PROJECT PERFORMANCE ASSESSMENT USING MODIFIED PROJECT QUARTERBACK RATING SYSTEM FOR INDIAN CONSTRUCTION PROJECTS

Thesis

Submitted in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

by

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D E C L A R A T I O N

by the Ph.D. Scholar

I hereby *declare* that the Research Thesis entitled **"Project Performance Assessment Using Modified Project Quarterback Rating System for Indian construction projects"** which is being submitted to the National Institute of Technology Karnataka, Surathkal in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy in Civil Engineering, is a *bona fide report of the research work carried out by me*. The material contained in this Research Thesis has not been submitted to any University or Institution for the award of any degree.

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C E R T I F I C A T E

This is to *certify* that the Research Thesis entitled **“Project Performance Assessment Using Modified Project Quarterback Rating System for Indian construction projects”** submitted by Prachi Vinod Ingle (Register Number: 155054CV15F04) as the record of the research work carried out by her, is *accepted as the Research Thesis* submission in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy.

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ABSTRACT

The Indian construction industry is facing challenges due to performance shortfalls. Construction projects are highly complex, distinctive, fragmented and do not have well-established performance assessment models to evaluate their project success. This study has focuses on developing a mathematical formulation of construction project performance assessment to suit Indian context by modifying the original PQR model. The original PQR model combines seven performance areas. Though previous studies have identified performance areas that can be used to assess the performance of construction projects, those areas are not comprehensive in indicating overall performance. In addition, major research work is from contractor's perspective. Hence, there is a need to contextualize the performance areas that contribute towards the Indian construction industry. To indicate the modification the word modified Project quarterback rating (MPQR) is adopted. MPQR model's output is a project score based on performance areas affecting project success and outcome. The objectives set include identifying performance areas for Indian construction industry, integrating all performance areas in MPQR model and validating the MPQR model. The modified model comprises of ten performance areas and twenty-eight performance metrics related to project performance.

The study used a mixed method research approach in data collection. The quantitative approach used survey questionnaires and case studies were used to obtain qualitative data from construction projects in India. Partial Least Square Structural Equation Modeling (PLS-SEM) technique was used in analyzing and establishing the relationship between the constructs. The PLS- SEM results show that all performance areas have a significant impact on project performance except productivity which was found to be insignificant. Even though the result shows productivity has no significant impact on performance it impacts construction time and cost overruns, and therefore it should not be ignored. Furthermore, the findings provide that customer relation, safety, schedule, cost, quality, finance, communication and collaboration, environment, productivity and stakeholder satisfaction are impacting project performance. It also emerged that all ten performance areas are important for

measuring project success for Indian construction industry. Case studies also supported this finding. The MPQR model is a comprehensive single score approach that can be utilized to compare performance over different projects. The identification of performance areas can help project management teams to better coordinate projects by analyzing the importance of performance areas. The findings of the study will guide project stakeholders to prioritize their efforts towards achieving excellence in performance.
Key Words: Project success, Project performance, Structural Equation Modeling (SEM), Partial Least Square (PLS), Performance Metrics, Performance areas.

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ACRONYMS

CI	Construction Industry
GDP	Gross Domestic Production
BSC	Balanced Scorecard
EFQM	The European Foundation for Quality Management
PQR	Project Quarterback Rating
KPIs	Key Performance Indicators
CSFs	Critical Success Factors
PM	Performance measurement
NIST	National Institute of Standards and Technology
MBNQA	Malcolm Baldrige National Quality Award
IDP	Integrated Project Delivery
CBPPB	Construction based Practice Programme Benchmarking
AVE	Average Variance Extraction
EFA	Exploratory Factor Analysis
SEM-PLS	Structural Equation Modeling-Partial Least Squares.
FA	Factor Analysis
PCA	Principal Component Analysis
CFA	Confirmatory Factor Analysis
KMO	Kaiser-Meyer-Olkin
MRA	Multiple Regression Analysis
PA	Path Analysis
SEM	Structural Equation Modelling
LA	Latent variable
SPSS	Statistical Package for the Social Sciences
MPQR	Modified Project Quarterback Rating
CUC	Construction unit cost
CGR	Construction Cost growth

RC	Rework cost
CS	Construction speed
SP	Schedule of payment
SC	Schedule growth
OS	OSHA recordable
LTI	Lost time injuries
F	Number of fatalities
PQ	Project quality
IBC	Item beyond cost
DLP	Defect liability period
DC	Defect cost
BOQ	Bill of quantitates
S	Social environment
T	Technical environment
P	Political environment
E	Economic environment
RFI	Request for Information
CMP	Communication Management Plan
FOM	Frequency of Meeting
IOM	Impact of client and contractor meeting
RB	Return Business
DC	Disputes Claims
FP	Feedback Policy
EP	Equipment Productivity
LP	Labour Productivity
RERA	Real Estate Regulatory Authority
MOM	Minutes of Meetings
CR	Composite Reliability
APC	Average Path Coefficient
ARS	Average R-squared
AARS	Average adjusted R-square

AVIF	Average block VIF
SPR	Sympson's paradox ratio
GoF	Goodness of Fit
RSCR	R-squared contribution ratio
SSR	Statistical suppression ratio
NLBCDR	Nonlinear bivariate causality direction ratio

CHAPTER 1

INTRODUCTION

This chapter presents an overview of the background of study, problem statement, research aim and objectives, scope of the research and organization of thesis.

1.1 Background and research motivation

Construction industry (CI) makes a significant contribution to national economy, creates employment opportunities, and it creates investments opportunities in various sectors. In India, CI contribution to gross domestic production (GDP) was 8% in 2017 (India Brand Equity Foundation 2018) along with a projected investment in infrastructure amounting Rs 50 trillion (US$ 777.73) billion. The expansion in infrastructure presents enormous opportunities. The industry is expected to grow on average by 7.1 percent per year by 2025. It affects and is affected by economic development of the nation. In recent times, construction projects are growing larger and becoming more complex (Toor and Ogunlana 2008). The Indian construction industry is gaining importance but still the performance of the industry is poor. In spite of the emphasis given to the growth of this industry, CI is facing problems due to serious performance shortfalls. These shortfalls are associated with low productivity, cost and time overruns and disputes. One of the reasons for poor performance of construction projects is due to the failure in determining the performance areas in construction phases (Takim et al. 2004). However, the poor performance of the industry is not limited only to the Indian context but also for other countries (Loganathan et al. 2017).

The importance given to improve performance of the construction industry has been recognized by various countries. Different initiatives have been taken by different countries for continuous improvement of the industry (Ofori 2000). Ankrah and Proverbs (2005) stated that despite the intrinsic importance of performance measurement, it is not extensively implemented because of the inadequacy of measures, complexity of measurement and the process being time consuming and costly.

Different methods/frameworks have been available to measure performance such as balance scored card (BSC), The European Foundation for Quality Management (EFQM) framework and performance prism. BSC and EFQM tool have been widely adapted in construction industry to measure project performance. For measuring performance of the project, one must first establish suitable performance areas that are most critical in determining project success at the start of the project. Comprehensive project performance can be measured by assessing various performance areas. Performance area evaluation can be used for setting benchmarks for a project and can help for continuous improvement. Even though the performance areas of a project may differ depending on context, the ultimate aim is to improve the overall performance of the industry. This is achieved by improving independent performance areas at various levels, ultimately leading to national development.

CI is project-based industry where different stakeholders such as contractor, client, consultant, subcontractor, construction managers need to work together to accomplish a project. A stakeholder should have the potential for continuous improvement in their performance (Ahmed and Mohamad 2016). The ultimate goal of all projects is success. Project Management teams should work on achieving project goals so that the project can be called successful, to be able to be competitive in organizations. CI is continuously changing with development of different business methods and new technologies (Koota 2003). Hence CI should seek efficient tools, techniques and develop strategies for achieving success in their projects. Recently, most extensive research topic in construction management is project success and standards to measure project performance (Chou et al. 2013). Traditionally, the approach used to measure project performance was through the most common performance areas i.e., time, cost and quality (iron triangle).

A project is considered successful when it is completed as per schedule, within budget and as per required specifications. Jari and Bhangale (2013) stated that construction project is successful if it is meeting the required expectation of the stakeholders and achieving its projected purpose. Project success criteria differs between stakeholders, as perceptions of stakeholders will interpret project success in different aspects. Thus, the concept of project success in CI is ambiguous among the minds of construction professionals. The review of literature does not provide a consistent and widely accepted definition of project success and there is no standard methodology of measuring it (Chovichien and Nguyen 2013). Therefore, there is a continuous need to identify performance areas that impact project success. Considering, above there is a need for a comprehensive study aiming to understand the performance areas for construction projects and devise mechanisms to assess project performance with reference to the Indian context.

1.2 Problem Statement

CI is becoming very competitive and risky due to its complex characteristics (Walker 2002). It is necessary to give additional attention to construction management research, due to the substantial competition in this industry. Most construction management research focuses on organizational level issues. This study explores various factors that affect performance at the project level. Considering global impact of CI, measuring project performance is very important. Hence, project level studies are necessary to give integrated solutions for issues that arise at various levels. Project level studies help to understand the nature of problems.

Major challenges faced by CI are due to traditional construction practices which need to be changed to new approaches (Kumaraswamy 2006). Even though CI of all countries face challenges and problems, the problems for developing countries are different such as global market conditions, limited resources, lack of skillful team members, budget, and tough competition for the construction business. Therefore, efforts to improve the performance of CI have now been recognized by different countries for continuous improvement of the industry at different levels. In support of continuous improvement, it is important to identify performance areas that impact construction project performance.

The assessment of construction projects is essential for project stakeholders to determine project success (Bannerman 2008). Project are unique in their size, complexity, functionality, scope, (Shishodia et al. 2018). Hence, criteria for measuring project success may vary from project to project. The perceptions of stakeholders will interpret project success in different perspective. Thus, measuring project success is a complex process and requires identification of various performance areas.

Performance areas affecting project performance are reported by different researchers and are discussed in detail in chapter 2. With the aim of identifying performance areas for Indian construction projects, majority of research studies have focused on measuring performance areas such as time, cost, quality, productivity and safety to name a few (PMI 2005; Iyer and Jha 2005). In spite of various similarities in literature, there is no accord among the researchers on what constitutes a comprehensive list of performance areas (Heravi and Ilbeigi 2012; Gudiene et al. 2013). Therefore, it is essential to have a set of predefined performance areas that positively influence project success. In addition, it is difficult to combine performance scores over different performance areas into a single project score for evaluating project performance. It is also tedious to develop a standard model that considers all performance areas as every project has different objectives and priorities which determine the impact of each performance area on project success (Yong and Mustafa 2013; Hanna et al. 2014).

Also, exisiting work is majorly country specific in context, making it impervative to develop project performance model for different contexts (Yong and Mustafa 2013; Ofori et al. 2016). Major research work is based on the contractor's perspective in their studies. Thus, this supports that there is need to contextualize the performance areas that contribute specifically towards Indian construction projects. However, using a standardized model leading to a single score is easy to use and implement for comparing scores of projects. Among the diverse assessment models in literature, Project Quarterback Rating (PQR) model (El Asmar et al. 2015; Hanna et al. 2014) stands out as a standardised approach which evaluates several performance areas. In this model, combining these performance scores over individual areas gives a consolidated performance score which can be compared across multiple projects.

Development of construction projects by improving the performance areas requires (i) understanding the performance areas and (ii) how to measure these performance areas. These lead to following research questions:

- ❖ *What are the different performance areas impacting construction project performance?*

- ❖ *What are the relationships between performance areas affecting project success?*
- ❖ *How to develop performance assessment model for Indian construction industry for improvement of construction project performance?*

1.3 Research Aim and Objectives

The aim of the research is to develop construction project performance assessment model for Indian construction projects based on the PQR model. The specific objectives of this research were:

- ❖ To identify performance areas responsible for successful projects in Indian construction industry.
- ❖ To study PQR Model in current form and identify additional metrics based on identified performance areas that contribute to overall project performance.
- ❖ To integrate identified additional performance areas into existing PQR Model for improved performance assessment.
- ❖ Validate modified PQR Model.

1.4 Research Scope

The research mainly focuses on performance areas that impact Indian construction projects. Therefore, the unit of analysis of this study is construction projects. Both public sector and private sector projects were included. The study was limited to key stakeholders such as contractors, clients and consultants. Data was collected from professional experts handling residential, commercial and infrastructure construction projects. This study specially focuses on performance areas from a general perspective.

The research explored the performance areas related to CI in the context of India. In terms of geographical coverage this study is confined to construction projects in Maharashtra. Only professional experts who work in this context participated in the survey. The case studies conducted were restricted to construction projects in Maharashtra.

1.5 Significance of the Research

Output of this study identifies performance areas that are important to develop a modified PQR model for Indian construction projects. This output will indicate performance areas that can help project management teams to better coordinate the project. This will improve the construction project management throughout the project life cycle. Also, researchers have explored different performance models, and frameworks for evaluating performance using a set of critical success factors or performance areas. These studies have been adapted from developed countries such as Europe, Australia, USA and UK and only a few studies have focused in context of developing country as India. Hence, there was a necessity to develop quantitative performance assessment model for Indian construction projects.

In addition to this contextualized contribution, this study adds to the project management body of knowledge. The performance areas adopted for this research for construction projects will help in understanding performance areas and will assist stakeholders in monitoring projects different phases of construction. As the performance of Indian construction projects improve, local industries grow in turn, which accelerates the growth of economic development of the nation.

1.6 Limitations

The findings are generalized based on data collected from industry practitioners and professionals from India. The findings have helped to modify PQR model for evaluating project performance. It is difficult to collect data from all stakeholders of projects. Hence, only key stakeholders were considered for this research. The precision of the findings is based on the quality of the responses obtained as per experience.

1.7 Organization of thesis

The thesis comprises of eight chapters.

Chapter 1: Introduction

This chapter presents an overview of the background of study, problem statement, research aim and objectives, and the scope of the research.

Chapter 2: Literature Review

This chapter gives a detailed review of literature on performance areas impacting project performance of CI. In addition, different types of performance models in construction industry are highlighted.

Chapter 3: Research Methodology

This chapter provides comprehensive discussions regarding the research methodology. Mixed research approach is adopted to achieve the objectives. Quantitative data is collected through questionnaire surveys, while case studies are used to obtain the qualitative data. It also provides details of methods used for sampling, data collection and analysis.

Chapter 4: Quantitative data analysis

This chapter presents data from quantitative part of the research. The results of statistical analyses are reported. Also, the relationships among various performance areas and project performance are interpreted.

Chapter 5: Development of modified PQR model

This chapter discusses relevance of PQR model, development of modified PQR model that combines performance areas into single comprehensive scores.

Chapter 6: Qualitative data analysis

This chapter presents data from the qualitative part of the study. The chapter discusses the results of the three different case studies. The case studies focus on answering two particular questions (i) to investigate whether these performance areas impact project performance (ii) are the identified performance areas sufficient to evaluate project performance in context of Indian construction projects. The findings from case studies were used for triangulation to support the model to consider all ten performance areas and twenty-eight performance metrics as important to measure project performance for Indian construction projects.

Chapter 7: Causal relationship of performance areas on project performance

This chapter discusses development and validation of the model. The chapter also presents the results of Partial Least Square Structural Equation Modelling as well as model fitness.

Chapter 8: Conclusions and Recommendations

This chapter presents conclusions that can be derived from the findings of this research. It also delineates the limitations, and further scope of the research.

CHAPTER 2

LITERATURE REVIEW

This chapter consists of basic definitions of project success. It also examines the problem concerning performance measurement in construction industry and provides a detailed literature review on project performance areas and criteria to measure success. It also highlights different performance models used to evaluate project performance.

2.1 Performance in Construction Industry

The problems of 'performance in construction' may lead to project failure. There are various factors resulting in project failure. The dimensions used to measure failure of a project are time and cost overruns, quality issues. The causes are limited resources and problems among project stakeholders (Ogunlana et al. 1996). Long et al. (2004) found that performance problems are found in large constructions project due to various reasons such as: incompetent designers, poor estimation and change management and social and technological issues. Avots (1969) found that the wrong choice of project managers, unplanned project termination and unsupportive top management are main reasons for project failure.

Performance problems are related to improper management of projects (Chitkara 1998; Hughes 1986; Morris and Hough 1987). Okuwoga (1998) remarked that performance problems are caused due to time and budget. Yaweli et al. (2005) stated that appointing of right contractors will ensure quality and save cost. Navon (2005) mentioned that performance problems can be divided in two categories: (i) planning and (ii) actual achieving. Kim et al. (2009) remarked that construction projects performance is affected by factors such as political, economic, social, cultural and internal risks within the project.

2.2 Definition and concept

Project success is important for the project management team and is an extensively researched topic. Project success can be achieved through good performance in desired performance areas. A project is considered as successful if the project meets the project specifications and stakeholder satisfaction (De Wit 1986). Chan et al. (2002) stated that construction project is considered successful when it is completed on time, within budget, and as per acceptable quality irrespective of the complexity and environment within which it is constructed. Bakert (1988) considered a project successful "if the project satisfies the technical performance standards and if there is level of satisfaction among all key people in parents' organization," key people being major project stakeholders.

There are multiple definitions of the term "project success" that often changes from project to project according to stakeholders involved, scope, project size, sophistication of the owner related to the design of facilities, technological implications, and a variety of other factors (Shokri-Ghasabeh and Kavoousi-Chabok 2009; Saqib et al. 2008). Yoke et al. (2012) remarked that the ability of the contractor to select appropriate subcontractors during the process of bidding, as well as the ability to suitably manage these subcontractors essentially result in a successful project.

Al-Momani (2000) classified project success into two important features (i) service quality by contactors and (ii) owner's expectations. According to Cleland and King (1986) project is successful if it fulfilled two criteria: project's technical performance objective with respect to time and budget, contribution that the project made to the strategic mission. Moreover, Munns and Bjeirmi (1996) argued that project success and project management are not certainly directly related. The objectives of both project success and the project management are different and the control of time, cost and progress, which are often the project management objectives, should not be confused with measuring project success. The role of project management is important for project success but it is affected by many other factors that are not in direct control of project manager. Meanwhile, Goatham (2016) stated that knowing the reasons for project failure is more important than defining project success. Defining project success is comparatively easy, but different people interpret project success in different ways. Even though definition of project success is different for each stakeholder, it is based on the basic concept of overall achievement of project objectives and expectations. According to Baccarini, (1999) project success consists of two components: (1) project management success and (2) product success. Project management success focuses on the project process and product success deals with the effect of project's final product. Project management success and product success are different, e.g., a project has been managed efficiently, but eventually does not meet customer or organizational expectation (Shrnhur et al. 1997). In order to properly assess project success performance areas should be identified. Existing studies related to performance measurement focus on performance areas (also referred to as factors, attributes, variables, metrics, Key performance indicators (KPIs) and critical success factors) (Molenaar and Navarro 2011; El Asmar et al. 2015; Tripathi and Jha 2018). The criteria for measuring project success varies depending on project stakeholders. It also depends on size of project and technological tools. If project management team defines the criteria for measuring project success in the beginning of the project it becomes easy to determine the project success (Baccarini 1999).

All the project requirements must be understood clearly and proper planning should be done to achieve project success. A project is considered successful when it is completed on time and allotted budget. The most common criteria of ensure project success are cost, quality and time (Jaria and Bhangale 2013).

2.3 Project performance areas

Performance area of projects are defined as "input" with different conditions and has an important role in determining success of project (Pandremmenou et al. 2013). Performance areas are indicators that determine the level of achievement in a project. A performance area helps to measure the performance and compare it with project goals and objectives. Several studies determined performance areas for measuring project success over different performance dimensions such as cost, time and safety (Chan et al. 2004; Walker and Shen 2002; Hanna et al. 2014). Rockart (1982) was the first to use the term "critical success factors" in the context of information system and project management. Critical success factors or performance areas are the factors which need to be monitored by project management team in order to ensure project success.

Different performance areas were used by different researchers and each area describes project performance in a different way. The following areas were the most common that had been used in literature.

2.3.1 Time and Cost

Chan and Kumaraswamy (2002) stated that time performance areas have been considered significantly in various countries in construction projects. Time is considered as the most common criteria to measure success or failure of project, and completion date of the project is important criteria in measuring project performance (Shokri-Ghasabeh and Kavoousi-Chabok 2009). Chan and Kumaraswamy (1996) remarked that various issues and changes from original design arise during the construction phase, leading to problems in cost and time performance. Cost and time performance have been identified as general problems in the CI (Okuwoga 1998). Tabish and Jha (2011) reported that performance of Indian projects has not been up to the mark due to delays.

Ahsan and Gunawan (2010), defined time overrun as the project completion duration excluding actual planned duration. The findings from analysis highlighted that contract durations and experienced consultants, procurement and government procedures, natural disasters are the most important factors that affect the duration of projects. The government constraints that delay projects are delay due to land acquisition issues and policies that are imposed by the government in procurement of land. According to Dissanayaka and Kumaraswamy (1999), type of client, project complexity, experience of project team and communication are highly correlated with time performance areas; whilst project complexity, client and contractors' characteristics are highly correlated with cost performance area. Chan et al. (2002) measured time performance by time overrun, speed of construction and construction time. Enshassi et al. (2006) found that delays caused due to closures that lead to material shortage, was the most significant factor in time performance area. This factor directly affects project duration.

Cost performance area is one of the most important area of project success used by major stakeholders (Li et al. 2012). Delay in project completion will lead to an increase in cost (Ahsan and Gunawan 2010). Ghasabeh and Chabok (2009), remarked that in project management, time, scope and cost are the three factors considered to measure project success. Cost is considered as most challenging issue in the construction industry in India. Iyer and Jha (2005) stated that the factors affecting cost performance are: top management support, decision making, project managers coordinating and leadership skill, social condition, coordination among project participants, feedback and monitoring among project participants, owner's competence and climatic conditions. Coordination among project participants has the most significant influence on cost performance of projects. Chan and Kumaraswamy (2002) proposed managerial and technical strategies to increase the construction speed. It is noticed that fast information transfer among project stakeholders, effective communication, proper selection and training of managers and use of advanced software will help to improve the performance of projects. The performance areas used by Sanvido and Konchar (1998) include: unit cost, construction speed, delivery speed, cost and schedule growth, turnover quality and systems quality. Time and cost areas should be monitored properly to avoid delays (Chan et al. 2002).

2.3.2 Safety and Health

Construction safety is of paramount importance in construction projects. Health and safety are defined as the degree to which the general conditions promote the project completion without major accidents (Chan et al. 2002). Accidents are caused because of unsafe conditions and unsafe acts. Safety area is important for Design/ Build contractor who is responsible for construction activity and where chances of occurring accidents are more. Therefore, it is advisable to restrain construction activities from starting until health and safety plan has been developed as per the client's requirement. A successful safety plan can be measured in terms of no injury to people working, no damage to environment and no damage to machine and tools (Aksorn and Hadikusumo 2008).

In the construction industry, site safety includes training, supervision, and leadership and not just compliance towards processes and policies. Safety area is measured by accidents occurring during construction duration of the project (Alzahrani and Emsley 2013). Construction safety is important because workers injuries cause tremendous losses (Ali et al. 2013). Thus, safety practices must be encouraged for workers to minimise lost time of construction projects. Numerous studies have adopted number of recordables incidents and lost time injuries for safety performance area (OSHA 2004; Leon et al. 2017) As number of recordables increase safety performance decreases and thus reduces stakeholder's satisfaction (Maloney 2002; Huang 2003; Leon et al. 2017).

2.3.3 Quality

The Quality performance area in the construction industry ensures that projects will achieve the requirements of conformance to quality standards. According to Sandivo et al. (1992), Quality is defined as a set of factors of a particular product or industry that meets a specific requirement. It is to be assessed in each phase of construction as it is a very important area of the "iron triangle". The final product quality and process quality are important for project success. Chan et al. (2002) defined quality as the degree to which the general conditions promote meeting of project requirement of workmanship and materials. Chou et al. (2013) considered the quality as project outcome.

Quality can be measured by number of non-conformance issues, rework cost and number of change requests. Molenaar et al. (1999) consider three factors for measuring quality in design-build projects: conformity with expectations, owners' satisfaction and administrative burden. Enshassi et al. (2006) identified quality factor from owner's perspective: conformance to specification, quality of equipment and materials, quality assessment system and quality training. Lepartobiko (2012) remarked that quality can be achieved by identifying and eliminating the factors that cause poor performance. El Asmar et al. (2015) used five performance metrics to measure quality for Integrated Project System: system quality, number of punch list items, number of deficiency issues, latent defect costs, warranty costs and number of deficiency issues.

2.3.4 Financial Profit

Finance is considered one of the most important performance areas. It measures financial success of the project. The competition is increasing and construction organizations are aware of it and hence projects should be managed properly to be profitable (Chan et al. 2002). Contractors will remain in business if they make a profit, which is a major motivation for construction organizations. Financial performance area is difficult to measure because major construction organizations would not be willing to reveal their profit margins. Chan et al. (2002) measured profit as total net revenue over total costs. The project is considered profitable when revenue earned by the contractor for the total amount of work achieved to date is greater than cost incurred for the same work (Leon et al. 2017). Profit is calculated when the final account is settled in construction phase. Profitability is an important factor to private sector clients as well as design-build projects, sooner the project is ready, faster will be rate of return.

2.3.5 Productivity

Productivity is considered as an important criteria to measure the performance of construction projects. Productivity is effective utilization of resources in producing goods or services (Chan et al. 2002). Productivity is majorly referred as to ratio of output value and input value to produce output (Yi and Chan 2013; Ayele and Fayek 2019). The term productivity is defined as maximizing of output while minimizing input (Durdyev et al. 2018). Improving productivity is important because proper management of resources in construction projects will help to save time and cost.

Construction labour productivity is defined as the units of work placed per man hours (Bekr 2017). Jarkas and Bitar, (2012) used two measures of productivity; total factor productivity and partial factor productivity. The total factor productivity is a ratio of total output to total input, which includes labour, materials, equipment and capital. The partial factor productivity is measured as ratio of outputs to a selected set of inputs or a single input. The major problems that influence productivity are materials, availability of tools, delays in material delivery and frequent changes in drawings. To improve project performance, it is advised that variability in labor productivity should be reduced considering the workload. The variability is defined as duration difference between planned and actual task duration.

2.3.6 Environment

Construction industry has to deal with increasing demands and pressures of the society. The environment in which the project is executed plays an important role in the project success. There are various factors which need to be taken into account for achieving project success such as social, political, economic and technical factors. Akinsola et al. (1997) found economic and political factors are the most important. According to Gudiene et al. (2013), the economic environment is the most important factor. Pheng and Chaun (2006), have categorised environment as: immediate environment and external environment. The immediate environment refers to project stakeholders such as investors and clients. The external environment of a project includes social, economic, technological and political environment. The changes in the environment during the life of project will influence decisions. They are more dynamic and impact more on project success.

2.3.7 Stakeholder satisfaction and customer relations

Stakeholder satisfaction has rarely been considered as important for measuring project performance (Liu and Walker 1998). Satisfaction refers to level of "happiness" of people, where 'people' include all project stakeholders such as client, consultants, contractors and architect (Lam et al. 2007). Stakeholder satisfaction is a measure of how a project meets its expectations. Project participants are considered as the key elements for project success. A study in United Kingdom construction industry measured stakeholder satisfaction as based on their pay, the amount of influence they have for job, sense of achievement and respect they get from the authorities. Ahmed and Kangari (1995) identified factors for measuring stakeholder satisfaction as: schedule control of project, project in client budget, effective communication, quality of work and response to complaints. Chan et al. (2002) measured satisfaction as; user expectations and participants satisfaction.

Project stakeholders are considered as key elements for a successful project. The success of project is also based on trust and understanding between stakeholders. In construction, customer relation has been considered as important factor. Customer relation area is difficult to measure as it does not consist of standardised metrics. Customers are stakeholders in project who are the potential users of facilities. The customer relations, when managed successful will result in stakeholder satisfaction and repeat business. El Asmar et al. (2015) measured customer relation with claims and return business. Claims arises from issues related to cost overrun and derlays. Disputes arise between contractors and client due to quality of work done (Shdid et al. 2018).

2.4.8 Communication and collaboration

Communication and collaboration are key for managing crisis arising among stakeholders and for achieving project success (Ulmer 2001). There exists a significant relationship between project success and communication (Ahmed and Mohamad, 2016). Improved communication plan leads to higher chances of project success (Chang and Shen 2009). Senior management should frequently communicate with various stakeholders to explain potential system changes. El Asmar et al. (2015) measured communication and collaboration with the help of seven metrics: (1) the number of requests for information (RFI) per million dollars; (2) the RFI processing time; (3) the extent of rework; (4) the number of resubmittals per million dollars; (5) the total percentage of project change; (6) the change-order processing time and (7) percent plan complete (PPC) trend.

2.4 Performance areas for developing countries

Shenhar et al. (2001) developed a framework for assessing project success with the help of Key performance indicators (KPIs). The identified KPIs are: impact on customer, preparing for future, project efficiency and organization success. These KPIs should be addressed during the life of the project.

Chan and Kumaraswamy (2002) remarked that project scope is one of the main components affecting construction duration and therefore project completion on time is important as it can be used for assessing performance of projects. Chan et al. (2002) established criteria for design/build projects in construction. They grouped the KPIs into objective indicators and subjective indicators. The objective indicators are quantitative that are tangible and measurable such as time, cost profitable, health and safety, whereas the subjective indicators are qualitative and difficult to measures; quality, productivity, satisfaction, environmental sustainability and technical performance.

In Hong Kong, Lam et al. (2007) aimed to develop project success index to benchmark the performance of design/build projects. The findings highlighted that design/build project participants suggest that cost, time, quality and functionality should be criteria to assess projects. In Ghana, Ofori et al. (2016) identified eight critical success factors (CSFs) in respect to Ghanaian contractors. The CSFs are work culture, client satisfaction, leadership, environment, organisation design, strategy, analysis of information and knowledge management. Ahadzie et al. (2008) conducted research in Ghana for mass housing projects. They identified four KPIs to determine project success as: environmental impact, quality, cost, time and customer's satisfaction. Cho et al. (2009) conducted a study in Korea to analyse the relationship among project characteristics and project performance. They identified quantitative KPIs; cost (i.e., award rate, unit cost and cost growth) and time (i.e., construction speed, delivery speed and schedule growth) and quality (i.e., turnover quality and system quality), and owner's satisfaction. Tripathi and Jha (2018) identified and evaluated successful attributes for construction organization. The attributes are experience and performance, top management's competence, project factor, supply chain and leadership, availability of resources and information flow, effective cost control measures, favorable market and marketing team, and availability of qualified staff.

Yong and Mustafa (2013) in Malaysia identified critical factors for success of construction projects. The findings highlighted strong consistency in perception between respondents in recognising the importance of human related factors such as commitment, communication, competence towards project success. Another study in Malaysia by Al-Tmeemy et al. (2011) proposed a framework for assessing project success for building projects. They identified 13 KPIs which are; cost, time, quality, safety, scope, customer satisfaction, technical performance, market share, profits, functional requirements and benefit to stakeholders.

2.5 Performance areas for developed countries

Atkinson (1999) identified KPIs for United Kingdom. He was one of the earliest researchers who concluded that the iron triangle i.e. cost, time and quality are not sufficient to measure project success. The study focuses on KPIs for project management. The study found that in addition to iron triangle, there were other criteria to be used to assess project performance such as; information systems, organisation benefits and stakeholders' benefits. In another study, Ojiako et al. (2008) aimed to develop different understanding of KPIs. Their findings indicated that KPIs vary from project to project as every project is unique in its own way. The author suggested that beyond iron triangle there are many other factors which must be discovered and quantified to measure project performance. Songer and Molenaar (1997) in United Kingdom investigated owner attitudes towards factor selection for design-build procurement. The success criteria identified are schedule, budget and conformance to user expectations.

In Australia, Yeung et al. (2008) conducted an empirical study to formulate a model to evaluate success of relationship-based construction projects in terms of KPIs using Delphi survey. After conducting four rounds of the Delphi survey, the KPIs identified are; client satisfaction, quality, time, safety, innovation and improvement, communications and aesthetics.

In South-eastern Europe, Radujkovic et al. (2010) identified 37 KPIs to assess construction projects. Molenaar and Navarro (2011) identified performance areas for highway design and construction projects as: cost, schedule, quality, safety, and environmental. Rankin et al. (2008) identified performance metrics for Canadian construction industry. The metrics identified are; cost, time, scope, quality, safety, innovation and sustainability that covered both construction and building phase of the project. The performance areas used by Konchar and Sanvido (1998) are: unit cost, construction speed, delivery speed, cost and schedule growth, turnover quality and systems quality. Table 2.1 summaries different performance areas used in literature.

Table 2.1. Literature summary for performance areas

Areas **References**	**C**	**T**	**Q**	**Sa**	**S**	**Pr**	**Fi**	**Env**	**Oth**	**C&C**	**SS**
Pinto and Slevin (1988)										*	
Sanvido et al.(1992)	*	*	*	*					*		
Walker (1995)			*	*	*					*	
Munns and Bjeirmi (1996)											*
Belassi and Tukel (1996)								*			*
Pocock et al. (1997)	*	*							*		
Songer and Molennar (1997)	*	*					*	*	*		
Okuwoga (1998)	*	*									
Reichelt and Lyneis (1999)	*	*	*	*		*					
Chan et al. (2002)	*	*	*	*		*	*				*
Chan and Chan (2004)	*	*	*	*	*				*		*
Navon (2005)		*	*			*					
Iyer and Jha (2005)	*	*	*	*		*		*			*
Menches and Hanna (2006)	*	*		*			*		*	*	
Yu et al. (2006)									*		*
Saqib et al. (2008)	*		*	*	*					*	
Enshassi et.al. (2009)		*	*								
Shokri-Ghasabeh and Kavoousi-Chabok (2009)	*	*	*	*	*			*			
Tabish and Jha (2011)	*	*	*					*		*	
Al-Tmeemy et al. (2011)	*	*	*	*		*					*
Omran and Mamat (2011)						*		*			

Pinter and Psunder (2013)	*	*	*	*							
El Asmar et al. (2015)	*	*	*	*			*			*	
Williams (2016)	*	*	*	*		*					*
Triptha and Jha (2018)	*					*					

C= Cost, T=Time, Q=Quality, Sa=Safety, S=Scope, Pr=Productivity, Fi=Finance, Env =Environment, Oth= Other (Changes/Modification), C & C= Communication and Collaboration, SS= Stakeholder satisfaction

Performance metrics are the measures to achieve project success in each performance area. Performance metrics identified from the previous studies, in both developed countries and developing countries are summarized in Table 2.2.

Table 2.2 Performance metrics and performance areas for the construction industry

Performance areas	Performance metrics	References
Cost	Cost estimation, Cost growth, budget cost	Molenaar (1995); Pocock et al. (1996); Konchar and Sanvido (1998); Atkinson (1999); Chan et al. (2004); Molenaar and Navaro (2011); Kim et al. (2012); PMI (2013); El Asmar et al. (2015)
Schedule	Construction speed, Delivery speed, Schedule growth	Molenaar (1995); Pocock (1996); Konchar and Sanvido (1998); Atkinson (1999); Chan et al. (2004); Menches and Hanna (2006); PMI (2013); El Asmar et al. (2015); Berssaneti and Carvalho (2015); Meng (2012).
Quality	Systems, Punch-list items, Warranty Costs, Defect costs, Defect liability period.	Molenaar (1995); Atkinson (1999); Chan et al. (2004); Molenaar and Navaro (2011); Marques et al. (2011); PMI (2013); El Asmar et al. (2015).
Safety	OSHA recordable, LTI, Fatalities	Chan et al. (2004); Menches and Hanna (2006); Molenaar and Navaro (2011); Cheng et al. (2012); El Asmar et al. (2015).
Productivity	Productivity factor, Labour factor, Resource factor	Chan et al. (2004); Nguyen et al. (2004); Menches and Hanna (2006); Meng et al. (2012).
Finance	Profit	Walker and Shen (2002); Chan et al. (2004); Menches and Hanna (2006); El Asmar et al. (2015).
Environment	Political, economic, technical, social	Belassi and Tukel (1996); Chen and Paulraj (2004); Molenaar and Navaro (2011). Fuertes et al. (2013); Goh and Rowlinson (2013); Shen et al. (2010); Testa et al. (2011).
Communication and collaboration/Modifications	RFIs, Modification, Material waste, Resubmittals	Pocock et al. (1996); Walker and Shen (2002); Chan et al. (2004); Menches and Hanna (2006); Meng et al. (2011); PMI (2013); Arriagada and Alarcon (2014); El Asmar et al. (2015).
Relations	Return business, Claims, Feedback	Col and Ries (2006); Belout, (1998); El Asmar et al. (2015).
Stakeholder satisfaction	Satisfaction expectation and commitment	Munns and Bjeirmi (1996); Yang et al. (2011); Jepsen and Eskerod (2009); PMI (2013); Missonier and Loufrani-Fedida (2014).

Others (Project related)	clear objectives and scope, contracting method, risk management,	Walker and Shen (2002); Turner and Muller (2005); Liu et al. (2010); Nevo and Chan (2007); PMI (2013); Arantes and Figueiredo (2014); Sousa et al. (2014); Zou et al. (2010).

2.6 Project performance models and frameworks

Measurement of project performance requires developing criteria by setting performance indicators for project success. Performance measurement (PM) was initially started in 1970s and was applied in the accounting sector and considered financial indicators (Nudurupati et al. 2007). Kagioglu et al. (2001) defined performance measurement as the process of determining the extent to which an organization or an individual has been successful in achieving objectives and strategies. Beatham et al. (2004), suggested performance measurement is a critical key for continuous improvement.

PM practice in construction is practiced at project level, organisation level and stakeholder level. PM requires monitoring and tracking of those performance areas that are important for project success (Love et al. 2002). Various researchers have attempted to measure performance of a project (Mizell and Malone 2007; Chou et al. 2013; Eastham et al. 2014; Berssaneti and Carvalho 2015). Chan et al. (2004) attempted to develop a conceptual framework to assess project success through critical success factors. The authors identified five groups that impact project success: project-related factors, project procedures, project management actions, human-related factors, and external environment. Iyer and Jha (2005) stated that measuring the performance of any construction project is a very complex process because construction projects are involving stakeholders such as designers, contractors, construction managers, consultants and specialists. Lehtonen (2001) developed a framework for measuring construction logistics performance by using two-dimensions in order to improve productivity. The first dimension is improvement measures and the other is monitoring measures.

2.6.1 Performance measurement models

Balanced Scorecard (BSC):

Figure 2.1 BSC model.

Kalpan and Norton, (1992) developed a balanced scorecard for measuring performance of organizations with the help of four dimensions viz., financial, customer, internal business process, and learning and growth (leading indicators) with the focus on financial measures (lagging indicators). The focus on lagging indicators is a limitation of BSC model. Kagioglou et al. (2001) have adopted BSC model to construction organizations and added two new dimensions: project and suppliers. Figure 2.1 shows BSC model.

The European foundation for quality management (EFQM) Excellence Model:

EFQM excellence model was formulated in 1989. This model measures organizations for European foundation of quality management. EFQM tool can help organizations in continuous improvement. The model is widely used in Europe. The EFQM model uses nine performance criteria that are divided into enablers and results. The enablers are what the organization does and results are what organization achieves. The first five are enablers – leadership, people, policy, partnerships and resources and processes, whilst people results, customer results, society results and key performance results are described as the "results" (Quality Scotland 2008) as shown in Figure 2.2.

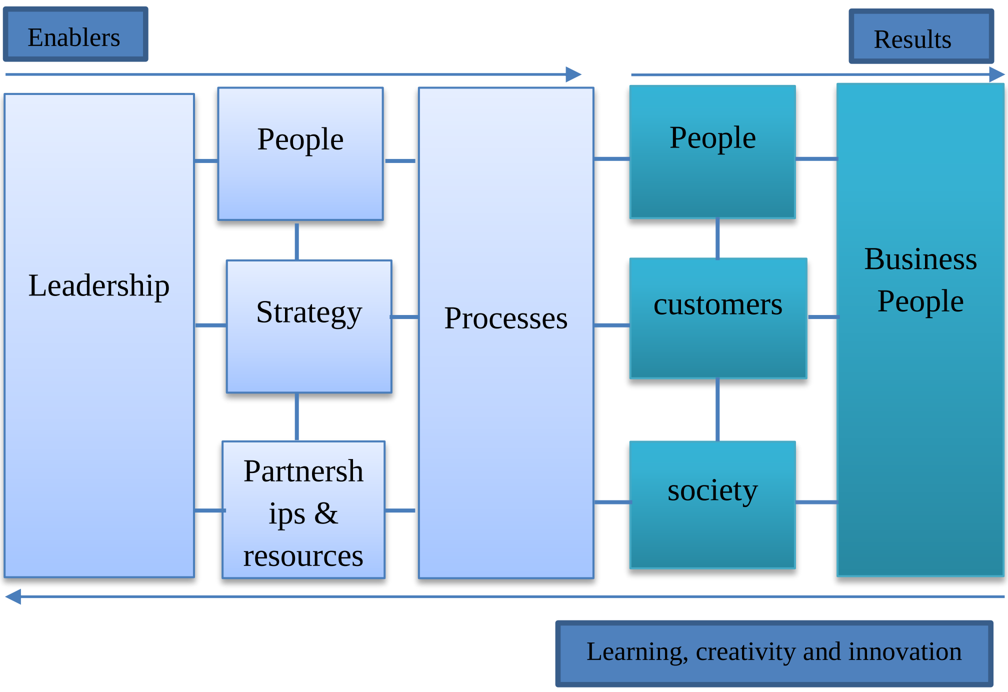


Figure 2.2 EFQM

***Construction Excellence Model*:**

Bassioni et al. (2008) developed a model for construction excellence which is similar to the EFQM Excellence Model. It divides success criteria into two classifications, enablers and results. The enablers are leadership, suppliers, customer and stakeholder focus, physical resources, strategic management, intellectual capital, information and analysis, risk management, people, work culture, partnership and process management. The results include internal stakeholders, project and external stakeholders, and organizational business results. The additional criteria considered by Bassioni, et al. (2008) are suppliers, strategic management, risk management, work culture, customer and stakeholder (National Institute of Standards and Technology (NIST) 2008).

Malcolm Baldridge National Quality Award:

The Malcolm Baldrige National Quality Award (MBNQA) is for designing and was developed during 1980s. It promotes excellence in business in the USA. It provides criteria which enable organizations to measure their performance for improving performance. It focuses on outcome of customer satisfaction and organization performance. The criteria considered are leadership, strategic planning, customer and market focus, measurement, analysis and knowledge management, workforce, process management and results (NIST 2008) (see figure 2.3). MBNQA gives more attention to leadership and customer satisfaction.

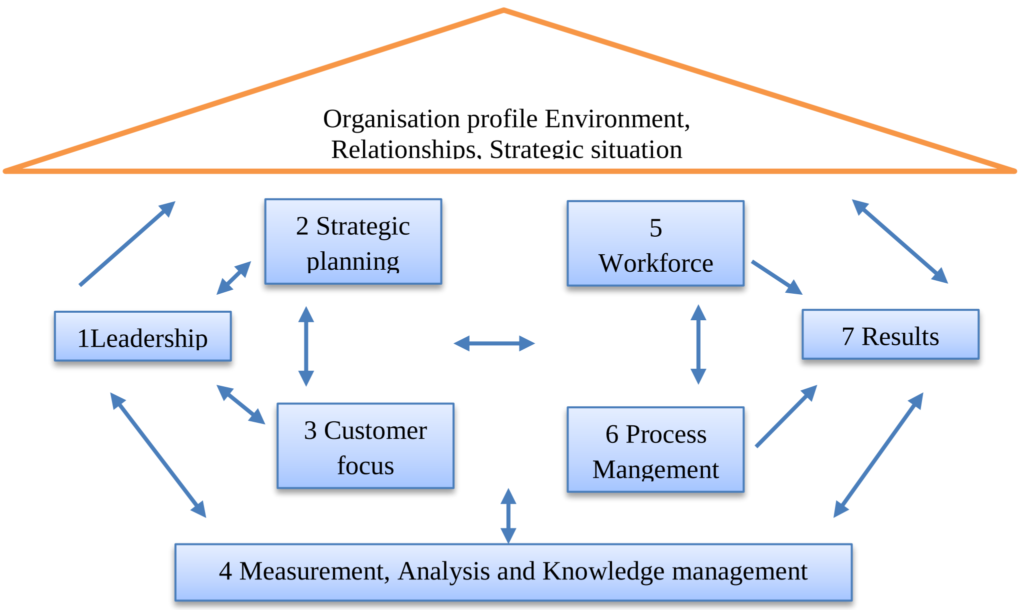


Figure 2.3 Malcolm Baldridge model

The SMART Performance Pyramid:

Lynch and Cross (1991) developed smart pyramid system. The smart pyramid consists of four levels as shown in Figure 2.4.

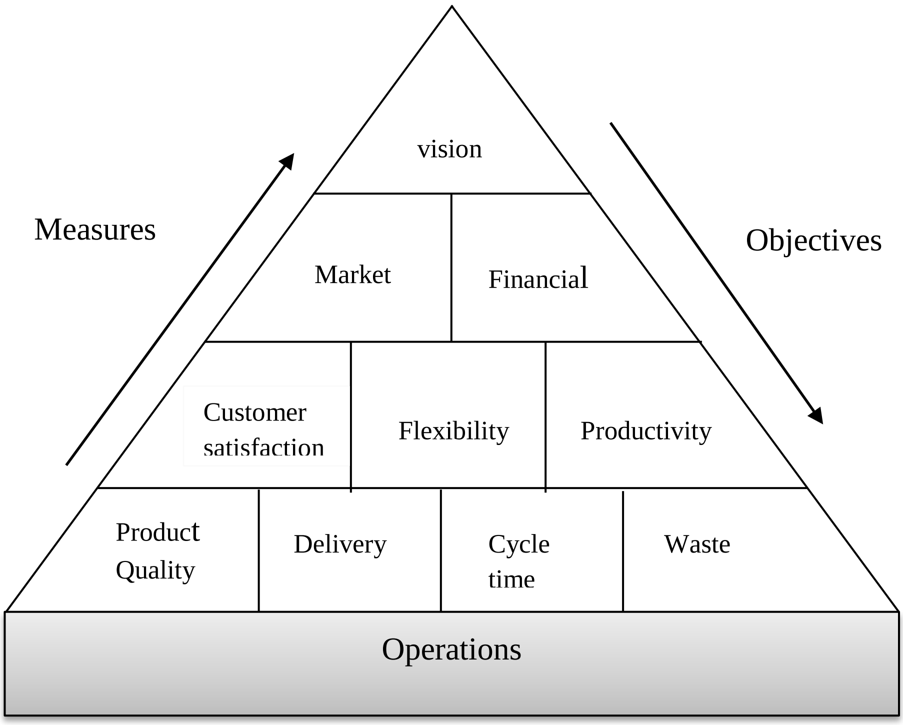


Figure 2.4 Smart Performance prism

The first level defines overall organizational visions. The second level consists of long terms goals (e.g. market), and short-term targets (e.g. of cash flow and profitability). The third level consists of operational measures (e.g. customer satisfaction) and the last level consists of four key indicators of performance: quality, delivery, cycle time and waste. It tries to attempt to integrate organization goals with operational performance indicators. There is no clear idea of how to measure key performance indicators.

Performance prism

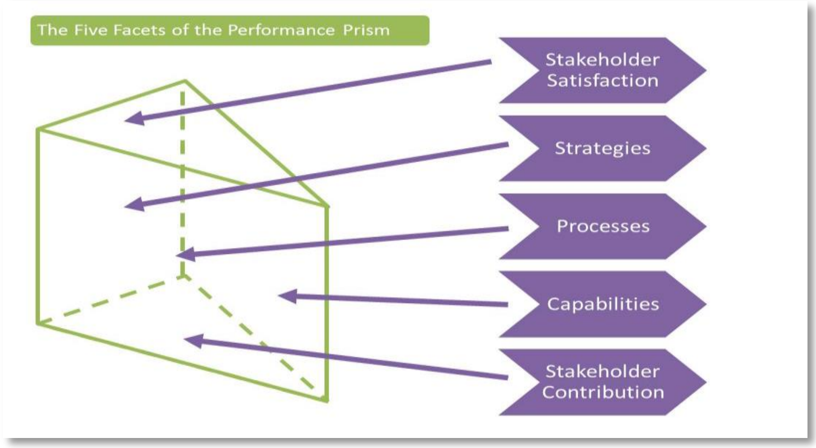


Figure 2.5 Performance prism

It is another model that addresses five fundamental areas such as stakeholder satisfaction, stakeholder contribution, strategies, process and capabilities for business success as shown in figure 2.5. (Neely et al. 2002).

Project Quarterback Rating (PQR)

PQR model developed by (El Asmar et al. 2015), combines seven key performance areas to compare different projects such as Design-Build, Design-bid build, and construction management using the emerging Integrated Project Delivery (IPD) system and delivers a single score for comparison. PQR model in construction combines seven performance metrics such as customer satisfaction, schedule, cost, profit, communication, quality and safety (Hanna et al. 2014). Figure 2.6 shows the structure of PQR model.

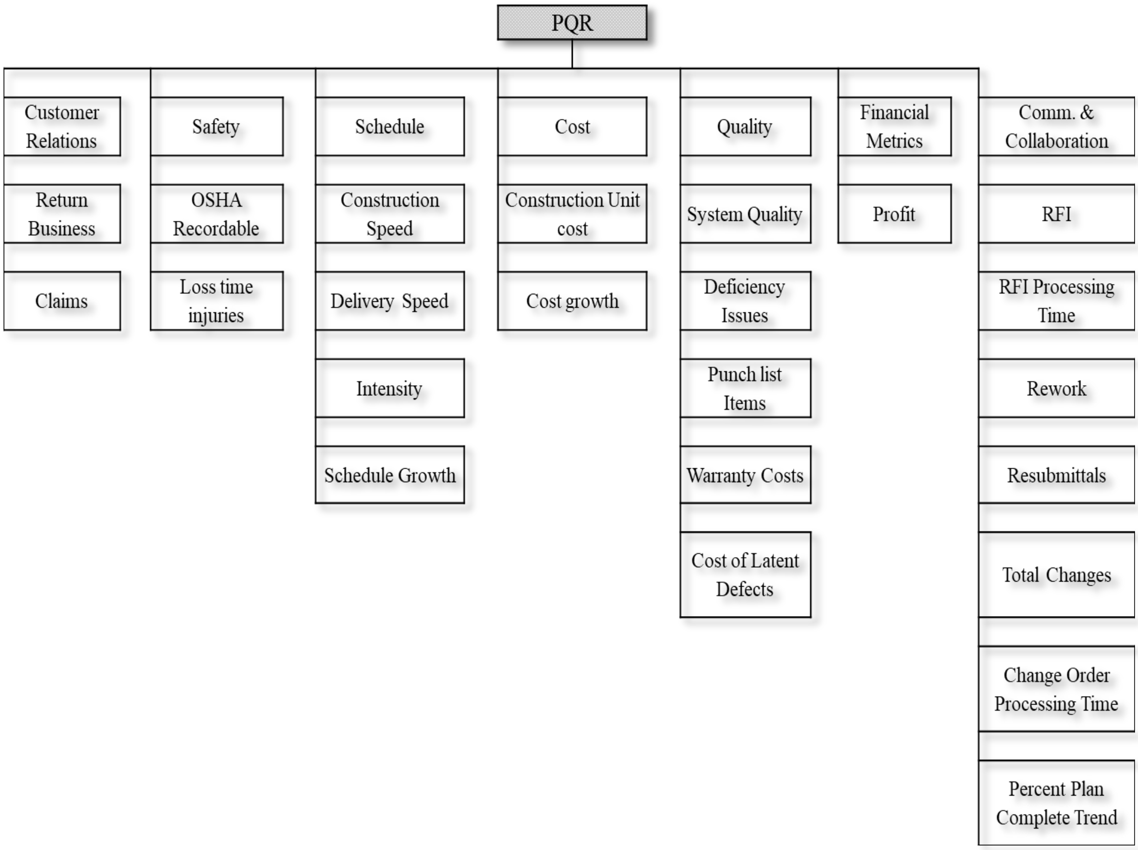


Figure 2.6 PQR Model

Major shortfalls of performance models

Many studies have been conducted concerning to measure performance such as balance scored card (BSC), The European Foundation for Quality Management (EFQM) framework and performance prism. BSC and EFQM tool have been widely adapted in construction industry to measure project performance. Different frameworks and models have been developed for measuring performance of construction projects (Bassioni et al. 2004; Khosravi and Afshari 2011; Lin et al. 2011; Jin et al. 2013; McLeod et al. 2012). A study by Belout and Gauvreau (2004) analyse the effect of human resource management on project success. Menches and Hanna, (2006) developed a quantitative performance model based on the project manager's qualitative evaluation for measuring performance of the project. These performance measurement models tend to focus on financial measures such as profit. Therefore, there is need to consider financial and non-financial measures for performance measurement. However, the performance measurement models should be able to describe how organizations do appropriate business; despite they cannot be utilized to analyse performance measurement models quantitatively. Performance models have been criticized for focusing on short term goals, conflict management rather than continuous improvement. Another limitation of models is the insufficient information on appropriate use of models. In terms of application of performance measurement models, there are few obstacles such as lack of information flow, understanding performance measurement and weak commitment of management. Previous studies have analysed performance models for construction organizations through opinion-based surveys. This type of methodology lacks an understanding of how to achieve performance in an organization.

Another shortfall of these performance models is that it concentrates on specific performance areas alone and lacks the ability to define relationship among performance areas to be able to simulate real-life complexities (Ingle and Mahesh, 2020). There is a need to focus on areas such as customer satisfaction, stakeholder satisfaction, safety and communication management. Nevertheless, every performance measurement model has few advantages and disadvantages. The most common limitation is not guiding the implementation of performance measurement. As the business environment is not constant, there is a need to develop and change the strategies of organizations with respect to time. To overcome the above-mentioned shortfall, performance areas are used to measure the success of construction projects which includes both financial and non-financial areas.

There is a progressive need in the construction management research area to develop new performance assessment models to evaluate numerous project performance areas. The extensive use of subjective weighting method focuses on experts' opinions and this has been widely used by researchers and industry practitioners in various domains, including construction industry. Developing quantitative measurement model for performance areas compared to qualitative model is a better practice for measuring project success. The qualitative models are subjective and unclear. Therefore, the development of quantitative measurement model has a significant impact on projects and contributes to better project performance in various areas such as cost, safety etc. Few papers found in the literature review address the concept of integration of performance measurement of construction projects. Construction researchers have carried out project evaluation through: single and multiple attribute measurement and organization effectiveness measurement (Nassar and AbouRizk, 2014). Therefore, all of these methods require subjective criteria and there is no method for integration of all performance areas. Hence these models are not suitable for project manager who requires information about current project's success.

Why PQR model should be adopted?

The Performance areas utilized by the sports industry provides benchmarks to compare teams and athletes. For example, the quarterback passer's rating used in the National Football League (NFL), which compares the performance of quarterbacks, is calculated by combining four values for each quarterback: completion percentage, passing yardage, touchdowns, and interceptions. This combination leads to a single number which then can be used to compare against the ratings of other quarterbacks. Although construction industry is much larger than sport industry (CSU Fresno 2012), it does not have a standard methodology to measure overall performance. Construction industry projects are unique, complex and dynamic in nature and require various performance areas to achieve project success. It is difficult to determine whether a project should be considered successful assuming it is completed on time and budget, yet the project may suffer from poor quality and safety issues. Project performance is a complex concept and involves various areas that need to be addressed.

A new performance assessment approach named as Project Quarterback Rating (PQR) to assess overall performance from the contractor's perspective was developed by Hanna et al. (2014). The PQR rating model combines seven areas namely, customer relations, communication, schedule, profit, safety, quality and cost and leading to a single score which is utilized to compare the performance of construction projects. In similar manner, to the quarterback rating in sports industry, the *Project Quarterback Rating* (PQR) combines performance metrics of a project into one number that can be used to compare projects. Following are the reasons to adopt PQR.

(1) Most studies identify performance areas and group them into various aspects but many do not attempt to integrate all these areas to get a single score that can be used to compare different projects.

(2) The complex nature of construction project performance involves the assessment of several performance areas. The focus is extended beyond the commonly addressed performance areas such as time, cost and quality and in addition to the less commonly addressed areas such as customer satisfaction and communication. One cannot combine different values for different performance areas e.g. safety and cost values. Even in same performance areas different performance metrics cannot be added. This shortcoming has been overcome by the model by standardising the values.

(3) To increase the potential implementation of PQR it is developed as linear function that acts as weighted average of several performance areas of construction projects. The use of model can be used to comprehensive comparison of a single score that illustrates overall project performance.

Limitation of existing PQR approach

However, the existing PQR cannot be directly adapted for Indian construction projects.

(1) The original PQR model is based on the contractor's perspective. For sustainable business of construction projects performance should be assessed from the perspective of major stakeholders of projects as well. Furthermore, in comparison to developed countries such as USA and UK, only a few studies have focused on developing countries. Hence, there was a necessity to develop quantitative performance assessment model for Indian construction projects. To address these gaps this study presents comprehensive approach to performance assessment by considering the perspectives of all major stakeholders. Moreover, it attempts, to develop mathematical formulation of the modified PQR, which can be adapted depending on the performance areas that are important for each unique project.

(2) The model also needs to be contextualised to account for performance areas that contribute specifically towards Indian construction projects.

(3) Also, existing work is majorly country specific in context, making it imperative to develop project performance model for different contexts (Yong and Mustafa, 2013; Ofori et al. 2016).

Therefore, to sum up the shortfalls, there is a need to develop comprehensive performance measurement systems in construction industry.

2.7 Benchmarking

Benchmarking can be defined as a process of continuously measuring and comparing an organization's processes with business leaders in the world to gain information which will help organization to take action to improve its performance (Shehata and El-Gohary 2012). Benchmarking is also defined as "systematic process of measuring one's performance against results from recognized leaders for the purpose of determining best practices that lead to superior performance when adapted and implemented" (Ali et al. 2013). Construction organizations can benchmark their performance to enable them to identify strengths and weaknesses and improve their performance.

The classification of benchmarking is as per content (functional or performance) or as per purpose (competitive) (Anand and Kodali 2008). Benchmarking can be classified as Internal, functional and competitive. Internal benchmarking consists within the same organization e.g. benchmarking among different projects in same organization. Functional benchmarking is best practice among organizations. Competitive benchmarking compares with products and services within the industry e.g. comparing different projects among organizations (Watson 2007). Rankin et al. (2008) implemented benchmarking system and categorized it into five levels: (1) assigned tasks in project (e.g. placing of concrete), (2) project (e.g. phases in projects with details estimate), (3) organization (profit of organization, human resource), (4) industry (productivity of industry) and (5) economy (international competition).

Benchmarking in construction industry

In construction industry, benchmarking uses key performance indicators (KPIs). Researchers in construction industry have found that stakeholders want their project to be delivered on time, in budget, complying with safety procedures and with profit. The KPIs developed by construction best practice program benchmarking (CBPPB) in

U.K consists of ten factors to evaluate project performance. Various researchers have agreed to that benchmarking is a tool to improve construction project performance (Chan et al. 2004; Costa et al. 2006; Dikmen et al. 2005).

Achieving effective project performance is challenging (Augusto et al. 2006). Every construction organization must have a benchmarking system to measure performance. Abdel-Razek et al. (2007) implemented benchmarking for improving labour productivity in Egypt. Luu et al. (2007) evaluated project performance by benchmarking approach. Systematic implementation of benchmarking will help to improve project performance.

2.8 Summary

According to previous literature, it can be said that performance areas are very important to assess project performance.. Performance areas are used to evaluate performance of construction projects. While some performance areas are common in many lists, there is no general agreement on the areas that need to be considered to measure project success. The concept of measuring project performance is still not clear in the construction industry.

Also, it is difficult to combine performance scores over different performance areas into a single project score for evaluating project performance. PQR model developed by (El Asmar et al. 2015), combines seven key performance areas to compare different projects using the emerging Integrated Project Delivery (IPD) system and delivers a single score for comparison.

Recent literature indicates that the focus should extend to less studied metrics such as customer satisfaction, stakeholder satisfaction, safety and communication management. Most studies identify success factors and group them into various aspects but many do not attempt to combine all metrics to get a single score so that it can be used for benchmarking projects. Considering the comprehensiveness and adaptability of PQR model it is considered an appropriate model to evaluate project performance for benchmarking in the Indian construction industry. The PQR model combines overall project performance by combining performance metrics into a single comprehensive score. The single score is resultant of the metrics and organization can compare their performance using it. PQR can be adapted depending on metrics which are important for project and can be used for comparing the performance of projects.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter presents an overview of the methodology used to address the objectives of the study and provides justifications for the same. In this regard, the chapter also outlines the approach of data collection, data analysis and validity of research design.

3.1 Research Approach

Research design is determined by research questions. The research design is affected by nature of objectives and that affects the methodology. Thus research design is important and should be recognised at an initial stage and should be designed critically to select approriate approaches for research work.

There are different types of research. The traditional approach employed in research is: quantitative and qualitative. Quantitative research approach refers to quantifying and validating the established theory and relationship among variables (Bryman 2004). Qualitative research approach focuses on research design and interpretations in form of words rather then numerical data.

According to Yin (2009), classification can also be based on what purpose of research is: descriptive, exploratory and explanatory. Descriptive research is used to describe characteristics of the phenomenon being studied and does not focus on the occurrence of the phenomenon. Exploratory research is conducted to investigate the research question that is not clearly defined. Explanatory research attempts to understand casual relationships among the variables. Depending on the research problem to be addressed, the most suitable approach is chosen. In the following subsections, research approaches and methodology are discussed.

3.1.1 Quantitative research approach

Quantitative research approach is based on research on observable facts such as experiments or surveys. The data is usually analyzed statistically to test hypothesis in terms of interrelationship among the variables. The study population can be generalized based on the study sample. Quantitative research approach also uses surveys in form of questionnaires to measure attitude and behaviors of the sample. Questionnaire survey covers a larger sample in a short duration of time (Bryman and

Bell 2003). Surveys evaluate the opinion of the population by studying the sample of the population. Surveys can be done in written form, face to face interviews or telephonic interviews.

3.1.2 Qualitative research approach

Qualitative research is a distinct methodology which is linked to theory that provides philosophical basis for researchers. The qualitative research approach does not contain numerical data and emphasis is on words. It involves observations and detailed investigations of data in the form of pictures or text or written information (Bryman 2004). According to Yin (1994), qualitative research is appropriate in the case of understanding complex phenomenon. The approach mainly focuses on process in explanation for complex phenomenon.

Common methods to carry out the qualitative approach is interviews, focus group discussions, observations, document analysis, and case studies (Creswell 2003). Interviews can be categorized as semi-structured, unstructured and structured. Observations can be direct, inconspicuous and participant observations (Bernard 1994). Document analysis involves detail analysis of documents which are related to the research study. Case studies comprise of an in depth study of the phenenomen. Yin (2003) provides protocol for detailed design and implemenation of case study research. Dainty (2008) argued that using single metholodogy cannot adequately justify the results. Therefore, integrating both quantitative and qualitative research approach, will help to strengthen the validation of results (Ash and Berg 2003).

3.1.3 Mixed methods approach

Various researchers have argued on which of these is an appropriate approach, qualitative or quantitative. Combining both approaches is extensively used in social science (Johnson et al. 2007). A mixed approach is used as an optimal solution in construction management research (Love et al. 2002). For understanding the factors influencing project performance in the construction industry, it is advisable to use a mixed approach. Dainty (2008) suggested that to understand interrelationship between factors in construction management, a single research approach will not be sufficient. The problem of bias, reliability, and validity will be avoided by using the mixed approach (Easterby-Smith et al. 2012). Mixed method can assist in combining theories of confirmatory and explorartory research at the same time and will generate stronger interpretations. The selection of research design to address the objectives in this thesis is discussed in detail in the next subsection.

3.2 Research approach adopted for the study

Based on the natue of objectives,a mixed research approach is adopted in this study. Figure 3.1 shows the flowchart of the adopted research methodology along with data collection methods and data analysis techniques for both quantitative and qualitative approach.

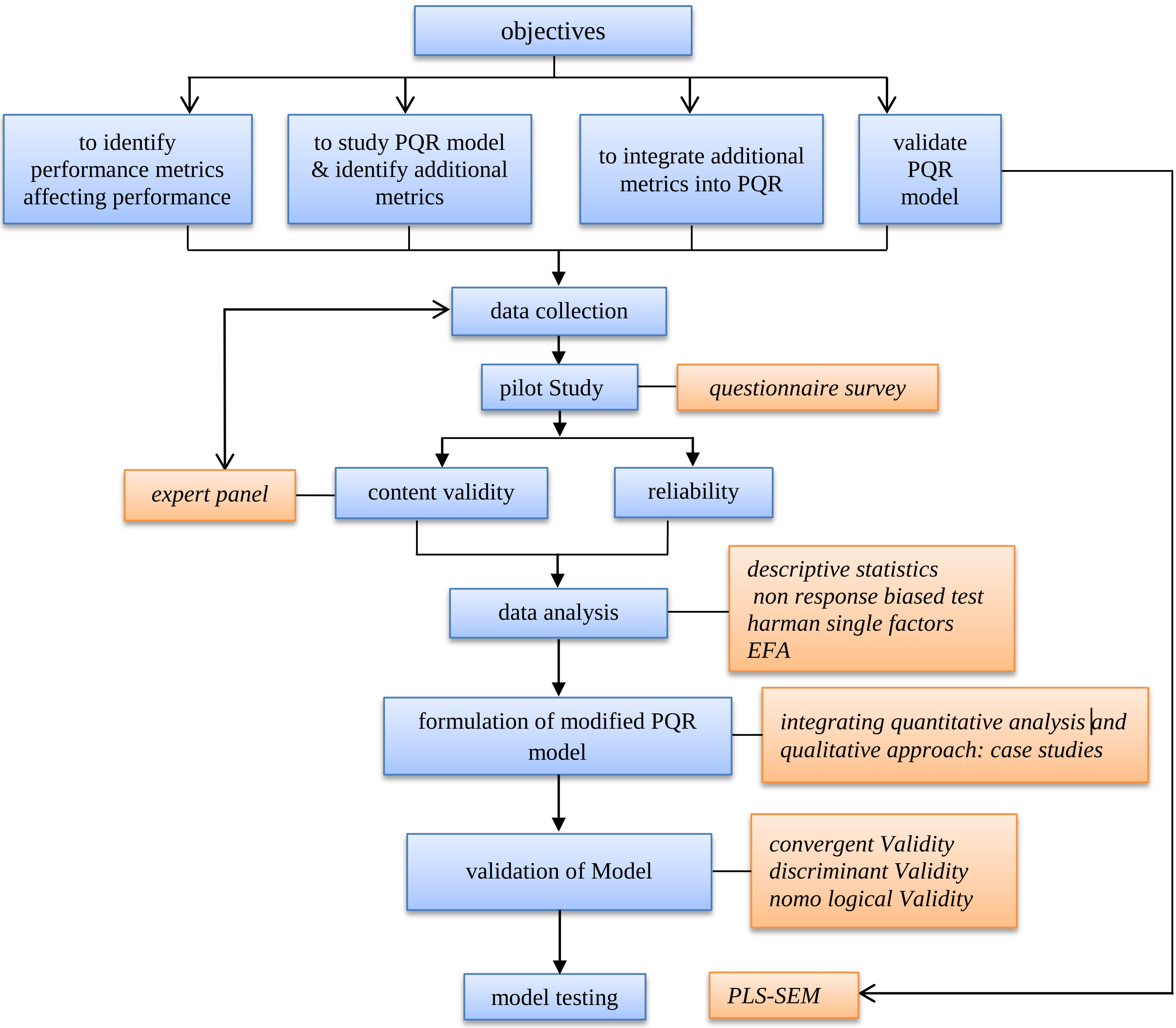


Figure 3.1 Flowchart of research methodology

The overall aim of the study is to develop a project performance assessment model for Indian construction projects. Research approach used to achieve the objectives is as follows;

Objective 1: To identify performance areas responsible for successful projects in Indian construction industry.

Literature on performance areas that influence project performance was reviewed. Based on review of literature, a detailed list of performance areas and metrics was prepared. The next step was to identify the performance metrics that measure performance areas. These performance areas were discussed with few professionals in India having more than 30 years of working experience to check their priority in Indian context. Necessary modifications were made to the list of performance areas and metrics, taking into consideration the suggestions given by professionals. Performance areas were considered as appropriate for formulation of modified PQR model if the response score was greater than 50%. Ten performance areas and twenty-eight metrics were finalized for further study.

Objective 2: To study PQR Model in current form and identify additional metrics based on identified performance areas that contribute to overall project performance.

A structured questionnaire survey approach was designed to understand the importance of different performance metrics that constitute performance areas. The questionnaire was discussed with professional experts in India to check its priority in Indian context. Various performance assessment models were reviewed and PQR model was considered an appropriate model to evaluate project performance for Indian construction projects. The PQR model was studied in its current form and a questionnaire survey was used to identify additional metrics that contribute to project performance.

Objective 3: To integrate identified additional performance areas into existing PQR Model for improved performance assessment.

The findings of the questionnaire were analyzed and findings of previous objectives were used as an input to integrate performance areas into the existing model and modify the PQR model for the Indian context. To indicate the contextualization, the word Modified Project Quarterback Rating (MPQR) is adopted. Three case studies were conducted for a clear understanding of the importance of the performance areas considered for Indian construction projects. The case studies also validated the findings from questionnaire analysis. The integration of quantitative and qualitative findings was used as a based to formulate the model. The mathematical formulation of the modified PQR model was done based on a weighted average formula which will be explained in detail in chapter 5. The weights were assigned using the Delphi technique which will be explained later in subsection 5.3.1

Objective 4: Validate modified PQR Model.

Validation of research design was done in different phases: face validity, reliability, internal and external validity. The quantitative and qualitative research approaches have different validity checks and hence to ensure the quality of data and results validation of MPQR model is done to improve research findings.

3.3 Data collection procedures

The purpose of the study was to investigate the following research questions:

What are the important performance areas that have an impact on project performance for Indian construction projects?

In answering this research question, data was collected using both quantitative and qualitative research approaches. There are various methods to collect data for both quantitative and qualitative approaches. Therefore, researchers must be clear of the research question (Creswell and Plano 2011).

3.3.1 Quantitative approach adopted for research

Saunders et al. (2009) suggested a questionnaire survey is a "most widely used technique for data collection" in research. This study has to understand the performance areas and its impact on project performance. Quantitative approach adopted for this research includes questionnaire development, sampling, data collection methods and data analysis techniques.

3.3.3.1 Performance areas used in the questionnaire design

Extensive literature review was carried out and a list of 13 performance areas was reviewed and verified by construction professionals operating in Indian context. Respondents were asked to pick project performance areas which contribute for project success.

Based on a threshold score greater than 50% of the responses, 10 performance areas were considered to be appropriate to be considered for the formulation of modified PQR model as shown in Table 3.1. these are: (i) Customer Relation (Cu), (ii) Safety (Sa), (iii) Schedule (S), (iv) Cost (C), (v) Quality (Q), (vi) Finance (F), (vii) Communication and Collaboration (Co), (viii) Productivity (Pr), (ix) Stakeholder Satisfaction (St), (x) Environment (E). These 10 performance areas were finalized and formulated.

Table 3.1 Percentage for performance areas

Performance areas	**Frequency**	**Percent (%)**
Customer relations	172	89
Cost	168	87
Safety	134	69
Schedule	122	63
Stakeholder satisfaction	128	66
Quality	168	87
Finance	149	77
Environment	153	79
Productivity	175	91
Communication and collaboration	162	84
Waste management	89	46
Procurement management	92	48
Organization and Project management	88	46

The performance areas that combine performance metrics in the modified PQR Model is as shown in table 3.2.

Table 3.2 Performance areas for study and sources.

Performance areas	**Performance metrics**	**Sources**
Cost	construction unit cost, cost growth, rework cost	Chan and Chan (2004); El Asmar et al. (2015); Pocock et al. (1997); Rojas and Kell (2008); Sanvido et al. (1992).
Quality	project quality, defect liability period, item beyond cost, defect	Chan and Chan (2004); Chou et al. (2013); Marques et al. (2011); PMI

	cost	(2013); Rad (2003); Sands (2010); Sanvido et al. (1992).
Schedule	construction speed, schedule payment, schedule growth	Chan and Chan (2004); El Asmar et al. (2015); Menches and Hanna (2006); Rojas and Kell (2008); Sanvido et al. (1992); Songer and Molennar (1997).
Safety	OSHA recordable, loss time in injury, fatalities	Chan and Chan (2004); El Asmar et al. (2015); Sands (2010); Songer and Molennar (1997); Walker and Vines (2000); Leon et al. (2017).
Customer relations	return business, claims, feedback policy	Belout (1998); Debella et al. (2006); El Asmar et al. (2015); PMI (2005).
Finance	profit and overheads	Baker et al. (1983); Chan and Chan (2004); El Asmar et al. (2015); PMI (2005).
Communication and collaborations	RFI, communication management plan, the frequency of meetings, the impact of client and contractors' meetings	Arriagada and Alarcon (2013) Belassi and Tukel, (1996); Chan and Kumaraswamy (2002); Chan and Chan (2004); Debella et al. (2006); Pinto and Slevin (1988); PMI (2013); Sands (2010).
Productivity	Labour productivity, equipment productivity	Chan and Chan (2004); Khang and Moe (2008); Nguyen et al. (2004); Sands (2010); Songer and Molennar (1997); Tripathi and Jha (2018).
Stakeholder satisfaction	Expectation and commitment	Menches and Hanna (2006); PMI (2013); Yang et al. (2011); Yu et al. (2006)
Environment	Social, political, technical, economic	Akinsola et al. (1997); Belassi and Tukel (1996); Chan and Chan (2004); Kaming et al. (1997).

3.3.3.2 Development of Questionnaire

The questionnaire was designed to gather data and to obtain a high response rate from the sample. Two approaches were adopted in the thesis: Internet survey and drop-off survey. The internet survey was through email attached with a cover page which included the objectives of research and an invitation to participate in the survey. The drop off survey was a print out of a questionnaire and was similar to the internet survey. The questionnaire was organized into three sections:

- Section one consisting of two parts, part one on General information covering demographic information of respondents, the experience of respondents and project performance assessment methods. Respondents less than three years of experience were not considered for analysis. Part B identifying important performance areas that contribute to project performance. Both parts of the sections included open-ended questions where respondents were asked for their opinion about project success and performance metrics they are managing in their project.

- Section two covers statements for each performance area that contributes to project success. Section two asked respondents to show the degree to which project performance areas contribute to achieving project success. The section consists of twenty-eight performance metrics to measure 10 project performance areas. Respondents were asked to rate their level of agreement towards the contribution of these performance metrics to project success. The agreement level was measured using a 5-point Likert scale (1 = totally disagree to 5 = totally agree).
- Section three measures the importance of identified performance areas for project performance. Respondents were asked to rate performance areas based on level of importance with respect to project success. A five-point Likert scale was used, which represents (1) strongly disagree to (5) strongly agree. Weights for all performance metrics were assigned using the Delphi technique which is explained in section 5.3.1 Questionnaire can be referred to in Annexure I.

3.3.3.3. Content validity

Content validity was established by extending the measurement variables used in the study. Content validity is used to evaluate how well the variables are represented in the questionnaire. Content validity is dependent upon the effectiveness of measurement items to cover the domain of variables being measured. Extensive literature review is one of the ways to establish content validity. The questionnaire survey was provided with a brief introduction of objectives of the study. These variables were then adapted to suit the present research context as it cannot be tested using statistical tools (Hair et al. 2010) A total of 7 industry experts and academicians were asked to comment on the face validity of all performance areas. These experts reported their observations on performance areas that were noted, as shown in table 3.3.

Table 3.3 Content validity

Performance areas	Experts opinion	Remark
Safety	Do not involve proactive and reactive hazards	Taken as considered
Communication and collaboration	Communication and collaboration	Taken as considered
Productivity	Eliminate a few questions	Taken as considered
Schedule	Project dates should be removed.	Taken as considered
Customer relation	No recommendation	-
Cost	No recommendation	-
Quality	Proper language is recommended	Taken as considered
Finance	No recommendation	-
Stakeholder satisfaction	No recommendation	-
Environment	No recommendation	-

Responses were recorded and the experts were asked to give their feedback on each construct covered in the questionnaire. Their suggestions on the words utlised were taken into account and necessary modifications were made. Before finalizing the questionnaire, a pilot study was carried out to refine the survey instrument.

3.3.3.4 Pilot testing of questionnaire

The purpose of the pilot study was to determine if there are any issues with the questionnaire, to ensure word clarity, understandability, to estimate the time required to complete the questionnaire and to address any recommendations by respondents. Pilot testing helps in initial elimination of difficulties that might be encountered by respondents while answering the questionnaire. It also eliminates threats to internal validity of data and helps to clarify and refine the questionnaire. A draft questionnaire was mailed to scholars and senior professional experts in the areas of construction management. A Total of 10 responses were received for pilot testing. The recommendations were adopted in the questionnaire and then circulated for the main survey.

3.3.2 Sampling technique and sampling size

Sample size is important as it supports the reliability and prediction of the hypothesized model based on the proposed theory (Zahoor, 2016). In a study having a large population size, it is obviously impractical to collect data from the entire population. So, it is important to select a sample that can be representative of the population. Hence the objective of sampling is to provide a practical means that facilitates data collection and processing whilst ensuring that the sample is representative (Fellows and Liu, 2015). A sample should, therefore, consists of good demographic representation of the study population. In this particular context, it is difficult, because of time limitations to collect survey responses for all ongoing construction projects in Indian construction industry. Hence, a purposive sample was adopted in this study. The minimum sample size adopted for this study is calculated using the formula in Equation (1) (Oyewobi 2014).

$$N = \frac{Z^2 * (p * q)}{e^2} \qquad (1)$$

Where: Z=1.96 at 5% level of significance, the p=Estimated proportion of an attribute that is present in the population (p=0.5), q is 1-p and e = acceptable margin of error for proportion being estimated (8%). A confidence level of 95% and 8% error value are considered to calculate sample size (Kotrlik and Higgins, 2001).

$$N = \frac{1.96^2 x 0.5(1 - 0.5)}{0.08^2}$$

The study population considered in this study were construction professionals. The study targeted construction industry professionals with minimum of 3 years of experience. Among them focus was on the professionals including, project managers, seniors project managers, project executives, quality engineers, safety engineers, designers, consultancies and academicians.

3.3.3 Questionnaire administration and collection

The final questionnaire survey was administered over a period of five month, starting in November 2017. The sample was selected based on the sampling technique (Oyewobi 2014) as explained in section 3.3.2. The targeted respondents were invited through email invitations for participating in the survey (Saunders et al. 2009). The questionnaire survey was prepared in Google Forms and the link was forwarded to the respondents. The questionnaire was attached along with an invitation letter. In order to reach a maximum number of respondents, internet survey was administered. Drop off survey option was used for senior respondents who were not comfortable with responding to an internet survey. Follow up through phone calls were made every two weeks to respondents as reminders.

3.4 Validity and reliability in research

3.4.1 Quantitative research

Validity

According to Pilot and Hungler, (1985) validity refers to the ability of an instrument to measure to what it is actually intended to measure. Achieving good quality scores from questionnaires and appropriate findings from analysis is main concern for validity. Thus, content validity, construct validity, convergent validity, discriminant validity, nomological validity, common method bias and nonresponse bias is essential for the researcher. Content validity is used to evaluate how well the variables are represented in questionnaire. In this research, the constructs used in the questionnaire were collected through extensive literature review and were ensured through content validity.

Construct validity measures a set of variables that actually reflect the latent construct. To establish construct validity of the questionnaire, content validity, convergent validity and discriminant validity need to be explored. Content validity results are shown earlier in table 3.3.3.3 Convergent validity refers to the correlation between the variables and construct used in research. Fornell and Larcker (1981) suggested examining convergent validity by factor loading and average variance extracted (AVE). Discriminant validity test measures how the constructs are correlated and how distinctly variables represented measure only those constructs (Hair et al. 2010). Fornell and Larcker (1981) suggested that discriminant validity can be examined by comparing the value of the AVE of the construct and values of squared correlation between latent variables. The presented research examines the construct validity of the questionnaire, where both divergent and convergent validities were explored.

Nomological validity

It refers to series of construct correlations and comparison with theoretical design. Nomological validity is evidence for consistency amongst structural relationships between constructs with theory and other researches. The direction of construct correlations is checked for nomological assessment (Hair et al. 2010). Nomological validity was conducted to understand the correlation between the constructs.

Reliability

Reliability in quantitative research indicates the degree of consistency with which it measures the attribute it is supposed to be measuring (Hair et al. 2010). The reliability of the survey instrument was measured using Cronbach alpha which is the most common approach (Mallery and George 2003). The Cronbach's coefficient alpha value range should be between 0.0 and + 1.0. The test results show that the alpha score is 0.775, indicating good internal reliability for the performance areas. This is in an acceptable range considering that a value greater than or equal to 0.6 is acceptable (Hair et al. 2006). The Cronbach alpha value for the research constructs used in this study will be discussed in section 4.2.

Nonresponse bias

Nonresponse bias occurs when some of the latent respondents included in the sample do not respond. This is important because the response may change with time. Nonresponse bias test is necessary before conducting statistical analyses. It was conducted to ensure the responses don’t differ between respondents and nonrespondents (Birks 2006).

Common method bias

The common method bias test represents the variance by a single factor test. In this method, the variance of a single factor solution is extracted using Exploratory factor analysis (EFA) to extract a single factor. If the extracted variance is less than 50%, the method is considered acceptable. There is high probability of common method bias due to self-reported data from multiple sources. Therefore, it was conducted to indicate that common method bias is not a significant problem with data and results.

3.4.2 Qualitative research

Results from multiple sources such as questionnaire surveys and case studies have helped in triangulation of results and validation. The careful selection of multiple case studies was used to address validity. Even the interview questions framed for case studies were based on initial findings from quantitative approach to ensure validity and reliability of the study.

3.5 Data Analysis Methods

The data analysis techniques adopted include descriptive statistics, correlation analysis, factor analysis, Delphi technique and Structural Equation Modeling-Partial Least Squares. IBM Statistical Package for the Social Science SPSS version 21 software (Field, 2013) is used for the analysis.

Descriptive statistics

The descriptive statistics of responses consists of mean, standard deviation, skewness, and kurtosis. The mean was used in analyzing the opinion of respondents on performance metrics. The mean score of each item was established to determine the significance of the item in that construct. The standard deviation measures the variation in an observation of the sample. Skewness and kurtosis were established to determine the shape of the distribution for each item that satisfies the normal distrubtion which is necessary for running statistical tests.

Factor analysis

Factor analysis (FA) is a multivariate statistical method to understand the interrelationships within variables (Hair et al. 2010). FA combines variables based on related variations. It determines how strongly the variables belong to a group. There are two methods for identifying factors: (i) Principal Component Analysis (PCA) and FA (Field 2013). The aim of both methods is data reduction to a smaller set of dimensions.

FA can be done in two approaches; Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). EFA checks the appropriateness of the grouping dimensions. Bartlett of sphericity and Kaiser-Meyer-Olkin (KMO) test checks the appropriateness of data for FA. The commonalities and factor loading values are also reviewed (Hair et al. 2006). CFA is a technique to confirm the measurement model. This is done through Structural Equation Modelling (SEM).

In this study, EFA was used to identify the underlying dimensions of different research constructs. FA was used to reduce those variables that measure similar constructs. The results will be discussed in chapter 4. The sample size for the study was 193, which is above the minimum limit of 50 as suggested Hair et al. (2010). It is therefore considered reasonable to proceed with FA with this sample size.

Correlation analysis

Correlation analysis was conducted to explore the nature of relationship between project performance and performance areas. The correlation values are in the range from +1 to -1. +1 indicates positive correlations, 0 indicate no correlation and -1 indicates negative correlations (Hair et al. 2010).

Structural equation modeling

There are different methods for analyzing the relationship among the set of variables such as Factor Analysis (FA), Multiple Regression Analysis (MRA), Structural Equation Modeling (SEM), Path Analysis (PA) (Norman and Streiner 2003). In this study, SEM was chosen as the analytical approach. SEM examines simultaneous relationships among dependent (endogenous) and independent (exogenous) variables in a model. FA, MRA, PA is not suitable for this study as FA will not provide any information about the relationship between latent variables/independent variables (structural model). Latent variables (LV) are unseen constructs that measure correlation among variables. MRA provides relationship between single dependent variable and many independent observable variables. It does not provide a test for validation and reliability for measuring latent variables. PA and MRA assumes that data is normally distributed and examine the observed variable rather than LV. SEM provides assessment of reliability and validity of measurement items of latent variables in model and simultaneously examines relationship between dependent variables and independent variables. SEM approach provides combining of theoretical with empirical approach which is not possible with multiple regressions, factor analysis, and path analysis.

Partial Least Squares- Structural equation modeling

PLS-SEM was developed by Joreskog, K.G. (1982). PLS-SEM is a method for estimating relationships between independent and dependent variables. PLS-SEM examines structural model and path coefficient. The PLS-SEM focuses on estimating and analyzing the relationships between the multiple latent variables. PLS-SEM has been used in various areas of construction management (Molenaar et al. 2000; Wong et al. 2008; Samee and Pongpeng 2016). According to Rigdon (1998), structural equation modelling (SEM) is developed out of demands to test complete theories and concepts. PLS-SEM tests complete theories, concepts and complex models by estimating the composite relationships between identified variables. Robins (2012) considers PLS-SEM as appropriate for studies in strategic management, as it allows researchers to develop and refine concepts and theories. PLS-SEM is particularly useful for exploratory research purposes (Hair et al. 2014). PLS-SEM is used in the study for the following reasons.

PLS relaxes distributional assumptions and is suitable for smaller sample size. PLS is more advisable when the objective of study is testing the causal relation and theory development (Hair et al. 2011). Software used for analysis is WarpPLS and developed by Kock. This study has used WarpPLS 6.0 version for analysis to explore relationships among constructs and factors. The path coefficient, model indices, and p values were checked. The details of how the model was generated are presented in chapter 7.

Delphi technique

Delphi technique is a qualitative research method in which survey instrument is used to provide answers with opinion of experts. According to Scholl et al. (2004) Delphi technique can be used when there is less information available about a topic. Delphi method encourages discussion on different opinions in an attempt to reach consensus.

Before using project data to formulate the modified PQR Model the weights for each performance metrics must be identified. The weights quantify the level of importance of individual performance metrics. Delphi technique was used for assigning appropriate weights for performance metrics that combine to form performance areas in the modified PQR Model. The most common delphi method is the 100 point method in which 100 points should be distributed among each performance criteria (Nijkamp et al.1990). The details of delphi survey results are presented in chapter 6.

3.5.1 Qualitative Approach adopted for research

There are several techniques for analysing qualitative data. Content validity has also been used which Fellow and Liu (2008) suggest, can either be qualitative, quantitative depending on nature of study.

Case study design and case selection

There is less attention given to project performance areas in India. Hence, the exploratory approach will be suitable to answer the research question in this study (Yin 2009). Case study approach investigates the issue in depth. Hence case study approach was chosen to understand and validate how they measure project performance and which performance areas impact Indian construction projects.

Case study designs can be classified into one of two categories; Holistic (single) and embedded (multiple) to reflect the unit of analysis in each case study (Rowley 2002). Multiple case studies category is preferred for detailed investigations. Case study selection includes various factors such as time available, number of cases, documents available and interviewees. The unit of analysis refers to which type of data is collected and analyzed (Collis and Hussey 2003). Unit of analysis may be individual, organization or a unit within the organization. The unit of analysis considered for this study are Indian construction projects. Three projects were selected which vary in size of the organization and type of project. To select these cases, 8 construction projects were contacted through mail and telephone and were invited to participate in research. Out of 8, 3 construction projects agreed to participate in this phase of the study. The findings from case studies are discussed in chapter 6.

In this study, data was collected through semi structured face to face interviews. The objective of interviews was to get an opinion from construction professionals on performance areas and its impact on project performance. The detail interview structure is shown in Annexure III. The data was analyzed and was used to integrate the findings in modified PQR model.

3.6 Summary

This chapter has explained detailed methodological approach used in this study. The study adopted a mixed method approach; data collection was done through a questionnaire survey. Purposive sampling method was adopted to account for major construction professionals in India. Statistical analysis such as descriptive analysis, factor analysis and correlation were done using IBM Statistical Package for the Social Science SPSS version 21 software (Field, 2013). Qualitative data was collected through case studies. The next chapter presents the results of data analysis as well as findings.

CHAPTER 4

QUANTITATIVE DATA ANALYSIS

This chapter presents the results of quantitative data analysis. Data for quantitative analysis for this study was obtained through questionnaire surveys. This chapter first presents a report about data editing and screening, demographic profile of respondents; and then descriptive statistics and analyses used for data collation.

4.1 Data screening and editing

Data was screened to check for missing data. After initial data screening, 2 responses were excluded from main analyses due to missing data. In these two cases, the respondent had not anwered key questions.

The purpose of editing is to check whether the data is accurate. The raw data received from respondents is saved and downloaded. The data is first entered, coded and edited for data analysis. In this thesis, major data was received through internet survey which was saved in google docs. The coding process involves assigning numbers or symbols where ever it was necessary, so that data can be analyzed further.

4.2 Reliability Test

Cronbach's alpha test was conducted to test the reliability and suitability of the measuring scale. (Fellows and Liu, 2008). This method evaluates core consistency depending on average correlations among the data that is identically computed. The reliability of the factors can be calculated as shown in Equation (4.1).

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\Sigma\sigma_i^2}{\sigma_i^2}\right) \qquad (4.1)$$

Where, n= number of items, σ_i^2= variances of sum of all scores, $\Sigma\sigma_i^2$= variance of sum of all standard deviations of all the items.

The analysis was carried out in SPSS software version 21. Reliability analysis provides an assessment of the degree of consistency between multiple measures of a variable. The acceptable range for Cronbach's alpha value should be greater than or equal to 0.7. The normal range of Cronbach's alpha is between 0.0 and +1, with a higher value reflecting a higher degree of internal consistency (Field 2009) and any value of Cronbach's Alpha higher than 0.60 can be considered reliable and suitable for further analysis (Hair et al. 2010). The value of alpha is affected by test length (number of variables in a construct) (Nunnally and Bernstein 1994). If the test length is too short, the value of alpha is reduced and vice versa. A low value of alpha could also be due to poor interrelatedness between items. Cronbach's alpha for all performance areas are summarized in Table 4.1.

Table 4.1. Cronbach's alpha value for each performance area

Performance area	**Performance metric**	**Alpha Value (α)**
Customer relations	Return Business	0.84
	Disputes Claims	
	Feedback Policy	
Safety	OSHA Recordable	0.74
	Loss Time Injuries	
	Fatalities	
Schedule	Construction Speed	0.78
	Schedule Payment	
	Schedule Growth	
Cost	Construction Unit Cost	0.72
	Cost Growth	
	Rework cost	
Quality	Project Quality	0.74
	Defect Liability Period	
	Item Beyond Scope	
	Defect Cost	
Communication and collaboration	Request for Information	0.78
	Communication Management Plan	
	Frequency of Meeting	
	Impact of Meeting	
Finance	Profit	0.69
Productivity	Equipment productivity	0.74
	Labour Productivity	
stakeholder satisfaction	Expectation Level	0.74
Environment	Social Environment	0.77
	Technical Environment	
	Political Environment	
	Economic Environment	

Test result shows that Cronbach's alpha score is above 0.60, indicating a good internal reliability (Hair *et al.*, 2006) for all performance areas. All performance areas identified in this study are considered reliable and are utilized for further analysis.

4.3 Nonresponse bias test

When data is collected over a period of time, there is a requirement to check non response bias of the responses (Chen and Paulraj 2004). Non-response bias occurs when some of the latent respondents included in the sample do not respond (Birks 2006). This is important because the responses may change with time. Paulraj (2004) argue that in case of statistical surveys the non-response bias test is one of the prerequisite requirements. Non response bias test helps to rule out biasness in terms of gender, demography, attitude, behavior and other characteristics. Hence by taking this into consideration, non-response tests were conducted. Armstrong and Overton (1997) advocated wave analysis technique to conduct non response bias test. A Non-Response Bias test was conducted to ensure that the responses of the people were not significantly different from the ones who did not, using Wave Analysis. In wave analysis, the difference between response at one point of time and difference between responses at the second point of time is checked by t-test. Chen and Paulraj (2004) suggested to split the data into two equal halves and to perform the test. The early wave group consisted of 97 responses while the late wave group consisted of 96 responses.

Null Hypothesis for non response bias test: There is no significant difference between the samples of wave 1 and wave 2 based on characteristics of the response received.

Wave 1: Responses received at early time of the period.

Wave 2: Responses received at late time of the period.

The test yielded no significant differences ($p > 0.05$) between two samples. Here, the corresponding value of $p = 0.11$ was found to be greater than the threshold limit of $p = 0.05$. Therefore, it can be concluded that non-response bias does not exist and null hypothesis is accepted.

4.4 General profile of the respondents

In this study, a total of 353 questionnaires were circulated. Out of 353 responses, 193 responses were received and utilized for data analysis. The response rate was 54%, which is sufficient for research in construction industry (Oyewobi 2014). Generally, to conduct factor analysis, a sample size should be 4 to 5 times that of the number of variables as per thumb rule for acceptance (Hair et al. 2010). This study had twenty-eight variables thus it is adequate to meet the statistical requirements.

Out of 193 responses, the experience of 118 respondents (61%) was below 10 years, 42 respondents (22%) were between 10 to 20 years, 17 respondents (9%) were between 20 to 25 years and 16 respondents (8%) were 26 years and above experience. 45 respondents (23%) were contractors, 39 were clients (20%), 45 were designers (23%), 26 were consultants (14%) and 38 were academicians (20%). The detailed demographic information of respondents is shown in Table 4.2

Table 4.2 Demographic profile of respondents

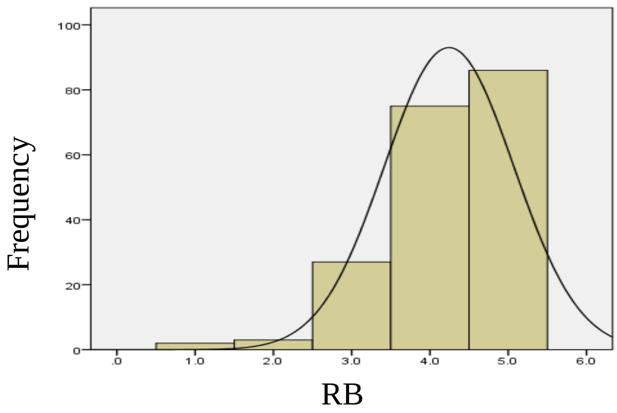
Category	Variables	Frequency	Percent %
Experience	1-5 (years)	45	23
	6-10(years)	73	38
	11-15 (years)	20	10
	16-20 (years)	22	12
	21-25 (years)	17	9
	26 and above	16	8
Type of stakeholder	Contractor	45	23
	Client	39	20
	Design	45	23
	Consultant	26	14
	Academicians	38	20
Designation	Project Manager	27	14
	Assistant Manager	45	23
	Project Consultant	38	20
	Engineer	38	20
	Others (Architect, MEP consultant, Structural consultant, Liaison consultant, academicians)	45	23
Type of project	Residential	54	28
	Commercial	67	35
	Infrastructure	72	37

4.5 Descriptive statistics analysis

Descriptive statistical analysis is carried out on a sample size of 193. The mean and standard deviation values for performance metrics are reported in Table 4.4. Testing for kurtosis is recommended for testing normality (Byrne 2010). For Likert scales, many of the respondents mark the same score repeatedly creating kurtosis related difficulties in the data. Hence, it is recommended to check kurtosis as a check of normality. The recommended value of kurtosis is in range of ±7 (Byrne 2010).

Skewness measures the symmetry in distribution. However, Curran et al. (1996) and Dubey et al. (2016) have said that for normal distribution skewness value can range between ±7 and kurtosis value in the range of ± 2. Therefore, the data is normally distributed. Hence, it is considered a representable mean. Table 4.3 shows the histogram for return business metric in customer relation area.

Table 4.3. Histogram for Return business (RB) metric in customer relation area

<table>
<tr><td colspan="2">RB: Return business is used to measure the performance of construction projects.</td></tr>
<tr><td>Mean 4.244
Std. deviation 0.827
Skewness -1.094
Kurtosis 1.421</td><td>
</td></tr>
</table>

In questionnaire section two, first three questions are related to rating the importance of customer relations in measuring the performance of construction projects. The mean value of 1st performance metrics (Return Business (RB)) in customer relation is 4.244 and SD value is 0.827. Since skewness (-1.094) is negative the curve is left skewed and the data is piled up at the left side of the mean. Kurtosis (1.421) being positive, the curve is tall and narrow. Skewness and kurtosis reaffirm the meaningfulness of the mean according to Curran et al. (1996). Hence, it is concluded that respondents agree that return business should be included to measure project performance. Histogram plots were examined to check normality of the performance metrics. If the variables are normally distributed, that indicates normal curve. The SD and mean, skewness and kurtosis value for all performance metrics are as shown in Table 4.4. While, there are few outliers, the overall histograms generally depict normal distribution.

Table 4.4. Descriptive statistics for performance metrics

Coding	Performance metrics	Mean	SD	Skewness	Kurtosis

RB	Return Business	4.244	0.827	-1.094	1.421
DC	Disputes Claims	3.710	1.041	-0.570	-0.163
F	Feedback Policy	3.953	0.953	-0.562	0.477
OS	OSHA Recordable	3.964	0.962	-0.711	0.70
LTI	Loss Time Injuries	3.622	1.107	-0.324	-0.893
Fa	Fatalities	3.902	1.068	-0.701	-0.148
CS	Construction Speed	3.902	1.068	-0.701	-0.148
SP	Schedule Payment	3.990	0.951	-0.785	0.985
SC	Schedule Growth	3.964	0.975	-0.811	0.425
CUC	Construction Unit Cost	3.958	1.022	-0.926	0.387
CG	Cost Growth	3.917	0.964	-0.747	0.293
RC	Rework cost	3.694	1.110	-0.744	-0.618
PQ	Project Quality	3.969	1.065	-0.905	0.105
DLP	Defect Liability Period	3.958	1.022	0.091	-1.132
IBS	Item Beyond Scope	3.166	0.975	-0.42	-0.994
DC	Defect Cost	3.943	0.951	0.064	-1.148
RFI	Request for Information	1.523	0.500	-0.094	-2.001
CMP	Communication Management Plan	3.943	0.990	-0.795	0.078
FOM	Frequency of Meeting	3.078	1.026	-0.023	-1.099
IOM	Impact of Meeting	4.093	0.902	-0.830	0.171
P	Profit	3.523	1.104	-0.95	-1.148
EP	Equipment productivity	4.228	0.974	-1.036	0.770
LP	Labour Productivity	4.228	0.853	-0.964	0.287
EL	Expectation Level	4.057	0.902	-1.144	1.606
S	Social Environment	3.886	0.982	-0.667	-0.084
T	Technical Environment	4.086	0.874	-0.966	-0.954
P	Political Environment	3.736	1.088	-0.608	-0.295
E	Economic Environment	4.026	0.991	0.991	-0.366

From the results, it is concluded that the respondents agree that all performance metrics considered in the study should be included to measure project performance. Histograms for all performance metrics can be referred in Annexure V.

4.6 Common Method Variance (Harman's single factor method)

There is a high chance of common method bias in case of self-reported data from multiple sources. This test was carried out to mitigate the risk of the common method bias in the sample. Harman's single factor test was conducted by entering all the measurement variables in EFA in SPSS. The sample would have a common method bias problem if a single construct explains more than 50% of the extracted variance (Podsakoff 2003). The results indicate that the single factor variance extracted is 21%, which is below 50%, and therefore there is no significant problem in the data and results. Table 4.5 shows the detailed results of common method variance test.

Table 4.5 Common Method Variance Test Result

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.280	21.788	21.788	8.280	21.788	21.788
2	4.230	11.132	32.921			
3	2.533	6.666	39.587			
4	1.616	4.252	43.838			
5	1.588	4.179	48.017			
6	1.502	3.952	51.970			
7	1.389	3.656	55.626			
8	1.147	3.018	58.644			
9	1.093	2.877	61.521			
10	1.047	2.756	64.277			
11	1.013	2.666	66.944			
12	0.989	2.604	69.547			
13	0.891	2.346	71.893			
14	0.863	2.270	74.163			
15	0.805	2.118	76.281			
16	0.753	1.983	78.264			
17	0.719	1.892	80.156			
18	0.699	1.839	81.995			
19	0.646	1.700	83.696			
20	0.640	1.685	85.381			
21	0.597	1.570	86.951			
22	0.514	1.352	88.303			
23	0.477	1.255	89.559			
24	0.441	1.162	90.721			
25	0.409	1.075	91.796			
26	0.389	1.023	92.819			
27	0.358	0.941	93.759			
28	0.322	0.847	94.606			
29	0.320	0.842	95.449			
30	0.290	0.763	96.211			
31	0.266	0.701	96.912			
32	0.254	0.669	97.582			
33	0.238	0.627	98.209			

34	0.186	0.490	98.699			
35	0.145	0.382	99.081			
36	0.141	0.370	99.451			
37	0.116	0.306	99.757			
38	0.092	0.243	100.000			
Extraction Method: Principal Component Analysis.						

4.7 Factor analysis technique

FA is a statistical tool used to identify a relatively small number of factors that can be used to represent the relationship among sets of many interrelated variables. After reliability and descriptive statistics, exploratory factor analysis was performed to group the items. PCA with varimax rotation was performed which maximizes the variance of the squared loading for each factor that produces a clear factor loading according to Hair et al. (2010). Statistical Package for Social Sciences (SPSS) version 21 software (Field, 2013) was used for factor analysis. FA was performed on 28 performance metrics. The main objective of FA is to reduce the large data set of performance metrics to those that represent the largest variation in that data set. Several iterations are carried out to determine the satisfactory number of factors that represent the intended performance areas of PQR model. An exploratory Principle Component Factor Analysis was performed to determine the resultant factors. Appropriateness of data for FA was ensured through Bartlett’s test of sphericity and KMO values. In the present analysis, only performance areas with a factor loading of > 0.5 were considered.

Kaiser Meyer Olkin Measure

KMO test checks the sampling adequacy. KMO test results are as shown in table 4.6.

Table 4.6 KMO test results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.690
Bartlett's Test of Sphericity	Approx. Chi-Square	1077.769
	df	321
	Sig.	.000

KMO results for performance metrics is 0.69 which is in above the recommended threshold of 0.5 according to Hair et al. (2006). This indicates that the sample is adequate for conducting factor analysis (Field 2009).

Bartlett's test

Bartlett's test of sphericity signifies whether the correlation matrix is an identity matrix. In this study, the results of Bartlett's test of sphericity were found to be significant as shown in Table 4.6. The test also indicated that varimax orthogonal rotation is suitable for factor extraction.

Results of Factor Analysis

Factor analysis resulted in nine performance factors with an eigen value greater than one. They accounted for 59.49 % of the total variance. At each stage of iterations, factor loadings were observed for all performance metrics. These nine factors explain the variability in the data set. Loadings for nine factors are as shown in Table 4.6. Factor 1 consists of quality area and hence it is renamed as *Quality factor*. Factor 2 consists of major scheduled area, such as schedule payment, schedule growth, and construction speed. Therefore, it is renamed as *schedule factor*. Factor 3 was named as *Environment and stakeholder satisfaction* as it comprises of social, technical, economical, political and expectation level. Factor 4 was named as *cost* as it consists of construction unit cost and construction cost growth. Factor 5 was renamed as *productivity* as it consists of labour productivity and equipment productivity. Factor 6 consists of LTI and fatalities, hence was renamed as *safety* factor. Factor 7 consists of disputes, communication management plan and the impact of client-contractor meetings. Hence, it was renamed as *communication and collaboration.* Factor 8 was named as *customer relation* as it consists of return business and feedback policy. Factor 9 consists of profit and Osha recordables so it was named as *Finance*. Rework and RFI performance metrics were removed due to less factor loading of less then 0.4 on the factors. RFI', 'Impact of meetings' and rework' performance metrics were also removed due to factor loading of less than 0.4.

Table 4.7 EFA result

Factor	**Eigen value**	**Variance%**	**variables**	**Factor loading**
Quality	4.20	8.959	Defect liability period	0.68
			Item beyond scope	0.76

			Defect cost	0.81
			Frequency of meeting	0.63
			Project quality	0.52
Schedule	2.53	8.14	Schedule payment	0.77
			Schedule growth	0.76
			Construction speed	0.56
Environment and stakeholder satisfaction	1.68	6.95	Social impact	0.54
			Technical impact	0.70
			Political impact	0.52
			Economic impact	0.68
			Exception level	0.51
Cost	1.59	6.69	Construction unit cost	0.60
			Construction cost growth	0.71
Productivity	1.47	6.53	Labor productivity	0.68
			Equipment productivity	0.75
Safety	1.37	6.33	Loss of time injuries	0.68
			Fatalities	0.75
Communication management plan	1.11	5.65	Disputes claims	0.68
			Communication management plan	0.75
Customer relation	1.06	5.12	Return business	0.76
			Feedback policy	0.53
Finance	1.01	5.13	OSHA	0.50
			Profit	0.69

The hypothesis that these nine factors are sufficient to represent the intended performance area was tested. It was revealed a Chi-squared statistic of [$\chi^2(321)$ =1077.769, P<0.000]. Since P value is significant, which indicates that the factors predict data well from stastical prespective. The nine factors are sufficent to summarize the performance areas of modified PQR model. Table 4.7 shows the results of Chi-Squared and KMO.

Table 4.8 Chi-Squared and KMO reporting for performance areas

Performance areas	Metrics	KMO	Chi-squared	Significance
Customer relation	RB	0.580	25.44	0.000
	DC			
	FB			
Safety	OS	0.544	42.216	0.000
	LTI			
	F			
Schedule	CS	0.571	85.616	0.000
	SP			
	SC			
Cost	CUC	0.578	36.864	0.000
	CG			

	RC			
Quality	PQ	0.673	132.428	0.000
	DLP			
	IBC			
	DC			
Communication and collaboration	RFI	0.530	37.411	0.000
	CMP			
	FOM			
	IOM			
Productivity	LP	0.500	22.64	0.000
	EP			
Environment	S	0.623	6	0.000
	T			
	P			
	E			

4.8 Relationship among performance areas and project performance

Pearson's correlation coefficient test is the most widely used correlation test to measure relationships between the dependent variables and independent variables (Hair et al. 2006). Hence, pearson correlation was used as a measure of relationship among these ten performance areas and project performance of Indian construction industry, The coefficient (R) ranges between -1 and +1. A positive value indicates a positive linear correlation, 0 indicates no linear correlation and negative values indicate a negative linear correlation between performance areas and project performance.

Null Hypothesis H0: There is no significant correlation between the ten performance areas (*Customer Relations, Safety, Schedule, Cost, Quality, Finance, Communication and collaboration, Productivity, Stakeholder satisfaction, Environment*) and project performance.

Alternate Hypothesis H1: There is a significant correlation between the ten performance areas (*Customer Relations, Safety, Schedule, Cost, Quality, Finance, Communication and collaboration, Productivity, Stakeholder satisfaction, Environment*) and project performance.

The relationship between performance areas and project performance (PP) is as shown in Table 4.9.

Table 4.9 Correlation result

	Cu	**Sa**	**Sc**	**C**	**Q**	**F**	**Co**	**Pr**	**St**	**E**	**PP**

Cu	r	1										
	p											
Sa	r	0.659**	1									
	p	.000										
Sc	r	.610**	.789**	1								
	p	.000	.000									
C	r	.655**	.784**	.759**	1							
	p	.000	.000	.000								
Q	r	.717**	.792**	.819**	.775**	1						
	p	.000	.000	.000	.000							
F	r	.700**	.773**	.749**	.728**	.781**	1					
	p	.000	.000	.000	.000	.000						
Co	r	.640**	.690**	.762**	.715**	.691**	.675**	1				
	p	.000	.000	.000	.000	.000	.000					
Pr	r	.530**	.707**	.708**	.618**	.671**	.623**	.692**	1			
	p	.000	.000	.000	.000	.000	.000	.000				
St	r	.582**	.712**	.752**	.714**	.662**	.684**	.764**	.663**	1		
	p	.000	.000	.000	.000	.000	.000	.000	.000			
E	r	.591**	.771**	.716**	.680**	.678**	.705**	.714**	.688**	.829**	1	
	p	.000	.000	.000	.000	.000	.000	.000	.000	.000		
PP	r	.549**	.749**	.762**	.700**	.728**	.742**	.676**	.651**	.699**	.722**	1
	p	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
**. Correlation is significant at the 0.01 level (2-tailed).												

The correlation values at α =0.05, r and p values are listed in Table 6, with p-value (significance) less than the level of significance, α = 0.05, which leads to rejection of the null hypothesis, H0. Hence, there is a significant relationship between these ten performance areas and project performance in the Indian construction industry. The values of Pearson correlations are 0.659, 0.610, 0.655, 0.717, 0.700, 0.640, 0.530, 0.582, 0.591 and 0.549 for Cu, Sa, Sc, C, Q, F, Co, Pr, St and E respectively. The result indicates that all performance areas were found to be significantly correlated to project performance ($p<0.01$). Correlation associations for safety, schedule, cost, quality, finance and environment had strongest coefficient values. Hence, are considered to be highly associated with project performance construct. The remaining four performance areas (customer relation, communication and collaboration, productivity and stakeholder satisfaction) also exhibit statistically significant relationships ($p<0.01$). From above findings, it can be concluded that the ten project performance areas are considerably important for construction project performance in the Indian construction industry.

4.9 Summary

This chapter presents statistical analysis; descriptive analysis, factor analysis and correlation results. IBM SPSS version 21 software (Field, 2013) was used for statistical analysis. Nonresponse bias and common method variance test was conducted which resulted in the conclusion that the sample doesn't have any presence of non-response and common method variance problem. Descriptive analysis was carried out for all 28-performance metrics and, it was concluded that respondents agree that all performance metrics should be included to measure project performance. Factor analysis concluded that nine factors are sufficient to represent the intended performance area of modified PQR model. Modified PQR is an adequate performance model which can be used for the Indian construction industry. The correlation analysis resulted in the acceptence of H1; that there is a significant correlation between all ten performance areas and project performance. The performance areas of customer relations (Cu), safety (Sa), schedule (Sc), cost (C), quality (Q), finance (F), communication and collaboration (Co), productivity (Pr), stakeholder satisfaction (St) and environment (E) are positively correlated with project performance in the context of the Indian construction industry. Chapter 5 will describe in detail the formulation of a modified PQR Model.

CHAPTER 5

DEVELOPMENT OF MODIFIED PQR MODEL

This chapter discusses the development and formulation of a MPQR in detail.

5.1 Relevance of PQR

The concept is adopted from the quarterback rating system used in U.S National Football League. The quarterback position in football is responsible for passing the ball to other players (Neft et al. 1994). The performance of a quarterback in comparison with other quarterbacks is called quarterback rating. This Quarterback rating is calculated by adding individual scores of Quarterback Pass Attempts, Quarterback Pass Completions, Total Passing Yards, Completed Touchdown Passes, and Total Interceptions. This consolidates to a single score that can be used to compare the performance of players. (Berssaneti and Carvalho 2015). Project performance is a complex concept and involves various performance areas that need to be accounted, some of which cannot be measured easily. Similarly, PQR is an approach to evaluate the performance of construction projects (El Asmar, et al. 2015). PQR model combines seven key performance areas into single scores to compare projects using the emerging Integrated Project Delivery (IPD) system to projects with Design-Build, Design-bid-build and Construction Management at Risk. This research developed a PQR model for construction projects that combines performance scores over given performance areas in Indian context. The PQR model has a linear function and is based on weighted average of performance metrics on Indian construction projects. It can serve as a tool that project stakeholders can use to monitor their projects' performance.

5.2 Development of MPQR model

MPQR Model approach combines ten performance areas identified by the questionnaire survey findings which are already discussed in chapter 3. These ten areas are as follows: (1) cost (C), (2) schedule (S), (3) stakeholder satisfaction (St), (4) safety (Sa), (5) quality (Q), (6) finance (F), (7) environment (E), (8) communication and collaboration (Co), (9) customer relation (Cu) and (10) productivity (Pr).

For the purpose of the formulation of $MPQR_j$ model weighted average formula of different performance areas (A_{ij}) was used as shown in Eq. (5.1)

$$MPQR_j = \sum_{i=1}^{I} W_i A_{ij} \qquad (5.1).$$

Where, W_i = weightage of performance area 'i'; I=10;

i= 1, 2, 3……10 as there are 10 performance areas

j=1, 2, 3……193 as there are 193 respondents.

A_{ij}= score of respondent j for performance area i for project.

Figure 5.1 shows the detailed structure of the MPQR model.

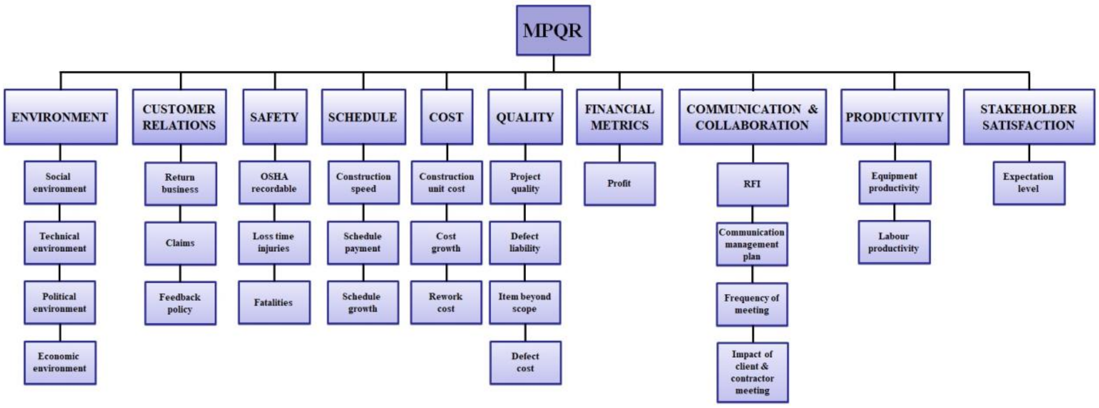


Figure 5.1 Modified PQR

The MPQR Model is linear and so it is a simple model that allows for addition of various performance areas. The $MPQR_j$ score depends on performance areas score'i' and is calculated as weighted average of the different performance areas (A_{ij}). Tier I give a single MPQR score, Tier II are performance areas that include ten areas (A_{ij}) and Tier III represents components of performance areas named as performance metrics (M_{ijk}). For example, Schedule performance area is forned by combining three performance metrics *construction speed, schedule payment, and schedule growth.* The performance score achieved by performance metrics is represented as 'M_{ijk}' where 'k_i' is 3, representing a number of metrics that combine schedule performance area 'i'. 'A_{ij}' represent performance area score for schedule area. The mean and SD values were calculated for each performance metric 'k' in each performance area 'i'. The unit of measurement is different for each performance area such as cost and quality hence there was a need for standardization. For instance, Quality performance area includes four metrics with a different unit of measurement. Project quality is related to civil, mechanical, structural and finished works. It is measured in the scale of 1-Economy, 2-standard, 3-High standard, 4-Premium, and 5-high premium. Item beyond scope of work is the unsatisfactory items remaining after substantial completion of a project. Deficiency issues are issues that arise during the execution of construction. Defect costs are measured after the end of the liability period. Items beyond cost, cost of defects and defect liability period are measured based on cost percentage relative to total construction cost.

Standardization shifts the mean value of distribution to zero (El Asmar et al. 2015). In a similar way, each project score 'M_{ij}' is standardized to 'Z_{ijk}'. The performance score for each performance area is calculated as shown in Eq. (5.2):

$$A_{ij} = \sum_{k=1}^{ki} W_{ik} Z_{ijk}$$

(5.2).

W_{ik}= Weight of each performance metric within a specific performance area 'i'. The 'Z_{ijk}' represents 'Z' scores. The 'Z_{ijk}' are centered on zero and will have positive and negative values. 'Z' scores are calculated using Eq. (5.3).

$$Z_{ijk} = (x_{ijk} - \mu_{ik})/\sigma_{ik}.$$

(5.3).

The mean score values and SD values are calculated for each performance metric. The formulas used are:

$$\mu_{ik} = B_{ik}(M_{ijk}) \text{ and } \sigma_{ik} = \sqrt{B_{ik}(M_{ijk} - \mu_{ik})^2}$$

B_{ik} denotes average of all 'M_{ijk}' performance area scores over 'j', fixing 'i' and 'k'.

In Eq. (5.2) and Eq. (5.3), normalization technique is used to standardize 'A_{ij}' resulting score. The mean value of all 'A_{ij}' is zero, 'A_{ij}' is then directly divided by overall standard deviation of all 'A_{ij}'. The final 'A_{ij}' result can be interpreted that a positive value represents above average performance and a negative value represents below average performance and zero indicates average performance. Lastly, the standardized performance area scores are combined into Eq. (5.1).

5.3 Modified PQR formula

Before using the survey data to formulate MPQR Model, weights for each performance metrics must be identified. The weights for ten performance areas were identified based on the last section of the questionnaire survey which is Annexure I. Weight for all performance areas were calculated as shown in equation (5.4).

$$\text{Weights of Performance areas} = \left[\frac{F_{PA}}{\sum_{PA=0}^{10} F_{PA}}\right] * 100 \qquad (5.4)$$

F_{PA}= Frequencies of each performance areas.

$\sum_{PA=0}^{10} F_{PA}$= Sum of all frequencies of all performance area.

The weights indicate the importance of performance metrics for construction projects. The findings indicate that cost was ranked the most important performance metrics. The schedule was ranked second and stakeholder satisfaction was ranked third. Safety was ranked at fourth place followed by quality. Finance was ranked at sixth position and environment seventh. Lastly, communication and collaboration was ranked eighth, customer relation as ninth and productivity as tenth. The coefficient for performance areas is calculated as shown in Figure 5.2

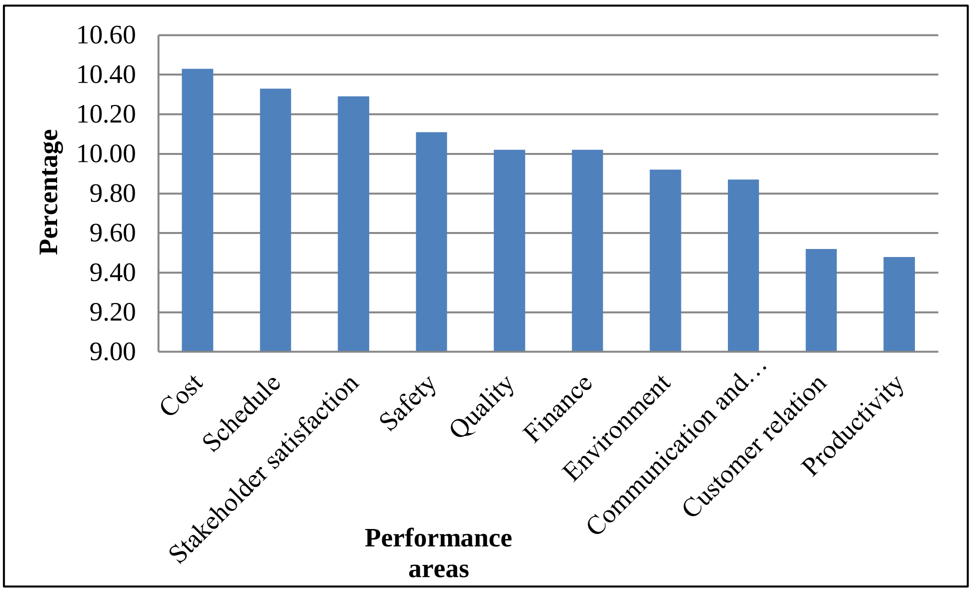


Figure 5.2 overall importance of performance areas

These percentages can be used to develop MPQR formula as shown below in Eq. (5.5).

$$MPQR = \frac{0.104*C+0.103*S+0.102*St+0.101*Sa+0.100*Q+0.100*F+0.992*E+0.987*Co+0.952*Cu+0.948*Pr}{1.002}$$

(5.5).

The denominator value 1.002 is the standard deviation for all performance area scores. However, since the numerator terms are already standardized, the mean value obtained will be zero. Further, for simplification, MPQR weight of performance areas is divided by the standard deviation to arrive at Eq. (5.6).

$$MPQR = 0.103 * C + 0.102 * S + 0.101 * St + 0.100 * Sa + 0.099 * Q + 0.099 * F + 0.990 * E + 0.985 * Co + 0.950 * Cu + 0.946 * Pr$$

(5.6).

5.3.1 Delphi technique

Before using the survey data to formulate MPQR Model, weights for each performance metrics was identified. The weights quantify the level of importance of individual performance metrics. Delphi technique was used for this purpose. Delphi method is a qualitative research method in which a survey instrument is used to provide answers with opinion of experts. According to Scholl et al. (2004) Delphi technique can be used when there is less information available about a topic. The Delphi technique is widely used and accepted in various fields of construction management. Consensus is achieved through several rounds of expert's opinion.

5.3.1.1 Questionnaire Development

A survey instrument was developed to gather responses from professionals in the construction industry as shown in Annexure II. There are various methods used for assigning weights for factors. The most common method is 100-point method, which was used and it consists of 100 points to be distributed among each performance area (Nijkamp et al. 1990). The respondents were requested to assign weights to performance metrics in order to reflect the impact on specific performance area and is expressed as percentage. In order to validate the survey, content validity was used to check whether the performance areas cover all performance metrics (Hair et al. 2010). The questionnaire was independently evaluated by 3 academic experts, 2 research experts and 2 industry experts for content validity. After content validity, questionnaire was refined by experts' opinion for assigning weights using Delphi technique. Sampling frame consists of project managers, academicians and industry experts. There is no exact sample size calculation for Delphi technique (Skulmoski 2007). The approach is based on open-ended questions to which experts were asked to answer.

Numerous studies have used two to three rounds to reach stable result to achieve the level of consensus. In this study, two rounds of Delphi questionnaire survey were conducted. Experts involved in the survey were having professional experience of minimum 10 years in the industry and having sound knowledge in construction management practices. Initially, 20 experts were willing to participate in the study. All 20 members were contacted via email. Descriptive statistics was analyzed for mean of performance metrics for both rounds and weights were finalized. An average of 4-6 weeks was required to collect data for both round of Delphi questionnaire survey. The data was analyzed and presented as final summary of assigned weights. The flowchart of survey activities is as shown in Figure 5.3.

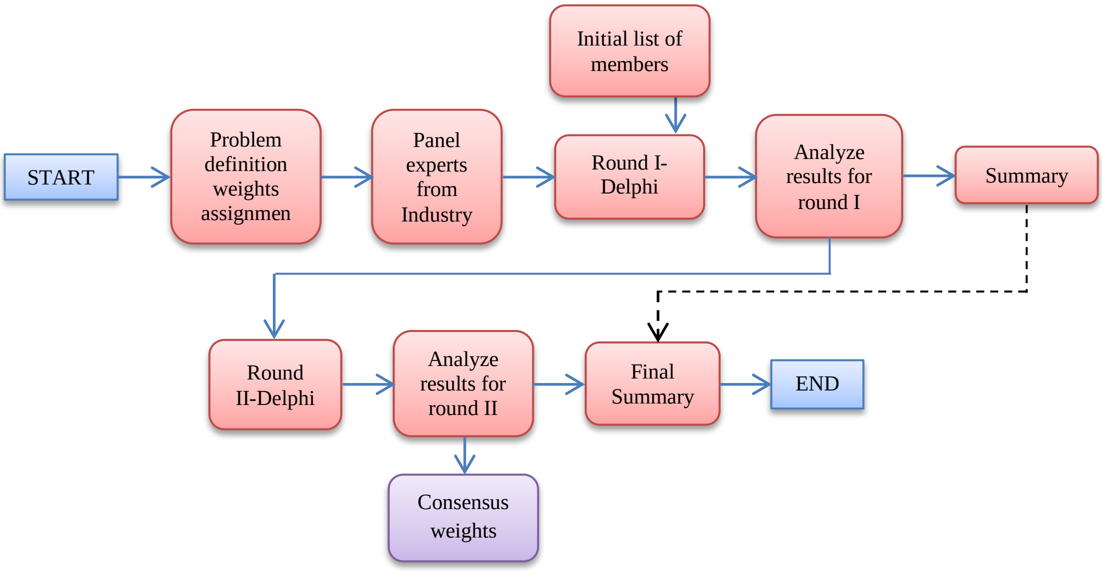


Figure 5.3. Flowchart of Survey

5.3.1.2 Delphi round-I

The round-I of the Delphi questionnaire survey is a structured questionnaire for collecting weights of performance metrics in specific performance areas. The first round includes (i) general details of respondents (ii) email id and (iii) assigning weights. The respondents were asked to provide weights in percentages (0-100%) for performance metrics to represent the impact of performance area in construction project. These weights represent the importance of each performance metric to the corresponding performance area. A detailed description about the survey is provided to the respondent before conducting round I of Delphi questionnaire survey. Round one is completed by 12 people with a response rate of 60%. The profile of experts for Delphi group is highlighted in Table 5.1.

Table 5.1. Demographic profile of experts

Projects	**Number of experts**	**Experience(years)**
Infrastructure	4	10-15
Commercial	2	10-12
Residential	2	10-11
Academicians	4	25-40

Respondents were asked to send response within 20 days. The responses received were summarized and analyzed to obtain the level of consensus. The mean score value is calculated to indicate the level of consensus from Delphi round- I (Singh and Singh 2017). The results of Delphi round I is shown in table 5.2.

Table 5.2 Delphi Round I result

Sr no.	**Area**	**Metrics**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**M1**
1.	C	CUC	50	70	30	60	40	60	65	80	40	30	50	40	51
		CGR	30	20	35	20	30	10	25	15	30	30	25	30	25
		RC	20	10	35	20	30	30	15	05	30	40	25	30	24
2.	S	CS	40	35	40	75	70	30	35	70	50	50	40	45	48
		SP	30	35	30	10	20	50	35	15	30	30	30	25	28
		SC	30	30	30	20	10	20	30	15	20	20	30	35	24
3.	Sa	OS	60	60	70	80	50	40	75	90	50	60	50	60	62
		LTI	20	25	15	10	30	30	20	05	30	20	25	20	21
		F	20	15	15	10	20	30	05	05	20	20	25	20	17
4.	Q	PQ	50	60	40	70	50	50	65	75	60	50	30	65	55
		DLP	20	10	20	10	20	20	15	10	10	20	30	15	17
		IBC	20	20	20	10	20	10	10	05	10	10	20	10	14
		DC	10	10	20	10	10	20	10	10	20	20	20	10	14
5.	E	S	30	20	30	20	30	10	10	60	20	30	10	15	24
		T	20	30	30	30	10	50	45	30	50	10	40	50	33
		P	20	20	10	20	30	20	15	05	10	20	10	15	16
		E	30	30	30	30	30	20	30	05	20	40	40	20	27

6.	Co	RFI	40	35	25	25	30	10	25	40	65	60	70	50	40
		CMP	20	20	25	25	20	40	25	10	20	20	10	30	22
		FOM	10	10	25	25	20	25	25	40	5	10	10	10	18
		IOM	30	35	25	25	30	25	25	10	10	10	10	10	20
7.	Cu	RB	70	50	50	75	60	60	60	70	40	70	80	60	62
		DC	10	25	20	10	20	30	10	25	20	10	10	20	18
		FP	20	25	30	15	20	10	30	05	30	20	10	20	20
8.	PR	EP	60	50	60	60	55	60	70	50	50	60	50	60	57
		LP	40	50	40	40	45	40	30	50	50	40	50	40	43

5.3.1.3 Delphi Round-II

Delphi round II is conducted five weeks after round one. In the second round of Delphi questionnaire survey, the results from the first round were presented to the respondents and were asked to modify the weights if necessary. The respondents were allotted a time period of 20 days to submit their responses. Round II is completed with same response rate of 60%. The results obtained have been summarized in Table 5.3. All responses were then analyzed collectively. The results obtained have been summarized in ‘results and discussion’ section of this study. Comparison of the results of round I and II showed a slight change in responses.

Table 5.3 Delphi Round II result

Sr no.	**Area**	**Metrics**	**R 1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R11**	**R12**	**M2**
1.	C	CUC	50	70	30	60	40	60	65	80	40	30	50	40	51
		CGR	30	20	35	20	30	10	25	10	30	30	25	30	25
		RC	20	10	35	20	30	30	15	10	30	40	25	30	25
2.	S	CS	40	35	40	75	70	30	35	70	50	50	40	45	48
		SP	30	35	30	10	20	50	35	15	30	30	30	25	28
		SC	30	30	30	20	10	20	30	15	20	20	30	35	24
3.	Sa	OS	60	60	70	80	50	40	75	80	50	60	50	60	61
		LTI	20	25	15	10	30	30	20	10	30	20	25	20	21
		F	20	15	15	10	20	30	05	10	20	20	25	20	18
4.	Q	PQ	50	60	40	70	50	50	65	75	60	50	30	65	55
		DLP	20	10	20	10	20	20	15	10	10	20	30	15	17
		IBC	20	20	20	10	20	10	10	05	10	10	20	10	14

		DC	10	10	20	10	10	20	10	10	20	20	20	10	14
5.	E	S	30	20	30	20	30	10	10	50	20	30	10	15	23
		T	20	30	30	30	10	50	45	20	50	10	40	50	32
		P	20	20	10	20	30	20	15	10	10	20	10	15	17
		E	30	30	30	30	30	20	30	20	20	40	40	20	28
6.	Co	RFI	40	35	25	25	30	10	25	40	65	60	70	50	40
		CMP	20	20	25	25	20	40	25	10	20	20	10	30	22
		FOM	10	10	25	25	20	25	25	40	5	10	10	10	18
		IOM	30	35	25	25	30	25	25	10	10	10	10	10	20
7.	Cu	RB	70	50	50	75	60	60	60	70	40	70	80	60	62
		DC	10	25	20	10	20	30	10	25	20	10	10	20	18
		FP	20	25	30	15	20	10	30	05	30	20	10	20	20
8.	PR	EP	60	50	60	60	55	60	70	50	50	60	50	60	57
		LP	40	50	40	40	45	40	30	50	50	40	50	40	43

The final weights assigned through Delphi survey analysis are summarized in Figure 5.4

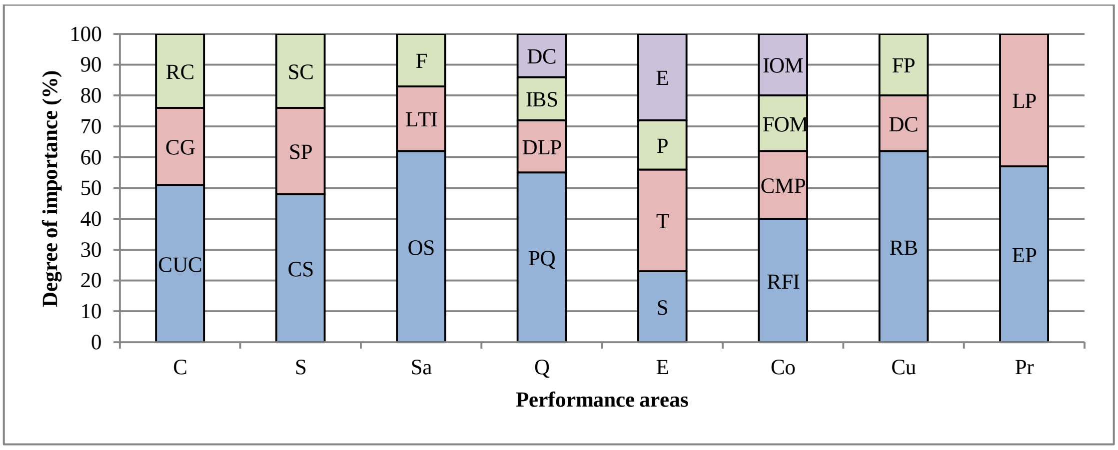


Figure 5.4. Weights for performance metrics

The next section explains how to formulate performance area scores for ten performance areas. The Calculation of standardized performance areas score is illustrated below as per top performance area identified in the questionnaire section.

5.3.2 Cost

The most important performance area identified is cost. Cost performance area consists of three performance metrics (1) Construction unit cost (CUC), (2) Construction Cost growth (CGR) and (3) Rework cost (RC). Construction unit cost is the cost per square feet of construction. It has five-point scales (1)-strongly disagreed, (2)-less agreed, (3)-moderately agreed, (4)-highly agreed, (5)-strongly agreed. The mean value for it is 3.958 and standard deviation of 1.022. Construction cost growth is a difference of final construction cost and original construction cost. It is measured using a five-point scale (1)-Strongly disagreed to (5)-Strongly agreed. The mean value for it is 3.917 and the standard deviation value is 0.965. Rework cost is measured in percentage of total construction cost. The mean value for it is 3.694 and the standard deviation is 1.111. The values are coded as 0-1% as 1, 1-2% as 2, 2-3% as 3, 3-4% as 4 and >4% as 5. Construction unit cost growth, and rework cost should be minimized. Delphi survey weights for CUC, CGR, and RC are 51%, 25%, and 24% respectively.

$$Cost(C) = \frac{\left(0.51*\frac{CUC-3.958}{1.022}\right)-\left(0.25*\frac{CGR-3.917}{0.965}\right)-\left(0.24*\frac{RC-3.694}{1.111}\right)}{1.069} \quad (5.7).$$

A negative sign for construction unit cost, cost growth and rework cost indicate that it should be minimized. Therefore, the formula can be used to calculate the score of cost performance area which can be used in the first part of MPQR Eq. (5.5). The negative sign indicates the adverse impact on the progress of the project indicating that it should be minimized while a positive sign indicates progressive impact on cost. CUC, CGR, and RC were standardized individually to obtain z-scores. After this standardization, a weighted average of the three new z-scores was calculated, and the result was standardized again, which provides 1.069 as the value of the denominator. The above equation can be used to calculate cost performance area scores for Indian construction projects. The performance area score '*C* 'obtained from Eq. (5.7) can be used in the MPQR Eq. (5.5).

5.3.3 Schedule

It consists of three performance metrics (1) construction speed (CS), (2) schedule of payment (SP) and (3) schedule growth (SC). Construction speed is measured from the day of the start of the construction activity (work order date) to the end of the project. It has five-point scales (1)-strongly disagreed, (2)-less agreed, (3)-neutral, (4)-highly agreed, (5)-strongly agreed. The mean value for it is 3.90 and a standard deviation value of 1.06. Schedule of payment is measured as per the milestone set for completing progress of work. The mean value for it is 3.99 and the standard deviation value is 3.964. Schedule growth is measured in percentage terms by the rate of progress compared with the expected construction schedule. The mean value for it is 3.964 and the standard deviation value is 0.975. CS, SP, and SC were measured on a five-point scale (1)-strongly disagreed to (5)-strongly agreed. Delphi survey weights for CS, SP, and SC are 48%, 28% and 24% respectively.

$$\text{Schedule: } Sc = \frac{\left(0.48*\frac{CS-3.902}{1.068}\right)-\left(0.28*\frac{SP-3.99}{0.952}\right)-\left(0.24*\frac{SC-3.99}{0.952}\right)}{0.999} \quad (5.8)$$

A negative sign for schedule payment and schedule growth indicates that it should be minimized. CS, SP and SC metrics is standardized individually to obtain z scores. The weighted average score is computed after obtaining Z scores. Schedule payment and schedule growth indicate that it should be minimized. A weighted average of the three new z-scores is computed, and the result is standardized again, hence the 0.999 denominator.

The above equation can be used to calculate schedule performance area scores for Indian construction projects. The performance score '*Sc*' obtained from Eq. (5.8) can be used in the MPQR Eq. (5.5).

5.3.4 Stakeholder satisfaction

Another important area is stakeholder satisfaction which is very difficult to quantify. Stakeholder includes everyone who is involved in the project. Stakeholder satisfaction is measured by expectation and commitment level. The expectation is being satisfied as per the expected standard (contract document) on a five-point scale:(1)-Strongly disagreed to (5)-Strongly agreed. The mean value is 4.057 and the standard deviation value is 1.48.

$$\text{Stakeholder satisfaction: } St=\left(\frac{EL-4.057}{1.209}\right) \quad (5.9)$$

To ensure project success, project stakeholders play vital roles. So, it has a positive impact on project performance. The above equation can be used to calculate stakeholder satisfaction performance area scores for Indian construction projects. The performance score '*St*' obtained from Eq. (5.9) can be used in the MPQR Eq. (5.5).

5.3.5 Safety

The safety performance areas were include (1) the number of OSHA recordable (OS), (2) the number of lost time injuries (LTI), and (3) the number of fatalities (F). OSHA recordable is measured in a number of recordable events. OSHA mission is to assure safe and healthful working conditions. The mean value for OSHA recordable is 3.96 and the standard deviation value is 0.962. Hence, it has a positive impact on project performance. LTI is calculated in by time lost in days. The mean value for LTI is 3.62 and standard deviation value as 1.10. LTI is lost work time in days which is more severe than recordable. OSHA mission is to assure safe and healthful working conditions. Fatalities are the occurrence of death by accident on site. LTI and fatalities should be avoided on site. Thus, it gives a negative impact on performance. The mean value for fatalities is 3.544 and standard deviation value of 1.21. Delphi survey weights for OS, LTI, and F are 62%, 21%, and 17% respectively.

$$Safety\text{: } Sa = \frac{\left(0.62*\frac{OS-3.964}{0.962}\right)-\left(0.21*\frac{LTI-3.622}{1.107}\right)-\left(0.17*\frac{F-3.544}{1.209}\right)}{0.209} \quad (5.10)$$

OS, LTI and F metrics is standardized individually to obtain z scores. After the initial standardization weighted average score is computed. The above equation can be used to calculate safety performance area scores for Indian construction projects. The performance score '*Sa'* obtained from Eq. (5.10) can be used in the MPQR Eq. (5.5).

5.3.6 Quality

The quality performance area includes (1) project quality (PQ), (2) Item beyond cost (IBC), (3) Deficiency liability period (DLP), (4) defect cost (DC). Project quality is related to mechanical, structural and finished works. PQ is measured as standards of quality on a five-point scale 1-Economy, 2-standard, 3-high, 4-Premium, 5-highly premium. It should be maintained throughout the project and has a positive impact on project performance. Item beyond scope of work are items beyond Bill of quantitates (BOQ). Deficiency issues are issues that arise during the execution of construction. Defect costs are measured after the end of the liability period. Item beyond scope of work, deficiency issues and defect costs should get minimized in percentages relative to total construction cost and has a negative impact on project performance. IBS, DLP, and DC were measured on an ordinal scale based on cost percentages relative to total construction costs. The values were coded from 0-0.5% it is coded as 1, 0.5-

1.0% is coded as 2, 1.0-1.5% is coded as 3, 1.5-2% is coded as 4 and ≤ 4% is coded as 5. The mean value of PQ, DLP, IBC and DC is 3.969, 3.098, 3.166,2.94 respectively and the standard deviation values is 1.065,1.293, 1.247, 1.299 respectively.

$$Quality:\ Q = \frac{\left(0.55*\frac{PQ-3.969}{1.065}-0.17*\frac{DLP-3.098}{1.293}-0.14*\frac{IBC-3.166}{1.247}-0.14*\frac{DC-2.943}{1.29}\right)}{1.453} \tag{5.11}$$

Items beyond scope of work, deficiency issues and defect costs should get minimized in percentages relative to total construction cost. Delphi survey weights for PQ (55%), DLP (14%), IBS (17%) and DC (14%) respectively. A weighted average of the four new z-scores is computed, and the result is standardized again, hence the 1.453 denominator. The above equation can be used to calculate quality performance area scores for Indian construction projects. The performance area scores '*Q*' obtained from Eq. (5.11) can be used in the MPQR Eq. (5.5).

5.3.7 *Finance*

The finance performance area includes one metric as Profit and overhead (P). Stakeholders can sustain their business if they are making a profit. Profit margin should increase. It is measured as per percentages of profit and overheads. The scale set for this metric is, less than 5% is coded as 1, 5-10% is coded as 2, 11-15% is coded as 3, 16-20% it is coded as 4, more than 20% is coded as 5. The mean value is 3.53 and the standard deviation value is 1.10.

$$Finance:\ F = \left(\frac{P-3.523}{1.218}\right) \tag{5.12}$$

The above equation can be used to calculate finance performance area scores for Indian construction projects. The performance area score '*F*' obtained from Eq. (5.12) can be used in the MPQR Eq. (5.5).

5.3.8 *Environment*

Environment area consists four metrics: (1) Social environment (S), (2) Technical environment (T), (3) Political environment (P) and (4) Economic environment (E). The political environment is concerned with government policy. The mean value is 4.057 and the standard deviation value is 1.48. The technical environment is important for strategic planning to complete the project successfully. Political and technical decisions affect construction projects. So, it has a positive impact. The mean value is

4.083 and the standard deviation value is 0.874. The social environment consists of customs, lifestyles, and values that characterize a society. Social environment influences or affects organizations operating within the society. So, it has a positive effect. The mean value is 3.886 and the standard deviation value is 0.983. The economic environment has the potential to ensure that a project is financially viable within a fluctuating economic environment. The economic environment is very important for successful completion of the project. Thus, it has a positive impact. The mean value of 4.026 and the standard deviation value is 0.992. Delphi survey weights for P (23%), T (33%) S (16%) and E (28%) respectively.

Environment: $E=\frac{\left(0.23*\frac{S-3.886}{0.983}\right)+\left(0.33*\frac{T-4.083}{0.874}\right)+\left(0.16*\frac{P-3.736}{1.089}\right)+\left(0.28*\frac{E-4.026}{0.992}\right)}{0.974}$ (5.14).

P, T, S, and E is measured as the level of impact on a five-point scale as (1)-Strongly disagreed to (5)-Strongly agreed. A weighted average of the P, T, S, and E z-scores is computed, and the result is standardized again, hence the 0.974 denominator. The above equation can be used to calculate environment performance area scores for Indian construction projects. The performance area score '*E*' obtained from Eq. (5.14) can be used in the MPQR Eq. (5.5).

5.3.9 Communication and Collaboration

The communication and collaboration consists of (1) Request for Information (RFI), (2) communication management plan (CMP), (3) Frequency of meeting (FOM), (4) Impact of client and contractor meeting (IOM). RFI is an important source for the project and is measured in total numbers. RFI is measured in binary scale that had two values which were assessed as (1) As soon as possible once RFI is sent and (0) as per contract provision. It is an important source for the project and consumes time hence has a negative impact. The mean value for it is 1.06 and a standard deviation value of 0.702. Communication management plan is important for all stakeholders for proper coordination and completion of the project. CMP is measured on the level of importance on a five-point scale (1) very less important to (5) very much important. The mean value for it is 3.943 and standard deviation value of 0.991. The frequency of meeting and impact of the meeting are very important for monitoring of project work. FOM is measured on a five-point scale. (1-weekly meeting, 2-onces in 15 days, 3-monthly, 4-quarterly meeting, 5-unscheduled meeting). The mean value is 3.078

and the standard deviation value is 1.33. IOM were measured on the level of effective (1- not effective to 5- more effective). The mean value is 4.09 and the standard deviation value is 0.902. Delphi survey weights for RFI (40%), CMP (22%) FOM (18%) and IOM (20%) respectively.

Communication & collaboration: Co= $\left(\frac{0.40*\frac{RFI-1.06}{0.702}+0.22*\frac{CMP-3.943}{0.991}+0.18*\frac{FOM-3.078}{1.33}+0.20*\frac{IOM-4.093}{0.902}}{1.014}\right)$ (5.15)

RFI, communication management plan, frequency of meeting and impact of the meeting gives a positive impact on project performance. The z-scores were computed for RFI, CMP, FOM, and IOM, and the result is standardized again, hence the 1.014 denominator. The above equation can be used to calculate Communication & collaboration performance area scores for Indian construction projects. The performance area score '*Co*' obtained from Eq. (5.14) can be used in the MPQR Eq. (5.5).

5.3.10 Customer Relations

The customer relation performance areas include (1) return business (RB) (2) disputes claims (DC) and (3) feedback policy (FP). The high-quality output will result in higher prospective clients. Return business gives a positive impact on project performance. The mean value for return business is 4.24 and the standard deviation value is 0.82. Disputes are the existence of legal claims between parties. Disputes consume time and resources. Thus, it has a negative impact. The mean value for disputes is 3.71 and standard deviation value as 1.01. Feedback policies are recommendations given to improve the performance of the project. Feedback policies give scope for improvement. So indirectly it has a positive impact on project performance. The mean value for feedback policy is 3.953 and standard deviation value as 0.953. RB, D, and FP were evaluated on a five-point scale (1)-Strongly disagreed to (5)-Strongly agreed. Delphi survey weights for RB (62%), DC (18%) and FP (20%) respectively.

Customer relations: Cu= $\frac{\left(0.62*\frac{RB-4.244}{0.828}\right)-\left(0.18*\frac{DC-3.71}{1.015}\right)+\left(0.20*\frac{FP-3.953}{0.953}\right)}{0.875}$ (5.16)

The z-scores were computed for RB, DC, and FP are standardized again, hence the 0.875 denominator. The above equation can be used to calculate customer relations performance area scores for Indian construction projects. The performance score '*Cu*' obtained from Eq. (5.16) can be used in the MPQR Eq. (5.5).

5.3.11 Productivity

Productivity performance area combines with equipment productivity (EP) and labour productivity (LP). Labour productivity is measured by the ratio of input to output. The mean value for equipment productivity is 4.22 and a standard deviation value of 0.85. Equipment productivity is measured in terms of the planned target to actually achievement of the target. LP and EP were measured as the level of impact on a five-point scale as (1)-Strongly disagreed to (5)-Strongly agreed. Equipment and Labour are the main resources for project completion in time and has a positive impact on project performance. The labour productivity mean value is 4.05 and the standard deviation value is 0.97. Delphi survey weights for LP (57%) and EP (43%).

$$\text{Productivity: } Pr = \frac{\left(0.57 * \frac{LP-4.228}{0.854}\right)+\left(0.43 * \frac{EP-4.057}{0.975}\right)}{0.839} \quad (5.17)$$

The z-scores were computed for EP and LP are standardized again, hence the 0.839 denominator. The above equation can be used to calculate productivity performance area scores for Indian construction projects. The performance area scores *'Pr'* obtained from Eq (5.17) can be used in the MPQR Eq. (5.5).

5.4 Summary

Chapter 5 highlights the development of the modified PQR Model. It also discusses the relevance of PQR Model and its implementation for obtaining a comprehensive single score for Indian construction projects. The modified PQR combines the following 10 performance areas: (1) Cost (C), (2) Schedule (S), (3) Stakeholder satisfaction (St), (4) Safety (Sa), (5) Quality (Q), (6) Finance (F), (7) Environment (E), (8) Communication and collaboration (Co), (9) Customer relation (Cu) and (10) Productivity (Pr). Delphi survey technique is used to allocate the weights for each performance metrics that combine to form performance areas.

CHAPTER 6

QUALITATIVE DATA ANALYSIS

This chapter presents findings, generated from three case studies of construction projects. The aim was to investigate and validate (i) if these performance areas impact project performance and (ii) whether are they sufficient to evaluate project performance for Indian construction projects. The purpose of qualitative data analysis was to provide an in-depth understanding regarding the performance areas used in this study and to triangulate the findings reported in chapter 5. The data was related to MPQR model, linking the performance metrics with performance areas and understanding its impact on project performance.

6.1 Case study analysis: Semi structured interview

Three case studies have been analyzed in these sections. Qualitative data was collected through semi structured interviews of construction professionals for each project (Refer Annexure III for interview structure). The unit of analysis for case studies was an individual.

Findings are presented using an approach adopted by Awodele (2012). Each case is discussed in detail. Background information about the case is presented, followed by the findings from the data analysis on that case. The main objective of the case studies was to used for triangulation to support the model to consider for MPQR Model.

6.1.1 Case study I- Background information

This case study focuses on performance metrics included in MPQR Model and how they are measured. The first case study was of an infrastructure project, reconstruction of a bridge located at Mundhwa, Pune. Detailed information regarding this project is summarized in table 6.1.

Table 6.1 Characteristics of Construction Project Mundhwa, Pune

Project Name	Construction of rail over bridge near passport office, Mundhawa, Pune
Project Location	Mundhwa, Pune
Project cost	36 crores
Length of bridge	288 Mts.
Width	18.5mts.
Approach side	Mudhawa side-75mts

	Kharadi side100mts.
Total span	9mts.
Construction methodology	In-situ pre stressed of girder.
Total project duration	24 months, 28/02/2018.
Actual project start date	01/11/14.
Expected completion date	28/03/18
Contractor	T n T Pvt Ltd.
Consultant	Stoop consultant Pvt Ltd.
Consultant Chargers	1.85% of total construction cost
Contract type	Item rate contract

6.1.2 Data collection method

Data collection method used for this case study was by project documentation, semi structured interviews and observations. Interviews were conducted with key stakeholders such as clients, contractors, and consultants. The interview was for short time duration and were focused on exploring performance areas impacting Indian construction projects. The semi structured interview questions allowed interviewees to be free to share their experience. Generally, interviews lasted a minimum of 20 minutes to a maximum of 60 minutes. Interviews involved face to face interactions between researcher and informants directed towards understanding their perspectives towards project performance, and sharing situations and experiences. Selection of the interviewees was done based on the nature of interviewees role and reasonability and time available. The demographic profile of interviewees is as shown in table 6.2.

Table 6.2 Demographic profile of interviewees- case study I

Job title	Stakeholder type	Experience (Years)
Head of technical department	Pune Municipal corporation as client	18
Project manager	Contractor	15
Consultant Engineer	Consultant office	14

6.1.3 Project performance areas

Monitoring of performance areas/metrics is a major issue for construction companies. Therefore, the interviews probed the interviewees for inputs regarding performance metrics considered for evaluating project performance. The interviewees explained the perceptions on adopted performance areas as follows:

"*There are four important performance areas which are considered from my experience to assess project performance. They are; Timely completions, Cost, Quality and Safety. These are on top priority*".

The ten performance areas were discussed individually with stakeholders.

Cost

"Cost is one of most important performance areas that should be considered for project performance. Cost and schedule are considered at top level and it also depends on project requirement. Considering this project, client is not responsible for bearing any cost for rework to be bared. Generally, rework can rise up to maximum 10-12% of total project cost. Cost growth is measured as final construction cost to original construction cost. Escalation clause is mentioned in contract document". *Safety cost should also be considered if there is high rise structure".*

Since this project is a government project, the funds for it are raised by the local body, state and central body. All consultants are aware of the budget.

Schedule

All key stakeholders; client, contractors and consultant agreed that 'schedule' is an important area that should be considered for measuring project performance. Regarding schedule area the interviewees opinion:

"Schedule helps in planning the cost and achieving timely completion of project. Construction speed, schedule payment and schedule growth should be included in measuring 'schedule' as performance area. Considering this case study, the project was delayed by 24 months".

There are various reasons behind it. Few reasons were listed as follows:

- High voltage electric line.
- Clear scope of the project.
- Obstruction of trees towards approach way from Mundhwa side.
- Environmental clearance.
- Land acquisition.

"Client requirement and nature of project should be considered for project performance as performance metrics" was the suggestion given by the contractor. He

also recommended that *"The extension of schedule should be communicated in the contract documents."*

Finance

"Is the internal cash flow which the contractor or company is investing in the project and the other part of finance includes payments received from client. If the client does not make timely payments, it impacts the progress of the project. The Running bills received help to continue cash flow towards the project. Payments from client also impact project performance. For 'budget planning' for any project two factors are important which are cost and revenue. Cost is required for execution and revenue is what is earned from it. There should be continuous flow of money. Project feasibility survey is also important. Benefit cost ratio should be monitored".

The important recommendation from client was adding cash flow as performance metrics in finance area.

Quality

The stakeholders agreed that quality should be measured with these four metrics; Project quality, Item beyond cost, Deficiency issues and Defect cost. Regarding quality area the interviewees opinion was:

"It eventually affects project completion. At the time of the final stage of a project, a list of minor issues that need to be rectified are listed. Client suggested that there is a need to rename 'system quality' to 'project quality' as that it is more appropriate. Quality assurance plan and mix design plans are approved initially to look after project quality. Defect cost can go up to 10-15% of total project cost. Defect cost involves labour, machinery cost and material cost. The defect cost is beard by contractor. Item beyond cost affect during the project progress Despite defect liability period directly affecting project completion period, payments are not released. The defect liability period is mentioned in the contract document as per activities. Project stakeholders are responsible for completing work as per contract standards".

Safety

"All safety norms are followed strictly on site. There is provision of three months training on safety for newly joined employees".

Multi-National Companies have safety norms. Work is not executed unless those norms are followed. Regarding safety area the interviewees opinion:

"No one is allowed to work if safety norms are not followed. LTI is there in contract and depends on client decision. Safety document is contracted. Based on site condition risks and incidents are recorded. Technical safety practice for quality and safety checklist is followed strictly on site. Contractor follows all safety practices. As per Indian laws if accidents happen, the owner is responsible and needs to get involved. Safety engineer look after all safety conditions. Safety plans are provided on site. Emergency response team is trained to look after employees if any accidents occur. On this project there were no fatalities.

All three metrics are sufficient to measure safety.

Communication and collaboration

Communication and collaboration are measured with four metrics: RFIs, communication management plan, frequency of meetings, impact of client and contractors meeting. The interviewee's opinion on communication and collaboration is as follows:

"In case of project review meetings, the discussion is about risk of project. Various stakeholders are involved so it's important to communicate all issues to all stakeholders. If there are any issues, they should be known to everyone and suggestions are welcome from stakeholders. Everyone should be aware of the challenges that are faced during the project. Communication management plan is as per hierarchy and responsibility. It also helps for scope of improvement. RFI should be renamed as 'RFI processing time'. The time taken for finding a solution might delay the project. Frequency of meetings depend on the duration of the project. If it's fast track project it should be monitored weekly. Frequency of meetings for this case study was conducted monthly. At an initial stage a higher number of meetings was required. "Impact of meetings should be renamed as 'outcome/effect of meeting', that will include issue identification and solution of issue".

Key stakeholders agreed that communication and collaboration is a very important area for project performance.

Customer relations

All stakeholders agreed to measure customer relations using return business, disputes and feedback policy. The interviewees opinion on Customer relations is as follows:

"If contractors keep good relations with client, it will help at the time of execution of the project. Good customer relations lead to timely payment and work progress. If contractors need a time extension it should be intimated in the contractual clause".

Disputes are another metric identified in these areas. It leads to time consumption and delay in project.

"For this case study, if any disputes happen, then as per contract condition chief engineer will take a decision. Feedback policy will play important role for improvement and will let us know the stakeholder satisfaction level".

Stakeholder satisfaction

"*All stakeholders should be involved and they should be considered as part of the project. Timely Payment plays an important role for the satisfaction of the stakeholders".*

Productivity

"Is related to time line and resources. While planning safety level, an additional buffer should be considered. Non-productive time need to be considered. Equipment productivity should consider breakdown as well as maintenance time. Backup and buffer should be allotted at project planning stage. Productivity is dependent on stakeholder satisfaction. Productivity is different for conventional method and advance technology, as it depends on construction methodology. Concrete boom placers were used for concreting hence use of labour was less compared to equipment".

Environment

"Economic, social, technical and political environment plays an important role in project performance. Government permission and approvals needs more time. Contractor suggested adding 'climatic condition' as one more metric that affects project performance. The contribution from this project is to reduce pollution caused due to traffic jams in that area and the underlying issue of congestion due to heavy traffic was also resolved. Commencement of this bridge will be done. 90% of the work is done at this stage. Existing bridge is not capable enough to manage the increasing traffic and it causes frequent accidents and traffic jams. Construction of new bridge will result into free traffic flow and reduction in accidents. It will also reduce air pollution." Key observations from case study-I is shown in table 6.3

Table 6.3 Recommendations from Case study -I

Recommendations	**Remarks**
Schedule performance area, client requirement and nature of project are important factors to be considered.	Already exist
Construction unit cost should also consider safety cost as performance metric.	Already exist
System quality should be renamed by project quality	Implemented
RFI should be renamed as RFI processing time	Implemented
Impact of meeting should be renamed as outcome of meeting	Implemented
Feasibility report is important for planning budget	Implemented
Cash flow should be added in finance performance metrics	Already exist
Climatic condition should be added in environment performance area	uncontrollable metric

6.2. Case study II - Background information

This case study was of a residential project consisting of 4 towers located at Ravet, Pune. The detailed information of the project is summarized in table 6.4.

Table 6.4 Characteristics of Construction Project, Ravet, Pune

Project Name	Construction of residential project
Project Location	Ravet, Pune
Project cost	500 crores
Client	Runal developers
Main contractor	Gouri infra Ltd
Structural consultant	J and W consultant LLP
Architect	Landmark design group
Plot area	30200 sq.m
Build up area	2 BHK is 1100 to1181sq.ft 3 BHK is 1557 to 1645 sq.ft.
Estimation consultant	Gensys
Contract type	Lump sum contract.
Project start date	2nd April 2016
Project end date	5th Dec 2018
Project duration	2.5yrs

6.2.1 Data collection method

The data collection method used was same as mentioned in section 6.1.2. The demographic profile of interviewees is shown in table 6.5.

Table 6.5 Demographic profile of interviewees- case study II

Job title	Stakeholder type	Experience (Years)
Safety Engineer	Contractor	15
Technical Head and project co-ordinator	Contractor	13
Project manager	Client	12
Consultant Engineer	Consultant	11

6.2.2 Project performance areas

The interviewees perceptions on adopted performance areas were as follows:

Schedule

Client, contractors and consultants agreed to consider 'schedule' as one of the important areas that should be considered for project performance. Construction speed, schedule payment and schedule growth should be included in measuring schedule performance area.

"*Runal gateway secured a contract in 2016 and expected to complete it till 2019. Construction speed for the project is satisfactory as 'Mivan aluminium formwork system' has been used. It is completing projects in record time with a 4-days-per-floor construction cycle. Schedule payment is measured as per milestones. Penalty clause is mentioned in contract document. Schedule growth is also measured as planned vs. actual growth of construction. There is no delay for project*".

Cost

"Cost is one of most important performance areas that should be considered for project performance. Considering this project, there is no rework cost as 'pre engineering aluminum shuttering' is used. Cost growth is measured as final construction cost to original construction cost. At initial stage it is maximum and later is goes on reducing".

Finance

"*Finance was done by ICICI bank. Detailed cash flow month wise is calculated. The initial cash inflow will be calculated as per booking amount. Land cost and overall* *profit are considered for the budget. Holding capacity in the market is important, with respect to the financial perspective.*

Quality

"ISO-9001. All is documented. Product quality for all materials is as per Indian Standard. All certified vendors are listed and material is supplied from them. Defect cost is nil as aluminum formwork shuttering has been used. Item beyond cost will be 2 to 3% for this project. Defect liability period is 5 years as per RERA (Real Estate Regulatory Authority)".

Safety

"*All safety norms are followed strictly on site as per OSHA. There is provision of three months training program of safety for newly joined employees. No one is allowed to work if safety norms are not followed on site. LTI is there in contract and depends on client decision. Safety document is contracted. Safety engineers look after all safety conditions. Safety plan is provided on site. On this project no fatalities have occurred".*

It was concluded that the three-performance metrics (OSHA, LTI and Fatalities) are sufficient to measure safety area.

Communication and collaboration

"Protocol is followed as per hierarchy level. Strong correspondence is recorded. RFI processing time is within 2 to 3 days. RFI processing time impacts project performance. Frequency of meeting once a week. Impact of meetings play important role. Meeting duration is 45 to 60 mins. Future plan is discussed and Minutes of meetings (MOM) is recorded and circulated. If a big decision is to be taken, all management is involved and a final decision is taken collectively. Overall monitoring is important and it should be added as separate metric in this area".

Customer relations

"*If contractors keep good relations with client, it helps at the time of execution of the project. Return business depends on feedback policy. Disputes are minor issues which gets resolved easily on site*".

Stakeholder satisfaction

"*If stakeholders are informed about all the issues, they will remain satisfied. Everyone should be considered as part of project. Project stakeholders should be satisfied".*

Productivity

"It's a very important area for completing project on time. The resource allocation is done at planning stage and it is monitored continuously. According to the activities, the arrangement of additional resources is done in prior".

Environment

"Economic, social, technical and political environment plays important role in project performance. Government permission and approval needs more time. Considering technical environment at initial stage HR was not appointed and the project was not much organized. There is no need of political environment metrics as per the suggestion of the client". Key observations from case study -II is shown in table 6.6

Table 6.6 Recommendation from case study II

Recommendations	**Remarks**
Communication management is made as per hierarchy level. There is no need of separate plan	Already exists
Overall monitoring should be added in communication and collaboration areas	Not implemented

6.3. Case study III- Background information

This case study is a commercial project - Infosys located at Hinjewadi, Pune. The project was for the construction of a multilevel car parking and food court. The structure is 11 stories high and will be used exclusively for parking four wheelers. The structure has been designed for dynamic vehicular loads. This project used Large span Double T Slabs, Hollow Core Slabs, Precast Columns, Precast Spandrel Beams, Precast Inverted T Beams, Precast Retaining Walls, Precast Compound Walls and Precast Facades for this project. Nearly 100% Components of the building are pre-casted at the factory and transported to the site for erection. The detailed information of this project is summarized in table 6.7.

Table 6.7 Characteristics of commercial project, Pune

Project Name	Construction of multilevel car parking and food court
Project Location	Hinjewadi, Pune
Project cost	60 crores

Client	Precast India Infrastructures Pvt. Ltd
Consultant	TRC ENGINEERING
Project start date	June 2016.
Area	4,50,000 sq.ft.
Parking capacity	1300 cars
Construction methodology	cast in situ concrete shear walls, prefabricated structural elements

6.3.1 Data collection method

Data collection method is same for all case studies. The approximate length of interview was 20-25 mins. The demographic profile of interviewees is shown in table 6.8.

Table 6.8 Demographic profile of interviewees- case study III

Job title	Stakeholder type	Experience (Years)
Project manager	Client	18
Consultant Engineer	Consultant	20
Quality head	Client	9

6.3.2 Project performance areas

Interviewees opinion on the ten performance areas are as follows:

Schedule

Schedule is one of the most important areas that should be considered for project performance. The interviewees opinion is as follow:

"Schedule helps in planning the cost and achieving timely completion of project. Construction speed, schedule payment and schedule growth are important to measure schedule as a performance area. Considering this case study, the project was delayed by 24 months. There are various reasons behind it. The main reason was due to forest department approval. The main role of the consultant was to finalize the drawing and later it will be circulated to stakeholders those who are involved in the project. SAS and Protrack, super SAAS software are used for tracking of schedule. Protrack is used for element tracking. Timely monitoring and coordination of the schedule is a major role of consultant".

Cost

Cost is one of the most important performance areas that should be considered for project performance. The interviewees opinion on cost area are as follows:

“Considering this project, there is no rework cost as pre engineering aluminum shuttering is used. Cost growth is measured as final construction cost to the original construction cost. The budget planning is done using Microsoft projects and there are four main stages involved; pre concrete during concrete, post concrete and pre delivery concrete. Every participant in project is asked to submit their budget for the prior month and it is to be monitored by the project manager. As per purchase order request, through email, the budget is released”.

Finance

“Finance is done by a bank. Detailed cash flow, month wise, is asked to be submitted to the project manager from all participants involved in the project. Later, a detailed cash flow is prepared”.

Quality

“ISO- 9001 is strictly followed. Product quality for all material is as per Indian Standard. All certified vendors are listed and material is supplied from that list. All material is checked on site after arrival and if defects exist, that material is directly rejected. The vendor is marked in black list till the next cycle. All the elements such as columns, beams, and slabs used for this project are precast, so before using it they are checked again on site. The defect cost goes up to 5 % of total construction cost. The defect liability period is 5 years. The item beyond cost vary from 5 to 10 % of total construction cost. Project stakeholders recommended quality is the most important aspect for project success and it should never be comprised”.

Safety

“All safety norms are followed strictly on site as per local safety norms. All the safety norms that are followed on site are documented in contract. The safety engineer takes a tool box talk daily for 15 minutes before starting any activity on site. All labours are given instructions and motivated. This platform helps them to open up and discuss their personal issues. Teamwork is important for coordination. Safety engineer reports the tool box talk to project manager and if there are any demands required to be fulfilled from labour’s perspective, it is addressed with the project manager. Appreciation is given in the form of words and that indirectly helps in motivation and productive output. There is a provision of three months training of safety for newly joined employees. No one is allowed to work if safety norms are not followed. There is

not much 'lost time in injuries' occurred on site. On present projects no fatalities have occurred. It was concluded that all three-performance metrics are sufficient to measure safety.

Communication and collaboration

"*Strong correspondence is maintained through email. Phone calls are not considered as a proof and everything should be on records. RFI processing time is within 2 to 3 days. RFI processing time affects project. Frequency of meetings is weekly in the initial stages of the project and during and later stages once in month is recommended. Impact of meetings play an important role. Meeting duration is 45 to 60 min in general. If important decisions are to be taken, then all management team gets involved*". The adopted Communication management plan is shown in figure 6.1.

	Client	PMC	Consultant	Vendor
Client		**P**	**P/S**	**OE/NC**
PMC	**P**		**P**	**P**
Consultant	**P/S**	**P**		**NC**
Vendor	**NC**	**P**	**NC**	

Legend		**Rule**
P	**Primary contact**	
S	Secondary contact	Always copy primary contact
OE	Only Escalation	Always copy primary contact
NC	No Contact	

Figure 6.1 Communication management plan

Customer relations

"If contractors keep good relations with the client, it will help to coordinate the project better. Return business depends on feedback policy. Disputes occurred are minor which gets resolved easily on site."

Stakeholder satisfaction

"Stakeholder involvement plays a major role and all issues that arise on site regarding project performance should be communicated with them. Everyone should be involved and they should actively participate".

It was concluded that if all stakeholders are satisfied, invariably, the project becomes successful.

Productivity

"While planning it is necessary to consider safety levels and additional buffers. Non-productive time also need to be considered. For machinery booking, use of super SAAS is done. If heavy equipment is used for projects, it is recommended to keep back up and buffer options. Proper cash flow should be maintained for resources".

Environment

Economic, social, technical and political environment plays an important role in project performance.

"Government permissions and approvals need more time. Forest department approvals needed 24 months for finalization. Getting these approvals delayed the project. After finalizing approvals, layout for site are finalized with coordination from MEP (Mechanical, Electrical and Plumbing) and the project manager. The technical consultants had thorough and strong knowledge of their field. Environment area is important for project success". Key observations from case study -III is shown in table 6.9.

Table 6.9. Recommendation of case study III

Recommendations	Remarks
In Schedule use of software	Taken into consideration
Communication management already exists.	Already existed
Political environment should be removed in environment areas	Not Implemented

6.4 Implications of the qualitative analysis for the modified PQR model.

The findings from case studies validate the findings from questionnaire results, and support the model to consider all ten performance areas and twenty-eight performance metrics as important to measure project performance for Indian construction projects. They support the significant relationship among project performance and performance areas as proposed in the MPQR model presented in chapter 5. The qualitative data provided a clear perspective of construction professionals for project performance evaluation. A few required recommendations, received from the interviewees, were considered in the modified model. Table 6.3, 6.6 and 6.9 highlight the modifications in the model. Hence the study incorporated the findings from the quantitative analysis which also validated the modified model. The model validation and testing will be represented in chapter 7.

6.5 Summary

The findings from case studies highlighted that measuring project performance is very important and there is no exact list of performance areas based on which it would be possible to measure project performance for Indian construction projects. The findings also indicate that ten performance areas have significant relations with project performance. It is also evident that construction organizations do not conduct strategic analysis for benchmarking projects. The recommendations suggested by interviewee respondents were integrated in the model. The MPQR model can assess project performance for Indian projects.

CHAPTER 7

CAUSAL RELATIONSHIP OF PERFORMANCE AREAS ON PROJECT PERFORMANCE

This chapter discusses the development of the PLS-SEM for testing MPQR Model. The modified MPQR model has been analysed and explained in two stages; measurement model and structural model.

7.1 Modified PQR Model development

In an effort to develop a comprehensive model to be used towards improvement of Indian construction projects, this study utilizes the results from both the quantitative and qualitative analysis which is presented in chapter 4 and 6 respectively. The findings from both approaches were integrated and an MPQR model is developed as presented in chapter 5 and 6. It is concluded through case studies that all ten performance areas and twenty-eight performance metrics are important for Indian construction projects. In addition, the findings from three case studies, presented in Chapter 6, identified the nature of the relationship between the performance areas and project performance in the presented model.

7.2 Model fitting and analysis using PLS-SEM

PLS-SEM was used in this research to investigate the impact of performance areas on project performance (dependent variables). The PLS-SEM focuses on estimating and analyzing the relationships between multiple latent variables. It provides very robust solutions for complex models. PLS-SEM particularly is useful for exploratory research purposes (Hair et al. 2014). The main objective of developing the MPQR model was to confirm significant relationship between constructs.

7.3 Evaluation of Measurement model

The PLS-SEM analysis was conducted using WarpPLS software to measure which measurement items are related to latent variables. PLS-SEM was used in creating the path model as illustrated in figure 7.1.

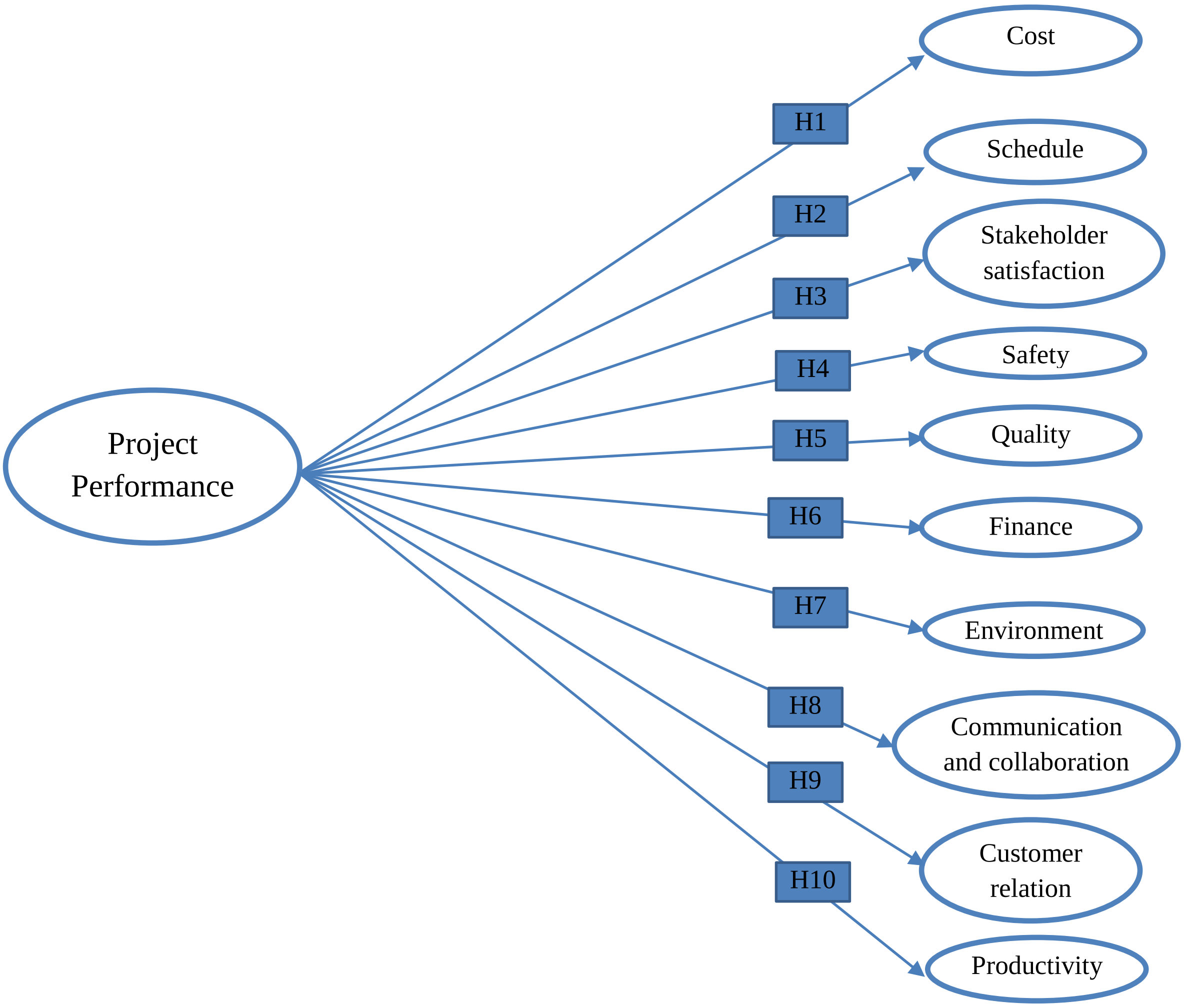


Figure 7.1 Representation of model

The model connects the variables and constructs based on the theories earlier discussed. The study evaluates the outer model (measurement model) as a reflective indicator. The reflective indicator combines all possible connections within the construct and is related to a construct through factor loadings (Hair et al. 2014). Each of the performance areas :(1) cost (c), (2) schedule (s), (3) stakeholder satisfaction (st), (4) safety (sa), (5) quality (q), (6) finance (f), (7) environment (e), (8) communication and collaboration (co), (9) customer relation (cu) and (10) productivity (pr) are assessed for reliability analysis.

After specifying inner and outer model, the next step is to run PLS algorithm for evaluating the reliability and validity of the constructs in the outer model. PLS composite reliability is more preferable to Cronbach's alpha values, since it gives a more suitable measure of internal consistency (Hair et al. 2014). Hence, composite reliability is used rather than Cronbach's alpha value. Next, the study examines construct validity. Confirmatory factor analysis using PLS-SEM was used to confirm performance metrics for project performance, reliability and validity. Construct validity measures a set of variables that actually reflects the latent construct (Hair et al. 2006). It is established by content validity, convergent validity, and discriminant validity. Content validity was established by adopting performance areas from literature.

7.3.1 Convergent Validity

Convergent validity indicates the extent to which multiple items are used in measuring a construct converge. Fornell and Larcker (1981) suggested examining convergent validity by factor loading and Average Variance Extracted (AVE). Factor loading should be greater than 0.5 and average variance extracted of each construct is either greater than or equal to 0.5.

Table 7. 1 Convergent validity results

Factor	Factor loading	AVE	CR
Quality	0.68 0.76 0.81 0.63 0.52	0.523	0.813
Schedule	0.77 0.76 0.56	0.472	0.723
Environment and stakeholder satisfaction	0.54 0.70 0.52 0.68 0.51	0.40	0.718
Cost	0.60 0.71	0.433	0.70
Productivity	0.68 0.75	0.512	0.70
Safety	0.68 0.75	0.512	0.70
Communication management plan	0.64 0.68	0.5	0.70
Customer relation	0.76 0.53	0.5	0.70
Finance	0.50 0.69	0.5	0.69

For assessing a better measure of reliability, composite reliability (CR) along with Cronbach alpha was also measured. CR value of above 0.7 is recommended for all construct by (Chin 2010). Convergent validity for all constructs is as shown in Table 7.1.

AVE scores of Quality (0.523), Productivity (0.512), Safety (0.512) are above 0.5. AVE of Schedule (0.472) is close to 0.5 and AVE of Environment and stakeholder satisfaction (0.40) are lower than 0.5 and for cost is (0.433). Fornell and Larcker, (1981) suggested that if AVE is less than 0.5, but CR is higher than 0.6, the convergent validity of the construct is still satisfactory. Hence measurement is consistent and further supports convergent validity of performance areas.

7.3.2 Discriminant validity

Discriminant validity measures how the constructs are correlated and how distinctly measured variables represent only that construct (Hair et al. 2010). Fornell and Larcker, (1981) suggested that discriminant validity can be examined by comparing the value of the average variance extracted (AVE) of the construct and values of squared correlation between latent variables. Table 7.2, shows that the model possesses discriminant validity, as the square roots of AVE of diagonal position should be greater than all off-diagonal elements.

Table 7.2. Discriminant Validity of performance areas

Squared correlations	Cu	Sa	S	C	Q	F	Co	Pr	St	E	PP
Cu	**0.7**										
Sa	0.659	**0.72**									
S	0.61	0.789	**0.7**								
C	0.655	0.784	0.759	**0.73**							
Q	0.717	0.792	0.819	0.775	**0.723**						
F	0.70	0.773	0.749	0.728	0.781	**0.63**					
Co	0.64	0.69	0.762	0.715	0.691	0.675	**0.7**				
Pr	0.53	0.707	0.708	0.618	0.671	0.623	0.692	**0.72**			
St	0.582	0.712	0.752	0.714	0.662	0.684	0.764	0.663	**0.63**		
E	0.591	0.771	0.716	0.68	0.678	0.705	0.714	0.688	0.829	**0.630**	
PP	0.549	0.749	0.762	0.7	0.728	0.742	0.676	0.651	0.699	0.722	**0.8**

Cu=Customer relation, Sa= Safety, S=Schedule, C=Cost, Q=Quality, F=Finance, Co= Communication and Collaboration Pr=Productivity, St= Stakeholder satisfaction, E=Environment, PP=Project Performance.

The low discriminant validity of measured constructs of environment and stakeholder satisfaction could be because the constructs are theoretically related to each other. Moreover, low discriminant validity can also be due to the presence of other dimensions to be explored (Chen and Quester 2005). Thus, the considered performance areas represent good construct validity. Thus, the measurement model achieved was satisfactory.

7.3.3 Nomo Logical Validity

Nomological validity is tested for a series of construct correlations and comparison with theoretical design. Nomological validity is evidence collection for consistency amongst structural relationships between constructs with theory and other research. The direction of construct correlations is checked for nomological assessment (Hair et al. 2010). As proposed in the research, the correlations between the construct are, as expected, positive with each other, thus indicating a good Nomological validity for all the constructs (Hair et al. 2010) as shown in Table 7.3

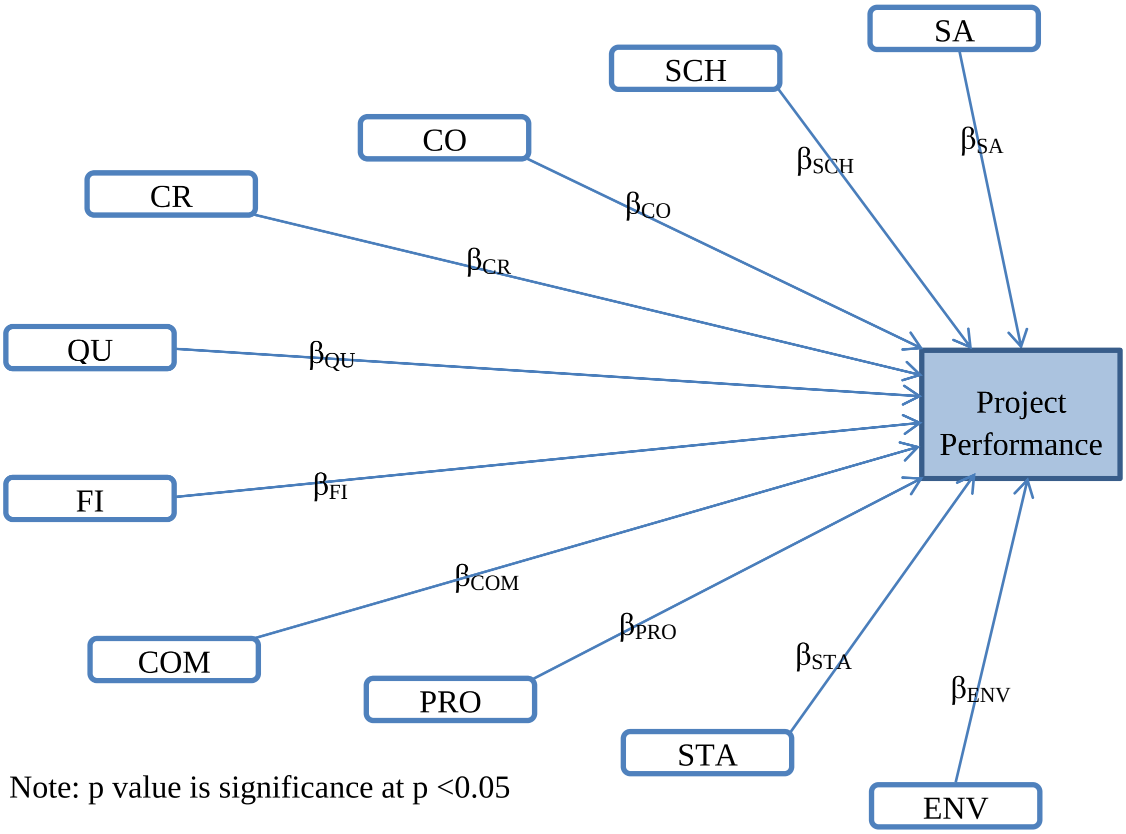
Table 7.3 Nomological Validity of performance areas

	Cu	**Sa**	**S**	**C**	**Q**	**F**	**Co**	**Pr**	**St**	**E**	**PP**
Cu	1.000	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sa	<0.001	1.000	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
S	<0.001	<0.001	1.000	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
C	<0.001	<0.001	<0.001	1.000	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Q	<0.001	<0.001	<0.001	<0.001	1.000	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
F	<0.001	<0.001	<0.001	<0.001	<0.001	1.000	<0.001	<0.001	<0.001	<0.001	<0.001
Co	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.000	<0.001	<0.001	<0.001	<0.001
Pr	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.000	<0.001	<0.001	<0.001
St	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.000	<0.001	<0.001
E	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.000	<0.001
PP	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.000

This shows that all performance areas have good factor loadings and have good construct validity hence it indicates that model has acceptable reliability and validity measures.

7.4 Evaluation of Structural results

The structural model is presented in figure 7.2.



Note: p value is significance at $p < 0.05$

Figure 7.2 Initial path model

WarpPLS version 4.0 is used to examine the final PLS algorithm to identify relationships among the constructs. The main objective is to identify variances explained by the ten performance areas included in the MPQR model, and at the same time to establish the significance level of all PLS path estimates (Chin, 2010). The structural model shows R^2 (coefficient of determination) of independent variables in the model. Structural model examined the effect of constructs in the MPQR model through coefficient of determination and path coefficient.

The constructs are classified into two categories: exogenous construct (dependent variables) and endogenous construct (independent variables). The exogenous construct is project performance and endogenous constructs are cost, schedule, stakeholder satisfaction, safety, quality, finance, environment, communication and collaboration, customer relation and productivity.

7.4.1 Coefficient of determination

R^2 determines the prediction power of the model. R^2 measures the amount of variance in the dependent variable explained by the independent variables. WarpPLS 3.0 determines R^2 for MPQR model. It shows that 77% of variance is explained by the model.

7.4.2 Model fitness

The model indices calculated by PLS-SEM are average path coefficient (APC), average R-squared (ARS), average adjusted R-square (AARS) and average block VIF (AVIF) are as shown in Table 7.4

Table 7. 4 Result of model indices of modified PQR model

Model indices	**Recommended values**	**Values from analysis**
Average path coefficient (APC)	$p < 0.05$	0.104, $p = 0.035$ (Rosenthal and Rosnow, (1991)
Average R-Squared (ARS)	$p < 0.05$	0.770, $p < 0.001$ (Rosenthal and Rosnow, (1991)
Average Adjusted R-Squared (AARS)	$p < 0.05$	0.758, $p < 0.001$ (Rosenthal and Rosnow, (1991)
Average block VIF(AVIF)	≤ 5, ideally ≤ 3.3	5.340 (Kock, 2015)

The VIF value for constructs is 3.858 which should be ≤5, indicating the measure of multicollinearity among performance areas is within the limit (Hair et al. 2006; Kock 2015; Kock and Lynn 2012). All the values for APC, ARS, and AVIF are found to be significant for all performance areas.

Different model fitness parameters shown in PLS-SEM analysis are discussed. All four parameters are above the threshold limits, indicating the model is robust.

- Sympson's paradox ratio (SPR)=1.000, acceptable if >= 0.7, ideally = 1.
  Ideally the SPR should equal 1, meaning that there are no instances of Simpson’s paradox in a model; acceptable values of SPR are equal to or

greater than 0.7, meaning that at least 70% paths in the model are free from SPR.

- Tenenhaus (GoF)=0.878, 0.36=large, 0.25=medium, and 0.1=small.

  GoF as the square root of the product between what they refer to as the average communality index and the ARS. GoF estimate values as 0.36=large, 0.25=medium, and 0.1=small. The GoF of the model is large.

- R-squared contribution ratio (RSCR)=1.000, acceptable if >= 0.9, ideally RSCR should equal 1, meaning that there are no negative R-squared contributions in a model; acceptable values of RSCR are equal to or greater than 0.9, meaning that the sum of positive R-squared contributions in a model makes up at least 90 percent of the total sum of the absolute R-squared contributions in the model.

- Statistical suppression ratio (SSR)=1.000, acceptable if >= 0.7.

  The SSR index is a measure of the extent to which a model is free from statistical suppression instances. Acceptable values of SSR are equal to or greater than 0.7, meaning that at least 70 percent of the paths in a model are free from statistical suppression.

- Nonlinear bivariate causality direction ratio (NLBCDR)=1.000, acceptable if >= 0.7.

  Acceptable values of NLBCDR are equal to or greater than 0.7, meaning that in at least 70 percent of path-related instances in a model the support for the reversed hypothesized direction of causality is weak or less.

7.5 Model path coefficient and significance

The final path model is as shown in Figure 7.3. The research included all constructs in the study to test both direct and indirect links among the constructs. The path between ‘environment’ and ‘project performance’ is found to be significant ($\beta=0.14$, $p=0.02$). Hence, it can be concluded that the ‘environment’ has a significant impact on ‘project performance’. The path between ‘stakeholder satisfaction’ and ‘project performance’ is found to be significant at $\beta=0.03$, $p=0.03$. The path between ‘communication and collaboration’ and ‘project performance’ is also found to be significant at ($\beta=0.08$, p=0.03). Hence, it can be concluded that ‘communication and collaboration’ has a significant impact on ‘project performance’

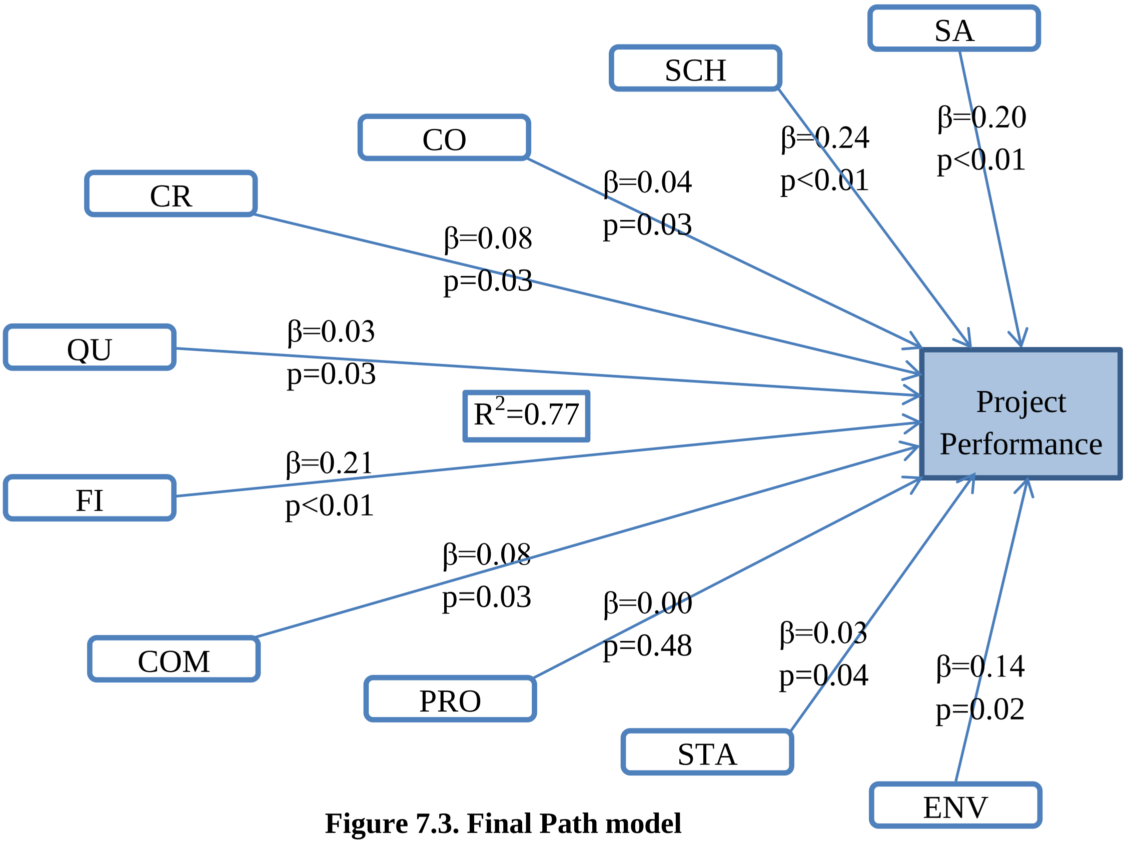


Figure 7.3. Final Path model

Path connection for ‘finance’, ‘quality’ and ‘cost’ are found to be significant at (β=0.21, p<0.01, β=0.03, p=0.03, β=0.04, p=0.03) respectively. The path between ‘schedule’ and ‘project performance’ is found to be significant at β=0.24 and p<0.05. The second last path between ‘safety’ and ‘project performance’ is also found to be significant at β=0.20, p<0.01. The last path between ‘customer relation’ and ‘project performance’ is found having estimates of β=0.08 and p=0.03 and thereby are significant. Hence, it is inferred that ‘customer relationship’ has a significant impact on project performance. The coefficient of determination R^2 = 0.77 as shown in Figure 7.3. This is regarded as substantial and indicated that 77% of the variance is explained by the model.

The path between ‘productivity’ and ‘project performance’ is found to be insignificant at p=0.48. Hence, it can be concluded that productivity has no impact on project performance. Productivity does not have any standard definition (Shehata and El-gohary 2011). A study conducted in Egypt concluded that the second most important performance criterion is *''the efficient utilization of resources*" by which construction managers would evaluate their performance). A considerable effort has been taken to understand the concept of productivity using different approaches by researchers (Lema, 1995; Alaghbari et al. 2019). Many construction projects suffer from cost and time delays in both developed and developing countries. Improving labor productivity has remained a major focus area for both researchers and construction practitioners. Jarkas (2015) studied various factors responsible for low productivity in Bahrain's construction industry. The author identified labour skills, lack of supervision, and coordination among different disciplines that were important influencing factors. Studies have found that productivity on construction site is adversely affected by poor working conditions and low quality (Abrey and Smallwood 2014). Productivity is a dominating aspect in construction industry as it encourages cost savings and effective utilization of resources. Productivity is dependent on efficient tools and equipment and hence there is a need for proper tools and techniques for improving performance (Zakeri et al. 1996). Productivity of the workforce assumes enormous importance in construction projects. However, this research was unable to uncover the statistical relation. Out of 10 linkages in the performance areas, 9 are found to be statistically significant. Table 7.5 shows the summary of casual links tested.

Table 7.5 Summary of casual links tested in PLS-SEM Model

Path label	**Relationship**	**Hypothesis tested**	**Effect on hypotheses**
C	Cost → Project performance	Cost area has an impact on project performance	Significant
S	Schedule → Project performance	Schedule area has an impact on project performance	Significant
St	Stakeholder satisfaction → Project performance	Stakeholder satisfaction area has an impact on project performance	Significant
Sa	Safety → Project performance	Safety area has an impact on project performance	Significant
Q	Quality → Project performance	Quality area has an impact on project performance	Significant
F	Finance → Project performance	Finance area has an impact on project performance	Significant
E	Environment → Project performance	Environment area has an impact on project performance	Significant
Co	Communication &	Communication and	Significant

→

	Collaboration → Project performance	collaboration area have an impact on project performance	
Cu	Customer relation → Project performance	Customer relation area has an impact on project performance	Significant
Pr	Productivity → Project performance	Productivity area has an impact on project performance	Not Significant

Even if the productivity is found to be insignificant in the analysis there can be various reasons for it such as material shortage, labour supply, poor planning, delay in arrival of material, subcontractors problems, lack of tools and techniques, poor planning, poor supervision. labour experience and skills. The construction organizations in India and elsewhere need to consider these factors to improve the productivity in construction projects. As a result, little effort has to be made to improve productivity by addressing these issues that have largely remained unexplained. Understanding these factors that affect productivity can help to develop strategies to reduce inefficiencies. This will help to improve the project performance of construction industry.

7.6 Summary

This study employed the PLS-SEM method to test the MPQR model for Indian construction projects. The ten performance areas are customer relations, safety, schedule, cost, quality, communication and collaboration, productivity, environment, finance and stakeholder satisfaction. In testing the individual item reliability, factor loading was assessed. Results indicated that all constructs were reliable. Further, in order to confirm the validity of each construct, convergent validity, discriminant validity, composite reliability and factor loading were assessed. The overall model indicated a variance of 77% which is greater than the recommended 10%. The PLS-SEM results show that all performance areas have a significant impact on project performance except productivity.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

The study began by reviewing literature in the area of project performance, understanding project success, identifying different performance areas and project performance models in the construction industry. The literature review provided a clear background for selection of performance areas to be included in the study. Further, the research was focused on developing a project performance assessment model for Indian construction projects. To achieve this, four specific objectives were set as shown in section 1.3.

A mixed research approach combining quantitative and qualitative research was adopted for the study. This chapter highlights the key findings, implications of research, limitations of the research and future scope for research.

8.1 Conclusions

Objectives

To identify performance areas responsible for successful projects in Indian construction industry.

The first objective focuses on identifying performance areas impacting project success within the Indian construction industry. The initial review helped to identify performance areas and how these areas are measured. The study found that a significant number of construction projects identified the need for measuring project success. After identifying performance areas these were discussed with construction professionals in India. Ten performance areas and twenty-eight performance metrics were finalized to be considered for assessment for the Indian construction industry.

To study PQR Model in current form and identify additional metrics based on identified performance areas that contribute to overall project performance.

This study investigates different performance models. Considering the comprehensiveness and adaptability of the PQR model, it is considered an appropriate model to evaluate project performance for Indian construction industry. This research evaluates and improves the comprehensiveness of the existing PQR model in considering the defined performance areas in the specific context of the Indian construction industry. The PQR Model is studied in its current form which combines seven areas and twenty-three metrics.

This research highlights the need for inclusion of three additional performance areas to the current PQR model for improving comprehensiveness and contextualization. These three additional performance areas are productivity, stakeholder satisfaction, and environment. The importance of these performance areas have been discussed in the forthcoming paragraphs.

Productivity encourages saving cost and utilization of efficient resources. Poor productivity may be due to insufficient labour, materials, equipment and funds. The contributing performance metrics for productivity are labour and equipment productivity. Productivity influences the success of the project. Hence the increase in productivity might influence cost and schedule performance areas.

Effective management of stakeholders can improve communication and understanding among the project parties to avoid any disputes. The valuable contribution of stakeholders will provide insightful knowledge for briefing a project at each stage. Therefore, it is necessary to balance different perspectives of key stakeholders for the successful delivery of a project. Further, Stakeholder satisfaction is a measure of how a project fulfils expectations.

The construction industry also has to face increasing demands and pressures of the society. Environment area benefits to society in both economic and social terms. Economic growth, social impact, investment, political impact influences project cost and schedule. The fragmented nature of the construction industry significantly impacts the financing sources. Hence, more attention is required on these performance areas.

To integrate identified additional performance areas into existing PQR Model for improved performance assessment

The identified performance areas were integrated to MPQR model. The model comprises of 10 performance areas consisting of: Cost (C), Schedule (S), Stakeholder satisfaction (St), Safety (Sa), Quality (Q), Finance (F), Environment (E), Communication and Collaboration (Co), and Productivity (Pr) and twenty-eight performance metrics related to project performance. It was further found that there is significant relationship that exists among these ten performance areas and project performance. It can be inferred that safety, schedule, cost, quality, finance and environment are highly associated with project performance construct. The remaining four performance areas (customer relations, communication and collaboration, productivity and stakeholder satisfaction) are also statistically significant. The PLS-SEM method was used to develop the MPQR model and it examined the combined effects of constructs on performance. The result of PLS-SEM indicated a significant relationship among all performance areas however, the relationship with productivity and project performance was found insignificant. The PLS model (measurement and structural model) indicated an overall predictive power (R^2) of approximately 77%. It also supports all fitness parameters of PLS-SEM. The case study's findings indicated that identified performance areas and metrics are sufficient to measure project performance.

Validation of modified PQR Model.

The findings from case studies were used for triangulation to support the model to consider all ten performance areas and twenty-eight performance metrics as important to measure project performance for Indian construction projects. They also support the significance of the relationship between project performance and performance areas as proposed in the MPQR model.

This model could focus on aspects of projects and performance areas that are important to project stakeholders. By integrating performance areas and providing a comprehensive performance assessment score, the analysis of this MPQR will offer a valuable new tool to assess overall project performance for developing countries. This research can be used as a strategic management tool for promoting the continuous improvement in the Indian construction industry. The model has accommodated different perceptions and expectations of multiple stakeholders.

8.2 Practical Implications of study and recommendations

This study was conducted to identify the performance areas that impact the success of construction projects. In construction industry, developing performance assessment model needs recognized performance areas which are of interest to project stakeholders. This is analyzed for its appropriateness and finally aided for progressive improvement in project success. Earlier research on project performance measurement has focused on traditional quantitative measures. Project management teams need to be prepared for the risks associated with the project and reliable forecasts about future project stages should be preempted. Such forecasts may assist stakeholders in monitoring projects during the construction phase. Therefore, a MPQR model was adopted that can forecast the performance of construction projects. These findings obtained from the study will assist project management practitioners to monitor project success in the construction industry.

As construction industry is project-based industry, such kind of project performance evaluation models help construction organizations to get general information about their project level performance. Hence, project managers have to understand their importance and devise mechanisms to make the practice of project evaluation integral to their organization's culture. The major task in project performance evaluation is data collection for performance metrics. Organizations have to devise data collection mechanisms at project level; which needs a commitment from the top management, training of professionals and setting monitoring mechanisms for accuracy of the data. As the industry is competitive, adopting such practices will help them to develop competitive advantages in the market. Monitoring the performance status of the project management team will involve the monitoring the performance status of the ten performance areas and metrics. The underperforming metric must be reported to highlight the root cause for poor performance. The findings of the study will help the project stakeholders to prioritize their efforts towards achieving excellence in project performance. It can also serve as a benchmark for projects to set up project specific goals and objectives.

The identified performance areas can help the project management team to better coordinate the project by analyzing the importance of performance areas. This will improve the project to perform better throughout the project's life cycle. It will also help the project manager's experience by improving project performance and will enable them to gain confidence for future projects. Low performing areas can be improved by adapting strategies for improvement. The model proposed in this study will assist project management practitioners to monitor project success in the Indian construction industry.

Recommendations

The study recommends improvements to certain performance areas to sustain project performance. These are: i) Schedule cost and quality performance areas are very important and should not be ignored. Project management teams should focus on project activities and determine critical activities and achieve accurate milestones. They are advised on enhancing cost related area by monitoring cash flows and conducting earned value analysis. Regarding quality area, the project should conduct quality audits and avoid non-conformities for projects. (ii) For performance areas safety, the project management team should organize frequent safety training program and enhance awareness of safety practices on site. For finance area, it is advised that construction project should assess their financial viability and resources before starting of projects. They should establish monitoring system of project for improving performance in finance areas of projects. For communication area, the project should have communication management plan to benefit from project-based knowledge management systems. Effective communication between stakeholders is required to clarify and represent requirements of parties. Customer relations with stakeholders should be maintained through minimum disputes among stakeholders and meeting their expectations will bring in continuous business with them. Regarding environment area, the Projects should pay attention to different environments such as political, social, economic and technology of the project. Effective management of stakeholders can improve communication and understanding among the project parties to avoid any disputes.

8.3 Limitations of the Study

Data was collected from professionals from the Indian construction projects and therefore, it reflects their experiences and opinions. The study was conducted within a specific time duration. The present study was specific to geographic constraints i.e., Maharashtra, India. As with any research in the construction industry, getting responses for questionnaire surveys and time for interviewing is a challenge. Hence mixed method approach was adopted to answer the research questions. Detailed case studies on each performance area can consolidate the findings further; however, the process of gathering that information was a challenge.

8.4 Future research

The present study was able to accomplish its research objectives. Based on the findings and limitations of this study there are few aspects that need to be investigated further. Future research should focus on replicating the study findings through longitudinal data. The performance areas considered in this study can be further verified for their effectiveness by implementation of the model on actual different case studies of construction projects. Future research will be required to explore the extent of improvements in the respective performance areas that affect overall performance considering different stakeholders. This can be useful in establishing benchmarking standards for stakeholders in a project. The MPQR model can also be used to compare the study outcome in other countries. The findings have presented a comprehensive performance assessment model for Indian construction projects mainly from key stakeholders' perspectives. Further, the findings of this study can be further extended to similar such developing countries where the construction industry operates in similar work environments and socioeconomic conditions. In addition, comparison of performance areas for different types of projects operational in India as well as other similar developing countries can be done, which might be valuable research.

Future research will be required to explore the interdependencies of different performance areas that affect overall performance considering different stakeholders in the construction industry.

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ANNEXURE I: QUESTIONNAIRE

Section 1: General Information and comparison with past projects.
Part (A)-

Personal information question

1. Name: -

___

2. Name of company you are currently working and Address:

___

3. Location (State):

___

4. Company Type:

- ☐ Contracting Firm
- ☐ Client
- ☐ Design
- ☐ Consultant
- ☐ Other

Professional experience

5. Total yrs. of experience in industry:
6. Job Designation:
7. Among various areas given which experience you have:

☐ Residential ☐ Infrastructure ☐ commercial

8. Project you are handling among this: ________________________
9. Project cost: _______________
10. Project Duration: ____________
11. Project start date: _________________
12. Project finish date: ________________
13. How many subcontractors: _______________
14. Which is most successful project in your organization?

___

15. How did you measure its success?

___

16. Please provide performance metrics you were managing recently in your project.

___

Part (B) Project performance and comparing with past project.

1. Do Project Manager have practice to evaluate Project Performance?

☐ Yes ☐ No

2. How project performance assessment is done?

___

3. Pick project performance dimensions which contribute for project success.

- ☐ Customer relation
- ☐ Cost
- ☐ Environment
- ☐ Safety
- ☐ Quality
- ☐ Comm.collator
- ☐ Schedule
- ☐ Financial Metrics
- ☐ Productivity
- ☐ Waste Mangt
- ☐ Procurement Mangt
- ☐ Organ. & PM

4. List other dimensions which are not listed in above list but contribute for project performance.

---

5. How successful was your previous projects compared with other project considering above performance metrics.

The range of weighting in the research survey scaled from 1 to 5, as shown below:

scale	Frequency
1	Very unsuccessful
2	unsuccessful
3	somehow successful
4	successful
5	Very successful

Sr no.	Performance Metrics	1	2	3	4	5
1	Customer Relations					
2	Safety					
3	Quality					
4	Financial Metric					
5	Communication & collaboration					
6	Productivity					
7	Stakeholder satisfaction					
8	Environment					
9	Planned objectives of project.					
10.	Schedule					
11.	Cost					

6. If you have any suggestions please be free to mention them here.

Section 2: Project Performance and success measures

From your experience rate the importance of the following performance metrics in measuring customer relation. *(1-very less imp, 2-less imp, 3-moderate imp, 4-much imp, 5-very much imp*) with each of following statement.

Performance metrics are used to measure performance of construction projects.

A.CUSTOMER RELATIONS

1. Return business
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
2. Number of legal claims resolved.
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
3. Analysis of Feedback policies.
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

B.SAFETY

From your experience give your level of agreement on importance of the following performance metrics to measure safety. (*1-strongly disagreed, 2-less agreed, 3-moderately agreed, 4-highly agreed, 5-strongly agreed*).

1. OSHA recordable:
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
2. Lost work days (Injuries/illnesses resulting in lost work days)
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
3. Fatalities:
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

C. SCHEDULE

From your experience give your level of agreement on importance of the following performance metrics to measure schedule. (*1-strongly disagreed, 2-less agreed, 3-neutral, 4-highly agreed, 5-strongly agreed*).

1. Construction speed (Construction speed is measured from day of start of construction and ends when a project is completed).
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
2. Scheduled of payment. (Schedule of payment is measured as per milestones set for completing progress of work).
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
3. Construction schedule growth (measured in percentage terms by comparing the final construction schedule to the original estimated construction schedule).
   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

D.COST

From your experience give your level of agreement on importance of the following performance metrics to measure cost. (*1-strongly disagreed, 2-less agreed, 3-moderately agreed, 4-highly agreed, 5-strongly agreed*).

1. Construction unit cost. (Construction unit cost is cost per square feet of construction)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2. Construction cost growth rate. (Construction cost growth is final construction cost to original construction cost and it be minimized)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

3. Rework. (Rework cost is measured in percentage of total construction cost and it be minimize considering progress of project.)

☐ 0-1% ☐ 1-2% ☐ 2-3% ☐ 3-4% ☐ >4%

E. QUALITY

Now to what extent do feel the standards of quality. (*1-Economy, 2-standard, 3-high, 4-Premium, 5-highly premium*) with each of following statement.

1. Overall system quality. (System quality is related to mechanical, structural and finishes).

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2. Cost of work performs in defect liability period. (Deficiency issues are issues that arise during the course of construction, such as failed field inspections and jurisdiction problems related to code observance)

☐ 0-0.5% ☐ 0.5-1% ☐ 1-1.5% ☐ 1.5-2% ☐ >4

3. Item beyond scope of work. (Item beyond scope of work is the uncompleted or unsatisfactory items remaining after the substantial completion of a project, such as components needing minor repairs or replacement)

☐ 0-0.5% ☐ 0.5-1% ☐ 1-1.5% ☐ 1.5-2% ☐ >4

4. Defect cost. (Defect costs are measured after the end of the one-year liability period)

☐ 0-0.5% ☐ 0.5-1% ☐ 1-1.5% ☐ 1.5-2% ☐ >4

F. FINANCE METRIC

1. Total % profit in construction project.

☐ Less than 5% ☐ 5-10% ☐ 11-15% ☐ 16-20% ☐ more than 20%

G. COMMUNICATION AND COLLABRATION

1. RFI processing time (days).

☐ As soon as possible onces RFI is sent ☐ As per contract provision

2. Communication management plan. (Communication management plan is important for all stakeholders for proper coordinating for completion of project)

(*1-very less imp, 2-less imp, 3-moderately imp, 4-much imp, 5-very much imp*)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

3. Frequency of meetings held for stakeholders. (Frequency of meeting and impact of meeting are very important for monitoring of project work.)

(*1-weekly meeting, 2-onces in 15 days, 3-monthly, 4-quaterely meeting, 5-unshedule meeting*).

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

4. Impact of client and contractor meeting.(It helps for assessment for client and contractors for completing projects)

(*1-not effective, 2-very less effective, 3-moderately effective, 4- effective, 5- more effective*)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

H. PRODUCTIVITY

Now to what extent this performance areas impact project performance

(*1-very low impact, 2-low impact, 3-moderate low, 4-high impact, 5-very high impact*)

1. Labour productivity impact project performance.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2. Equipment productivity impact project performance.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

I. STAKEHOLDER SATISFACTION

1. Your involvement as (*1-owner, 2-contractor, 3-sub contractor, 4-architect, 5-PMC*)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2. Do you want to work again with them?

☐ Yes ☐ No

Now to what extent do you agree or disagree (*1-strongly disagreed, 2-less agreed, 3-moderately agreed, 4-highly agreed, 5-strongly agreed*)

3. Expectation is being satisfied as per excepted standard (contract document).

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

J. ENVIRONMENTAL

The following performance metrics are practical to measure environmental performance (*1-strongly disagreed, 2-less agreed, 3-moderately agreed, 4-highly agreed, 5-strongly agreed*)

1. Social impacts

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

2. Technical impacts

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

3. Political impacts

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

4. Economic impacts

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Section 3: PQR Model:

Now to what extent do you think important or unimportant?

scale	Frequency
1	Very less important
2	Less important
3	Moderate important
4	Highly important
5	Very much important

1. To what extent do you think customer relation is important metrics for project success?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
2. To what extent do you think safety is important metrics for project success?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
3. To what extent do you think schedule is important metrics for project success?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
4. To what extent do you think cost is important metrics for project success?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
5. To what extent do you think quality is important metrics for project success?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
6. To what extent do you think Finance is important metrics for project success?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
7. To what extent do you think communication and collaboration is important metrics for project success?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
8. To what extent do you think Productivity is important metrics for project success?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
9. To what extent do you think stakeholder satisfaction is important metrics for project success?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
10. To what extent do you think environmental is important metrics for project success?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
11. From your experience how do you rate the overall performance of projects in Indian construction Industry**? (***1- Poor, 2-fair, 3-good, 4-very good, 5-Excellent*)
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

ANNEXURE II. DELPHI SURVEY QUESTIONNAIRE

Objective: To assign weightages for MPQR Tier II.

Read it carefully and understand the impact of performance metrics.

Sr no.	Performance area	Performance metrics	Explanation
2.	Cost	Construction unit cost. Construction cost growth Rework cost	• Construction unit cost is cost per square feet of construction. • Construction cost growth is difference of final construction cost and original construction cost. • Rework cost is measured in percentage of total construction cost.
3.	Finance	Profit	• Stakeholder can sustain their business if they are making profit.
4.	Quality	System quality Item beyond scope Deficiency issues Defect costs	• System quality is related to mechanical, structural and finished work. • Item beyond scope of work are the uncompleted or unsatisfactory items remaining after the substantial completion of a project. • Deficiency issues are issues that arise during the course of construction. • Defect costs are measured after the end of the one-year liability period.
5.	Communication & Collaboration	Request for information. Communication management plan Frequency of meeting Impact of meeting	• RFI is measured in total numbers that is important source for project. • Communication management plan is important for all stakeholders for proper coordination and completion of project. • Frequency of meeting and impact of meeting are very important for monitoring of project work.
6.	Customer Relations	Return on business. Disputes Feedback policies	• High quality output will result in higher prospective clients. • Disputes are existence of legal claims between parties. • Feedback policies are recommendations given to improvise the performance of project.
7.	Safety	OSHA Loss time in numbers Fatalities	• OSHA recordable is measured in number of recordables. • LTN is calculated in by time lost in days • Fatalities are occurrence of death by accident on site.
8.	Stakeholder satisfaction	Expectation level	• Stakeholder includes everyone who is involved in project.
9.	Productivity	Labour Productivity Equipment Productivity	• Equipment productivity is measured in terms of planned target to actual achieved target. • Labour productivity is measured as ratio of input to output.

10.	Environment	Political Environment Technical Environment Social Environment Economical Environment	• Political environment is concerned with government policy. • Technical environment is important for strategic planning to complete project successfully. • The social environment consists of customs, lifestyles, and values that characterize a society (William 2002). • Economical environment has potential to ensure that a project is financially viable within a fluctuating economic environment.

➢ ***From your experience of construction projects, please give weightages in percentages for impacting performance metrics on project performance.***

<u>Round I:</u>

Please give your details.

Designation: _____________

Mail Id: _________________

Performance Areas	**Performance metrics**	**Expert's weightages (%)**
Customer Relations	• Service Speed • Claims • Feedback Policy	
Safety	• OSHA Recordable • Loss time injuries • Fatalities	
Schedule	• Construction speed • Schedule payment • Schedule growth	
Cost	• Construction unit cost • Cost growth • Rework cost	
Quality	• System Quality • Defect liability Period • Item beyond scope • Defect cost	
Communication and collaboration	• RFI • Communication management plan • Frequency of meeting • Impact of client and contractor meeting	

Productivity	• Equipment productivity • Labour productivity	
Environment	• Social environment • Technical environment • Political environment • Economic environment.	

DELPHI ROUND II

Performance Areas	**Performance metrics**	**Round I assigned weights(%)**	**Final weight**
Customer Relations	• Service Speed • Claims • Feedback Policy		
Safety	• OSHA Recordable • Loss time injuries • Fatalities		
Schedule	• Construction speed • Schedule payment • Schedule growth		
Cost	• Construction unit cost • Cost growth • Rework cost		
Quality	• System Quality • Defect liability Period • Item beyond scope • Defect cost		
Communication and collaboration	• RFI • Communication management plan • Frequency of meeting • Impact of client and contractor meeting		
Productivity	• Equipment productivity • Labour productivity		

Environment	• Social environment • Technical environment • Political environment • Economic environment.		

ANNEXURE III: CASE STUDY SEMI STRUCTURED INTERVIEW QUESTIONS

Objective: To validate performance metrics for Model.

(Semi Structured Interview)

Questions to the interviewee:

1. What is your current position in the company?
2. What is your designation in your company?
3. Which type of project you were working before?

Questions related to success in project:

1. How was your last project?
2. What is your opinion to make project successful?
3. Was your last project successful (considering schedule, cost, Finance, Quality, communication n collaboration, customer relations, safety, stakeholder satisfaction, productivity, Environment).
4. Do you think these metrics are sufficient to measure project performance?
5. Do you have any example of successful completion of project?
6. What efforts are taken so that performance will get increase?

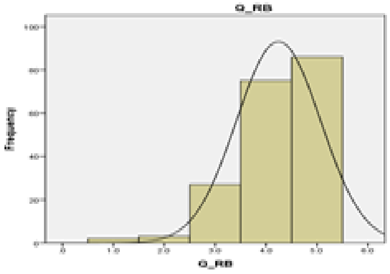
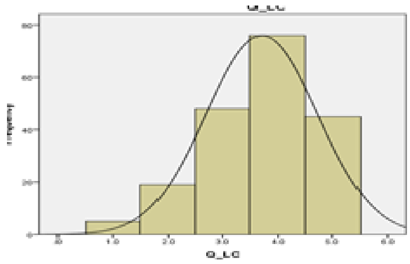
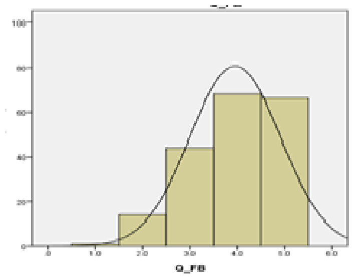
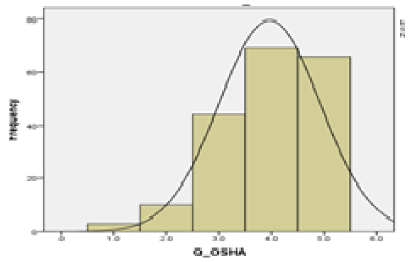
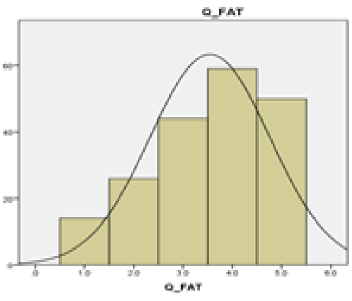
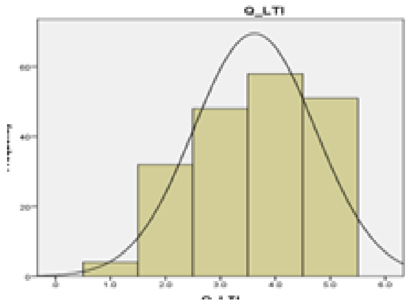
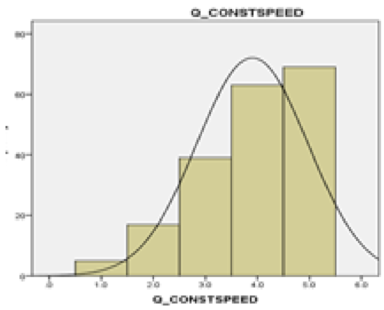
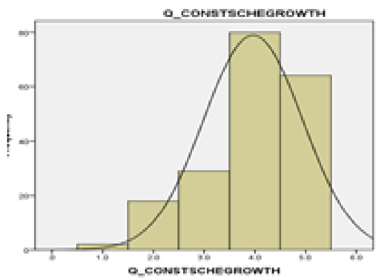
ANNEXURE IV: MODIFIED PQR MODEL FOR INDIAN CONSTRUCTION PROJECTS

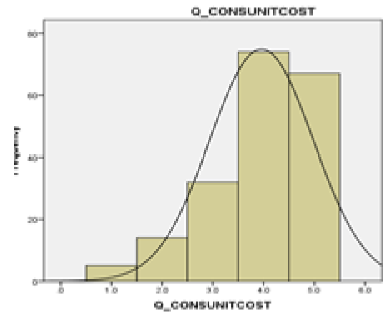
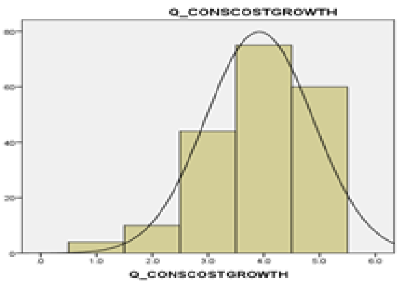
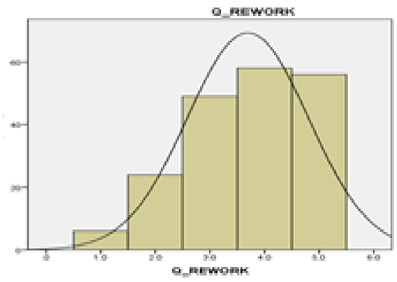
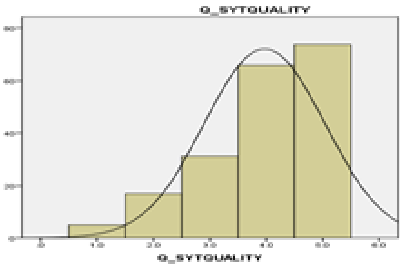
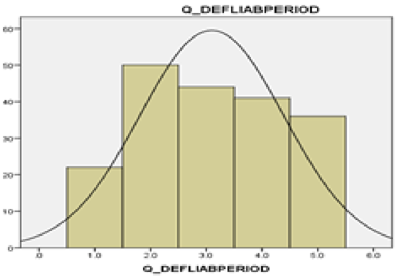
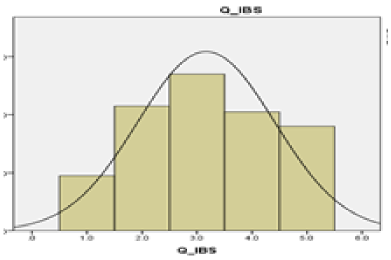
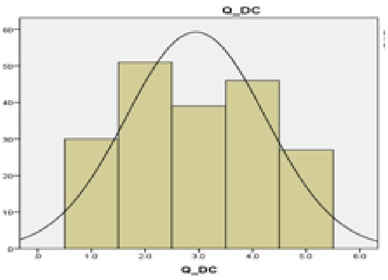
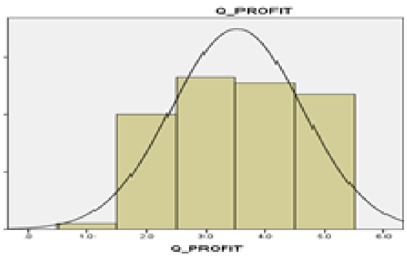
Performance area	Performance metrics	Measurement scale	Impact
Cost	CUC (51%) CGR (25%) RC (24%)	• Construction unit cost is cost per square feet of construction. • Construction cost growth is a difference of final construction cost and original construction cost. CUC and CGR were measured on a five-point scale (1)-Strongly disagreed to (5)-Strongly agreed. • RC is measured in percentage of total construction cost and coded as 0-1% as 1, 1-2% as 2, 2-3% as 3, 3-4% as 4 and >4% as 5.	Construction unit cost growth, and rework cost should be minimized. Rework is a major contributing metrics to schedule and cost overruns on construction projects. Hence it impacts negatively for project performance.
Schedule	CS (48%) SP (28%) SC (24%)	• Construction speed is measured from the day of the start of the construction (work order date) and ending of the project. • Schedule of payment is measured as per the milestone set for completing progress of work. • Schedule growth is measured in percentage terms by the rate of progress compared with the expected construction schedule. • CS, SP, and SC were measured on a five-point scale (1)-Strongly disagreed to (5)-Strongly agreed.	Schedule payment and schedule growth indicate that it should be minimized.
Stakeholder satisfaction	EL (100%)	• Stakeholder includes everyone who is involved in the project. A stakeholder satisfaction is measured by expectation and commitment level. • Expectation is being satisfied as per the expected satndard(contract document) on a five-point scale (1)-Strongly disagreed to (5)-Strongly agreed.	To ensure project success, project stakeholders play vital roles. So it has a positive impact on project performance.
Safety	OS (62%) LTI (21%) F (17%)	• OSHA recordable is measured in number of recordable events. • LTI is calculated in by time lost in days • Fatalities are the occurrence of death by accidents on site. • OSHA recordable, LTI and F were measured on a five-point scale (1)-Strongly disagreed to (5)-Strongly agreed.	• OSHA mission is to assure safe and healthful working conditions. So it has a positive impact on project performance. • LTI and fatalities should be avoided on site. So it gives a negative impact on performance.
Quality	PQ (55%) DLP (14%) IBS (17%) DC (14%)	• Project quality is related to mechanical, structural and finished works. PQ were measured as standards of quality on a five-point scale (1-Economy, 2-standard, 3-high, 4-Premium, 5-highly premium). • Item beyond scope of work are	• Project quality should be maintained throughout the project. • Item beyond scope of work, deficiency issues and defect costs should get minimized in percentages relative to total construction cost.

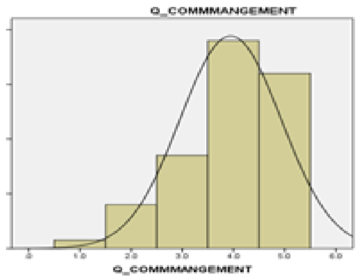
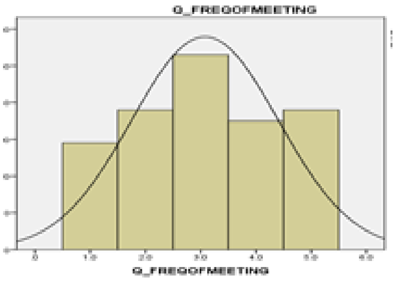
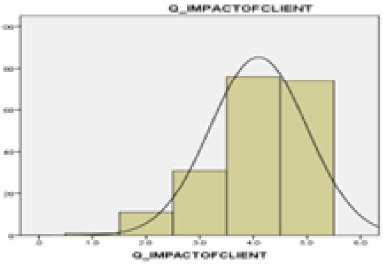
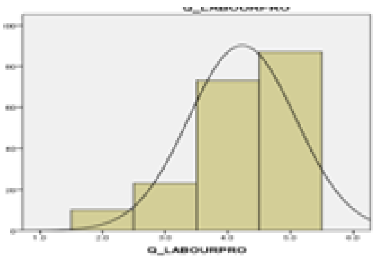
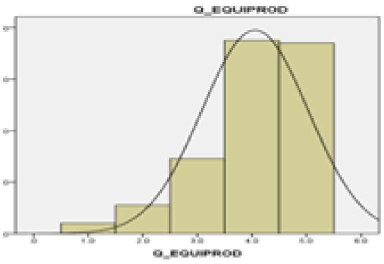
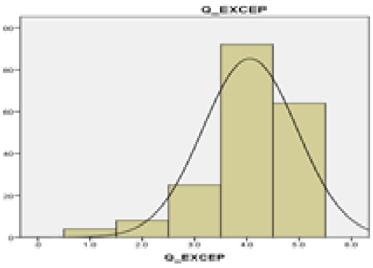
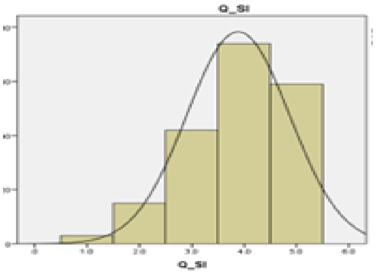
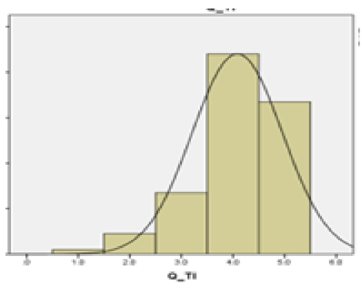
		items beyond Bill of quantitates (BOQ). • Deficiency issues are issues that arise during the execution of construction. • Defect costs are measured after the end of the liability period. • IBS, DLP, and DC were measured on an ordinal scale based on cost percentages relative to total construction costs. • The values were coded as coded as 0-0.5% as 1, 0.5-1% as 21-1.5% as 3, 1.5-2% as 4 and >4% as 5.	
Finance	P (100%)	• A stakeholder can sustain their business if they are making a profit. • It was measured as per percentages of profit and overheads on a five-point scale as Less than 5% as 1, 5-10% as 2, 11-15% as 3, 16-20% as 4 and more than 20% as 5.	• Profit margin should increase.
Environment	P (23%) T (33%) S (16%) E (28%)	• Political environment is concerned with government policy. • The technical environment is important for strategic planning to complete the project successfully. • The social environment consists of customs, lifestyles, and values that characterize a society. • The economic environment has the potential to ensure that a project is financially viable within a fluctuating economic environment. • P, T, S, and E was measured as the level of impact on a five-point scale as (1)-Strongly disagreed to (5)-Strongly agreed.	• Political and technical decisions affect construction projects. So it has a positive impact. • Social environment influences or affects organizations operating within the society. So it has a positive effect. • Economic environment is very important for successful completion of the project. So it has a positive impact.
Communication & Collaboration	RFI (40%) CMP (22%) FOM (18%) IOM (20%)	• RFI is an important source for the project and is measured in total numbers. RFI was measured in binary scale that had two values as (1) As soon as possible once RFI is sent and (0) as per contract provision. • Communication management plan is important for all stakeholders for proper coordination and completion of the project. CMP was measured on the level of importance on a five-point scale (1) very less important to (5) very much important. • The frequency of meeting and impact of the meeting are very important for monitoring of project work. FOM was measured on a five-point scale. (1-weekly meeting, 2-onces in 15 days, 3-monthly, 4-quarterly meeting, 5-unscheduled meeting).	RFI, Communication management plan, Frequency of meeting and impact of the meeting gives a positive impact on project performance.

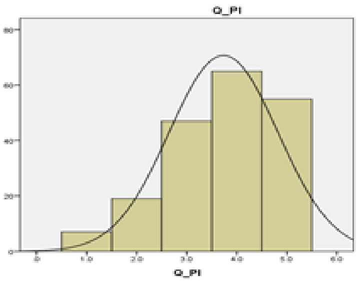
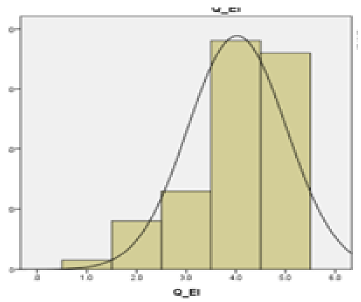
		• IOM were measured on the level of effective (1- not effective to 5- more effective).	
Customer Relations	RB (62%) DC (18%) FP (20%)	• High quality output will result in higher prospective clients. • Disputes are existence of legal claims between parties. • Feedback policies are recommendations given to improvise the performance of the project. • RB, D, and FP were evaluated on a five-point scale (1)-Strongly disagreed to (5)-Strongly agreed.	• Return business gives a positive impact on project performance. • Disputes consume time and resources. So it has a negative impact. • Feedback policies give scope for improvement. So indirectly it has a positive impact on project performance.
Productivity	LP (57%) EP (43%)	• Labour productivity is measured as the ratio of input to output. • Equipment productivity is measured in terms of the planned target to actually achieved target. • LP and EP were measured as the level of impact on a five-point scale as (1)-Strongly disagreed to (5)-Strongly agreed.	• Equipment and Labour are main resources for project completion in time and has a positive impact on project performance.

ANNEXURE V : HISTOGRAM FOR ALL PERFORMANCE METRICS

 RB	 DC
 FP	 OS
 F	 LTI
 SP	 SG

 CUC	 CCG
 RC	 PQ
 DLP	 IBC
 DC	 P

 CMP	 FOM
 IOM	 LP
 EP	 EL
 S	 T

Q_PI 80 60 40 20 0 .0 1.0 2.0 3.0 4.0 5.0 6.0 Q_PI P	.0 1.0 2.0 3.0 4.0 5.0 6.0 Q_EI E

ANNEXURE IV: APPLICATION OF MODIFIED PQR MODEL

$$(C) = \frac{\left(0.51*\frac{CUC-3.958}{1.022}\right)-\left(0.25*\frac{CGR-3.917}{0.965}\right)-\left(0.24*\frac{RC-3.694}{1.111}\right)}{1.069}$$

$$S = \frac{\left(0.48*\frac{CS-3.902}{1.068}\right)-\left(0.28*\frac{SP-3.99}{0.952}\right)-\left(0.24*\frac{SC-3.99}{0.952}\right)}{0.999}$$

$$Cu=\frac{\left(0.62*\frac{RB-4.244}{0.828}\right)-\left(0.18*\frac{DC-3.71}{1.015}\right)+\left(0.20*\frac{FP-3.953}{0.953}\right)}{0.875}$$

$$St=\left(\frac{EL-4.057}{1.209}\right)$$

$$Sa = \frac{\left(0.62*\frac{OS-3.964}{0.962}\right)-\left(0.21*\frac{LTI-3.622}{1.107}\right)-\left(0.17*\frac{F-3.544}{1.209}\right)}{0.209}$$

$$Pr = \frac{\left(0.57*\frac{LP-4.228}{0.854}\right)+\left(0.43*\frac{EP-4.057}{0.975}\right)}{0.839}$$

$$\boldsymbol{PQR = 0.103 * C + 0.102 * S + 0.101 * St + 0.100 * Sa + 0.099 * Q + 0.099 * F + 0.992 * E + 0.985 * Co + 0.950 * Cu + 0.946 * Pr}$$

$$Q = \frac{\left(0.55*\frac{PQ-3.969}{1.065}-0.17*\frac{DLP-3.098}{1.293}-0.14*\frac{IBC-3.166}{1.247}-0.14*\frac{DC-2.943}{1.29}\right)}{1.453}$$

$$F = \left(\frac{P-3.523}{1.218}\right)$$

$$Co= \left(\frac{0.40*\frac{RFI-1.06}{0.702}+0.22*\frac{CMP-3.943}{0.991}+0.18*\frac{FOM-3.078}{1.33}+0.20*\frac{IOM-4.093}{0.902}}{1.014}\right)$$

$$E=\frac{\left(0.23*\frac{S-3.886}{0.983}\right)+\left(0.33*\frac{T-4.083}{0.874}\right)+\left(0.16*\frac{P-3.736}{1.089}\right)+\left(0.28*\frac{E-4.026}{0.992}\right)}{0.974}$$

In case of any newly developed model, testing and validation are needed to test that the Modified PQR model is adequate. Illustration of the implementation of MPQR model is added in Annexure VI to understand the implementation aspect.

Implementation of MPQR model

In this section, a detailed methodology of how to implement the MPQR model for evaluating overall performance in construction industry has been formulated. In this study, the most pertinent performance areas affecting project performance in construction projects are studied through a questionnaire survey conducted in Indian construction industry.

In order to compute project performance, a set of performance metrics, denoted by x_j, were used to measure each of the performance areas. The performance metrics are functions of a vector $\vec{d}$ composed of different areas of a project, as presented in Eq. (1). The vector $\vec{d}$ represent performance areas.

$$x_j = f\left(\vec{d}\right) \qquad (1)$$

where, j= 1,2, ..n, j is total number of performance metrics, $\vec{d} = \begin{pmatrix} d_1 \\ d_2 \\ . \\ . \\ d_i \end{pmatrix}$

The MPQR model consists of a three- tier of computations leading to an overall single project score. (1) Tier-I in calculating the project score of a project consists of evaluating for 28 performance metrics for each of the ten identified performance areas.

(2) Tier II involves combining all ten performance areas to a numerical score for each performance areas.

(3) The third tier III consists of combining the performance areas scores of the ten areas into a single project score that allows the user to quantitatively evaluate the overall project performance.

Step 1: Identifying importance of performance areas

The weights for each of the ten performance areas must be identified. The weights quantify the level of importance for individual performance areas. The project management team should discuss with the project stakeholders and determine the importance of the performance area considering the objective and priority of project. The last section of the data collection survey shown in Annexure I can be used for this purpose. Weight for all performance areas were calculated as shown in equation (5.1), chapter 5. Further, based on the frequencies computed for each of the performance areas, converted to percentages by dividing the frequency value for each item by the total sum of all item frequencies. Thus, weights for each performance areas are determined. This is in explained with the research findings as explained in the earlier section (refer section 5.3).

Summary of important performance areas

Performance areas	Percentage	Rank
cost	10.43	1
schedule	10.33	2
stakeholder satisfaction	10.29	3
Safety	10.11	4
quality.	10.02	5
Finance	10.02	6
environment	9.92	7
communication and collaboration	9.87	8
customer relation	9.52	9
productivity	9.48	10

These percentages can be used in the formulae MPQR formula as follows (*Eq.5.4*). However, users can adjust the percentages based on specific needs and success factors of their own project priorities.

Step 1I: Importance of performance metrics

In order to establish performance scores of each performance areas refer Annexure: IV.

The performance areas score achieved by performance metrics (M_{ijk}). Since the performance metrics used in the study have different units, different measurement scale for different metrics hence it is difficult to add together and thus standardization is necessary. Standardization method is used that can transform any set of numbers to their equivalent values on the standard normal distribution.

The performance score 'A_{ij}'for ten performance area is calculated as shown in Eq. (5.4)., Chapter 5.

$$A_{ij} = \sum_{k=1}^{10} W_{ik} Z_{ijk}$$

(4)

'A_{ij}' represent performance area score.

where,

W_{ik}= users assigned weights of each performance metric within a specific performance area '*I using Delphi technique*'.

The 'Z_{ijk}' represents 'Z' scores. The final 'A_{ij}' result can be interpreted that a positive value represents above average performance and a negative value represents below average performance and zero indicates average performance. Moreover, the values above or below average can be interpreted as numbers of standard deviations relative to the average.

After the computation, the standardized scores for the ten performance areas then are combined into the MPQR formula as expressed in Equation (5.4)

$$MPQR_j = \sum_{i=1}^{I} W_i A_{ij}$$

(5.4).

The resulting scores undergo final last standardization procedure to warrant the interpretation presented above. The weights for each performance metrics are assigned using Delphi technique explained in section:5.3.1.

Next, the performance scores of each area are combined to determined overall performance score of projects. The score obtained to formulate the model represent the actual project performance of construction project. For the purpose of the formulation of $MPQR_j$ model weighted average formula of different performance areas (A_{ij}) was used as shown in Eq. (2).

$MPQR_j = \sum_{i=1}^{I} W_i A_{ij}$ (2).

Where, W_i = weightage of performance area ‘i’; I=10;

i= 1, 2, 3……n as there are n=10 performance areas

j=1, 2, 3……N as there are N respondents.

A_{ij}= score of respondent j for performance area i.

After computing all values for all performance metrics under each performance areas that needs to be standardised individual to used in MPQR. The score will be computed for each performance areas which can be used in Equ. (2) to obtain overall performance rating for each project. Users can apply this exact formula to their project, and can be interpret the score.

The final ‘A_{ij}’ result can be interpreted that a positive value represents above average performance and a negative value represents below average performance and zero indicates average performance. Moreover, the values above or below average can be interpreted as numbers of standard deviations relative to the average.

Illustration: Case study for infrastructure project

For demonstration purpose, a case study using sample project data was compiled to illustrate the application of the unified score presented in this research. The sample project is an infrastructure project of rail over bridge. The questionnaire was given to four of the project management team members, namely the project manager, project engineer, planning engineer, and project coordinator, and were asked to fill in the inputs. The performance scores for projects are as follow:

Area	Input	Performance area formulas	Score
C	CUC- 5 CGR- 4 RC- 3	$\frac{\left(0.51 * \frac{CUC-3.958}{1.022}\right) - \left(0.25 * \frac{CGR-3.917}{0.965}\right) - \left(0.24 * \frac{RC-3.694}{1.111}\right)}{1.069}$	0.687

Sc	CS- 4 SP- 4 SC- 3	$$\frac{\left(0.48*\frac{CS-3.902}{1.068}\right)-\left(0.28*\frac{SP-3.99}{0.952}\right)-\left(0.24*\frac{SC-3.99}{0.952}\right)}{0.999}$$	0.291
St	EL- 5	$$\left(\frac{EL-4.057}{1.209}\right)$$	0.779
Sa	OS- 5 LTI- 3 F- 1	$$\frac{\left(0.62*\frac{OS-3.964}{0.962}\right)-\left(0.21*\frac{LTI-3.622}{1.107}\right)-\left(0.17*\frac{F-3.544}{1.209}\right)}{0.209}$$	5.466
Q	PQ- 5 DLP- 4 IBC- 3 DC- 2	$$\frac{\left(0.55*\frac{PQ-3.969}{1.065}-0.17*\frac{DLP-3.098}{1.293}-0.14*\frac{IBC-3.166}{1.247}-0.14*\frac{DC-2.943}{1.29}\right)}{1.453}$$	0.368
F	*P*- 4	$$\left(\frac{P-3.523}{1.218}\right)$$	0.391
E	S- 3 T- 5 P- 1 E- 5	$$\frac{\left(0.23*\frac{S-3.886}{0.983}\right)+\left(0.33*\frac{T-4.083}{0.874}\right)+\left(0.16*\frac{P-3.736}{1.089}\right)+\left(0.28*\frac{E-4.026}{0.992}\right)}{0.974}$$	0.158
Co	RFI- 1 CMP- 5 FOM- 4 IOM- 4	$$\left(\frac{0.40*\frac{RFI-1.06}{0.702}+0.22*\frac{CMP-3.943}{0.991}+0.18*\frac{FOM-3.078}{1.33}+0.20*\frac{IOM-4.093}{0.902}}{1.014}\right)$$	0.304
Cu	RB- 5 DC- 2 FP- 4	$$\frac{\left(0.62*\frac{RB-4.244}{0.828}\right)-\left(0.18*\frac{DC-3.71}{1.015}\right)+\left(0.20*\frac{FP-3.953}{0.953}\right)}{0.875}$$	1.004
Pr	LP- 5	$$\frac{\left(0.57*\frac{LP-4.228}{0.854}\right)+\left(0.43*\frac{EP-4.057}{0.975}\right)}{0.839}$$	0.054

	EP- 3		

$$MPQR = 0.103 * C + 0.102 * S + 0.101 * St + 0.100 * Sa + 0.099 * Q + 0.099 * F + 0.990 * E + 0.985 * C + 0.950 * Cu + 0.946 * Pr$$

$MPQR$ =2.609

The project score for infrastructure project is 2.60, that interprets a positive value which represents above average performance.

LIST OF PUBLICATIONS

International Journals

1. Ingle, P.V and Mahesh, G. (2020). "Construction project performance areas for Indian Construction Projects." *International Journal of Construction Management Taylor & Francis, doi* (10.1080/15623599.2020.1721177).
2. Ingle, P.V and Mahesh, G. (2019). "Assigning weights for construction project performance model." *International Journal of Mathematical, Engineering and Management Sciences*, Vol 4 (4), pp.895-904.
3. Ingle, P. V, Mahesh, G and Deepak, M.D (2020). "Identifying the performance areas affecting the project performance for the Indian construction projects." *Journal of Engineering, Design and Technology, Emerald*. [Accepted for publication].
4. Ingle, P. V and Mahesh, G. (2016). "*Project Performance Appraisal using PQR: A Review*", *Journal of construction engineering, technology and Management*, Vol 6 (2), pp. 25-33.
5. Ingle, P. V and Mahesh, G. "Developing a performance assessment model for the Indian construction projects. [Communicated].

International Conferences

1. Ingle, P.V. and Mahesh, G. (2017). "Construction project performance assessment for Indian Construction Industry. *ICSECM 8th International Conference on Structural Engineering and Construction Management*, 7th – 9th December 2017 Earl's Regency Hotel, Kandy, Sri Lanka.
2. Ingle, P.V. and Mahesh, G. (2018). "Performance areas for measuring project success- An Indian Construction Industry." *International Conference on Construction, Real Estate, Infrastructure and Project Management (ICCRIP–2018), M. G. Korgaonker (Ed.), Financial and Other Issues in CRIP Sector* (pp 57-65), NICMAR, Pune, India.

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- T & T Infra Pvt Ltd (May 2013– May 2014) Job Title: Junior Engineer.