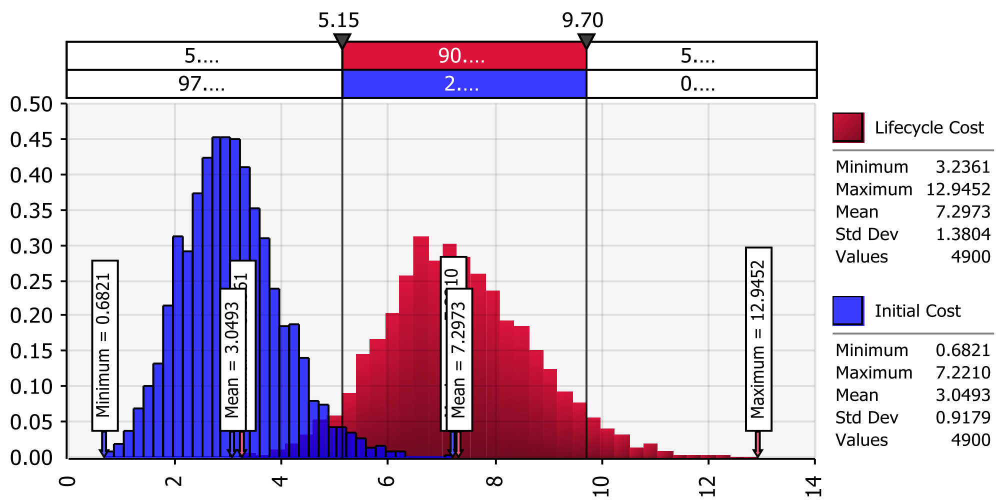

Figure 4.10 Comparison of risk scores for financial sustainability indicators

the comparison of the probabilistic distributions of the risks on the two indicators of financial sustainability, it is to be noted that overall, there is life cycle is more sensitive towards risk. The minimum risk score for life cycle cost is greater than the mean value of risk score on initial cost. Additionally, even the maximum computed score for initial cost is lesser than the life cycle cost.

4.4.2 **Risk Ranking for Social Sustainability:**

In relevance to socioeconomic repercussions, the mean risk score is 5.0373 with a minimum limit of 1.8526 and maximum limit of 10.7012 as shown in Figure 4.11. There is 45.6% probability that the risk score for socioeconomic repercussions will be higher than the mean value.

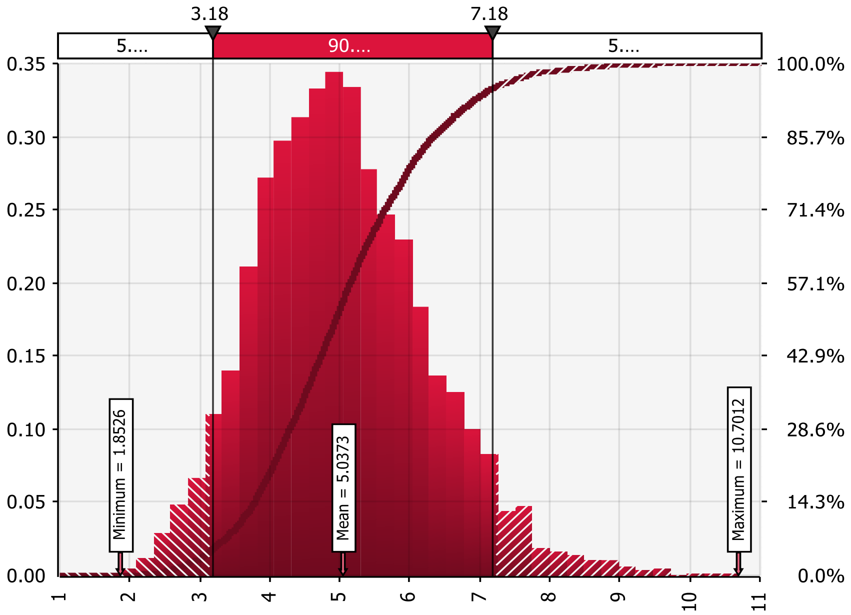

Figure 4.11 Probabilistic risk score for Socioeconomic repercussions

According to the tornado graph shown in Figure 4.12, market forces causing fluctuating inflation and availability of resources are the most critical risks effecting socio-economic repercussions indicator of social sustainability. Following them, environmental degradation, inadequate legal and regulatory framework, corruption, and lack of support from government share the same regression coefficients.

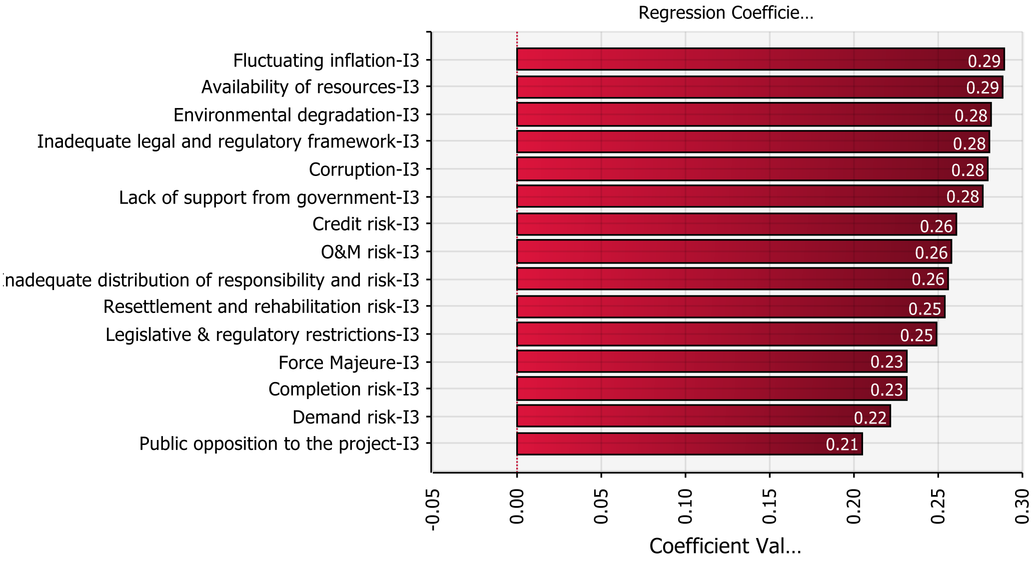

Figure 4.12 Risk Ranking for Socioeconomic repercussions

For Health and Safety, the mean value for risk score came out to be 1.4713 with a 44.4% probability that the value of risk score will be above this mean value as shown in Figure 4.13. The minimum value of risk score for Health & Safety is 0.0379 and the maximum value of 5.2609. Overall, there is a 90% probability for the risk score to be in a range of 0.57-2.67 i-e for the risk score to be 2.67, the probability is 95%.

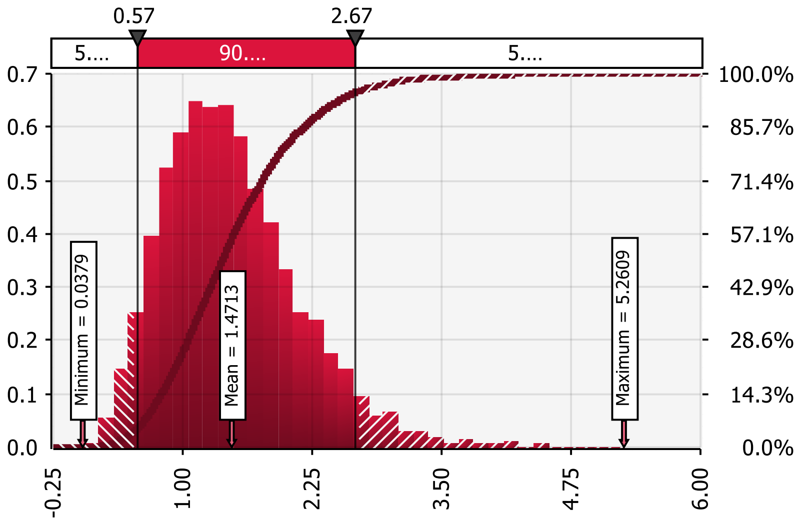

Figure 4.13 Probabilistic risk score for Health & Safety

For health & safety, environmental degradation is identified as the most critical risk, followed by design risk as shown in Figure 4.14.

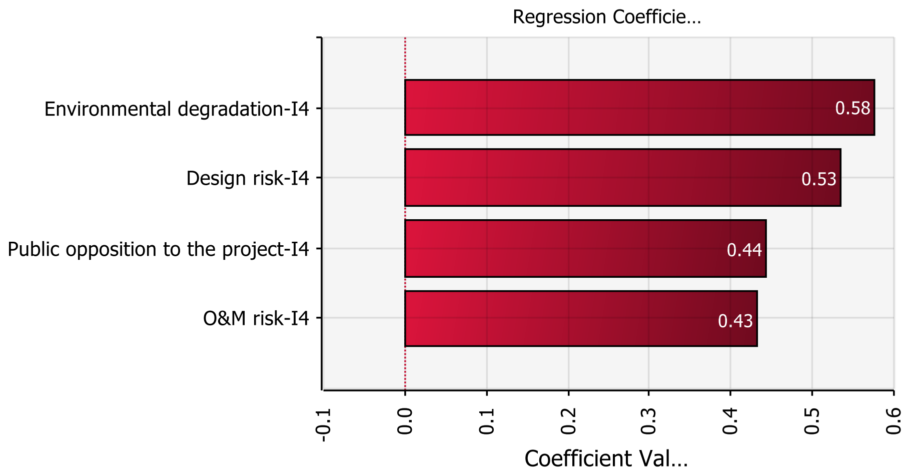

Figure 4.14 Risk Ranking for Health & Safety

For Cultural Heritage, the mean value for risk score came out to be 0.3719 with a 44.4% probability that the value of risk score will be above this mean value as shown in Figure 4.15. The minimum value of risk score for cultural heritage is -0.012 and the maximum value of 0.920. Overall, there is a 90% probability for the risk score to be in a range of -0.012-0.920 i-e for the risk score to be 0.920, the probability is 95%. There is only one risk found to be significantly impacting cultural heritage; land use and acquisition / resettlement and rehabilitation risk. It is to be noted, that although risks are assessed independently, to clearly identify the focus point of a risk chain for a particular type of impact, the analysis is useful.

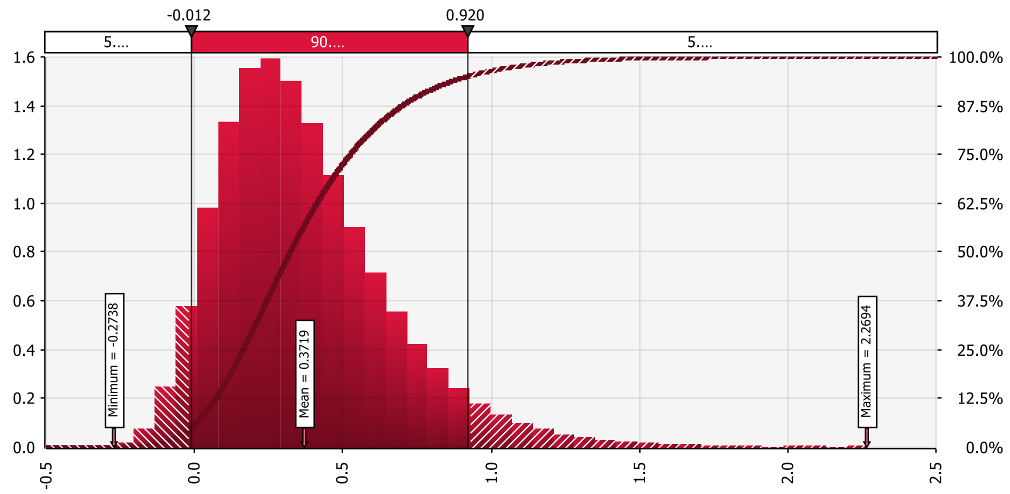

Figure 4.15 Probabilistic risk score for cultural heritage

In the present case, if there is a possibility that an existing cultural landmark is in the way of the proposed design of the project, it can trigger a chain of events if not mitigated timely. In the initial phase, it can significantly cause time and cost delays due to permission issues of constructing on a sensitive site. Changing the design, may create a rehabilitation and resettlement issue while protecting the religious or cultural sites. In both scenarios, there is a significant resulting risk of public opposition to the project involved. If the public is unaware of the social impacts of the project, then during construction, public opposition can even hamper the project performance to failure due to resulting litigation.

For Governance, the mean value for risk score is 2.7330 with a 47.4% probability that the value of risk score will be above this mean value as shown in Figure 4.16. The minimum value of risk score for governance is 0.4123 and the maximum value of 6.5135. Overall, there is a 90% probability for the risk score to be in a range of 1.46-4.17 i-e for the risk score to be 4.17, the probability is 95%.

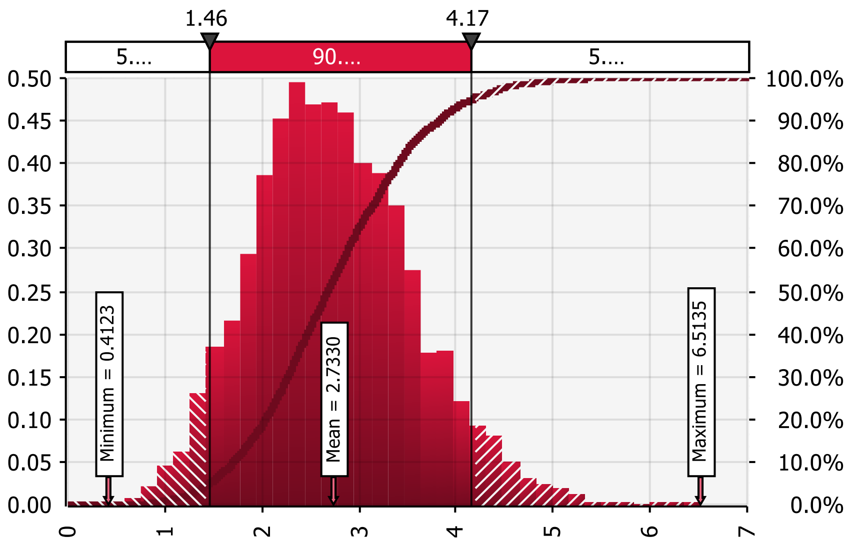

Figure 4.16 Probabilistic risk score for Governance

According to the tornado graph shown in Figure 4.17, lack of support from government, inadequate legal and regulatory framework, and corruption are the most critical risks effecting governance indicator of social sustainability.

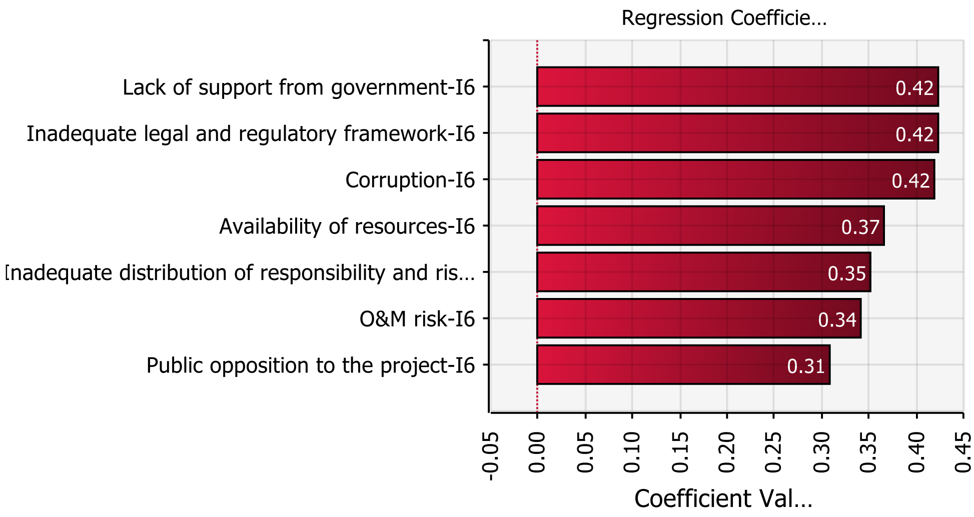

Figure 4.17 Risk Ranking for Governance

In case of human rights, the mean value for risk score is 1.1792 with a 48.4% probability that the value of risk score will be above this mean value as shown in Figure 4.18. The minimum value of risk score for governance is 0.299 and the maximum value of 2.155. Overall, there is a 90% probability for the risk score to be in arrange of 0.299-2.155 i-e for the risk score to be 1.1792, the probability is 95%.

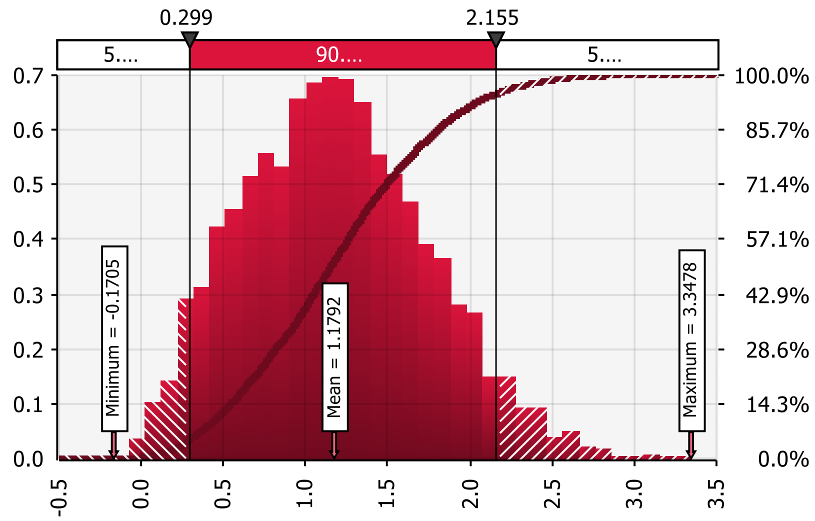

Figure 4.18 Probabilistic risk score for Human rights

Examining the regression tornado graph presented in Figure 4.19, corruption is found to be the most critical risk in case of human rights consideration in sustainability.

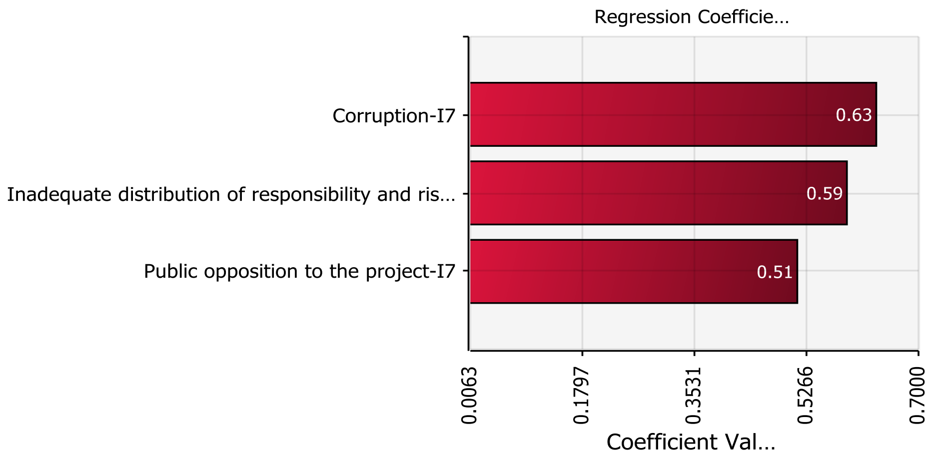

Figure 4.19 Risk Ranking for Human rights

In case of social sustainability, the highest value for mean risk score is for socio economic repercussions, while the lowest is for cultural heritage as shown in the comparative analysis in Figure 4.20.

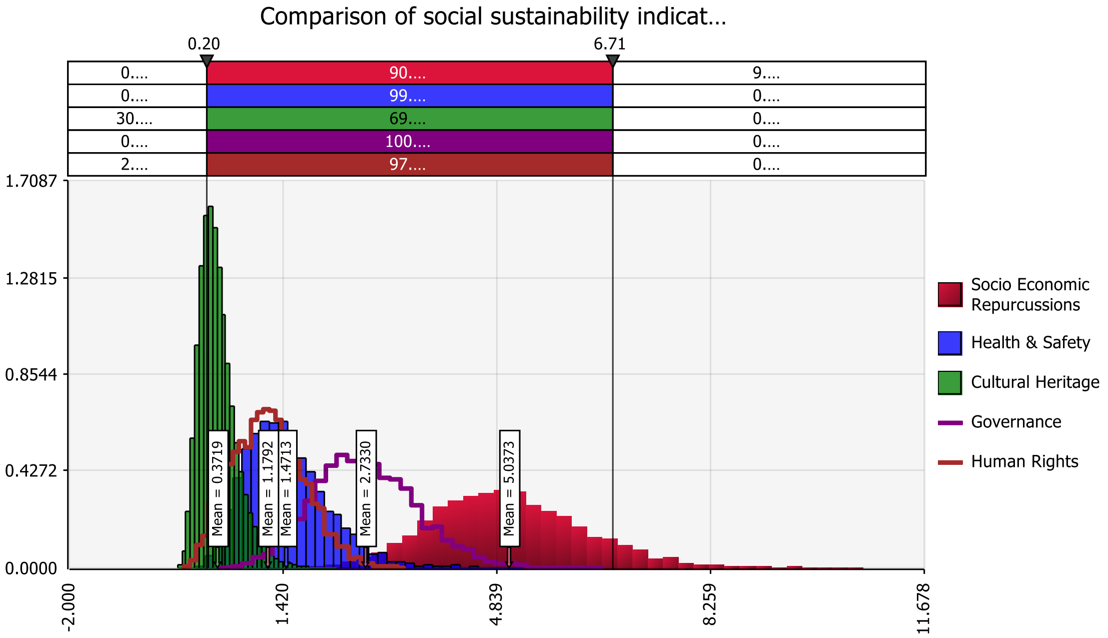

Figure 4.20 Comparison of social sustainability indicators

4.4.3 Risk Ranking for Environmental Sustainability

In case of resource damage, the mean value for risk score is 0.3730 with a 48.4% probability that the value of risk score will be above this mean value as shown in Figure 4.21. The minimum value of risk score for governance is 0.0992 and the maximum value of 6.9489. Overall, there is a 90% probability for the risk score to be in a range of 0.01-1.08 i-e for the risk score to be 1.08, the probability is 95%.

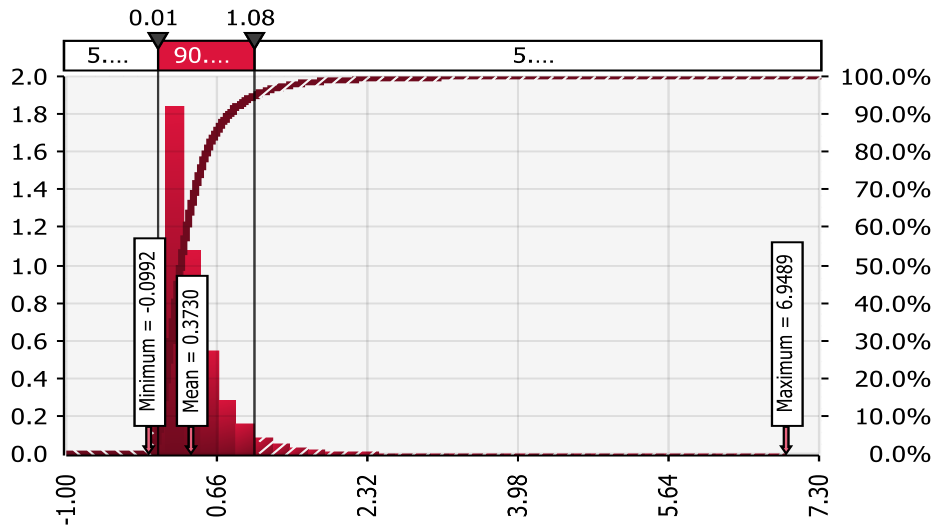

Figure 4.21 Probabilistic risk score for Resource damage

In case of ecosystem damage as shown in Figure 4.22, the mean value for risk score is 0.4536 with a 47.5% probability that the value of risk score will be above this mean value. The minimum value of risk score for ecosystem damage is 0.00202 and the maximum value of 1.00. Overall, there is a 90% probability for the risk score to be in a range of 0.005-0.989 i-e for the risk score to be 0.989, the probability is 95%.

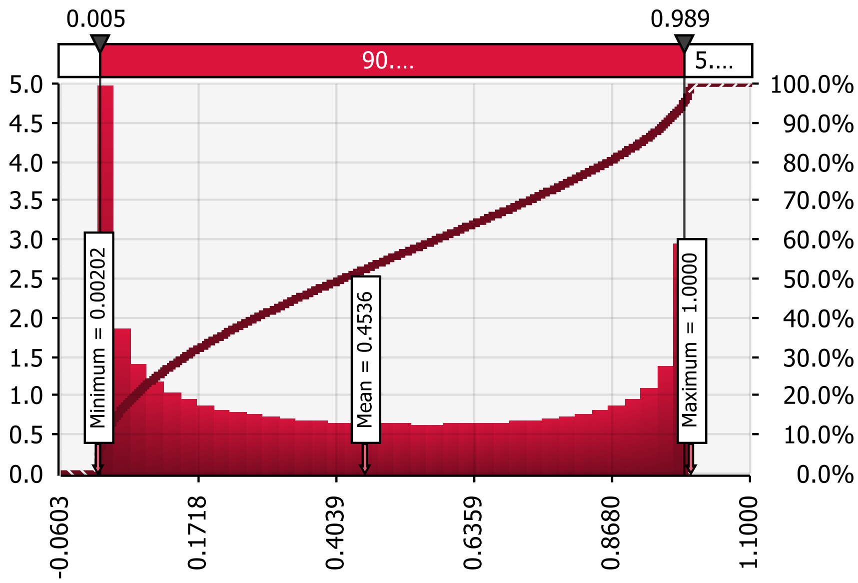

Figure 4.22 Probabilistic risk score for ecosystem damage

In case of human health, the mean value for risk score is 2.7691 with a 29% probability that the value of risk score will be above this mean value as shown in Figure 4.23. The minimum value of risk score for human health damage is 0.3503 and the maximum value of 329.64. Overall, there is a 90%

probability for the risk score to be in a range of 1.11-5.01 i-e for the risk score to be 5.01, the probability is 95%.

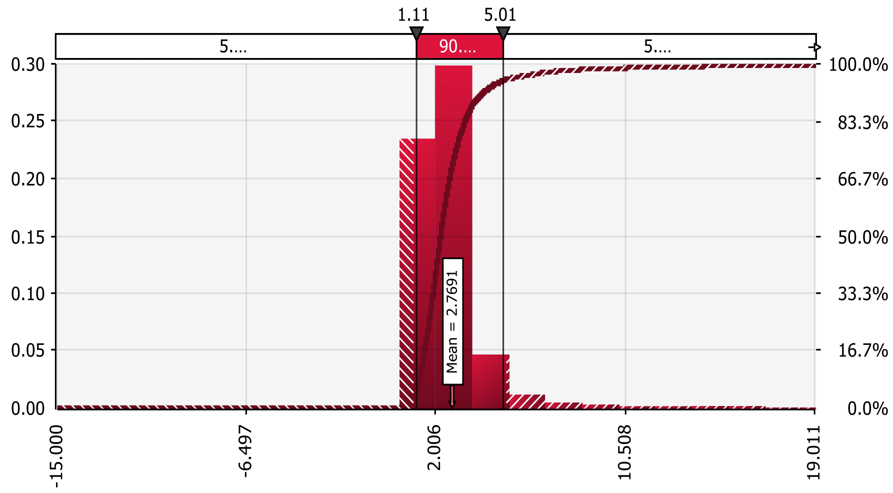

Figure 4.23 Probabilistic risk score for Human health damage

The regression coefficients show the strength of a relationship between the input and output, while the correlation coefficients show the consistency of the relationship between the input and output. In the case, that R^2 values after regression are significantly low, it is preferable to use correlation coefficients for ranking of factors. From the Table 4-2, it is apparent that 5 out of 7 input factors have a relatively low R^2 value. Thus, in this case, correlation coefficients are used for the sake of risk prioritization.

Table 4-2 Comparison of regression and correlation coefficients for environmental sustainability

Rank	Risk factors (INPUTS)	Regression Coeff. RSqr=1	Correlation Coeff.
1	Completion risk-I10	0.952	0.399
2	Environmental degradation-I10	0.295	0.427
3	Legislative & regulatory restrictions-I10	0.051	0.283
4	Design risk-I10	0.048	0.292
5	Inadequate legal and regulatory framework-I10	0.048	0.294
6	O&M risk-I10	0.043	0.24
7	Resettlement and rehabilitation risk-I10	0.043	0.283

According to spearman’s rank correlation coefficients, environmental degradation is the most critical risk effecting human health indicator of sustainability as shown in Figure 4.24.

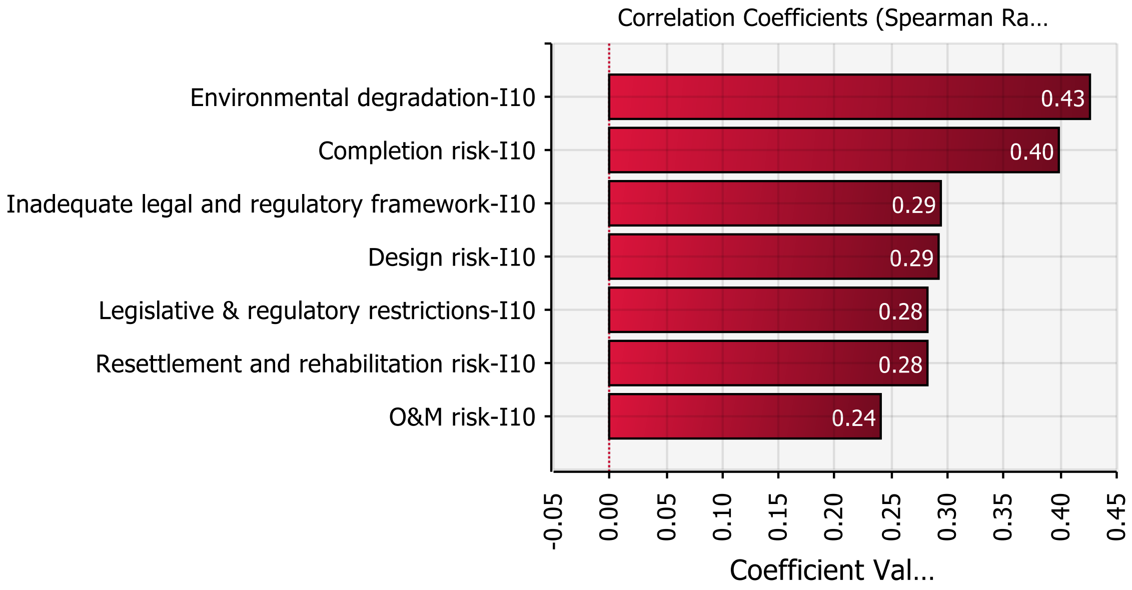

Figure 4.24 Risk Ranking for Human Health

It can be noted that, although the curves for all the environmental indicators are quite steep, overall risk score for human health damage is the most critical environmental sustainability indicator as shown in Figure 4.25.

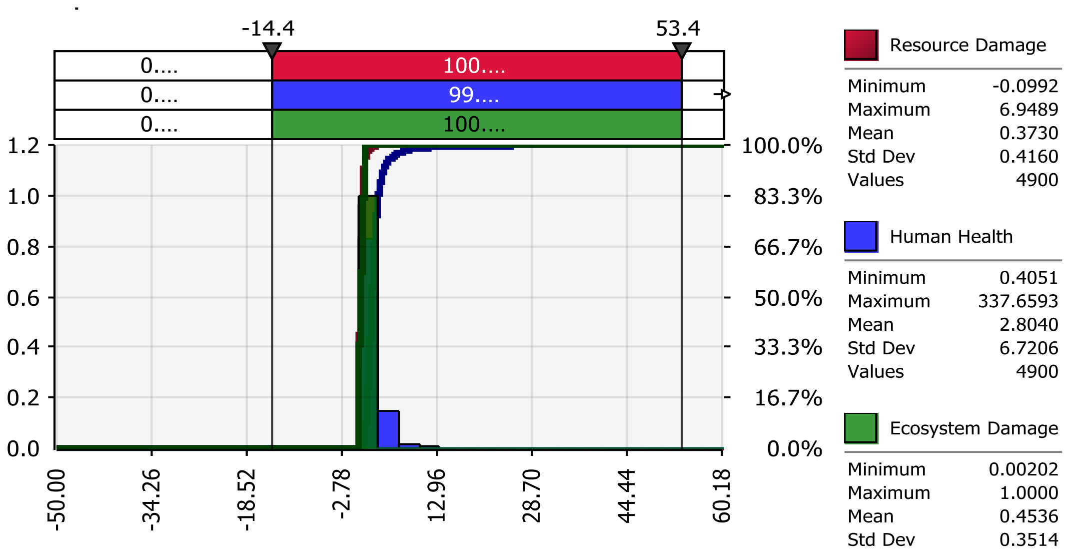

Figure 4.25 Comparison of risk scores for environmental indicators

4.4.4 **Overall Risk Ranking for Sustainability**

Overall, the mean value of risk score for sustainability is 24.6210 with a 47% probability that the value of risk score will be above this mean value as shown in Figure 4.26. The minimum value of overall risk score for sustainability is 17.8255 and the maximum value of 68.1750. Overall, there is a 90%

probability for the risk score to be in a range of 20.3-24.6 i-e for the risk score to be 24.6, the probability is 95%.

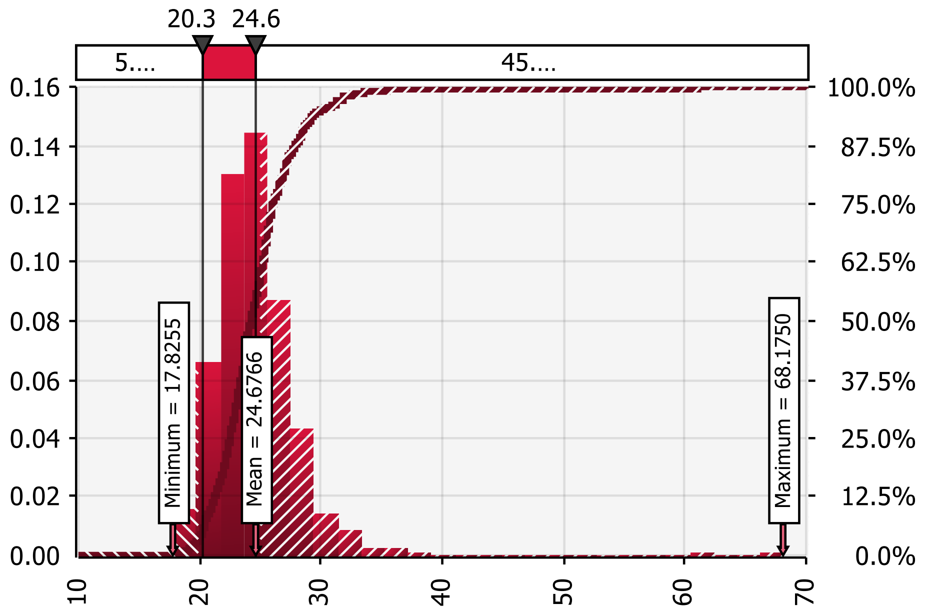

Figure 4.26 Probabilistic overall risk score for sustainability

The tornado graphs of the simulation results for overall risk score for sustainability are shown in Figure 4.27. It is to be noted that in this case, the ranking based on regression coefficients and correlation coefficients is different. According to the regression tornado graph, human health is the indicator most sensitive to risk. In contrast, according to correlation coefficients based on spearman's ranking, Life cycle cost turns out to be the most critical indicator.

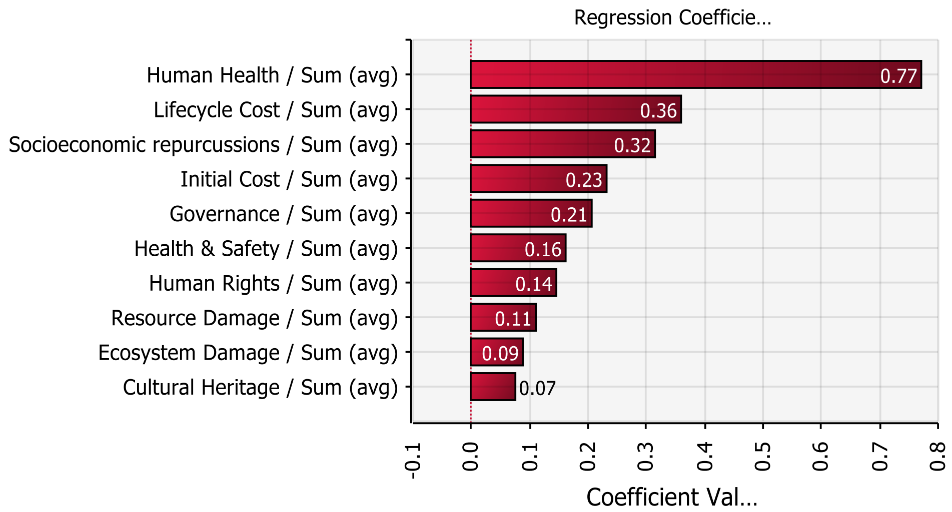

Figure 4.27 Overall Risk Ranking for Sustainability

In case of spearman's ranking as shown in Figure 4.28, socioeconomic repercussions and human health are equally critical, followed by governance.

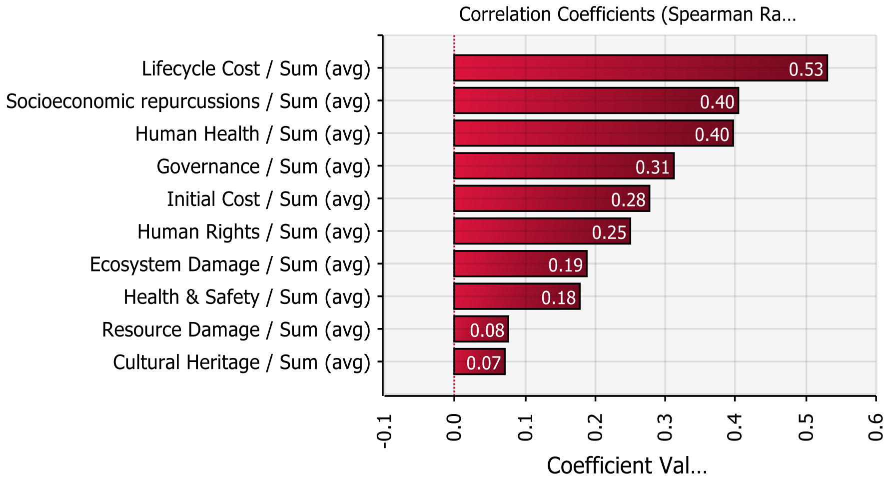

Figure 4.28 Correlation coefficients for Sustainability

In examining the case, the rank of human health can be argued as the life cycle cost has a correlation coefficient higher but as the values of regression coefficients for human health is significantly high, human health has been preferred for rank 1, as shown in Table 4-3.

Table 4-3 Comparison of regression and correlation coefficients for sustainability

Overall rank	Sustainability Indicators (Inputs)	Regression Coeff. RSqr=1	Correlation Coeff.
1	Human Health	0.771	0.395
2	Lifecycle Cost	0.361	0.531
3	Socioeconomic repercussions	0.316	0.405
4	Initial Cost	0.231	0.277
5	Governance	0.206	0.313
6	Health & Safety	0.163	0.177
7	Human Rights	0.144	0.251
8	Resource Damage	0.112	0.076
9	Ecosystem Damage	0.09	0.188
10	Cultural Heritage	0.074	0.072

4.5 Risk mitigation strategies

Materialization of any possible critical risk can significantly hamper project performance, even resulting in complete failure (Hwang, 2013). In the project environment, any particular risk identified as critical helps unearth the most sensitive areas of decision-making over the life cycle (Demirag, 2011; Shi et al., 2016; Zou et al., 2008). Therefore, PPP projects require provision of an integrated detailed strategic mitigation framework for proper redress and management of risks (Iyer and Sagheer, 2010; Kunreuther, 2001b). Also, in the concession agreement of PPP projects, setting the risk allocation structure has primary importance (Carbonara et al., 2015; Heravi and Hajihosseini, 2012). This allows the concession agreement to be the main instrument for risk mitigation in these projects. This is enabled through clarification of roles and responsibilities of contracting parties (De Schepper, 2014) as well as empowering the legitimate party to deal with different risky situations over the life cycle of the project (Soomro and Zhang, 2015) . Generally, risk is allocated to the party which is best equipped to handle the risk (Ke et al., 2013). However, it does not mean that other stakeholders will not be affected by that risk. Therefore, it is crucial that the party responsible for mitigation be supported for completing its said responsibilities.

This study opts to devise potential mitigation strategies for the most sensitive risks, and allocate risks to the parties best suited to respond that risk. For this purpose, in-depth semi-structured interviews of experienced PPP experts were conducted. Based on their relevant experience and project roles, interviewees suggested possible risk manifestations corresponding to project sustainability indicators for the selected nine most critical risks. Furthermore, in context of real time project scenarios impacts of risks over each sustainability indicator were discussed, for clear and contextualized understanding the risk cause-effect chains and propose mitigation accordingly. In the following sections all the proposed mitigation strategies and their corresponding liable parties are discussed in detail.

4.5.1 Financial Sustainability

For the financial sustainability two indicators considered in this study are, initial cost (capital cost) and life cycle cost (O&M cost). Table 4-4 presents critical risk factors (CRFs) for the indicators of financial sustainability and their corresponding mitigation strategies.

Table 4-4 Risk mitigation strategies for financial sustainability indicators

SI	CRFs	Mitigation strategies
Initial Cost	Availability of resources	Sovereign guarantees
		Prioritization of projects where political risks are less
		Government investment to ensure support (VGF)
		Cynosure Insurance
		Selection of appropriate PPP model
		Tax incentives
		Pre-booking of supply chains
	Corruption	Hiring of financial experts
		Studying past trends
Life Cycle Cost	Availability of resources	Stringent monitoring policies
		Alternative construction techniques or resources
		Life cycle based-financial sustainability assessment
		Early completion
		Innovative techniques in design
		Contract clauses
	Fluctuating Inflation	Built into the financial model
		Hedging
		Government guarantee for exchange rate
		Extension in concession term
		EPC contracts
	Corruption	Hiring of quality control assurance inspector
		Appropriate financial structuring of the project

The risk of 'availability of resources' covers the sources of uncertainty in availability and management of finances, material and manpower for sustaining the project over its life cycle. Particular to the case of required initial capital, various factors related to the country environment (country risk) can create the risk of finance availability for the project (Lehmann, 1999) or the financial close is reached at a much higher initial cost than anticipated by the government (Kunreuther, 2001a; Lee et al., 2013). The financial structure and choice of PPP model are believed to have a significant role in making the project financially sustainable. But in countries belonging to emerging markets and developing economies (EMDE), unpredictable political environment, law and order instabilities, and corruption exposure is the cause of investor apprehension while making an investment decision (Tecco, 2008; Wang et al., 2000). In opinion of few interviewees, although the private party assess the country profile for managing such risks, however, the unforeseen risks of 'changes in law' or 'change in scope' are hard to assess based on limited information of on-ground reality (Kong et al., 2008). Due to shortcomings in assessment, the private party may put the conditions so high that it may deem the project unfeasible for host government, for example, cynosure insurance (Interviewee#1). This insures the investor over losses due to war and terrorism and is applied to projects being constructed in the warzone (Kunreuther, 2002). In this regard, the government support to the PPP projects is crucial for successful and realistic financial close (Sachs et al., 2007). To prevent any unrealistic conditions, proper appraisal by the government with due diligence involving all sort of market tests is necessary (Interviewee#3). If the project is financially non-viable, the government can inject funds through viability gap funding (VGF) (Mahalingam, 2009), which would not only reduce the overall project cost but also would enhance the investors' confidence. However, it is mainly upon the private sector to secure the required amount of funding for project financing and manage the funds throughout the project life cycle till the transfer of facility to the public entity at the end of concession period (Regan, 2017; Tsamboulas et al., 2000).

It was highlighted mainly by the interviewees of the private sector that, to mitigate the risk of resource availability for the life cycle costs of projects, concessionaire can manage finances in execution stage by exploring alternate techniques, innovative design methods and pre-booking of supply chains to reduce life cycle cost impacts of resource availability (Dmitrieva and Guseva, 2017) .

In case, the life cycle cost overruns occur due to any political force majeure events, an interviewee suggested that minimum revenue guarantees (MRGs) and tax & duty incentives can be provided to the private party, for example, allowing private party a duty-free import of equipment and machinery (Armada et al., 2012). This can facilitate the private party to maintain its resources during the project execution.

Additionally, contract conditions to mitigate the effect of cost overruns due to government and political risks, risk threshold limits and upper caps of risk exposure of the private party can be utilized for mitigation. However, if government is unable to bear the risk, it can be transferred to the local firms using EPC or JV contracts, or to banks using hedging techniques (Schaufelberger, 2003). If there is an unexpected project scope variation during project life cycle, renegotiation on financial terms is required (Estache et al., 2009). In the situation, the risk of changes in scope and the risks emerging from the scope variation should be borne by the stakeholder directly benefitting from the scope add-ons. For example, Interview# 5 pointed out that emergence of new hitherto unidentified stakeholders during construction phase of the project can prove to be a potential source of scope increase. According to the expert, in one motorway expansion project from 4-lane to 8-lanes, being constructed under the BOT model, two additional stakeholders were identified. One was a private land developer, owning a major housing scheme in the project location vicinity demanding the construction of the interchange to allow access of its residents to the highway, connecting two big cities of the country. The other was the armed forces of the country, which demanded the construction of a landing strip as compensation for its land acquired for the project. In this scenario, the parties directly benefitting are the local property developer and the armed forces. While making the decision of facilitating the private stakeholders, the government's interest is to retain the social value of the project (Repolho, 2016). E-g the decision to make an additional interchange can be made in case it doesn't choke the motorway.

Another critical risk on the private party having high life cycle cost impacts is the fluctuating inflation. Although, short-term inflation effects can be adjusted into the financial model of the project on the basis of consumer price index (CPI), inflation has long term effects, as well. For example, inflation can create foreign exchange risk which can be mitigated through acquiring guarantee for exchange rate from the government. The private party can adopt inflation hedging techniques like forward contracts, and bond financing to manage inflation effects and unforeseen market changes (Roumboutsos, 2013; Wang et al., 2004).

In the EMDE countries, where the institutions are not as strong as developed countries, corruption is an important risk hampering large infrastructure projects (Ke, 2010). In order to minimize its effects, it is important to ensure transparency in bidding and negotiation procedures (Holmes, 2006). The public party can hire financial experts on their team to analyze the legitimacy of the project cost being quoted by the bidders. The negotiating team should make themselves aware of the past trends of such issue to learn from experience for making better, informed decisions. For controlling the life cycle impacts of corruption, a quality inspector is hired for quality assurance and control.

4.5.2 **Social Sustainability**

There are five indicators of social sustainability identified in the study; (i) Socio-economic repercussions (ii) Human Rights (iii) Governance (iv) Health & Safety (v) Cultural Heritage. Together, they encompass the overall social value creation areas being generated from the project. The risks critical to the realization of the desired social value of the project, and their potential mitigation strategies are given in Table 4-5.

Table 4-5 Risk mitigation strategies for social sustainability indicators

SI	CRFs	Mitigation strategies
Socio-economic repercussions	Fluctuating Inflation	Compensation given by the government
		Conducting detailed EIA
		Renegotiations
		Toll adjustments
		Incorporating effects of deflation
	Inadequate legal and Regulatory Framework	Win-win-win based negotiation
		Public feedback
	Lack of support from government	Subsidies on tolls
		Sharing the risk with local JVs
	Environmental Degradation	Design requirements for access of people and animals
		Design Innovation (Use of ITS)
Human Rights	Inadequate legal and regulatory framework	Policy development for human rights protection
		Insurance for workers
	Corruption	Improve transparency of record
		Public feedback mechanism
		Strong accountability system
Governance	Inadequate legal and Regulatory Framework	Organizational sustainability assurance
		Dispute resolution mechanisms
		Organizational experiences be translated into policy procedures
		Govt. support in taking clearances from EPA and other departments
	Corruption	Internal and external audit
		Online land record system
		Committee for corruption control
		Experienced negotiation team of the public party
	Lack of support from government	Private party be allowed appropriate time for bid development and financial close to quote a fair price
		Guarantee on toll rate
		Good relations with local government
		Execution level involvement of public party
		Increasing federal PPP authority role in the PPP projects
Cultural Heritage	Land use and acquisition/ resettlement and rehabilitation risk	Due and timely land compensation plan
		Additional revenue streams
		Proper rehabilitation plan
		EPA approval criteria should be tough
		Better relationship management with local community and local government
		Exploring alternate routes in case of permitted encumbrances
		Idling charges
		Adjustment in revenue sharing mechanism
		Extension in concession term
		Social factors be included during selection of road alignment
Health & Safety	Environmental Degradation	Developing relevant methodological statements/ execution policy/ Under specifications

	Design Risk	Better QA/QC
		Design innovation included in bidding criteria
		Use of new technology
		Performance monitoring & procedural control system over the project life cycle
		Design be adhered to safety standards

In public service delivery projects, social viability of the projects is more important than financial viability during project initiation and prioritization (Domingues, 2015). In such a case, governments are either politically motivated to gain public approval (Wang and Zhao, 2014) and socially motivated for delivering long-term social benefits to its people. However, to meet the infrastructure needs of the country, governments face issues of budget deficits, in-experience, and a resulting lack of confidence in locally available resources (Kunreuther, 2001b). In this scenario, partnering with private sector in the form of PPP seems like the most feasible option. But it has its constraints. In a PPP association, the private party's priority is to maximize its return on investment while the government seeks to maximize the social capital (Repolho, 2016). Such conflicting goals over project outcomes make the contracting parties motivated during negotiations to seek a balance in costs and benefits adopting a win-win-win approach (Zhang, 2009). In order to maximize the social benefits of the project, a detailed life cycle based EIA needs to be done, under which a socio-economic impact assessment (SEIA) should be including assessing the social, cultural and economic assessment of the project and coming up with opportunities to increase the positive social impacts of the project while mitigation for negative impacts can be suggested (Chen, 2017).

In road sector projects, the main revenue generating source is the toll collection from public (Wang, 2000b). The project will not be able to self-finance itself if the estimated traffic does not meet get diverted on the new facility. In addition to the market fluctuations, one of the most important factors in this regard is the willingness –to-pay of road users (Jou and Huang, 2014). Due to rising inflation, the public purchase power parity decreases, due to which their willingness-to-pay decreases, resultantly lowering the demand of the constructed facility (Interviewee#4). These factors need to be considered, while estimating the future demand, upon which a toll regime is designed (Chen and Subprasom, 2007b). In this way, public feedback can be timely accounted for in the concession design upon which government can consider offering subsidies to road users to maintain the estimated future demand of the project. Normally, in PPP projects, the traffic shift towards the new facility is slow, as it takes time for the public to fully understand the social benefits of reduced travel time and cost of the road users, and the safety benefits (Tan and Yang, 2012).

Although public hearings and social and print media promotion can be used for creating awareness among the public, and avoiding any public opposition and displeasure in the later stages, there are several social sustainability issues that can be addressed through the design at the time of project development and construction (Podgorski and Kockelman, 2006). Access of people of surrounding localities is permanently closed. Interchanges may be provided where the settlements impacted are large. In case of villages or cultivated land, crops have to be transported, trucks or tractors have to pass. To facilitate these activities, cattle creeps, underpasses and bridges may be constructed to facilitate the economic activities of the surrounding local community. These design variations also help in reducing the environmental degradation that can significantly increase the negative socio-economic challenges. For example, cutting of trees, access issues, quarrying, and construction waste, noise pollution and air pollution can destroy the local habitat, flora and fauna effecting the wellbeing of the people (Forman and Deblinger, 2000; Redwood, 2012; Trombulak and Frissell, 2000). However, these design requirements should be within acceptable limits of project budget. Noise and air pollution during and after construction cause different health and safety impacts not only on the on-site workers but also the surrounding population (Dadvand et al., 2014; Foraster et al., 2014). These impacts significantly increase while developing an old alignment passing through the cities where they have severe detrimental effects on commercial activities, ease of access and safety of the people. Safety, if interpreted during construction, applies to risk of accidents and health impacts on workers and surrounding populace (Glendon and Litherland, 2001; Zhou et al., 2015). Site safety is ensured through the execution policy and abiding by the safety standards during the construction. During operation, roads can be made safe to travel for users by the use of technology innovation (Organization, 2015). As PPP is an output-based contract, it provides the necessary flexibility to drive innovation. For example, one motorway has been fully covered with CCTV cameras, with three stations covering the entire length of the road. In another motorway project, electronic toll and traffic management (ETTM) system has been used for long queues for toll collection (Chang and Hsueh, 2006; Yang, 2017). Attempts are being made to introduce machine readable number plates for automatic collection of tolls, and greater check and balance of the roads. Additionally, emergency response team and trauma centers are also required to enable timely response in case of accidents (Deshpande, 2014; Goniewicz et al., 2016). Procedural controls are identified in this regard for performance control. If there has been an accident, emergency clearance of the road is also enabled. This is important to make the road available to users as fast as possible. Traffic police monitors the roads 24/7 to prevent violations of speed limits. The road users are sent weather reports and cautions through text messages on their mobile phones. In a certain project, weight stations are installed at the interchange to prevent over-loaded vehicles to enter the road. This prevents damages to the pavement performance which create additional maintenance costs and can increase the number of accidents on the road. Performance monitoring using clear and measurable key performance indicators is a useful tool for preventing or mitigating such risks (Liyanage, 2015). The interviewees remarked that independent auditors (IA) and independent engineers (IE) are hired for monitoring the performance of the project.

All interviewees agreed that in PPP projects, land use and acquisition risk has serious implications (Raghuram et al., 2009). This can be interpreted as a combination of social risk and site risk (Babatunde et al., 2017). It is the responsibility of the public party to provide the private party the land required for construction, free from encumbrances (Bing, 2005; Ismail, 2006). These encumbrances can range from fertile land, shops, houses, existing utilities, illegal encroachments, religious shrines, mosques, to even graveyards etc. The sites with very significant cultural importance like historical or cultural landmarks and archeological sites come under ‘permitted encumbrances’. Modifications in the design are made to prevent such sites to be affected. If the alignment is already there, then there are settlements in the surroundings which are really difficult to remove. In new alignment (green-field projects), there are less chances of resistances. Overall, the government’s strategy is to minimize the resettlement and relocation impacts while demarcating the right of way (ROW) of the project. Still, it is an issue of prime importance affecting the sustainability performance of PPP projects (Amiril et al., 2014). The local government and bureaucracy plays an important role in successful and smooth acquisition of land. The local government conducts negotiations with the elders of the families, politically affluent members of the affected society and other pressure groups of the area, after which a compensation plan is developed based on estimated damages (Price, 2015). This is difficult because there are sentiments, emotions and a will for preservation for their cultural identity and legacy is associated. For example, relocating a graveyard is a very sensitive issue among all religions. To mitigate the cultural risk, a well-though out compensation and relocation plan should be developed in order to satisfy the local community and maintain their confidence in government's intention for their greater social benefits (Modi, 2009). Managing good relations at every level of hierarchy is important to manage such long-ranging risks. A possible mitigation for enabling the government to sufficiently compensate the landowners, is through private sector support in exchange of a better profit sharing mechanism during operations. Additional revenue streams can be created in cases of sites of tourism importance. If the government fails to clear the land, then the public party has to pay the idling charges and compensation claims of the private party. Delays in project completion have several implications, the most important of which is the delay in the delivery of service to the users. For example, on one project, encroachments could not be cleared so the interchange cannot be constructed. In another project, a toll plaza is incomplete, because the government has not been able to remove the impeding transmission lines. Concession contracts are time based contracts in which time translates into cost. In this scenario, government is liable for compensation. The government may also provide an extension in the concession period to make up for the time losses.

After project completion, if the demand falls short of the estimated value, private party can face debt servicing issues (Chen et al., 2001). To mitigate this risk, banks can create a reserve account. If for a certain year, the toll collection is more than estimated, the money goes into the reserve which can be later used to make up for losses. The project can also be opened after sectional completion, if possible, to prevent any extension in concession period of the project. If the government fails to increase the toll due to any force majeure event, the private party needs to be duly compensated for the project to sustain itself. To compensate the private party, the government can increase the profit share of the private party. This is workable when there are good relations between the private and public party which can be ensured through government support. A major issue in this regard is the country risk profile, corruption exposure and inadequacy of legal and regulatory framework for addressing issue related to human rights, governance and socio-economic repercussions (Galilea, 2010; Wang, 2000a). In EMDE countries, general risks of food and water crises, unsustainable population growth, and slow macroeconomic performance can be found (Cohen, 2006). This make them prone to social unrest, law and order crises, anarchy or political turmoil. To carry out successful and sustainable projects amidst an unpredictable country environment create risk of government default (Mahalingam, 2010). In worse situations, the private parties fear the expropriation or nationalization of assets, terrorism activities, or forced confiscation of assets (Babatunde et al., 2015). In emerging economics, governments have to address the risk of bad reputation to secure funding and establish trust with the private party (Babatunde and Perera, 2017). While working in areas sensitive to law and order situations, foreign personnel should be provided due security. Moreover, the government should support the private party in acquiring approvals from different organizations. It is to be noted that 'inadequate legal and regulatory framework' is a major risk on SER, HR, and GOV (Ameyaw, 2015). In Pakistan, there was no federal law or central PPP organization to oversee the private sector involvement in the country, till now (Mubin, 2008). A PPP authority has been recently established to develop the projects under principles of good governance. The projects need to maintain equity, fair play, competition and transparency during negotiations. Accountability of parties is ensured both internally by the parent organization of the public party and externally by the relevant government institution (Agarchand and Laishram, 2017). One major impeding factor in establishing transparency and trust among parties is corruption which includes a general disregard for rules and regulations (Sabry, 2015). Corruption at local level can materialize in the form of bribery and red tapes, and nepotism during hiring of project team. To uphold the rule of law, institutions need to be strengthened (Fombad, 2015). For example, hiring of quality assurance inspector and making anti-corruption committees can play an important role in upholding social justice. Additionally, online land records have proven to be an effective mitigation strategy for corruptions.

4.5.3 **Environmental Sustainability**

Environment sustainability means to facilitate the people while maintaining a human-environment equilibrium (Little et al., 2016). There are three possible environmental impact categories used in this study; Resource damage (depletion of abiotic resources), ecosystem damage (climate change), and human health damage (emissions). There suggested mitigation strategies are presented in the Table 4-6.

Table 4-6 Risk Mitigation Strategies for Environmental Sustainability Indicators

SI	**CRFs**	**Mitigation strategies**
Resource damage	Environmental degradation	Environmental monitoring over the life cycle
		Recycling and reuse of waste material (asphalt)
		Selection of environment friendly materials
		Proper hydrology studies conducted before design
Ecosystem damage	Environmental degradation	Conducting detailed life cycle-based EIA
		Tree plantation
		Implementation and safeguard of environmental policies
		Selection of environment friendly materials
		Hiring of environmental specialists on the project team
		Stringent Environmental plan for the project
Human Health Damage	Environmental degradation	Conducting detailed EIA
		Public hearing before EPA approval/ Stakeholder conference
		Recycling and reuse of waste material (asphalt)
	Completion Risk	Environment and safety controls
		High liquidated damages on delay
		Incentives for early completion

To address the environmental impacts, a detailed life cycle-based EIA addressing both short-term and long-term impacts is really important in long-term contracts (Chowdhury et al., 2010). This gives the opportunity to the parties to initiate and enable environment friendly practices (Zhou, 2015). A stakeholder conference must be organized to involve the possible stakeholders as part of EIA efforts (Blicharska et al., 2011). This gives a clear idea of the project sustainability issue both at present and in future. Interviewee agree that EPA should have strict criteria for giving environmental clearances to the project. Environmental policies act as benchmarks for the project environmental performance (Lamb, 2018). Environmental degradation in relevance to the identified impact categories needs to be monitored over the life cycle of the project (Haque and Ntim, 2018). At present, awareness regarding environmental issues is increasing among the EMDE countries. In PPP projects, environmental sustainability is a more desired, prioritized project outcome as compared to conventional projects (Koppenjan, 2015). Hiring environmental specialist for conducting EIA, monitoring and control of environmental impacts is a necessity. Detailed environmental plan should be developed in light of the conducted EIA. During bidding, bidders using environmentally friendly and efficient practices should be given extra points to extend commitment towards realization of environmental goals of the project (Hueskes et al., 2017; Jefferies, 2006). For example, as suggested by an interviewee, in establishing an ETTM for toll collection, if a certain bidder proposes the use of alternate energy for un-interrupted electric supply, instead of using generators, it will gain more points. The material choice of environmentally friendly materials can help reduce human health and ecosystem damages (Wang et al., 2018). For example, cement roads create dust-related issues which are prevented using asphalt (Chowdhury et al., 2010). Additionally, recycled material can be used to reduce environmental losses (Petkovic et al., 2004). To reduce resource damages like loss of habitat and deforestation, trees plantation can be used. Cutting of trees increases risk of floods, and can add to global warming (Cross et al., 2013). Thus, it is important to replenish the land with plantation. Green belts should be maintained properly in this regard (Islam et al., 2012).

The unforeseen site conditions can cause significant cost overruns to the private party (Doloi, 2012). In this duration, it is not possible for the private party to make assessments at a physical level. For-example, in one motorway project, the land was a water-logged area. Preparing the soil for the construction demanded confining the soil and using sand layers. This involved an extra cost of $2Billion. The private party mitigates the cost overrun risk by quoting an overestimated project cost. The private party should be given ample time for conducting hydrology studies on the site. It so happens that in Pakistan, the duration offered to the bidders is only 45 days. Additionally, environmental clearances from irrigation department and forest departments are required. After which EPA can give final approval. EPA should not give approval if hydrology studies are not conducted properly.

Overall, the most significant risk increasing the environmental impacts is the risk of project completion (Kokkaew and Wipulanusat, 2014; Raghuram et al., 2009). The risk encompasses the failure of project management resulting in delays. For example, if the duration of construction was 2 years and it has been delayed to 6 years, then the community and workers alike will be exposed to more emissions during construction activities creating breathing problems, eye infections or other serious diseases (Chang et al., 2010). Design changes or scope increase can also translate into human health impacts e-g by lane expansion and interchange provision in one of the projects; dust, smoke and noise pollution levels will increase due to additional traffic on the road. This will have impact on the community and the users. So, completion risk can increase significantly the human health damage.

Chapter 5

Conclusions and Recommendations

The study evaluates the impact of PPP risks on sustainability. Sustainability has been broken down into a TBL hierarchy over which the impact of various risks is traced both quantitatively and qualitatively. Through a sensitivity analysis, probabilistic risk scores of the various risk impacts were assessed over the three groups of sustainability; financial, environmental, and social. Additionally, mitigation strategies for the most sensitive risk relationships are devised with the help of experts.

i. Overall, human health damages indicator of environmental sustainability has the highest range of risk score for completion risk. This implies that if the projects fail to be completed within the stipulated time, the most significant impact will be on the human health due to increased and prolonged level of exposure to pollution, emissions, dust, smoke causing both disease, and emotional trauma.

ii. However, life cycle cost indicator of financial sustainability has the most amount of risks acting on it. This implies that during planning of the projects, life cycle cost impacts of the execution phase should be given more consideration for efficient project delivery.

iii. For social sustainability, the socio-economic repercussions indicator has the highest value of risk score range as compared to other impact categories. This can be due to the fact that for the other indicators, the impact may vary according to the project specific context. Also, for the socio-economic repercussions, unforeseen risks can create wide-ranging impacts.

iv. Risks should be handled by the party which is in the best position to handle that risk. However, if one party fails to deliver the agreed upon responsibilities, then, overall, the project will suffer. Thus, strong commitment and support should be extended between parties for managing risk in PPP projects to ensure sustainability.

v. Concession agreement should be flexible for handling the changing risk dynamics of the PPP environment. Parties should establish a strong risk-reward system earlier on in order to prevent conflicts.

The study can help PPP decision makers to explore the effect of risks in the changing environment of the project over the life cycle. Projects can be made sustainable if stringent efforts are expended to manage the relationships between the partners on the project. The risk responses are context-specific and for different risk scenarios, the mitigation strategies vary. The present study deals with a meso-level risk interpretation. For future researchers, it is recommended to explore the relationship of risks with each other focusing on how the risk interaction may affect the project outcomes. Furthermore, risk pricing efforts can also be made for valuation of the impact of different risks on the sustainability indicators. This can help develop the percentage cost allocation required for mitigation. This will be possible after looking deeper into the micro-level risk-indicator interaction.

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