Project Management Institute

HOSTED BY

IIT BOMBAY

PMI Research & Academic Virtual Conference 2021

Enhancing project performance: Application of AI and Decision Science

3 - 6 March, 2021

HOSTED BY

PMI Research & Academic Conference

(Virtual Conference 2021)

3 – 6 March, 2021

Theme:

Enhancing project performance:
Application of AI and decision science

Conference Proceeding

Editors:

Prof. Albert Thomas
Prof. Venkata Santosh Kumar Delhi
Prof. (Ms.) Karuna Jain

First Impression: 2021

Project Management in the Emerging World of Disruption
ISBN: 978-81-926239-9-3

Published by:
PMI Organization Centre Pvt. Ltd.,
#105, WeWork, 1st Floor, Oberoi Commerz II,
International Business Park, Oberoi Garden City,
Off Western Express Highway,
Goregaon (East), Mumbai 400063

Email: pmi.india@pmi.org
Website: www.pmi.org.in

Preface

Advancements in the domain of Artificial Intelligence (AI) and Decision Science is creating revolutionary changes in different spheres around the world. Project management is of no exception, and has become more indispensable to embrace these new paradigms to enhance the handling of complex projects. Therefore, high end research in this domain is essential and could be a game-changer for better project management. However, the conventional principles of project management cannot be overshadowed by the advent of new tools and techniques. A progressive up-gradation synchronised with project management's well-established fundamentals should be enabled through quality research and development. AI is a broad term that encourages to rethink how information and data are processed and how these results can be used to better the existing practises. AI is more of an algorithmic technique as compared to a statistical analysis method such as decision science which involves huge amounts of data processing. AI tries to replicate human behaviour based on the information obtained, creating more response-based decisions. A combination of both creates an ideal mix for better decision making for complex problems that are influenced by a multitude of factors.

Introducing such modern techniques could have two spectrums of impact on project management. On one hand, these technologies will increase the demand for new complex projects and the need to execute them in shorter time frames. On the other hand, these technologies also have the potential to disrupt the fundamentals of traditional project management. For a 60-year-old profession such as project management, continuous evolution has provided solutions to handle complex projects ranging from large Olympic venues to skyscrapers and several other massive infrastructure projects. Project management's future looks to battle even more complex challenges ranging from human-crewed space missions, hyperloop technologies, and high-speed rails. Therefore, a mere facelift of project management approaches might not suffice and AI and decision sciences can enable the effective management of these challenges.

The PMI RAC conference of 2021 tries to bring in meaningful insights to enhancing project performance by applying AI and decision science techniques. Of the 74 papers received for the conference, these proceedings present 25 high quality selected papers that provide interesting insights on the transformation of Project Management with the advent of AI and Data Science.

Bill Gates once said that "The advance of technology is based on making it fit in so that you don't really even notice it, so it's part of everyday life". Therefore, AI and decision science-based techniques should be smoothly moulded into the existing practices to make it as a way of doing, then a forced practice in project management. We hope that this PMI-RAC 2021, would enlighten the project management community to upgrade themselves to embrace modern innovative tools and techniques for better performance and delivery.

Profs. Albert, Venkata, Karuna
IIT Bombay

Acknowledgements

We are happy to bring out the proceedings of the PMI South Asia Research and Academic Conference 2021 on the theme, “Enhancing Project Performance: Application of AI and Decision Science” hosted by IIT Bombay, Mumbai. We congratulate all the authors who have contributed to this volume. We are confident that both practitioners and researchers will be able to derive benefits out of this proceeding. We thank the reviewers whose inputs helped in enhancing quality of the papers. The administrative support and encouragement given by PMI South Asia India officials is also gratefully acknowledged.

Editors

Profs. Albert, Venkata and Karuna

Committees

Conference Chairs

Karuna Jain, IIT Bombay

Venkata Santosh Kumar Delhi, IIT Bombay

Conference Co-chair

Albert Thomas, IIT Bombay

Advisory Committee

Ganeshan Kannabiran, Director, IIIT Sricity
Head Civil, IIT Bombay
Head SJMSOM, IIT Bombay
K.N. Satyanarayana, Director IIT Tirupati
Karuna Jain, IIT Bombay Mumbai
Kesavaswamy, Global Head, Academic Interface, TCS
Krishna Moorthy, Ex-Dean, Sun Pharma Academy, Vadodara
Saji Gopinath, Director. IIITMK, Trivandrum
Srini Srinivasan, Regional Managing Director, PMI
Tapash Kumar Ganguli, Dean-Executive Education, NICMAR, Pune
VTCS Rao, Dean L&T Institute of Project Management, Vadodara

Technical Committee

Abhishek Raj Singh, Indian Institute of Technology (IIT) Bombay
Albert Thomas, Indian Institute of Technology (IIT) Bombay
Ann Francis, Indian Institute of Technology (IIT) Bombay
Ashwin Mahalingam, Indian Institute of Technology (IIT) Madras
Ganesh Devkar, CEPT University
Ketan Kotecha, Symbiosis Institute of Technology, Pune
Kirti Ruikar, Loughborough University, United Kingdom
Kishor Bhagwat, Indian Institute of Technology (IIT) Bombay
Koshy Varghese, Indian Institute of Technology (IIT), Madras
Murali Jagannathan, Indian Institute of Technology (IIT) Bombay
Pankaj Dutta, Indian Institute of Technology (IIT) Bombay
Prashanth Kumar Sreram, National Institute of Construction Management and Research (NICMAR), Hyderabad
Rupesh Kumar Pathi, Indian Institute of Management (IIM) Kozhikode
Shobha Ramalingam, National Institute of Construction Management and Research (NICMAR), Pune
Sidhardha S Padhi, Indian Institute of Management (IIM) Kozhikode
Sivakumar Palaniappan, Indian Institute of Technology (IIT) Bombay
Venkata Santosh Kumar Delhi, Indian Institute of Technology (IIT) Bombay

Organizing Committee

Bindu S. Kelaskar, IIT Bombay
Pankaj Dutta, IIT Bombay
Priya Awasare, PMI South Asia
Roger Rodrigues, PMI South Asia
Suvarna Naik Desai, PMI South Asia
Uday Yedur, PMI South Asia

Our Volunteers

Abhishek Raj Singh, IIT Bombay
Akhila Padmajan, IIT Bombay
Ann Francis, IIT Bombay
Guntu Venkata Sai Teja, IIT Bombay
Kishor Bhagwat, PhD Student
Omprakash R R, IIT Bombay
Prasanth Kumar Sreram, IIT Bombay
Sudheer Nanduri, IIT Bombay
Tripti Singh Rajput, IIT Bombay

(Names in alphabetic order)

CONTENTS

Preface.....i

Acknowledgements.....ii

Committees.....iii

Section I: Data Analytics in Managing Projects 1

Editor's Note.....2

1. **Integrating Artificial Intelligence in Project manager's decision-making process: A look at Built Environment projects**.....3

   Tushar JADHAV[1],, Rahul DESHPANDE[1], Tapash GANGULI[1] 3*

2. **A Framework to Manage Data Science Initiatives** 20

   Sandeep MATHUR[1], Shankar SANKARAN[2], Samuel MACAULAY[3] and Ivor TSANG[4] 20

3. **Data Analytics to Evaluate Public Value from Megaprojects** 30

   Ganesh DEVKAR[1], Shankar SANKARAN[2], Yongjian KE[3], Johan NINAN[4], Sandeep MATHUR[5], Ivor TSANG[6] and Lauri VUORINEN[7].....30

4. **Classification of safety observation reports from a construction site: An evaluation of text mining approaches**.....50

   Jai KEDIA[1], Vurukuti TARANI[2], Nikhil BUGALIA[3], Ashwin MAHALINGAM[4].....50

5. **Blockchain Technology in Project Management** 67

   K.C. IYER[1] and Purva GUPTA[2].....67

Section II: Advanced Construction Project Management 77

Editor's Note.....78

6. **Enhancing Decision Quality to Manage Risks in Complex Long Gestation Projects** 79

   Dr. G Srikantha SHARMA[1] and Ms. Suparna KAPOOR[2].....79

7. **Success Traits of Power Projects: Empirical Analysis**.....98

   Achintya GHATAK[1] and Adarsh GARG[2].....98

8. **Developing an Integrated Framework for Heavy Construction Equipment Management Platform**.....111

   Nandan KUMAR[1] and Jyoti TRIVEDI[2] 111

9. **Development of a Feasibility Study Framework for UAVs in the Indian Construction Industry**.....122

   Georgie JACOB[1] and Bhargav DAVE[2] 122

10. **Role of Modern Tools in Construction Projects** 143

    Dhruv PATEL[1], Rohan JAIN[2] and Dr. J.S. SUDARSAN[3].....143

Section III: ICT in Construction Management........156

Editor's Note........157

11. **Integration of Project Management in Construction Industry 4.0 Framework**.....158

    A V S S Surya SRINIVAS[1], Vijaya DIXIT[2]........158

12. **A Critical Review on BIM for Construction Safety Management**........176

    Shalaka HIRE[1] Kirti RUIKAR[2] Sayali SANDBHOR[3] Amarnath CB[4]........176

13. **An Experimental Study Integrating BIM And Green Building Concepts For A Residential Project**........194

    Ankita ANAND[1], Shobha RAMALINGAM[2], Dhiraj R.K SHARMA[3], Akshita PATEL[3], Mohit KUMAR[3], Vaibhav KUMAR[3]........194

14. **Modelling Interactions of Lean-Agile Enablers in Construction Project Management using Interpretive Structural Modeling (ISM)**........207

    Vijayeta MALLA[1], Saniya Faiyaz PATHARWAT[2], Ravindranadh K.CHOWDARY[3]........207

15. **Life Cycle Asset Management of Buildings Using Database Management System** 225

    Akansha KUNJAM[1] and K V JAYAKUMAR[2]........225

Section IV: Challenges in Project Management........234

Editor's Note........235

16. **Overcoming Barriers to Creating Integrated Global Teams**........236

    Anand LOKHANDE........236

17. **Financial Drivers of Binding Dispute Resolution in Construction Firms: A Panel Data Investigation from India**........262

    Murali JAGANNATHAN[1], Harish Kumar SINGLA[2] and Venkata Santosh Kumar DELHI[3]......262

18. **The Challenge of Megaprojects in Oil & Gas industry: A Report from the Field**.280

    G. UNNIKRISHNAN........280

19. **One Nation One Market Project- Identifying challenges and way forward**........295

    Bade Mihir UMESH, Aveek DUTTA, Rupesh Kumar PATI........295

20. **Construction Project Risk Management using Change Propagation Method**........308

    Vijayashree T M[1] and Jyoti TRIVEDI[2]........308

Section V: Project Cost and Risk Management........318

Editor's Note........319

21. **Factors influencing the efforts to estimate project indirect cost accurately in construction projects: An exploratory study from Indian perspective**........320

    Harish Kumar SINGLA[1], Srividya Raju, SRIDHARAN[2] and Murali JAGANNATHAN[3]........320

22. **Correlation between Project completion time and cost in a project crashing analysis for a Research Project** 341

Shivam SHARMA[1], Nishit BEDI[2], Vijay Kumar SUKHWANI[3]* *341*

23. **Critical Risk Factors in a BIM Project & their Significance in the Indian Real Estate/Infrastructure Sector** 351

Pallab GOSWAMI *351*

24. **Applications of Taguchi Design and Monte Carlo Simulations for Effective Risk Mitigation in Road Projects** 367

Harish L REDDY[1] and Nagakumar M S[2] *367*

25. **Linking Project Risk Management and Top Management Commitment with Project Success: Mediating Role of Project Innovativeness and Project Flexibility in Financial Services** 377

Pankaj TIWARI[1] and Suresha B[2] *377*

Authors Index 397

Section I

DATA ANALYTICS IN MANAGING PROJECTS

Editor's Note

This section presents five interesting studies that investigates on various data analytics techniques in managing projects. For instance, Jadhav et al. focuses on the extent of implementation of AI, its familiarity or awareness, and advantages in project management activities in building services, where a lot of time is spent in planning prior to execution. This study also discusses various AI applications that are currently used in the infrastructure development and building services. Through many semi structured interviews of the stakeholders, the paper features the degree of AI adoption and preferences in building services, which serves as a set of key insights for all the AI application developers related to the building and building services industry.

Meanwhile, Mathur et al. discusses various design principles to be adopted in the delivery framework of data science initiatives (DSIs) that would potentially increase the obtained value against the investment. The study explains the proposed framework with five core domains which is intended to deliver higher value from implementation of DSIs.

With the introduction of many mega projects across countries to promote economy while addressing the concern to build environmentally fit society, Devkar et al. investigates in monitoring and creating maximum public value from these projects through big data analytics. The study also addresses various challenges faced by governments and public agencies to effectively use big data. The authors also identified opportunities where big data analytics could play a greater role in enhancing public value creation in mega projects. Likewise, Iyer and Gupta discusses the application of blockchain technology to automate the contractual processes, performance and administration of construction projects. This study provides a more collaborative and transparent framework to address the challenges in contractual management in the construction sector.

Similarly, Kedia et al. analyses the knowledge obtained from a building construction site featuring near-miss safety observations. The analysis tests the suggestions that different ML algorithms are highly efficient in automatically classifying three types of site findings - "Unsafe Act," "Unsafe Condition" and "Good Observation." The research utilizes a supervised approach to machine learning using F1 scores, and tests six different algorithms. Analysis of errors are also performed to identify the techniques for increasing the precision of the forecast.

Integrating Artificial Intelligence in Project manager's decision-making process: A look at Built Environment projects

Tushar JADHAV[1],*, Rahul DESHPANDE[1], Tapash GANGULI[1]
[1]*Faculty, SOPRIM, National Institute of Construction Management and Research, Pune 411045, Maharashtra, India.*
* Corresponding author: *tjadhav@nicmar.ac.in*

ABSTRACT

The applications of artificial intelligence (AI) can be seen in many areas, predominantly in information technology, financial services and automotive industries. There is also increasing interest on use of AI for agriculture, education and healthcare services. However, the role of AI seems to be modest in the construction sector. The construction projects at present lacks the requisite digitization which can minimize the complications of completing these projects within the framework of schedule, cost and quality. The main emphasis of this paper is to address the applicability of AI tools in decision making process of built environment projects. The outcomes of this paper will provide significant insights to the stakeholders involved in the development of AI software tools. The study will also benefit the end users (project managers / project management consultants) interested to integrate and leverage AI more effectively and efficiently in their projects.

KEYWORDS: Artificial intelligence; built environment; project management; building services

1. INTRODUCTION

In recent years, the term 'Artificial intelligence' has gone from being a buzzword to the core interest amongst industries and research communities. The most common understanding about artificial intelligence (AI) is replication of human intelligence in machines. AI offers a variety of applications that can offer promising solutions for sustainable development (Goralski & Tan, 2020). Across the globe, there is an increasing economic and social trend towards development and application of AI (Aayog, 2018). The role of AI in construction projects was limited to use of single technique in the early research. However, the last decade saw use of multiple AI techniques to address the complexity in construction projects (Xiao, 2018). The Engineering and Construction (E&C) sector is worth more than $10 trillion a year. However, it lacks the required digitization. The adoption of AI seems quite low in E&C in comparison with other industries (Blanco, 2018).

2. RESEARCH OBJECTIVES AND METHODOLOGY

The objective of this paper is to investigate the application of AI in project management with specific emphasis on building services. Considerable time is spent by architects and engineers in the planning phase of infrastructure building projects which certainly involves lots of iterations. This paper discusses the role of AI in the decision-making process of various project management activities.

The present study investigates the applicability of AI for built environment projects (specifically building services) and is divided into four parts. The first part presents literature review of various application of AI in project management as well as combination of AI with Building Information Modeling (BIM). The second part of this research provides insights from the semi structured interviews of stakeholders working on built environment projects. In the third part, a case study of air conditioning system is presented utilizing Autodesk Revit software. Finally, discussions and research directives are specified in the last part.

3. LITERATURE REVIEW ON AI AND BUILT ENVIRONMENT

The literature review is divided in to four parts. In the first part, the literature review presents the application of AI for project management in general. In the second part, literature review related to the application of AI along with BIM tools is presented. In the third part, studies related to AI and BIM tools specifically for building services are discussed. Lastly, in the fourth part, research focusing on AI for building performance is highlighted.

3.1 AI for Project Management

The project managers dealing with construction projects has to deal with the complexities in terms of various phases of the project as well as coordinating the various knowledge areas involved in a given project. The project managers are required to make very dynamic decisions involving various levels of expertise, prediction and judgment. AI can assist project managers in multiple ways (Munir, 2019). The role of AI is finding increasing application in project management tools and techniques thereby offering multiple benefits to the project managers (Schmelzer, 2019). The study also highlighted the benefits of AI in minimizing the time spent by project managers in various administrative tasks. In the past, few researchers have attempted to find the role of AI in making construction project plans (Levitt, 1988), modeling site layout (Tommelein, 1992) and predicting project success (Ko, 2007). Cost estimation is one of the tricky tasks in construction projects. This is one of the criteria for project feasibility study and decision making during the initial stages of the project. Juszczyk (2017) has discussed the non-parametric cost estimation of construction projects using AI. Elmousalami (2020) has identified the most common AI techniques for parametric cost estimation of construction projects. Fuzzy Logic (FL), Artificial Neural Network (ANN), regression models, Case Based Reasoning (CBR), Supportive Vector Machine (SVM), Genetic Algorithm (GA) were some of the commonly used AI techniques. The study made a comprehensive literature review on the use of AI techniques for estimating the cost of construction projects such as highway projects, building projects, water treatment cost, structural steel buildings, tunnel construction, field canal improvement projects, pavement maintenance, pump stations, bridge construction projects, etc. An Analytic Hierarchy Process (AHP) model can assist in appropriate selection of project delivery method (Al Khalil, 2002).

3.2 AI and BIM

The increasing complexity of building technologies has resulted towards in depth analysis of architectural modeling (Mahdavi, 1998). Building modeling as well as building performance simulation is a time consuming process. It involves defining the relevant building parameters as well as the impact of variations in the building components and systems on the overall performance of the building. BIM offers multiple benefits to project managers in terms of coordinating various project management knowledge areas. BIM is way forward for management of construction projects. Petrova (2019) demonstrated the role of AI to formulate complex engineering knowledge and help in decision making of sustainable design using BIM. Cost management is seen to be one of the significant benefited knowledge areas by implementation of BIM (Bryde, 2013). Sacks et al. (2019) illustrated framework for automated design review using AI and BIM. Sacks et al. (2020) focused on the key elements of BIM and AI that needs basic research to support commercial development. There is also increasing trend in construction management towards integrating Life Cycle Assessment (LCA) and BIM. Though BIM has the requisite potential to enhance the performance of LCA of buildings, yet an adequate framework is necessary that can be adopted efficiently in Architecture, Engineering and Construction (AEC) industry (Nwodo, 2017). Arunkumar (2019) highlights the role of AI in BIM to be more predefined and precoded. It involves the use of vast construction knowledge database. The findings of the study reveal that the construction industry will have to implement AI in its distinct form.

3.3 AI and BIM for building services

Coordination of building services (or commonly called as Mechanical Electrical & Plumbing (MEP) services) is a major challenge in industrial and commercial buildings and involves locating equipments, finalizing the route, detecting clashes, etc. This activity being a multi-disciplinary in nature needs requisite knowledge of each system over the project life cycle (Korman et al., 2003). The number of equipments and components in the MEP systems makes it more challenging while constructing the MEP model in BIM. It is also important to make a logical chain between these MEP components to make the facility management more effective. Instead of doing these activities manually, Xiao et al. (2019) proposed an automatic generation of logic chain of MEP systems in BIM. Kwon et al. (2019) developed a model based on GA and CBR to estimate the service life of MEP components. Construction managers have found BIM useful for visualizing the project, in reducing the overall cost and assisting in conflict resolution (Gerges et al., 2019). In order to have efficient schedule and cost planning of building fabric maintenance, Chen & Tang (2019) proposed an innovative workflow which integrated BIM with digital programming. The paper emphasized on the need of AI in Building Life cycle Management (BLM) across various stages. Some of the organizations working in building services (or MEP services) have started realizing the potential benefits of using AI as a tool for effective coordination of these services.

3.4 AI for building performance

It has been observed that most of the project managers constantly concentrate on the triple constraint of time, cost and quality while working on the project. However, in case of a building project, it is equally important to understand the behaviour of the building during post occupancy. Therefore during planning and execution of construction of state-of-the-art buildings, it is necessary for the project managers to have a comprehensive understanding of the life cycle cost. Ustinovičius et al. (2015) proposed research directives in the area of BLM. The use of artificial intelligence algorithms such as swarm intelligence, neural networks and evolutionary algorithms can be used in the architectural practice (Cudzik & Radziszewski, 2018). Use of AI for buildings (Loveday & Virk, 1992) and building management systems (Clark & Mehta, 1997) has also been an area of interest in the past for few researchers. Dounis

(2010) conducted a review of various AI technologies for energy conservation in buildings. Among the various AI tools for Heating Ventilation and Air Conditioning (HVAC) control, more emphasis is seen on weather forecasting, optimization and predictive controls (Cheng & Lee, 2019). The authors (Cheng & Lee, 2019) also investigated the performance of AI assisted HVAC controls for six water cooled chillers. Recently Mehmood et al. (2019) conducted a review on use of AI for design and operation of energy efficient building. The authors observed that GA, FL and AHP are the most commonly used AI techniques. The contribution of AI can be limited to monitoring the performance of building. However, integrating Big Data (BD) with AI is more effective to decide the mode of operation of various building components. Several building performance simulation tools are available that can perform the building simulation. ANN can be used as a significant tool towards predicting the energy performance of the building (Krarti, 1998) as well as for comparison of various building performance simulation tools (Yezioro, 2007).

As can be seen from the above literature review many researchers have leveraged AI (in combination with and without BIM) to tackle issues of technical nature as well as issues related to project management.

In the next section we present point of view of selected stakeholders working in building services domain and the applicability of AI to the issues faced by them.

4. SEMI STRUCTURED INTERVIEWS

Though the literature review addresses the various applications of AI for buildings and building services, its use amongst AEC industries is uncertain. Therefore the authors have tried to investigate what are the current practices adopted while managing building projects and to what extent is the use of AI and BIM for project management of building projects.

The authors are actively involved in training programmes for working professionals in construction project management and building services. Therefore, to understand the issues and challenges faced by the project managers for building projects, semi structured interviews were conducted with the participants during the training programme.

The profile of respondents is specified in Table 1.

Table 1 Profile of Respondents

Organization	**'A'**	**'B'**
Background	Company A is one of the leading MEP companies in Asia providing end-to-end solutions for building services (MEP services).	Company B is one of the public limited company owned by Government of India and has high rise office buildings in various parts of India.
Respondent's profile	The respondents are into planning and coordination of MEP projects, energy retrofit projects, etc.	The respondents are involved into coordination of facility management, building retrofits, new building projects, etc.
Designation of respondents	Area manager – Estimation / Project / Sales / Planning / Procurement	Executive Engineer
Number of respondents	27	25
Respondent's experience	Min: 3 years, Max: 14 years Average experience (27 respondents): 8 years	Min: 6 years, Max: 35 years Average experience (25 respondents): 16 years

4.1 Observations:

Following are the salient observations based on the interactions with the respondents.

1. The project managers from company 'A' were having some technical understanding of HVAC but respondents from both company 'A' and 'B', agreed that they needed more comprehensive understanding about the mechanism of building services (MEP services), especially HVAC as it constitutes the major part of building services.
2. The fundamental understanding about MEP services and its integration in the overall scope of project was seen missing. Therefore, majority of the respondents were unable to understand the impact of some changes in the system design and selection, on the overall project in terms of cost, risk and procurement.
3. The engineers and project managers from company 'A' and company 'B' were using planning software such as Microsoft Project, Primavera. Respondents from company 'A' were also aware of design software such as Carrier Hourly Analysis Program (HAP), psychrometric calculator, duct sizer, fan selection, chiller selection, etc. But

these software are mostly standalone software and the integrated approach is missing when one uses such software. BIM on the other hand offers an integrated approach towards designing, scheduling, costing and other project management activities.

4. The average industrial experience of project managers from company ‘A’ was 8 years whereas from company ‘B’ was 15 years. Yet, the respondents were not aware of the benefits of BIM and how to use BIM for project management activities such as system sizing, costing, scheduling, etc. Majority of them were also of the view, that AI is mostly suitable for non-construction projects.
5. Lack of good project management practices while doing the cost estimation, was another major observation revealed during the interaction.
6. Respondents from company ‘B’ were also involved in the facility management of buildings. However, the awareness and implementation of asset management of building services was missing in their project activities.
7. Though the respondents were handling multiple projects, yet the technical project management was seen as an area that needed significant improvement. Majority of the respondents were lacking the requisite skills of the elements of technical project management such as schedule, cost, quality, risk and procurement. Therefore, in many cases they had to rely on the analogous data, some thumb rules and unnecessary oversizing the systems to avoid operational failures.
8. The majority of the respondents admitted the missing of integrated approach during their project implementation.

5. CAN AI ASSIST IN TECHNICAL PROJECT MANAGEMENT?

The three key skill sets necessary for a competent project manager includes technical project management, strategic & business management and leadership (PMBOK guide, 2017). Technical project management plays a key role in construction project management. Technical project management is influential in knowledge areas such as schedule, cost, quality, risk and procurement. The objective of this case study is to demonstrate the applicability of AI in technical project management. To address the role of AI, the authors have selected a case on air conditioning system (as a part of HVAC system) as specified in Fig. 1. This case addresses the current process in BIM and the possible future role of AI in BIM. It is to be noted that the model suggested in Fig. 1 is for discussing the HVAC challenges while using BIM and hence detailed architecture (doors, windows and other supplementary building components) is not provided.

The elements for discussion include building envelope, HVAC system sizing and selection, air distribution, duct layout, duct schedule and costing.

The authors have used Autodesk Revit software (BIM software) to illustrate the specific challenges faced by architects, engineers and project managers working on building project.

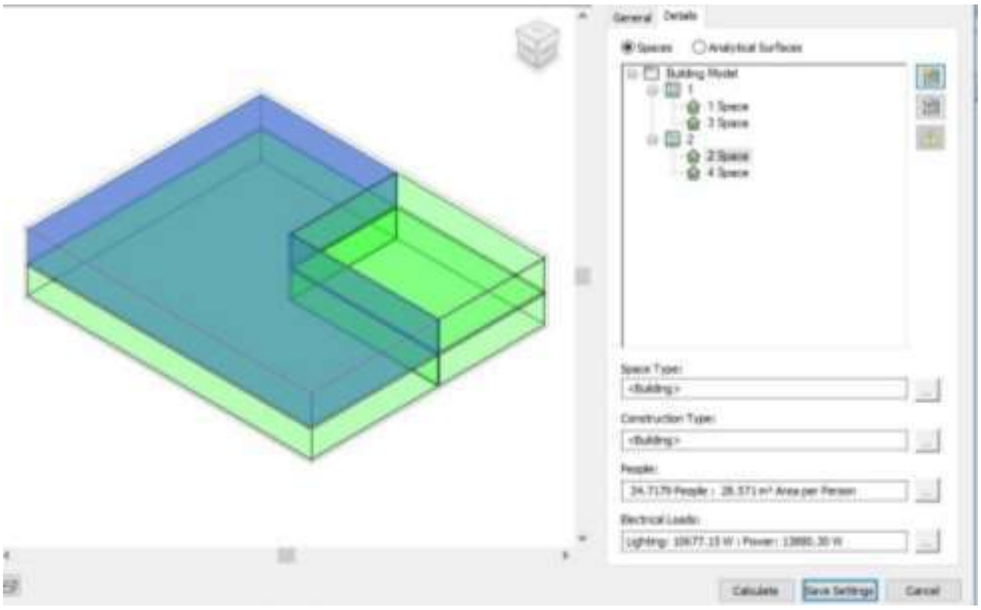


Figure 1 Building layout under study

5.1 Selection of building envelope

Several combinations can be made while selecting the building envelope as shown in Fig. 2.

Analysis Properties

By default, analysis properties are generated from information in model elements.
Properties of Analytic Constructions are used when override is selected or model information is missing.

Category	Override	Analytic Construction
Roofs	✓	4 in lightweight concrete (U=1.2750 W/(m²·K))
Exterior Walls	✓	8 in lightweight concrete block (U=0.8108 W/(m²·K))
Interior Walls	✓	Frame partition with 3/4 in gypsum board (U=1.4733 W/(m²·K))
Ceilings	✓	8 in lightweight concrete ceiling (U=1.3610 W/(m²·K))
Floors	✓	Passive floor, no insulation, tile or vinyl (U=2.9582 W/(m²·K))
Slabs	✓	Un-insulated solid (U=0.7059 W/(m²·K))
Doors	✓	Metal (U=3.7021 W/(m²·K))
Exterior Windows	✓	Large double-glazed windows (reflective coating) - industry (U=2.9214 W/(m²·K), SHGC=0.13)
Interior Windows	✓	Large single-glazed windows (U=3.6898 W/(m²·K), SHGC=0.86)
Skylights	✓	Large double-glazed windows (reflective coating) - industry (U=3.1956 W/(m²·K), SHGC=0.13)

Figure 2 Selection of building envelope

When the process of building envelope is carried out, the software does not indicate whether the building envelope will comply with the energy conservation standards / green building standards. The architect / engineer has to physically check the selected Overall heat transfer coefficient (U) values and Solar Heat Gain Coefficient (SHGC) values for the building envelope with the available energy conservation standards / green building standards.

5.2 HVAC system sizing and selection

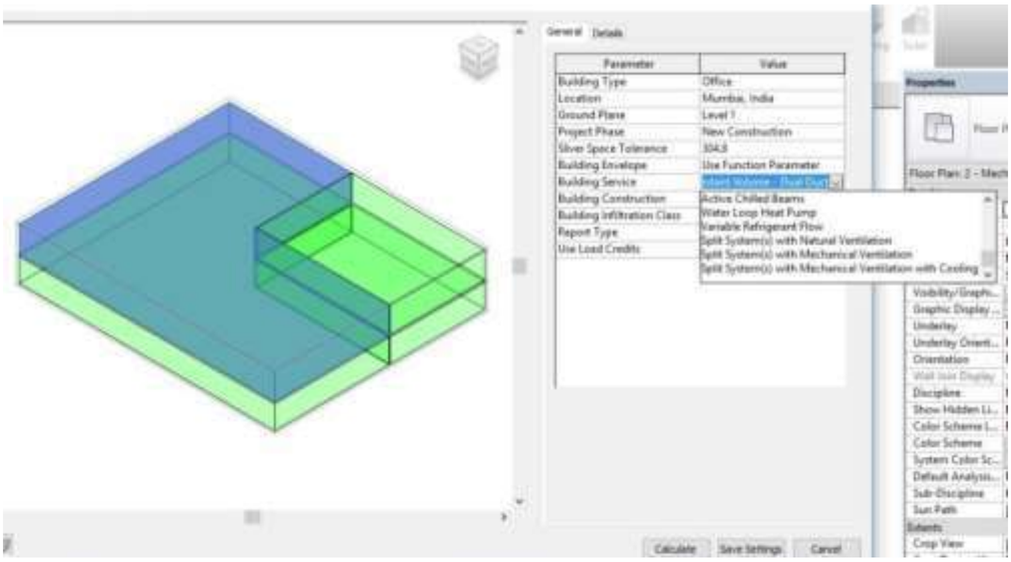


Figure 3 HVAC system sizing and selection

HVAC designer performs the air conditioning load calculations considering the factors such as location, internal loads and external loads. The designer then decides the type of system depending upon the total capacity, occupancy schedules, budget, space constraints, etc.

It is to be noted that selection of parameters indicated in Figure 2 and Figure 3 is not a part of AI. However, after the selection of relevant parameters as indicated in Figure 2 and 3, the further steps such as air conditioning load calculations, energy simulations are performed with the help of building algorithms (Fruin, 2019).

5.3 Air distribution

For centralized air conditioning system, the designer has to decide on the type of air outlets (supply and return) such as grilles or diffusers and their location (Refer Fig. 4).

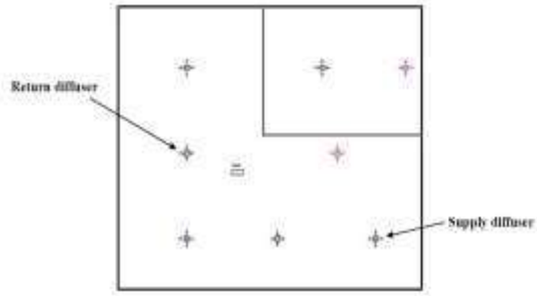


Figure 4 Air outlets (supply / return) positioning and selection

5.4 Duct layout

Once the location of air outlets and air handling unit is finalized, the software provides the various possible combinations of duct layout as shown in Fig. 5.

5.5 Duct schedule and costing

The duct sizing is then performed in Autodesk Revit (Refer Fig. 6). The finalization of duct layout (as seen in Fig. 7) is made based on the costing (Table 2), space available and checking the clash with other building services and building components.

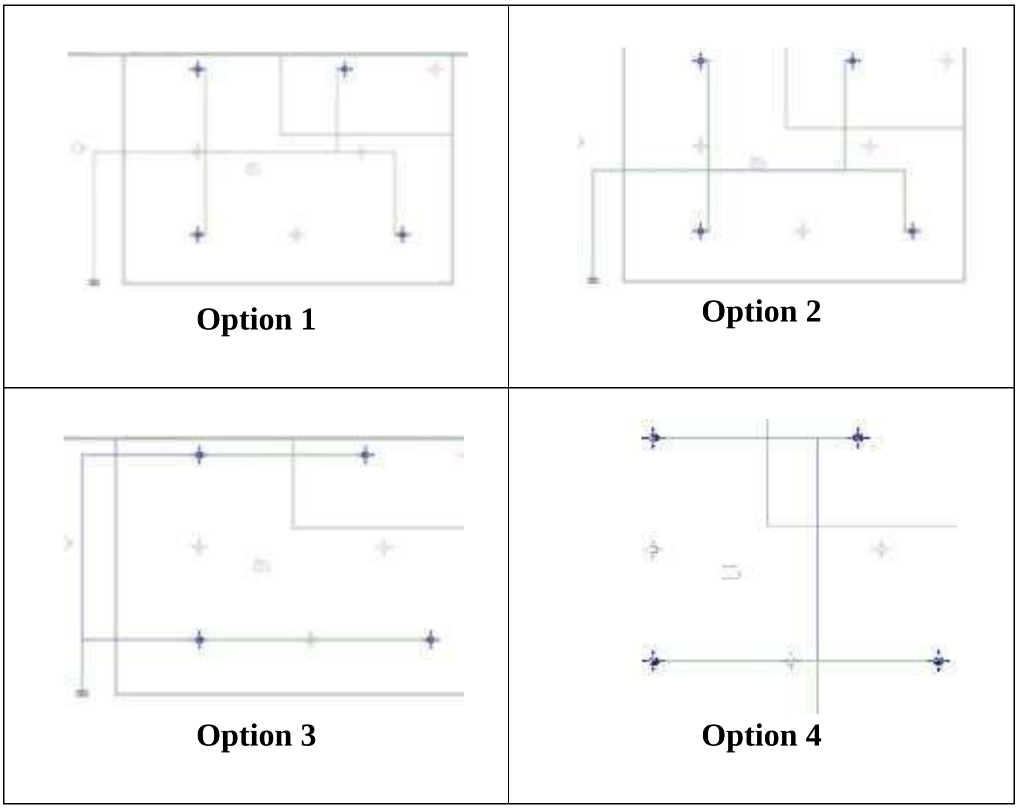


Figure 5 Various combination of duct layout

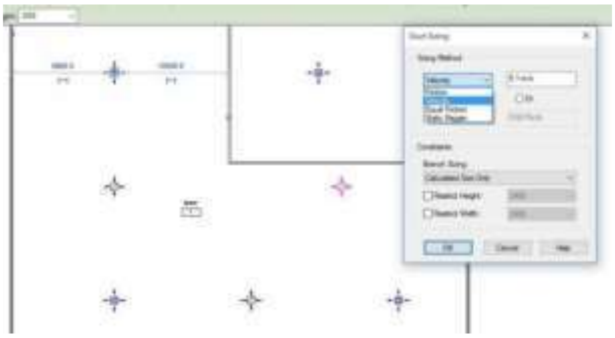


Figure 6 Duct sizing

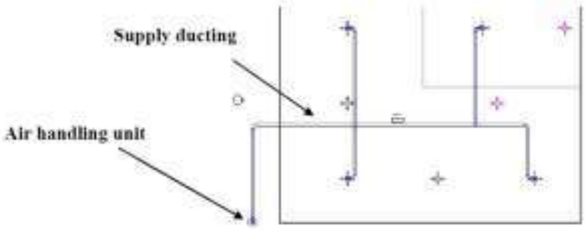


Figure 7 Duct layout

Table 2 Duct costing (for layout specified in Fig. 7)

Area	**Size**	**Flow**	**Pressure Drop**	**Unit Cost in INR per square metre**	**Total cost INR**
3 m²	300x300	235.0 L/s	0.7 Pa	750	1979
3 m²	300x300	235.0 L/s	0.7 Pa	750	1979
3 m²	300x300	235.0 L/s	0.7 Pa	750	1979
3 m²	300x300	235.0 L/s	0.7 Pa	750	1979
24 m²	406x356	470.0 L/s	5.2 Pa	750	17944
18 m²	406x356	940.0 L/s	14.0 Pa	750	13408
19 m²	406x356	940.0 L/s	15.2 Pa	750	14563
1 m²	406x356	940.0 L/s	1.0 Pa	750	1005
15 m²	300x300	235.0 L/s	3.7 Pa	750	10915
15 m²	300x300	235.0 L/s	3.7 Pa	750	10915
7 m²	300x300	235.0 L/s	1.9 Pa	750	5604
7 m²	300x300	235.0 L/s	1.9 Pa	750	5622
8 m²	300x300	235.0 L/s	1.9 Pa	750	5743
				Total cost INR	**93634**

5.6 AI and decision making

In this section we attempt to answer the question, can AI assist in decision making? The authors have summarized the current role of BIM (Fig. 1 to 7 and Table 2) in technical project management activity for the above case. The last column of Table 3 summarizes the expectations from AI in the decision making process.

Table 3 Challenges in building projects – A look at few HVAC activities

Activity	**Current BIM process**	**Role of architects, engineers and project managers**	**Associated major project management knowledge area**	**Can AI take the decision?**
Building envelope	Iterations is possible in selecting building envelope materials	Planning	Cost and Procurement management	Can AI decide the optimum selection of building envelope? (Refer Fig. 2)
HVAC system sizing and selection	Iterations is possible in HVAC sizing	Planning	Schedule, Cost, Risk and Procurement management	Can AI decide the selection of best air conditioning system and its components for a particular project? (Refer Fig. 3)
Duct layout and costing	Various possible layouts are generated	Planning and Execution	Schedule, Cost, Risk and Procurement management	Can AI decide which layout is relatively better considering the factors such as cost, space, etc? (Refer Fig. 5 to 7) Can AI perform the cost calculations specified in Table 2? Can AI completely design the air distribution? (Refer Fig. 6 and 7)

5.7 Inferences from the case study

There is no doubt that AI can assist project managers in technical project management. However, from the above example it is very clear that at present AI has a limitation in terms of decision making. 'Expert Judgment' is considered as one the significant technique in various knowledge areas of Project Management (PMBOK guide, 2017). At present, AI can assist the AEC team, but whether it can entirely deliver the role of Expert Judgment is uncertain at the moment. AI can assist architects, engineers and project managers in the decision making process but 100 percent replacement of humans by AI seem to be doubtful in the current era. For example, in the above case, the basic understanding of fluid flow, fundamental of air conditioning, system fundamentals, guidelines specified in the standards, project constraints such as space, cost, etc is interpreted by the architects, engineers and project managers before arriving at the final conclusion. Thus it involves an integrated approach of multiple stakeholders with specific expertise. Integrating such comprehensive data into software and validation of the same will be a challenging task for researchers in near future.

6. RESEARCH DIRECTIVES

AI certainly will have an impact on the current project management practices (Kerzner, 2018). Most of the IT related companies such as Microsoft, Google, IBM, Amazon, etc are considered to have excellent project management practices but their knowledge interface is limited to software industry. The construction industries are in the transformation phase trying to adopt more digitalization. AI is expected to play a significant role throughout the entire value chain of building projects (Schober, 2020). Tatum (2018) has highlighted that different application of modeling tools would be a promising alternative for future research in construction projects. In another investigation, the author also specified an increasing trend towards the technical content and specialization for successful implementation of project (Tatum, 2018). The lack of trained personnel in BIM and willingness to learn this new software are few of the limitations why BIM is not yet popular in majority of the construction companies (Gerges et al., 2019). The role of AI cannot be ignored in the future research in construction project management. AI will play a significant role in future design of buildings through the concept of generative design (Rao, 2019). Data collection and standardization will be one of critical step while using AI in BIM for generative design (Fruin, 2019). Lahmann (2018) has specified the transformation of project management methodology due to AI.

Following are the some of the specific research questions that need to be addressed in near future to integrate AI more effectively in construction project management.

1. What must be the framework for integrating AI in construction project management?

2. What type of case studies must be developed to have in depth understanding of AI in construction project management?
3. What must be the role of academic institute towards integrating AI in construction project management?
4. What are the various mechanisms to be adopted by AEC industries towards use of AI in their project management activities?
5. What must be the process flow for synchronization of work, by companies working in development of AI tools and project management companies who wish to use these tools for their project management activities?

7. CONCLUSIONS, LIMITATION AND FURTHER RESEARCH

At present there are several AI tools that support the project managers in their daily administrative task (Lahmann, 2018; Munir, 2019). However, the focus of the present study was towards use of AI for BIM.

The purpose of this paper was to provide significant insights into the use of AI for built environment projects. The authors have attempted to address the current issues faced by the AEC personnel through semi structured interviews and by illustrating few examples from building services.

The semi structured interview clearly identified that most of the respondents were not aware of and were not using latest techniques such as BIM in their project management activities. This is where the academic institutes need to contribute in educating the project management personnel on use of AI and BIM. Similar observation was also pointed out by Goralski and Tan (2020) while promoting AI for larger section of business. AI certainly can contribute towards streamlining the project management activities. There is some degree of uncertainty amongst AEC industries on the impact of AI and BIM in construction project management (Pampliega, 2019). The accuracy of data and integrating the data in standardized form will be one of the significant challenges for the future developments of AI in BIM.

Since the built environment projects are quite exhaustive, the present study limits its research only on buildings and attempts to find the significance of AI in dealing with the project management for building projects. The present study has a limited role towards the mechanism of various types of AI tools. As identified by Goralski (2020) AI can come up with further complex problem that must be thoroughly studied. Further scope of research extends to developing in depth case studies on integrating AI in construction project management. Whether AI can fully replace the role of project managers in future will be an interesting area for investigation.

REFERENCES

Aayog, N. I. T. I. (2018). "National strategy for artificial intelligence". *Paper. June*.

Al Khalil, M. I. (2002). "Selecting the appropriate project delivery method using AHP". *International journal of project management*, 20(6), 469-474.

Arunkumar (2019, May). "BIM & Artificial Intelligence". https://www.ibima.co.in/post/bim-artificial-intelligence

Blanco, J. L., Fuchs, S., Parsons, M., & Ribeirinho, M. J. (2018). "Artificial intelligence: Construction technology's next frontier". *Building Economist, The*, (Sep 2018), 7.

Bryde, D., Broquetas, M., & Volm, J. M. (2013). "The project benefits of building information modelling (BIM)". *International journal of project management*, 31(7), 971-980.

Chen, C., & Tang, L. (2019). "BIM-based integrated management workflow design for schedule and cost planning of building fabric maintenance. *Automation in Construction"*, 107, 102944.

Cheng, C. C., & Lee, D. (2019). "Artificial Intelligence Assisted Heating Ventilation and Air Conditioning Control and the Unmet Demand for Sensors: Part 2. Prior Information Notice (PIN) Sensor Design and Simulation Results". *Sensors*, 19(15), 3440.

Cheng, C. C., & Lee, D. (2019). "Artificial Intelligence-Assisted Heating Ventilation and Air Conditioning Control and the Unmet Demand for Sensors: Part 1. Problem Formulation and the Hypothesis". *Sensors*, 19(5), 1131.

Clark, G., & Mehta, P. (1997). "Artificial intelligence and networking in integrated building management systems". *Automation in Construction*, 6(5-6), 481-498.

Cudzik, J., & Radziszewski, K. (2018). "Artificial Intelligence aided architectural design". *AI for Design and Built Environment*, Vol. 1, 77-84.

Dounis, A. I. (2010). "Artificial intelligence for energy conservation in buildings". *Advances in Building Energy Research*, 4(1), 267-299.

Elmousalami, H. H. (2020). "Artificial intelligence and parametric construction cost estimate modeling: state-of-the-art review". *Journal of Construction Engineering and Management*, 146(1), 03119008.

Gerges, M., Mayouf, M., Watson, P. D. J., John, G. A., Ahmed, E. K., & Wenman, B. (2019). "BIM Role within the Conceptual Design Phase: A Case Study of a UK Construction Project". *International Journal of Architecture, Engineering and Construction*, 8(1), 54-62.

Goralski, M. A., & Tan, T. K. (2020). "Artificial intelligence and sustainable development". *The International Journal of Management Education*, 18(1), 100330.

Juszczyk, M. (2017). “The challenges of nonparametric cost estimation of construction works with the use of artificial intelligence tools”. *Procedia engineering*, 196, 415-422.

Kai-Stefan Schober (2020, February). “Artificial intelligence in the construction industry - How to increase efficiency over the entire lifecycle chain”.https://www.rolandberger.com/en/Point-of-View/Artificial-intelligence-in-the-construction-industry.html.

Kerzner, H. (2018), *Project management best practices: Achieving global excellence*. John Wiley & Sons.

Ko, C. H., & Cheng, M. Y. (2007). “Dynamic prediction of project success using artificial intelligence”. *Journal of construction engineering and management,* 133(4), 316-324.

Korman, T. M., Fischer, M. A., & Tatum, C. B. (2003). “Knowledge and reasoning for MEP coordination”. *Journal of Construction Engineering and Management,* 129(6), 627-634.

Krarti, M., Kreider, J. F., Cohen, D., & Curtiss, P. (1998). “Estimation of energy savings for building retrofits using neural networks”. *Journal of solar energy engineering,* 120(3).

Kwon, N., Song, K., Park, M., Jang, Y., Yoon, I., & Ahn, Y. (2019). “Preliminary service life estimation model for MEP components using case-based reasoning and genetic algorithm”. *Sustainability,* 11(11), 3074.

Levitt, R. E., Kartam, N. A., & Kunz, J. C. (1988). “Artificial intelligence techniques for generating construction project plans”. *Journal of Construction Engineering and Management,* 114(3), 329-343.

Loveday, D. L., & Virk, G. S. (1992). “Artificial intelligence for buildings”. *Applied Energy,* 41(3), 201-221.

Mahdavi, A. (1998). “Computational decision support and the building delivery process: a necessary dialogue”. *Automation in Construction,* 7(2-3), 205-211.

Marc Lahmann (2018, September). “AI will transform project management. Are you ready”? https://www.pwc.ch/en/insights/risk/ai-will-transform-project-management-are-you-ready.html.

Mehmood, M. U., Chun, D., Han, H., Jeon, G., & Chen, K. (2019). “A review of the applications of artificial intelligence and big data to buildings for energy-efficiency and a comfortable indoor living environment”. *Energy and Buildings,* 202, 109383.

Munir, M. (2019). “How Artificial Intelligence can help Project Managers”. *Global Journal of Management and Business Research*.

Nwodo, M. N., Anumba, C. J., & Asadi, S. (2017). “BIM-based life cycle assessment and costing of buildings: current trends and opportunities”. In *Computing in Civil Engineering 2017* (pp. 51-59).

Pampliega, C. J. (2019). “Artificial inteligence in construction sector”. Building & Management, 3(2), 1-5.

Petrova, E. A. (2019). "*AI for BIM-Based Sustainable Building Design: integrating knowledge discovery and semantic data modelling for evidence-based design decision support"* (Doctoral dissertation, Aalborg Universitetsforlag).

PMBOK guide (2017), *A guide to the project management body of knowledge*, 6th edition, PMI Inc.

Ron Schmelzer (2019, July). "AI in Project Management". https://www.forbes.com/sites/cognitiveworld/2019/07/30/ai-in-project-management/#2fde19cab4a0.

Sacks, R., Bloch, T., Katz, M., & Yosef, R. (2019). "Automating Design Review with Artificial Intelligence and BIM: State of the Art and Research Framework". In *Computing in Civil Engineering 2019: Visualization, Information Modeling, and Simulation* (pp. 353-360). Reston, VA: American Society of Civil Engineers.

Sacks, R., Girolami, M., & Brilakis, I. (2020). "Building Information Modelling, Artificial Intelligence and Construction Tech". *Developments in the Built Environment,* 100011.

Sean Fruin (2019). "Getting into the Flow of Generative Design for MEP". https://www.autodesk.com/autodesk-university/class/Getting-Flow-Generative-Design-MEP-2019.

Sean Fruin (2019). "Algorithms for MEP Design". https://www.sigma-aec.com/post/algorithms-for-mep-design.

Sumana Rao (2019, January). "The Benefits of AI in Construction". ttps://constructible.trimble.com/construction-industry/the-benefits-of-ai-in-construction.

Tatum, C. B. (2018). "Construction engineering research: integration and innovation". *Journal of Construction Engineering and Management*, 144(3), 04018005.

Tatum, C. B. (2018). "Learning Construction Engineering: Why, What, and How"? *Journal of Construction Engineering and Management*, 144(3), 04018004.

Tommelein, I. D., Levitt, R. E., & Hayes-Roth, B. (1992). "Site-layout modeling: how can artificial intelligence help"? *Journal of construction engineering and management*, 118(3), 594-611.

Ustinovičius, L., Rasiulis, R., Nazarko, L., Vilutienė, T., & Reizgevicius, M. (2015). "Innovative research projects in the field of Building Lifecycle Management". *Procedia Engineering, 122,* 166-171.

Xiao, C., Liu, Y., & Akhnoukh, A. (2018). "Bibliometric Review of Artificial Intelligence (AI) in Construction Engineering and Management". In *ICCREM 2018: Innovative Technology and Intelligent Construction* (pp. 32-41). Reston, VA: American Society of Civil Engineers.

Xiao, Y. Q., Li, S. W., & Hu, Z. Z. (2019). "Automatically Generating a MEP Logic Chain from Building Information Models with Identification Rules". *Applied Sciences*, 9(11), 2204.

A Framework to Manage Data Science Initiatives

Sandeep MATHUR[1], Shankar SANKARAN[2], Samuel MACAULAY[3] and Ivor TSANG[4]

Director, Transport for NSW, Level 1, 22 Ennis Road, Milsons Point, NSW 2061, Australia. email: Sandeep.Mathur@transport.nsw.gov.au [1]
Professor Organizational Project Management, University of Technology Sydney, School of the Built Environment, UTS City Campus, PO Box 123, Broadway, NSW 2007, Australia. email: Shankar.Sankaran@uts.edu.au [2]
Senior Lecturer, University of Technology Sydney, UTS Business School, UTS City Campus, PO Box 123, Broadway, NSW 2007, Australia. email: Samuel.Macaulay@uts.edu.au [3]
Professor of Artificial Intelligence, University of Technology Sydney, Australian Artificial Intelligence Institute, UTS City Campus, PO Box 123, Broadway, NSW 2007, Australia. email: Ivor.Tsang@uts.edu.au [4]

ABSTRACT

Data is increasingly ubiquitous in organizational life and Data Science Initiatives (DSIs) have emerged as a popular mechanism for extracting value from it. However, the track record of these programs has drawn substantial criticism. For example, the success rate of delivering DSIs is not perceived as high with Gartner estimating that 85% of projects fail. DSIs have unique characteristics and pose challenges delivering the envisaged value when using traditional processes for managing ICT-enabled programs. There are occasions when DSIs should be managed as Exploratory Projects.

In this theoretical paper, we review the related delivery frameworks and propose a framework synthesizing program management, change management, scaled agile, data management and data science domains. The framework covers people and processes and specifically excludes products and technologies. The framework may enable consistency in how the practitioners plan and execute the initiatives potentially leading to an improvement in the success rate of DSI implementations.

KEYWORDS

Exploratory Projects; Program Management; Change Management; Scaled Agile; Data Management; Delivery Framework.

Declaration of Conflicting Interests: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding: This research is supported by an Australian Government Research Training Program Scholarship.

INTRODUCTION

Data Science Initiatives (DSIs) have unique characteristics and pose challenges delivering the envisaged value when using traditional processes for managing ICT-enabled programs. Due to uncertainty they carry in data, scope and schedule, DSIs often present themselves as candidates to be managed as Exploratory Projects. Furthermore, the Waterfall approaches to program management adopted by peak bodies, set up structural tensions between business case development, program design, delivery and benefits realizations that decouple value creation from capture and thus undermine coherent governance across the investment life-cycle. In this paper, we expand on existing frameworks proposed in the program management, change management, scaled agile, data management, and data science domains and propose a synthesized framework to deliver DSIs as Exploratory projects. In context of this paper, we use the term Data Science Initiative (DSI) to include investments in Data Analytics, Business Intelligence and Data Science including Machine Learning and Artificial Intelligence.

Balancing exploration and exploitation is key to organizational success and survival (March, 1991). Exploitative projects focus on optimizing cost-quality-time triple constraints to deliver new products and services whereas exploratory projects are those projects where neither the goals nor the means of attaining them are clearly defined from the outset (Lenfle, 2008).

In this paper, we draw on in-depth case-studies of six Data Science Initiatives (DSIs) delivered over last four years at Transport for NSW (Transport). Transport is a state government enterprise responsible for delivering safe, integrated and efficient transport systems to the people of NSW. Figure 1 provides an overview of the six DSIs used as case studies which includes the delivery timeline and complexity. Case Study of six DSIs has showed that they have unique characteristics (Mathur, 2019) around degree of uncertainty; enablers for decision-making; unclear goals; interdependency and skills requirement.

We aim to contribute to project and program management research by proposing a synthesized framework explicating the different logic (Lenfle, 2016) required to deliver DSIs as exploratory projects and incorporating program management, change management, agile delivery, data management, and data science domains.

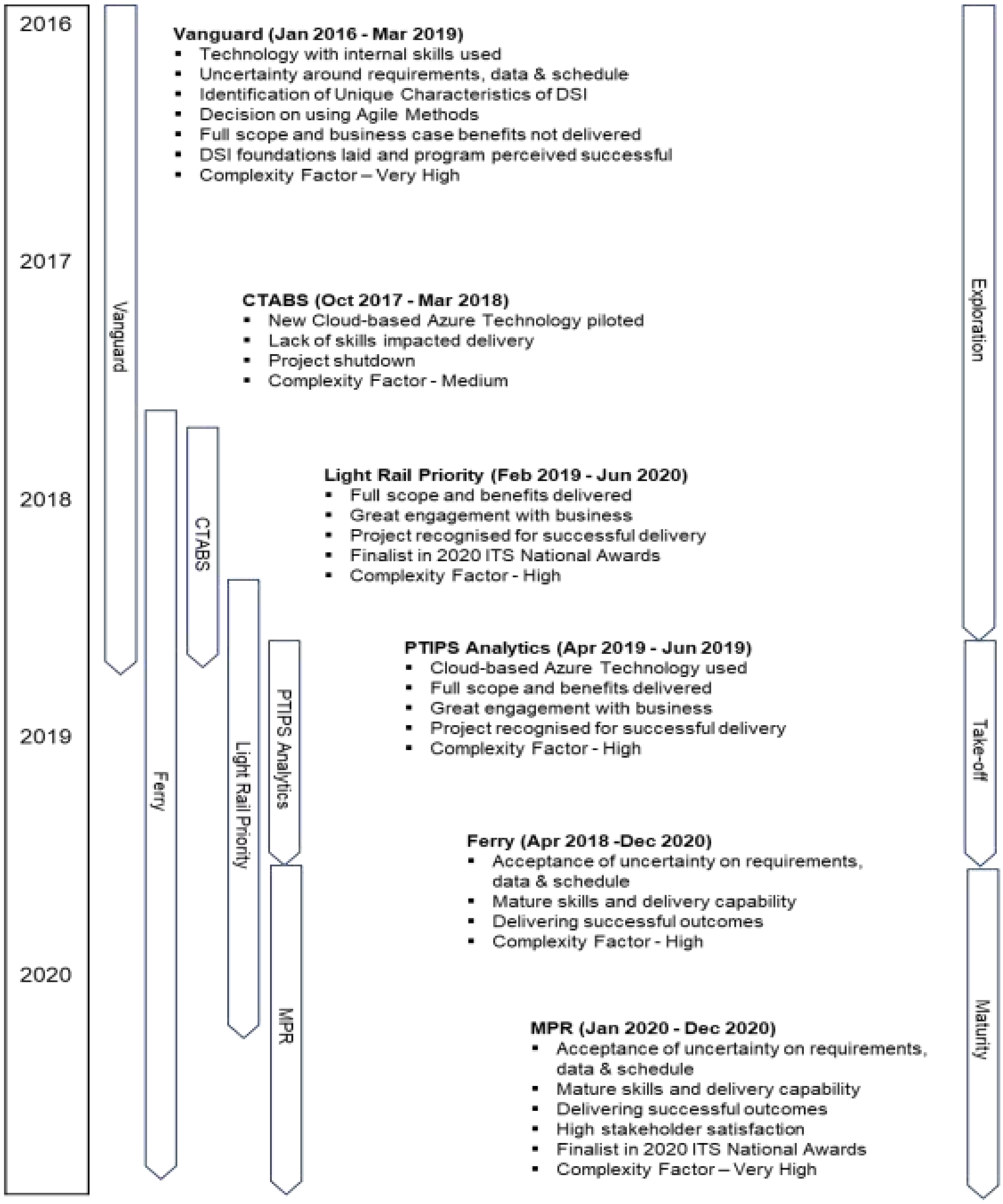


Figure 1. **Overview of six Transport for NSW DSIs**

MOTIVATION

Creation of a comprehensive program delivery framework for DSIs requires understanding of several domains and this section attempts to cover all such domains.

We see DSIs being typically implemented as a Program on a continuous spectrum rather than a single one-off project and will focus on Program Management rather than Project Management processes for delivery. A review of Program Life Cycle has identified gaps in using it for delivery of DSIs. Both PMI (Project Management Institute, 2017) and Managing Successful Programmes (MSP) (OGC, 2004) standards are widely accepted and used in the industry with PMI being principle-based and OGC providing detailed guidance on program management.

Value realization for any program occurs when the product and service created is adopted by users. Change management is a systematic approach that includes dealing with the transition or transformation of organizational goals, core values, processes or technologies. Kotter's Change Management Model (Kotter, 2007); McKinsey's 7-S Change Management Model (Lorenzi & Waterman, 1985); ADKAR Change Management Model (Hiatt, 2006) and Kübler-Ross Five Stage Change Management Model (Kübler-Ross, 2009) are some of the popular models used because of the simplicity in understanding them.

A need for large projects which are often globally distributed with teams requiring collaboration and coordination has led to popularity of scaled-agile frameworks such as Scaled Agile Framework (SAFe), Large-Scale Scrum (LeSS) and Lean Scalable Agilty for Engineering (LeanSAFE) (Ebert & Paasivaara, 2017; Leffingwell, 2007). In context of DSIs, we see the relevance of scaling is high as often multiple geographically spread teams within an organization are involved in delivering data science outcomes. A comparison of various five scaled agile framework shows each of them have strengths depending upon the use case in an organization.

Data Management is the development, execution, and supervision of plans, programs, and practices that deliver, control, protect, and enhance the value of data and information assets throughout their lifecycles (Earley, 2017).

Development of a DSI Delivery Framework requires good understanding of Data Mining and Data Science delivery processes. The Knowledge Discovery in Databases (KDD) (Fayyad, Piatetsky-Shapiro, & Smyth, 1996); Cross-Industry Standard Process for Data Mining (CRISP-DM) (Chapman et al., 2000); Sample, Explore, Modify, Model and Assess (SEMMA) model (SAS Institute, 2009); OSEMN model (Mason & Wiggins, 2010); Team Data Science Process

(TDSP) (Severtson, Franks, & Ericson, 2017) and Foundational Methodology for Data Science (FMDS) methodology (Rollins, 2015) are models considered appropriate in this context.

This view of the literature motivated us to ask the following research question: *"What design principles should be incorporated in a Data Science Initiative (DSI) Delivery Framework so that program managers can adopt a predictive path to realize value from such investments*?".

RESEARCH SETTING AND METHODS

Our research insights emerged from primary author's desire to deliver DSIs effectively underpinned by Future Transport 2056 Strategy to embed technologies such as big-data, internet of things, machine learning and artificial intelligence to deliver and improve customer journeys. Taking a practice lens on delivery of DSIs guided us to focus on full life-cycle of DSIs. Such a focus requires deep engagement in the field, observing and interacting with decision-makers, business stakeholders, program managers and delivery team members. As a result, we chose to study delivery of DSIs within a single organization (Transport) where the primary author of this paper is employed full-time and is setting up DSI delivery capability while delivering DSIs. This gave him access to data to conduct the case studies. To obtain granularity of program life-cycle as well as variation for analytical comparisons, we used an embedded case design (Yin, 2018) to track the unfolding of six DSIs in Transport, each of which provided a unique scope and opportunity to build DSI delivery capability. The six DSIs provide us with an opportunity to use an embedded case study research method covering all three purposes – exploratory, descriptive and explanatory (Scholz & Tietje, 2002; Yin, 2018). Our interest was to understand DSI delivery as experienced by the organizational participants themselves and identify uniqueness with this portfolio of initiatives to bring in improvements within the organization.

We used a variety of evidence including documents, artifacts, and participant observations from each DSI. Consistent with inductive research approaches, our research question emerged over time, as we engaged iteratively with evidence from the field and extant research that helped us make sense of what we had found.

The primary author is the program manager of the six DSIs chosen as case studies which were delivered between January 2017 to December 2020 or are still being delivered and thus brings in-depth insights of the program life-cycle.

This paper organizes the case by bracketing it into three project-stages: Exploration, Takeoff and Maturity stages Transport went through while six DSIs were delivered. The stages can be roughly mapped to DSIs delivery timeline of Exploration stage mapping to Vanguard & CTABS; Take-off stage mapping to Ferry, Light Rail Priority and PTIPS Analytics; and Maturity stage mapping to MPR. *Figure 1* shows the timeline and highlights of the six DSIs indicating author's journey from uncertainty and frustration of not being able to deliver program outcomes as per the schedule to acceptance of exploratory nature of DSIs and ability to plan the uncertainty and engage the stakeholders effectively. While each of the six DSIs were unique, this paper focuses on first (Vanguard) and sixth (MPR) as they represent boundary conditions of story presented here i.e., we present details of initial Exploration stage and close with that of Maturity stage.

DATA COLLECTION AND ANALYSIS

Six DSIs from Transport managed by the author have been used to collect data. Four DSIs are closed and two are still being delivered which has allowed us both real-time and retrospective data collection. While the scale of the DSIs is different, together they paint a good picture of unique characteristics and business cases. Table 1 shows the gaps and issues identified across three program phases.

DSI DELIVERY FRAMEWORK

In this section we review the design principles used to build the framework, the framework, and processes of the framework.

The Design Principles

Considering the exploratory nature of DSIs, the framework will conform to the following design principles:

- End-to-end delivery of solution and value realization;
- Core and non-core domains identification;
- Use agile methods to support exploratory nature of DSIs instead of waterfall;
- Support both single team and scaled agile delivery of data science capability;
- Specify people, process and deliverables; and
- Agnostic to tools and technologies

Table 1. Program Life-Cycle Deliverables & DSI Gaps & Issues

Key Phase Deliverables	**Gaps & Issues for DSIs**
Program Definition Phase	
Key deliverables of this phase are Business Case, Program Charter and Program Management Plan.	• For DSIs, risks associated with both costs and benefits are high. Considering the time it takes to develop and get a Business Case approved in both public and private sectors, the accuracy of the documents is questionable. • Unless the Program Management Plan stays at a high level, the accuracy of scope and schedule is low. The delivery mechanism will evolve as the Components are identified and executed.
Program Delivery Phase	
In this phase, individual Components are initiated, planned, executed, transitioned, and closed while benefits are delivered, transitioned and sustained in accordance to the Program Management Plan.	• For DSIs, identification of all Components upfront is difficult at the time Program Management Plan is developed and hence only limited planning can be done due to high degree of uncertainty • The Benefits will be discovered as the Components are planned & executed again due to high degree of uncertainty
Program Closure Phase	
In this phase, the Program Benefits are transitioned to sustaining organization and program is closed.	• While sponsor and stakeholders are continuously communicated and kept informed on both the costs and benefits delivered, for an un-initiated stakeholder the value delivered by the program may be questionable. The outcomes are often enablers to organizational decision-making capability rather than absolute financial and non-financial metrics.

The **F**ramework

The proposed framework has five core domains and integrates PMI's The Standard for Program Management (Project Management Institute, 2017) for program management; Proscii Framework (Hiatt, 2006) for people change management; Scaled Agile (SAFe) (Scaled Agile,

2020) for solution delivery; DAMA's DMBoK (Earley, 2017) for data management; and CRISP-DM (Chapman et al., 2000) for data science processes as per Figure 2 representing methods for the five domains.

As the domains are modular, it allows organizations to replace methods. For example, in program management domain PMI's methods (Project Management Institute, 2017) can be replaced with MSP (OGC, 2004). Furthermore, the framework is flexible to allow integration with other organizational domains such as Risk Management, Procurement Management, Asset Management, etc. Each process in the domain has been described in detail for the framework to be adopted by an organization implementing DSIs.

CONCLUSION

Limited availability of methods and standards in delivery of DSIs has caused the business managers and program managers to chart their own path and thus introduce inconsistency in how DSIs are treated and delivered in different organizations. With emergence of research such as this, it is expected that the standardization on DSIs will increase and provide guidance to the practitioners in efficient delivery of the DSIs.

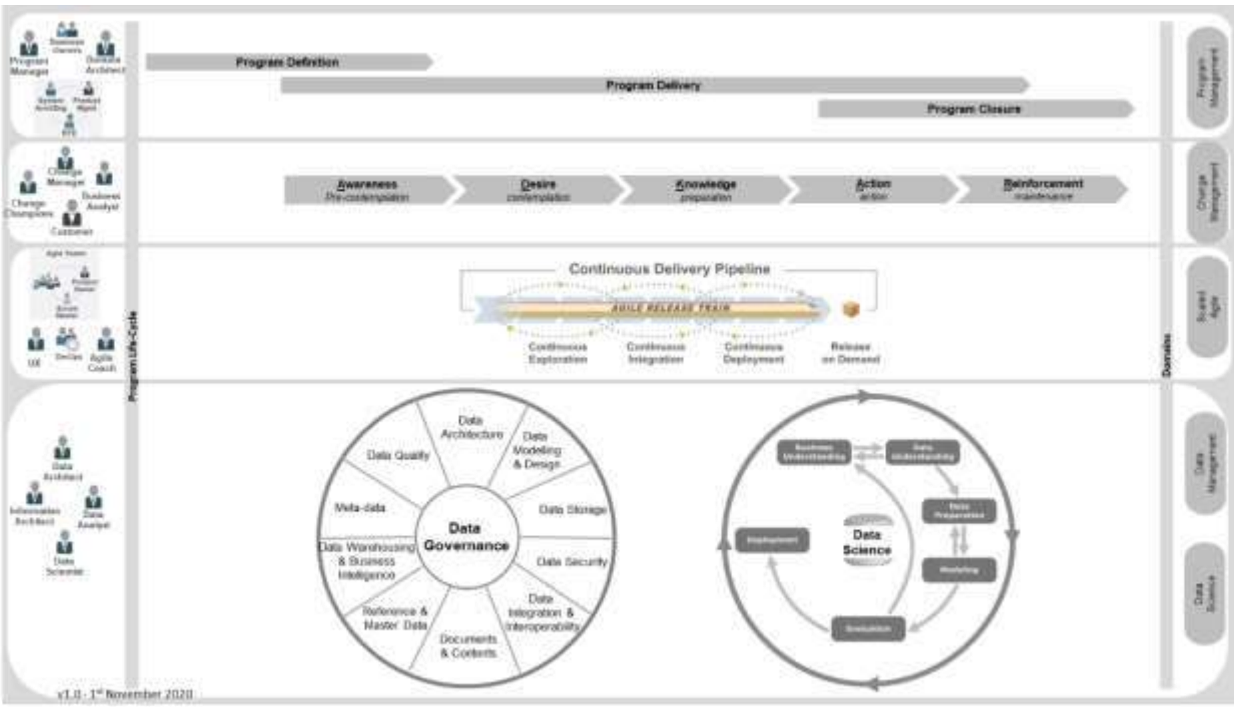


Figure 2. **DSI Delivery Framework**

Program Management for ICT-enabled Programs has rich literature and proven delivery frameworks which have matured over the past three decades (Project Management Institute, 2016, 2017; OGC, 2011). This paper makes a significant contribution to the theory and practice of the emerging field of data science.

The current Program Management literature does not adequately support delivery of DSIs and instead focuses on risk elimination and rapid delivery of business outcomes. We propose a DSI Delivery Framework which has five core domains and integrates PMI's The Standard for Program Management (Project Management Institute, 2017) for program management; Proscii Framework (Hiatt, 2006) for people change management; Scaled Agile (SAFe) (Scaled Agile, 2020) for solution delivery; DAMA's DMBoK (Earley, 2017) for data management; and CRISP-DM (Chapman et al., 2000) for data Science processes as per *Figure 2* representing methods for the five domains.

We suggest additional research to fine-tune the proposed DSI Delivery Framework which currently has been used for one public sector organization (Transport). The authors of the paper already intend to validate the trustworthiness and reliability of the framework through monitoring the use of framework at Transport as well as semi-structured interviews with practitioners and portfolio managers from other organizations. The framework proposed in this research will deliver a significant contribution to the body of knowledge for Program Management relevant to both literature and practitioners. Without this work, there will be more failed programs, dissatisfied sponsors and delay much needed investment in this emerging field as well as delay the benefits that will flow from harnessing the data and the nuggets in it.

REFERENCES

Chapman, P., Clinton, J., Kerber, R., Khabaza, T., Reinartz, T., Shearer, C., & Wirth, R. (2000).

CRISP-DM 1.0: Step-by-step data mining guide. *SPSS inc, 9*, 13.

Earley, S. E. (2017). DAMA-DMBOK: Data management body of knowledge. *Technics Publications*.

Ebert, C., & Paasivaara, M. (2017). Scaling Agile. *IEEE Software, 34(6), 98-103*.

Fayyad, U., Piatetsky-Shapiro, G., & Smyth, P. (1996). The KDD process for extracting useful knowledge from volumes of data. *Communications of the ACM, 39*(11), 27-34.

Hiatt, J. (2006). *ADKAR: a model for change in business, government, and our community*: Prosci.

Kotter, J. (2007). Leading change: Why transformation efforts fail. *Harvard business review, 86*, 97-103.

Kübler-Ross, E. (2009). *Death: The Final Stage*: Simon and Schuster.

Leffingwell, D. (2007). *Scaling software agility : best practices for large enterprisesAgile software development series* (pp. 1 online resource (xxix, 349 pages)).

Lenfle, S. (2008). Exploration and project management. *International Journal of Project Management, 26*(5), 469-478.

Lenfle, S. (2016). Floating in space? On the strangeness of exploratory projects. *Project Management Journal, 47*(2), 47-61.

Lorenzi, P., & Waterman, R. H. (1985). In Search of Excellence. *Journal of Organizational Behavior, 6*(3), 246-247.

March, J. G. (1991). Exploration and exploitation in organizational learning. *Organization science, 2*(1), 71-87.

Mason, H., & Wiggins, C. (2010). A taxonomy of data science. *Dataists. com*(9).

Mathur, S. (2019). Unique Characteristics of Data-Analytics Programs. *PMI Australia Conference, Gold Coast*. Retrieved from https://www.pmiaustraliaconference.org.au/wp-content/uploads/2019/06/Sandeep-Mathur.pdf

OGC. (2004). *Managing successful programmes*: TSO.

Project Management Institute. (2017). *The standard for program management,*(Fourth edition. ed.).

Rollins, J. (2015). Foundational methodology for data science. *Domino Data Lab, Inc., Whitepaper*.

SAS Institute. (2009). *Getting Started with SAS Enterprise Miner 6.1*: SAS Institute.

Scaled Agile. (2020). SAFe for Lean Enterprises 5.0. Retrieved from https://www.scaledagileframework.com/

Scholz, R. W., & Tietje, O. (2002). *Embedded case study methods: Integrating quantitative and qualitative knowledge*: Sage.

Severtson, W. R. B., Franks, L., & Ericson, G. (2017). What is the team data science process? *Microsoft Azure*.

Yin, R. K. (2018). *Case study research and applications : design and methods* (Sixth edition. ed.). Thousand Oaks, California: SAGE Publications, Inc.

Data Analytics to Evaluate Public Value from Megaprojects

Ganesh DEVKAR[1], Shankar SANKARAN[2], Yongjian KE[3], Johan NINAN[4], Sandeep MATHUR[5], Ivor TSANG[6] and Lauri VUORINEN[7]

CEPT University; email: ganesh.devkar@cept.ac.in [1]
University of Technology Sydney; email: shankar.sankaran@uts.edu.au [2]
University of Technology Sydney; email: yongjian.ke@uts.edu.au [3]
Indian Institute of Technology Guwahati; email: johanninan@gmail.com [4]
Transport for New South Wales; email: sandeep.mathur@transport.nsw.gov.au [5]
University of Technology Sydney; email: ivor.tsang@uts.edu.au [6]
Tampere University; email: lauri.vuorinen@tuni.fi [7]

ABSTRACT

The unprecedented investment in megaprojects that has been witnessed in recent years seems likely to accelerate post Covid-19 with several countries, like Australia and the United Kingdom, announcing large infrastructure projects for economic revival. COVID-19 has also created social challenges due to increased unemployment that could result in increase in poverty which could be helped when these projects become a reality. However, some scholars caution that rapid urbanisation and inappropriate development of infrastructure could work against containing a pandemic like COVID-19. The creation of value delivered by megaprojects has been gaining a lot of interest by scholars studying megaprojects. Big data sets are increasingly used to help public managers derive real-time insights into behavioural changes, public opinion, or daily life. Big data has been used to evaluate customer agility and responsiveness for public value creation. Based on this need this paper we would like to address the following question in our paper: How can data science enable evaluation and monitoring of delivery of public value over the life cycle of a megaproject?. Some work towards this aim has already been carried out by the authors but more is needed. The authors have been collected and analyzed social media data from transport projects from Australia and India to see how large amounts data collected from these media can aid in the evaluation of benefits realized from these projects

KEYWRODS

Public value, Big data, Megaprojects, Metro Rail

INTRODUCTION

The unprecedented investment in megaprojects that has been witnessed in recent years seems likely to accelerate post Covid-19 with several countries, like Australia and the United Kingdom, announcing large infrastructure projects for economic revival. COVID-19 has also created social challenges due to increased unemployment that could result in an increase in poverty which could be helped when these projects become a reality. However, some scholars caution that rapid urbanisation and inappropriate development of infrastructure could work against containing a pandemic like COVID-19. The environmental damage caused by rapid urbanisation has prompted urban planners to rethink the ways in cities can be developed in the future. Future cities need to foster both individual and collective wellbeing, with realization of ambitions, aspirations and other immaterial aspects of life and providing contentment and happiness. How do we ensure that such aspirations are not neglected in a rush to build more infrastructure? How do we ensure that social and environmental issues will be taken into account while responding to an urgent economic need for building more megaprojects? This brings us to be concerned about how public value will be taken into account and monitored in the building of new infrastructure in post Covid-19.

LITERATURE REVIEW

The centrality of public value in the spheres of public service delivery has been increasing over the years owing to the emphasis and debates over "substantive values" the organizations, involved in public service delivery, should be producing (Alford et al. 2017). These debates have immensely contributed to the conceptualization of the term "public value" as well as ways and means of imbibing, enhancing and assessing the public values. There exist diversity in the construct of public value, proposed by different scholars. Reynaers (2014) has created this construct in the context of infrastructure project delivered via PPP mode, which includes elements like accountability, transparency, responsiveness, responsibility and quality. The ambiguity over what constitutes public value and need for greater clarity, was the foundation of a paper by Andersen et al (2012). This paper has classified and empirically tested values of public managers and identified distinct public value dimensions alike public at large, rule abidance, balancing interests, budget keeping, efficient supply, professionalism and user focus. Alford & O'Flynn (2009) have made good sense of the concept of public value, by revisiting the origin of the term public value and current state of debates, and discussed emergent meanings of public values as paradigm, retheroic, narrative and performance. While the researchers are striving towards the better and more clearer conceptualization of public values, the another stream of literature has been elaborating on creation of public values in infrastructure development and value conflicts faced by public managers in the areas of infrastructure development and megaprojects implementation. For example, how stakeholder engagement in co-creation sessions helped in cocreation of public values in front end of infrastructure development programs has been discussed by Liu et al (2019). In similar vein, Thøgersen et al (2020) discussed the value creation through public innovation from the perspective of Danish public sector managers. Another set of empirical studies indicate dilemmas and trade-offs faced in pursuing public values and come up with various strategies or coping behaviour to manage or tide over these value conflicts (Oldenhof et al. 2014; Steenhuisen and van Eeten 2008).

While discussing the foundational issue over the use of the concept of "public value" or that of "public values", Alford et al.(2017) have aptly drawn attention towards an interesting aspect of "created public value - CPV" and "recognizing public value - RPV". They mention this aspect as follows:

> *'The utility notion of value suggests that what is being 'created' (as in CPV) and should be 'recognized' (in RPV, now in the sense of being 'measured') is an aggregate, a net resultant of what in reality are a wide range of concepts of utility or worth, which moreover can pertain both to the content of the service being delivered and the manner in which it is being produced.'. (p. 593).*

The authors of this paper are of the opinion that this aspect - CPV and RPV mentioned by Alford et al.(2017), indicates the emergent trend in the direction of "evaluation", "assessment" and "measurement" of public value. Interestingly, this paper is also focusing on evaluation of public value and is in line with this emerging trend.

The creation of value delivered by large infrastructure projects in the transport sector has been gaining a lot of interest by scholars studying megaprojects (Merrow 2011; Vickerman 2013). These scholars have explored diverse facets like stakeholder engagement in the megaproject delivery process; evaluation of social responsibility; cocreation of commercial, intellectual and collaborative values; and value creation in megaprojects through jointly planned and governed design principles, and value leveraging activities. A common concern of scholars researching in megaprojects is how to measure value perceived by the public from these projects (Lehtinen et al. 2019).

Simultaneously big data sets are increasingly used to help public managers derive real-time insights into behavioural changes, public opinion, or daily life (Mergel et al. 2016). Big data has been used to evaluate customer agility and responsiveness for public value creation. It is predicted that new smart technologies and strategies will shape and will be shaped by the future of public organizations and management and could lead to transformative practices in the public sector. Thus, there is a growing need to examine how smart technologies, such as Internet of Things (IoT), can be installed to collect large amounts of data to help in the measurement of value from megaprojects.

Based on this need this paper we would like to address the following broad question:

How will big data and data analytics help us to take into account and monitor public value creation from megaprojects?

And to delimit the scope for this paper based on reviewer comments we like to ask:

What are the barriers and opportunities for using big data and data analytics in public value creation from metro rail projects in Australia and India?

Big Data

According to Mergel et al. (2016)

> *Public administration researchers and practitioners for most of the fields history have bemoaned the lack of data for analysis and operations. In the space of roughly two decades, the Internet has turned this problem on its head. Now, scholars and practitioners are scrambling to realize the opportunities and face the challenges that "big data" presents. These "big" data sets are increasingly used to help public managers derive real-time insights into behavioural changes, public opinion, or daily life. p. 928*

However according to Kim et al. (2014)

Although the business sector is using bigdata in decision making the public sector is also catching up to support decision making in real time by fast growing dynamic data. But there is scepticism about Government's use of big data as it takes time to develop new capabilities and adopt new technologies. There are also difference in the way business and government use big data based on their attributes. p.80

While big data seems to have enormous potential for public administration there is scepticism about whether this can be realised in practice. There are also differences in which big data is can be valuable to public organizations compared to private organizations

Let us examine some key differences between how businesses and governments get value from big data. See Table 1.

Table 1 Comparison of value created by big data for private and public enterprises . (Adapted from Kim et al. (2014), p.80)

Attribute	**Business Firm (Private)**	**Government (Public)**
Value	Profit to stakeholders by achieving value for money	Promoting domestic tranquillity and sustainable development
Achievements	Achieving competitive edge, customer satisfaction	Enabling security of basic rights (equality, liberty, justice), promotion of general welfare and economic growth
Decision Making	Maximizing self-interest and minimizing cost for short term gain	Promoting public interest through long-term decision-making
Financial gains	Revenue	Taxes
Collective activities	Competition and engagement	Cooperation and compliance verification

The three qualities of big data that make it difficult to make sense from it are (Kim et al. 2014):

Volume: Big Data can be generated in large volumes in terabytes, even petabytes requiring enormous storage and capacity to handle data.

Velocity: The data can be generated and processed in a very short time making it easier to make decisions faster. However, the pace of decision making may not be commensurate with the pace of generation and processing of big data.

Variety: It can be collected in a variety of forms – structured, semi structured and unstructured from a variety of sources posing problems for sensemaking.

While big data is a term used in several disciplines, a report proposed by the National Science Foundation is adopted by the US Government (Favaretto et al. 2020). According to this definition, big data is:

> *large, diverse, complex, longitudinal, and/or distributed data sets generated from instruments, sensors, Internet transactions, email, video, click streams, and/or all other digital sources available today and in the future p. 3*

On the other hand, the European Commission defines big data with a broader perspective (Favaretto et al. 2020)

> *large amounts of different types of data produced from various types of sources, such as people, machines or sensors. This data includes climate information, satellite imagery, digital pictures and videos, transition records or GPS signals. Big Data may involve personal data: that is, any information relating to an individual, and can be anything from a name, a photo, an email address, bank details, posts on social networking websites, medical information, or a computer IP address P. 2/3*

However, Favaretto et al. (2020) who recently carried out a survey of researcher's' understanding of big data as the phenomenon of the decade suggested that the definition varies across disciplines but overall there is an agreement that big data '*as huge amounts of digital data produced from technological devises that necessitate specific algorithmic or computational processes in order to answer relevant research questions*' (p.14). However, they found some challenges in advocating a precise definition due to the flexible meaning that big data provides to social science fields as opposed to computational science. Therefore '*Big Data in its current cultural meaning it's a tremendously vast concept that includes different subcategories and specifics that are characterised by different technical and regulatory challenges'* (p.16).

A similar sentiment was expressed by Mergel et al. (2016) on the disparity between how big data is defined across disciplines. See Table 2. You can see that as the disciplines change the tone of the definition changes.

Table 2: Differences in defining big data across disciplines (Extracted from Mergel et al. 2016, p. 929).

Source	Discipline	Definitions
(Janssen and van den Hoven 2015)	IT	"massive quantities of information produced by and about people, things, and their interactions" (p. 662)
Lazer et al (2020).	Computational Social Sciences	"Second-by-second picture of interactions over extended periods of time, providing information about both the structure and content of relationships" (p. 2)
George et al.(2014)	Management	"Big data is generated from an increasing plurality of sources, including Internet clicks, mobile transactions, user-generated content, and social media as well as purposefully generated content through sensor networks and business transactions such as sales queries and purchase transactions" (321)
Clark and Golder (2014)	Political Science	"Technological innovations such as machine learning have allowed researchers to gather either new types of data, such as social media data, or vast quantities of traditional data with less expense" (p. 65)
Pirog (2014)	Public Policy	New formats, quality, and availability of administrative data (volume, velocity)

Mergel et al. (2016) argue that:

> *These perspectives from across related fields highlight the need for cross-isciplinary collaboration among social scientists, who have substantive depth on research methods and theory, and computer scientists, who have the computational and methodological skills to construct and analyze algorithms on data structures p. 930*

Next we discuss the challenges that will be faced by governments and public agencies to make effective use of big data.

Challenges to the Use of Big Data

The challenges faced by governments and public agencies to derive benefits are summarised in Table 3.

Table 3: Challenges to effective use of big data

Source	Nature of challenge	Specific challenges
Kim et al. (2014); Kilevink et al (2017)	Comes in many forms	Multiple channels (web, crowdsourcing, social networks) and sources (institutions, agencies, departments and other countries
	Silo	Government divisions may have their own data warehouses without integration
	Format	Lack of a cohesive format even when structured as agencies may use different types of solution that make it difficult for extraction
	Security	The sources may hold confidential information about the public. Legality and privacy issues. Autonomy may create increased responsibility for results.
	Capability	Availability of data scientists and statisticians. Lack of competence among public officials to make sense of big data and opportunities. Lack of tools and readiness to make clear judgments and organizational maturity.
Azzone (2018); Klievink et al.(2017)	Speeding up legislation	How to avoid violating democratic principles while changing laws
	Equity	Deciding on fair level of service
	Dark side	Unleashes the dark side of big data.

Andrews (2019) carried out a 18 month qualitative review of various sources including papers, media, reports to look at algorithmic risks arising from the use of big data and listed six broad challenges to the use of big data to create public value:

1. Selection error that could be caused by facial recognition data which could lead to targeting specific communities and even sacking people unfairly.
2. Law breaking by using special devices to create data to show positive results or avoid penalties as it happened with the recent Volkswagen scandal with emission data.
3. Manipulation of data that creating less reliable news and influencing the public as it is happening in national elections.

4. Propaganda based on false information similar to how elections are being influenced from foreign countries.
5. Contamination: Triggering buying decisions such as targeted advertising.
6. Complexity: Fear that data science techniques such as machine learning may make it very difficult for humans to make sense of decisions being made.

Big Data Opportunities

Despite all the challenges several opportunities have been identified, which has made several governments develop national strategies to promote big data applications.

Mergel et al. (2016) pointed out that:

> *Public administration researchers and practitioners for most of the field s history have bemoaned the lack of data for analysis and operations. In the space of roughly two decades, the Internet has turned this problem on its head. Now, scholars and practitioners are scrambling to realize the opportunities and face the challenges that "big data" presents. These "big" data sets are increasingly used to help public managers derive real-time insights into behavioural changes, public opinion, or daily life. p. 928*

Azzone (2018) pointed out the following opportunities using big data to improve government policies:

1. Design of personalized policies with precision moving away from polices developed for an average population. As an example, relief can be targeted to more vulnerable populations in risky situations instead of doling out funds uniformly.
2. Using weak signals to anticipate policy changes: Use of even unintentional signals to evaluate socio economic trends or identify threats such a position data by tracking mobile phones.
3. Anticipating and creating new services: Sentiment analysis of social media data can help in this strategy. Also helps in testing out co-designed services.

Klievink et al. (2017) added that using big data in the public sector would enable better decision support; informed policymaking; a better picture of evolving reality; and even help to solve lingering social issues such as more equitable healthcare provision, sustainable energy production and alleviating transport congestion.

Government Initiatives

According to Kim et al. (2014), several countries are now collaborating with major technology providers like IBM to establish large scalable infrastructure for big data. The US government is an example of how they launched data.gov with the help of IBM. In Europe, a digital agenda has been formed to overcome challenges in handling big data. The UK set up the Horizon Scanning Centre as a way of working across disciplinary challenges. Asian countries like Japan, Korea and Singapore have been at the forefront with the use of big data. The Australian Government Information Management Office is taking the lead on big data for public use. The Indian Government has rolled out a big data initiative called project insight. Thus governments are exploring how open data can bring national benefits.

Big data and public value in the context of megaprojects

How can big data assist in the quest for public value? According to Mergel et al (2016) '*the ambiguous, multifaceted, and contested 'bottom line' of creating 'public value' (Bryson, Crosby & Bloomberg 2014, Moore 1995, Moore (2014) generate a set of important questions and concerns*'. They suggested that in the context of big data these issues must be paid special attention.

Despite these concerns project management researchers, are demanding expectations from megaprojects to create social and societal value which are also in line with the expectations of public value. Ma et al. (2017) argued that 'The prolonged lifecycle and heterogeneous stakeholders of megaprojects have posed great challenges for the governance of the economic, social, and environmental issues involved' (p. 1365). Wang et al. (2020) raised another concern about megaprojects - sustainable development. They suggested that the boom in megaprojects is having 'a significant impact on social and economic developments (e.g., immigrant settlement, poverty eradication, and public health) as well as the natural environment (e.g., ecological processes and biodiversity)' (p. 831). This is also echoed by Lin et al. (2017) who have developed 'a holistic indicator system' by 'integrating project life-cycle dynamism, stakeholder heterogeneity, and social responsibility interactivity' (p. 1415). Such indicators can help us to find ways to evaluate the creation of public value from megaprojects.

This paper looks at five dimensions of public value based on a public value framework (Reynaers 2014)

1. Accountability
2. Transparency
3. Responsiveness
4. Responsibility
5. Quality

Accountability denotes the ability of the procurer to account for the project to the responsible minister in terms of the financial, juridical, and technical content of the project and the actual performance of the consortium. Transparency means the availability, accessibility, and accuracy of the information on juridical, financial, technical, and operational aspects of the project. Responsiveness is the ability of elected officials and public servants to determine, influence, and adjust the contractual agreements and the output specifications before and after contract closure. Responsibility measures the degree to which the consortium complies with the contractual agreements and the output specifications. Quality denotes the degree of satisfaction of the procurer in relation to the asset and the actual exploitation as provided by the consortium.

Some work towards this aim has already been carried out by the authors, but more is needed. The authors have been collecting and analysing social media data from transport projects from Australia and India to see how large amounts of data collected from these media can aid in the evaluation of benefits realised from these projects

Big data can be generated from a wide range of sources to create value in infrastructure megaprojects. Sensors can record the people movement in stations (Alawad and Kaewunruen 2018) and can help decision-makers increase or decrease the frequency of trains for certain periods of the day. The way people move within the stations can also help decision-makers allocate commercial space in the stations effectively. Another source of big data generated by infrastructure users is the data available on social media. Social media data can enable us to understand megaprojects better as many conversations relating to projects are only evident online and they are not currently captured or analysed (Ninan 2020). Even though there are large amounts of data generated in the social media regarding infrastructure projects daily, researchers have not explored the scope of using this big data for decision-making in infrastructure projects. It is in this context that we situate our research to understand the scope of using social media to generate public value in infrastructure megaprojects.

METHODOLOGY

To understand how big data from social media can be used to create value in infrastructure megaprojects, we chose a qualitative research methodology. Scholars have suggested that such a method is apt for exploratory research when the aim is to gain familiarity with a problem or to generate new insights for future research (Eisenhardt 1989; Scott 1965). Within the qualitative research methodologies, we chose to use multiple case study method as it provides excellent opportunities to enhance contextual understanding and simultaneously enable the generalization of findings (Flyvbjerg 2006; Yin 2017).

We chose the case study of a metro rail project in Australia and India to understand the scope of using big data for creating public value. We selected the Sydney metro rail project from Australia and the Chennai metro rail project from India because of their similarities. Both the projects started operation around the same time and had similar track length, 36 kms and 45.1 kms respectively. All twitter posts of the Sydney metro rail project and Chennai metro rail project was captured through a Twitter search API. The keywords are the titles of two projects, i.e. "Chennai Metro" and "Sydney Metro". It is acknowledged that some tweets would not be retrieved if they discussed the two projects without using the keywords. No duplicates were observed on checking the unique ID of each tweet, and the collected data were stored as a comma-separated values (CSV) file. We collected the tweets for a 90-day period from 1 July 2019 to 30 September 2019, during which both the metro rail projects were operational. There were 5960 tweets relating to the Sydney metro rail project and 1064 tweets relating to the Chennai metro rail project. All the tweets were in English.

For analysis, we used content analysis and open coding of the tweets collected to understand what each tweet conveyed. The process was very iterative and we took multiple readings of the tweets as some categories are often not obvious until the second or third reading (Steger 2007), due to the focus on content and meaning. We employed manual coding as automatic methods could create a barrier to understanding in this exploratory study (Kozinets et al. 2014).

FINDINGS AND DISCUSSION

For the analysis of the social media tweets collected from the Sydney metro rail and Chennai metro rail, we find that there is potential in using social media for generating value in infrastructure projects. Value can be created by using big data in social media for addressing real time operational issues, collating the suggestions to improve, and capturing the live sentiments associated with the project.

1. Big data for addressing real time operational issues

Issues relating to operation of the infrastructure service have to be addressed as soon as possible for smooth service. The users widely shared operational issues relating to the project on Twitter across both projects. In Chennai metro rail, one user complained in Twitter that the doors were not opening in one of the stations as below,

> *"Crazy. @chennaimetro rail's doors didn't open when it stopped @Pachaiyappas metro station, at around 11am today, putting the passengers to hardships. What's happening?" (2 Sept 2019)*

Similarly, in the case of Sydney metro rail, a user complained about lifts being out of service in one of the stations.

> *"The lift between the concourse and the platforms at North Ryde is out of service"* (29 Sept 2019)

Social media provides an excellent platform where users of the infrastructure service post day to day operational issues surrounding the projects. We can create more value in infrastructure projects if we can systematically collect this big data, analyse them through algorithms, and efficiently communicate it to the service team to mitigate the current issue through timely action.

2. Big data for collating suggestions to improve

Many users are active stakeholders offering multiple suggestions to improve the services. In contrast to operational issues, suggestions to improve are more than addressing an operational defect on a particular day. For example, in the case of the Sydney metro, a user offered a suggestion to fix the 15 second door opening duration before people get hurt, as below.

> *"@SydneyMetro Your 15 second door opening is stupid and dangerous. People cannot get off the train in the fifteen seconds. Fix it before people get hurt"* (16 Sept 2019).

Similarly, in the case of Chennai metro, a user suggested to bring down the ticket costs and this will lead to more traffic and hence revenue, as below.

> *"Volumes shud b the mantra & increased patronage vl automatically bring in more revenue & help in bridging gap btw cost & income."* (30 Sept 2019).

Collating such suggestions to improve can help the project create more value for the society as decision makers would know the main issues raised by the community.

3. Big data for capturing the live sentiments associated with the project

The users also communicated their feelings regarding the project on social media. They posted selfies and took pride in the megaproject being in their city. In one instance, a user in the Sydney metro rail claimed they are having fun and feel like they are on a holiday, as below.

> *"Tbh going on the Sydney metro makes me feel like I'm on holidays … So fun"* (30 Sept 2019)

In the case of Chennai metro rail, a user claimed that the project is a step towards public transport as many are leaving their cars and choosing to travel by metro. The user also claims that the metro rail is a safe, convenient and clean means of transport, as highlighted below.

> *"Yes, of course. It's getting there. It's visible in office as there are many of us who leave our cars at the station and take the Metro. So many people exercising this option that safe and convenient and clean"* (20 Aug 2019)

Capturing live sentiments can give guidance to investors to make long term strategic decisions such as which route has to be expanded. It can also help the project take suitable steps to improve the sentiment associated with the project such as offering complimentary rides for school children or celebrating a regional festival (Ninan et al., 2019). By using big data from social media to analyse sentiments, decision-makers can take proper strategic decisions to create more value to the public.

While the analysis of the big data from social media can help create value in infrastructure projects, there are certain challenges in analysing the data. Challenges such as the predominance of negative tweets and presence of interest groups can bias the findings from the big data.

1. Predominance of negative tweets

People generally log into social media to criticize rather than to praise (Park 2015). There were more tweets with complaints about the infrastructure service than compliments about it. In the case of the Chennai metro rail project, the community complained about different aspects of the project such as its unaffordability and poor design. Similarly, in the case of the Sydney metro rail project, besides complaints about specific facilities such as USB points, air conditioning, thermometers and escalators, the most common complaints were about train delays. The community often had fun at the expense of the infrastructure project often trolling the project. The predominance of negative tweets can offer challenges to extracting sentiments from the big data.

2. Presence of interest groups

One of the pressing issues of public infrastructure projects is a change for the most vocal instead of most affected. The most vocal opposition tend to challenge infrastructure development and often get what they want from the project (Bornstein 2010). In the case of the Chennai metro rail project there was an interest group campaigning against land acquisition often posting the same message daily on social media. Similarly, some tweets were often re-tweeted and this can also create a challenge in analysing the big data and making decisions relating to suggestions to improve.

DISCUSSIONS

As mentioned in the beginning of this paper, the conceptulizations of big data varies across disciplines, however, there is no doubt over the fact that big data has immense potential to add public value. In the context of megaprojects, we have made an attempt to indicate big data (structure, semi structured and unstructured) which can be harnessed for public values in megaprojects. We have provided examples of these data types with reference to Australian and Indian megaprojects. See Table 4.

Table 4: Examples of Big Data in Megaprojects

Public Value	Structured	Semi Structured	Unstructured
Accountability	Project Reports Cost and Schedule Business Case Risk Management Plans Performance Scorecards / Dashboards (GoI 2020)	Case Studies Surveys	Social Media handle of responsible minister
Transparency	Policy Dcouments' Procurement Reports Electronic Toll Collection Records Ridership records	Interviews	Public information Media
Responsiveness	Post Contract Management Reports Performance Report of Service Providers(TRAI 2020)	Incident reports	Social Media handle of public entity, service providers, interest groups and general public Media
Responsibility	Audit Reports	Interviews	Media
Quality	Project Review	Post project evaluation	Social Media handles of users

CONCLUSIONS

We tried to address two questions in this paper:

How will big data and data analytics help us to take into account and monitor public value creation from megaprojects?

A review of the literature on big data and its application in public affairs clearly shows that big data (structured, semi structured and unstructured) has the potential to enhance public value in megaprojects. There are already some examples from around the world that big data has been useful in providing more transparent information to the public and citizens such as. healthcare (Raghupathi and Raghupathi 2014; Ziora 2015); public sector performance (Bovaird and Loeffler 2015) and smart cities (Al Nuaimi et al. 2015).

However, challenges remain as governments are unprepared for using big data effectively due to availability of technology, capability, funding and expertise. The data collected by government departments are also in silos and data integration is not easy. It is also difficult to justify the cost of investment as the costs and benefits cannot be predicted. Despite these concerns several governments including the Australian and Indian governments are investing is open data being available to the public.

The second question we asked is

What are the barriers and opportunities for using big data and data analytics in public value creation from metro rail projects in Australia and India?

We have reported on two case studies in the paper which we analysed social media data to see if we can get an indication of how value created is perceived by the public from two metro projects – one in Sydney, Australia and the other in. Chennai, India. The evidence collected shows that sentiment analysis of tweets could provide an indication of how the user of transport infrastructures derive value from these projects. However, a more detailed study of structured and semi structured data is required.

The authors are also planning to conduct further research into how big data is currently being used by governments to contribute to provide public value information from metro projects.

REFERENCES

Al Nuaimi, E., Al Neyadi, H., Mohamed, N., and Al-Jaroodi, J. (2015). "Applications of big data to smart cities." *Journal of Internet Services and Applications*, 6(1), 25.

Alawad, H., and Kaewunruen, S. (2018). "Wireless Sensor Networks: Toward Smarter Railway Stations." *Infrastructures*, 3(3), 24.

Alford, J., Douglas, S., Geuijen, K., and ‘t Hart, P. (2017). "Ventures in public value management: introduction to the symposium." *Public Management Review*, 19(5), 589-604.

Alford, J., and O'Flynn, J. (2009). "Making Sense of Public Value: Concepts, Critiques and Emergent Meanings." *International Journal of Public Administration*, 32(3-4), 171-191.

Andersen, L. B., Jørgensen, T. B., Kjeldsen, A. M., Pedersen, L. H., and Vrangbæk, K. (2012). "Public Value Dimensions: Developing and Testing a Multi-Dimensional Classification." *International Journal of Public Administration*, 35(11), 715-728.

Andrews, L. (2019). "Public administration, public leadership and the construction of public value in the age of the algorithm and ‘big data’." *Public Administration*, 97(2), 296-310.

Azzone, G. (2018). "Big data and public policies: Opportunities and challenges." *Statistics & Probability Letters*, 136, 116-120.

Bornstein, L. (2010). "Mega-projects, city-building and community benefits." *City, Culture and Society*, 1(4), 199-206.

Bovaird, T., and Loeffler, E. (2015). *Public Management and Governance*, Routledge, Abingdon.

Clark, W. R., and Golder, M. (2014). "Big Data, Causal Inference, and Formal Theory: Contradictory Trends in Political Science?: Introduction." *PS: Political Science & Politics*, 48(1), 65-70.

Eisenhardt, K. M. (1989). "Building Theories from Case Study Research." *Academy of Management Review*, 14(4), 532-550.

Favaretto, M., De Clercq, E., Schneble, C. O., and Elger, B. S. (2020). "What is your definition of Big Data? Researchers’ understanding of the phenomenon of the decade." *PLOS ONE*, 15(2), e0228987.

Flyvbjerg, B. (2006). "Five Misunderstandings About Case-Study Research." *Qualitative Inquiry*, 12(2), 219-245.

George, G., Haas, M. R., and Pentland, A. (2014). "Big Data and Management." *Academy of Management Journal*, 57(2), 321-326.

GoI (2020). "Peroformance Dashboard - Real Time Updates on Flagships Government Schemes ", <https://transformingindia.mygov.in/performance-dashboard/>. (November 09, 2020).

Janssen, M., and van den Hoven, J. (2015). "Big and Open Linked Data (BOLD) in government: A challenge to transparency and privacy?" *Government Information Quarterly*, 32(4), 363-368.

Kim, G.-H., Trimi, S., and Chung, J.-H. (2014). "Big-data applications in the government sector." *Commun. ACM*, 57(3), 78–85.

Klievink, B., Romijn, B.-J., Cunningham, S., and de Bruijn, H. (2017). "Big data in the public sector: Uncertainties and readiness." *Information Systems Frontiers*, 19(2), 267-283.

Kozinets, R. V., Dolbec, P., and Earley, A. (2014). "Netnographic analysis: Understanding culture through social media data." *The SAGE Handbook of Qualitative Data Analysis*, U. Flick, ed., Sage, London, 262-276.

Lazer, D. M. J., Pentland, A., Watts, D. J., Aral, S., Athey, S., Contractor, N., Freelon, D., Gonzalez-Bailon, S., King, G., Margetts, H., Nelson, A., Salganik, M. J., Strohmaier, M., Vespignani, A., and Wagner, C. (2020). "Computational social science: Obstacles and opportunities." *Science*, 369(6507), 1060.

Lehtinen, J., Peltokorpi, A., and Artto, K. (2019). "Megaprojects as organizational platforms and technology platforms for value creation." *International Journal of Project Management*, 37(1), 43-58.

Lin, H., Zeng, S., Ma, H., Zeng, R., and Tam, V. W. Y. (2017). "An indicator system for evaluating megaproject social responsibility." *International Journal of Project Management*, 35(7), 1415-1426.

Liu, Y., van Marrewijk, A., Houwing, E.-J., and Hertogh, M. (2019). "The co-creation of values-in-use at the front end of infrastructure development programs." *International Journal of Project Management*, 37(5), 684-695.

Ma, H., Zeng, S., Lin, H., Chen, H., and Shi, J. J. (2017). "The societal governance of megaproject social responsibility." *International Journal of Project Management*, 35(7), 1365-1377.

Mergel, I., Rethemeyer, R. K., and Isett, K. (2016). "Big Data in Public Affairs." *Public Administration Review*, 76(6), 928-937.

Merrow, E. W. (2011). *Industrial Megaprojects: Concepts, Strategies, and Practices for Success*, Wiley., Hoboken, NJ.

Ninan, J. (2020). "Online naturalistic inquiry in project management research: Directions for research." *Project Leadership and Society*, 1, 100002.

Oldenhof, L., Postma, J., and Putters, K. (2014). "On Justification Work: How Compromising Enables Public Managers to Deal with Conflicting Values." *Public Administration Review*, 74(1), 52-63.

Park, C. S. (2015). "Applying "Negativity Bias" to Twitter: Negative News on Twitter, Emotions, and Political Learning." *Journal of Information Technology & Politics*, 12(4), 342-359.

Pirog, M. A. (2014). "Data will drive innovation in public policy and management research in the next decade." *Journal of Policy Analysis and Management*, 33(2), 537-543.

Raghupathi, W., and Raghupathi, V. (2014). "Big data analytics in healthcare: promise and potential." *Health Inf Sci Syst*, 2, 3-3.

Reynaers, A.-M. (2014). "Public Values in Public–Private Partnerships." *Public Administration Review*, 74(1), 41-50.

Scott, W. R. (1965). "Field Methods in the Study of Organizations. ." *Handbook of Organizations*, J. G. March, ed., Rand McNally and Co., Chicago, 261-304.

Steenhuisen, B., and van Eeten, M. (2008). "Invisible Trade-Offs of Public Values: Inside Dutch Railways." *Public Money & Management*, 28(3), 147-152.

Steger, T. (2007). "The Stories Metaphors Tell: Metaphors as a Tool to Decipher Tacit Aspects in Narratives." *Field Methods*, 19(1), 3-23.

Thøgersen, D., Waldorff, S. B., and Steffensen, T. (2020). "Public Value through Innovation: Danish Public Managers' Views on Barriers and Boosters." *International Journal of Public Administration*, 1-10.

TRAI (2020). "Performance on Key Quality of Service Parameters -Comparative Performance Report." <https://www.trai.gov.in/release-publication/reports/performance-reports>. (November 09, 2020).

Vickerman, R. (2013). "The wider economic impacts of mega-proejcts in transport." *Ingternational Handbook of Megaprojects*, H.Priemua, and B. v. Wee, eds., Edward Elgar, Cheltenham, 381-397.

Wang, G., Wu, P., Wu, X., Zhang, H., Guo, Q., and Cai, Y. (2020). "Mapping global research on sustainability of megaproject management: A scientometric review." *Journal of Cleaner Production*, 259, 120831.

Yin, R. K. (2017). *Case study research and applications: Design and methods*, Sage publications, Thousand Oaks, California.

Ziora, A. C. L. (2015). "The Role of Big Data Solutions in the Management of Organizations. Review of Selected Practical Examples." *Procedia Computer Science*, 65, 1006-1012.

Classification of safety observation reports from a construction site: An evaluation of text mining approaches

Jai KEDIA[1], Vurukuti TARANI[2], Nikhil BUGALIA[3], Ashwin MAHALINGAM[4]

Indian Institute of Technology - Madras; email: ce17b037@smail.iitm.ac.in[1]
Indian Institute of Technology - Madras; email: ce19m012@smail.iitm.ac.in[2]
Indian Institute of Technology - Madras; email: nbugalia@iitm.ac.in[3]
Indian Institute of Technology - Madras; email: mash@iitm.ac.in[4]

ABSTRACT

With the advent of new sophisticated machine learning (ML) algorithms in the field of language processing, the horizons of generating insights from textual data have broadened exponentially. The application of these natural language processing tools is not new in the field of construction safety. However, specific gaps yet remain in the applications pertaining to analysing the near-miss observation reports obtained directly from a construction site, which has been explored in detail in this study. This study utilizes the data obtained from a construction site containing near-miss safety observations. The study aims to test the proposition that a high efficiency of different ML algorithms in automatically classifying the observations from the site into three categories - "Unsafe Act", "Unsafe Condition", and "Good Observation" can be achieved. The study uses supervised machine learning approach and evaluates six different algorithms using F1 scores. Error analysis is also conducted to identify the strategies to increase the prediction accuracy. It is found that Random Forest classifier has high prediction accuracy with F1 score being 0.74 initially and improved to 0.77 after refining the stop-words that are excluded in the data cleaning process. Further, the reasons for the wrong prediction related to data quality are identified that could help improve the efficiency of the classifiers in future studies.

KEYWORDS

Construction; Safety; Safety Observations; Text-mining

1. INTRODUCTION

Managing risk of accidents and injuries at the construction site is one of the essential tasks for which the project managers bear utmost responsibility. While construction continues to be among one of the most dangerous occupations around the world, some examples of good construction sites achieving very high levels of safety also exist (Oswald et al., 2018). In such safe sites, the emphasis is on a proactive approach for safety management. As part of that, importance is given to observing and reporting safety-related concerns, commonly known as Safety Observations (SOs), at the site (Oswald et al., 2018). However, academic evidence has also pointed out that sustaining a reporting culture, where workers at the site actively contribute to observing potentially hazardous events and are willing to report them, is extremely difficult (Oswald et al., 2018). When workers start reporting, the project managers soon find it very difficult to cope with the cumulative volume of reports that they receive from the workers. In the absence of timely follow-up and feedback on each of these reports, the worker's motivation to report quickly decreases, and the reporting culture is not sustained (Oswald et al., 2018).

To solve these practical issues faced by the project managers at the site, efficient processes for the analysis of the text-based information (such as the SOs) at a construction site are therefore deemed necessary (Goh and Ubeynarayana, 2017; Tixier et al., 2017, 2016b, 2016a). The current study aims to develop an efficient strategy for analysis of SOs obtained directly from the construction sites. To remove the need for manual analysis of the SOs, the objective of the study is to test the proposition that a high efficiency of different Machine Learning (ML), and Text-Mining based approaches in automatically classifying the text in SOs obtained from a construction site into different categories can be achieved.

Section 2 of the study presents a summary of the existing literature on usage of ML and Text-Mining based approaches in classifying various reports related to construction and other industries. Section 3 presents an overview of the data used and the methodology adopted in this study. Main analysis results have been summarized in Section 4. Discussions of the study focussing on ideas for improving the accuracy of the various ML methods, as well as the implications for the management are then discussed in Section 5. Overall conclusions from the study are discussed in Section 6.

2. LITERATURE REVIEW

As highlighted by the several recent review papers, the importance of the ML-based techniques in analyzing a variety of safety-related observations for enhanced efficiency in safety management is gaining momentum (Sarkar and Maiti, 2020; Tixier et al., 2016a; Yan et al., 2020). With reference to the literature mentioned in the review papers, salient features of the literature pertinent to the objectives of the present study are described here.

Text mining is an Artificial Intelligence (AI) technique that uses Natural Language Processing (NLP) in transforming textual data into meaningful information. Using such tools and the data from the past hazard reports, Wang et al., (2018) could identify the causal factors for a hazard and therefore was able to develop a method to improve workplace hazard prediction. However, the efficiency of such a comprehensive causal prediction tool, enabling end-to-end automation for safety management decision-making is yet very low, and most other studies focus on improving the efficiency of the individual steps that could support management decisions. For example, Tixier et al., (2016) predict the safety outcomes such as type of injury, the body part affected, and injury severity utilizing two ML algorithms on the textual reports. Overall, they found high-predictive skills reached by a variety of models, relying on commonly occurring "attributes" at the construction sites, and concluded that underlying patterns and trends affecting construction safety do exist and with sufficiently large datasets, the construction safety could be studied empirically. Goh and Ubeynarayana (2017) implemented an automatic classification scheme for classifying the construction accident narratives into accident categories provided by Workplace Safety and Health Institute[1] using various supervised machine learning algorithms (refer Table 1). The algorithms that are experimented in this study can be evaluated based on three measures known as precision, recall and F1 score (Goh and Ubeynarayana, 2017). Precision measures how accurate the actual predictions are whereas recall measures the proportion of actual positives that are identified by the classifier. F1 score, an overall measure of the prediction efficiency of a given classifier, combines both precisions and recalls. F1 score could typically range between 0 and 1, and a high F1 score corresponds to better prediction efficiency. Goh and Ubeynarayana (2017) relied on F1 scores to evaluate the performance of the different ML algorithms. Typical F1 score of the best performing classifier in Goh and Ubeynarayana (2017), ranged from 0.55 to 0.92 for different labels. Further, they highlighted the importance of tokenization and hyper-parameter tuning for improving the F1 score of different classifiers. Literature also provides evidence that the performance of the automatic classifiers is generally low. The prediction performance of the classifiers can be significantly enhanced (F1 score up to 0.95) when manual inputs such as the classification rules, lexicons etc., especially about expert's review on rare and ambiguous observations, are assimilated with the automated classifying techniques (Marucci-Wellman et al., 2017; Tixier et al., 2016b).

[1] https://www.wsh-institute.sg/

Table 1 Description of various ML Classifiers

Classifier	**Description**
Support Vector Machine (SVM)	Hyperplanes are generated based on the training set and optimized which form the basis for the classification among classes,
Logistic Regression (LR)	The data is fit to a logit function to calculate the probability of occurrence of an event.
Naïve Bayes (BNB)	Utilizes bayes rules with an assumption of independence among features. The probabilities of each feature belonging to a given class label are considered independent of all features.
Multinomial Naïve Bayes (MNB)	Multinomial Naive Bayes classifier is a specific instance of a Naive Bayes classifier which uses a multinomial distribution for each of the features.
Random forest (RF)	A random forest classifier constitutes a set of decision trees. Each tree in the forest predicts its final class label. The collection of trees then voted for the most popular class as the final class label.
Decision Trees (DT)	The decision trees classifier forms a tree structure by breaking down data set into smaller and smaller subsets while at the same time developing an associated decision tree, eventually creating a tree with decision nodes and leaf nodes.

The quality and quantity of the text data being used also affect the prediction efficiency of the classifiers. Generally speaking, more data is deemed necessary to improve the prediction efficiency of the classifiers (Goh and Ubeynarayana, 2017; Tixier et al., 2016a). On the other hand, before analyzing the textual data, it needs to be cleaned for training the classifier. For any study, steps for data cleaning such as removing punctuations, converting all letters to lower case to maintain uniformity, spelling correction, tokenization, etc. need to be incorporated (Goh & Ubeynarayana, 2017). In this regard, several previous studies have used structured, high-quality data available from various web sources. For example, Goh and Ubeynarayana (2017) used accident narratives (1000 out of 4470 available) from a regulatory agency in the USA.

Similarly, Tixier et al., (2016b) used various online resources such as terms from regulatory agencies for the enhancement of the dictionary to be used in ML classification. Tixier et al., (2017) used 5298 injury reports which are obtained from more than 470 private construction organizations for identifying safety critical associations.

However, in many large-scale construction sites, often involving workers from several different countries, the safety-critical textual description could be provided directly by the workers. In such cases, the quality of the data itself could be jeopardized, both in terms of quality of the textual descriptions, and the content of the description (Oswald et al., 2018). None of the databases used in previous studies was such that they required extensive pre-processing steps (such as the spell-checking), as the original databases were stored in English language and were adequately managed by individual agencies, ensuring the quality of the textual descriptions. Hence, the research gap yet remains in testing the efficiency of the ML classifiers for the "real" data obtained directly from a construction site, as opposed to the "databases" maintained by regulatory agencies.

On the other hand, several of the above-mentioned studies have relied on data about "lagging indicators", such as after the mishap has happened. However, Sarkar and Maiti, (2020) have stressed on the scarcity of the literature focussing on the analysis of accident precursors, near-miss reports from construction sites using ML techniques. The near-miss reports obtained from accidents are commonly categorized into labels such as Unsafe Act (UA), Unsafe Condition (UC) or Good Observation (GO). The time-series analysis of UA, UC and GO then forms the basis for the construction managers to proactively take corrective actions, such as the focus on worker's training or improving the safety management practices at the site, etc. (Oswald et al., 2018).

Based on the description provided above, several critical research gaps can be identified. For example, while the idea of improving the prediction efficiency for the ML classifiers for data related to construction safety is not new, the review suggests that rarely have previous studies relied on near-miss observation data as well as the data obtained directly from the sites. Naturally, implementation of the ML algorithms to automate the processing of the textual data in such "real" conditions will be a significant contribution towards enhanced safety management. The current study then aims to contribute to the gap, by testing the proposition that high efficiency of different ML approaches in automatically classifying the text in SOs obtained from a construction site ("real" data) into different categories can be achieved.

3. DATA AND METHODOLOGY

The data is collected from a large-scale construction site on a natural gas plant in Kuwait. At this site, the workers from several non-English speaking countries gathered and, have provided SOs in a textual format while also providing a classification of the SOs, such as being UA, UC or GO. Some essential attributes available in the data obtained are summarized in Table 2.

Table 2 Attributes and their description for the data obtained from the site

ATTRIBUTE	***DESCRIPTION***
OBSERVATION	Worker describing the incident he observed on the site.
Corrective Action	Worker describes the action taken to make the situation better.
Category (UA, UC, GO).	Worker classifying the incident observed among the three.

The data contains about 12000 statements made for 3 months at the given site (See Figure 1). This is a large data set compared to the data used in previous studies. For example, Wang et al., (2018) used 165 hazard data sets containing a total of 29,002 observations for 3 years between 2013 and 2015. Such trends illustrate the vastness and complexity of the data being utilized in the current study.

The study presents a quantitative evaluation of the classification prediction efficiency of different types of ML classifiers. It demonstrates the steps that could be taken to enhance the efficiency of the classifiers. The novelty of the study lies in its attempt to utilize the ML approaches for automatic classification for "real" data on near misses, obtained directly from a construction site. Such "real" data contains the description provided by the workers "as is", and thus contains elements which could negatively affect the efficiency of text-mining classifiers, such as grammatically incorrect descriptions, site-specific abbreviations etc. In contrast, previous similar studies had relied on large-scale standard "databases" having information on injuries, where many issues from the "real" data are not present. The differentiates between the "real" and "database" information quantitatively to demonstrate the challenges of implementing ML-based data processing in site locations. For example, Table 3 shows that the "real" data obtained from the field had a larger percentage of unknown words as per the commonly used English dictionaries used in ML analysis, emphasizing the necessity of additional pre-processing steps required in the overall analysis.

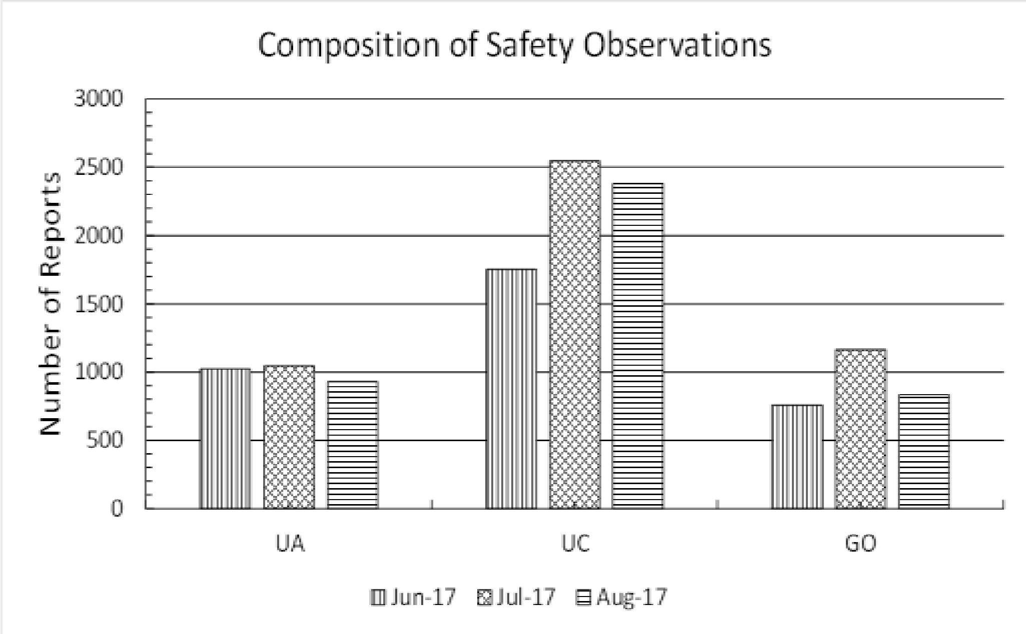


Figure 1 SOs obtained from site by observation type

Table 3 Comparison of the "Real" data used in this study and "Database" data in previous studies

	"Real Data"		***"Database Data"***
Data After Removing stop words.	***Before spell-check***	***After spell-check***	
Total number of words	109657	109657	67974
Percentage of unknown words	7.26%	2.24%	1.87%
Average word count	8.8	8.8	50+

3.1 Methodological Steps

Data pre-processing steps, steps for analysis are discussed briefly in this section. The entire methodology is demonstrated through the help of two flow charts, namely Figure 2 and Figure 3. Figure 2 describes the steps taken in the initial data pre-processing block. Figure 3 depicts the steps taken in the model generation and error analysis.

3.1.1 Data Pre-Processing

The "OBSERVATION" column of the data had the information about the incident which formed as the base for the classification of the experience into – UA, UC, or GO. The whole entry in each row was stripped to individual words, and all these individual words were lowercased to ensure uniformity. This process of stripping a longer string into individual words is known as 'tokenization', and the individual words are referred to as tokens (Bird et al., 2009). The next step employed was 'lemmatization.' This process involves obtaining the "lemma" of each of the token produced from the above step (Bird et al., 2009) to ensure uniformity in the text . An example for lemmatization is: "the boy's cars are different colours" $\Rightarrow$"the boy car be different color."

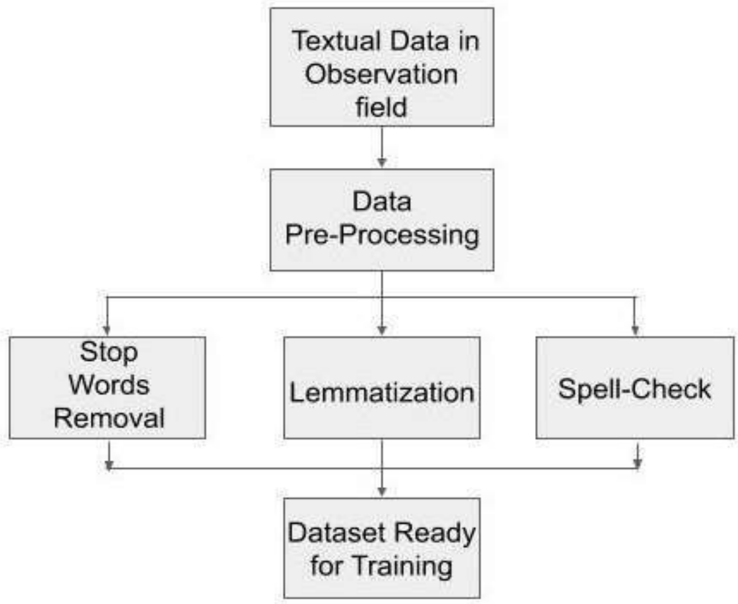


Figure 2 Steps followed in data pre-processing

This set of lemmatized tokens had punctuations, numbers and many other words which added significantly less to no meaning to the overall textual observation. It is, therefore, necessary to remove these punctuation, numbers and stop-words which do not have much lexical significance, using the commonly used list of stop-words (Bird et al., 2009). This step ensures that only meaningful tokens are taken further as features.

There are a lot of spelling mistakes and other unknown words that existed in the dataset which need to addressed to improve the quality of the text. Levenshtein distance was utilized to find similarity between the unknown words and the known set of words and replace them with the best alternative[2.] Levenshtein distance between two words is the minimum number of single-character edits (insertion, deletion or substitution) required to change one word into the other. In addition to the inbuilt English dictionary, a manual external dictionary was created focussed on specific terms pertaining to construction. This dictionary, in addition to the English dictionary, was then compared with all the tokens produced and a significant proportion of the unknown words were corrected (see Table 3). Few examples of the transformed data, after the pre-processing have been provided in Table 4.

Table 4 Safety observations before and after pre-processing

OBSERVATION	**OBS (after pre-processing steps)**
Observed sparking tools using inside running Unit in ST-0 Unit-12 for structural erection,	observed sparking tool using inside running unit st unit structural erection
WORKER FOUND NOT WEARING HIS SAFTY GLASS	worker found not wearing safety glass
Fire watch is continously available on welding site.	fire watch continuously available welding site

3.1.2 Model Generation and Error - Analysis

The cleaned dataset obtained after the data pre-processing steps were then split into two sets of training and testing data. Stratified sampling was used to take 20% of the 12428 observations as the test set to evaluate the performance of the machine learning classifiers. The stratified sampling ensures an equal percentage of observations across the three categories (GO, UA, UC). Goh and Ubeynarayana (2017) used a stratified split of 25% of data as the test set. Considering the size of their dataset. The number of data points we have in this study is enormous; hence 20% split ensures sufficient data points for testing. The algorithms used in this study were derived from the scikit-learn library (Pedregosa et al., 2011), Natural Language Toolkit (nltk) library (Bird et al., 2009) and Pyspellchecker library[3].

The first step in processing this data is to convert it into a corpus of words from which uni-grams, bi-grams and tri-grams can be chosen for further steps. Words, “uni”, “bi” and “tri” refer to the number of items in a given token, where the item can be considered as an individual unique word. Bi-grams and tri-grams are essential and need to be analyzed to understand the difference between specific terms like "not proper" and "proper".

[2] https://pypi.org/project/pyspellchecker/
[3] https://pypi.org/project/pyspellchecker/

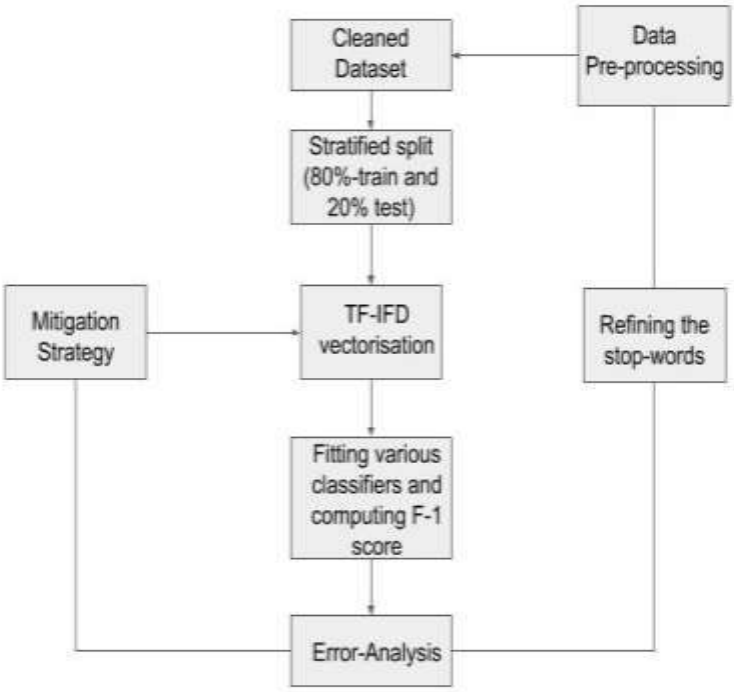


Figure 3 Model generation and error analysis

Term Frequency Inverse Document Frequency (TF-IDF) vectorizer (Peng et al., 2014) was then used to convert this meaningful text into an array which can be used as features to develop the model. TF-IDF is the measure of the originality of a word by comparing the number of times a word appears in a document with the number of documents the word appears in. The measure (TF-IDF), which is calculated for all the uni-grams, is taken to build a supervised learning model. This vectorization creates an array with each token (uni-gram or bi-gram) having a specific id and each column according to the availability of the token had an associated TF-IDF value associated and was assigned that value. A visual representation of a sample text before and after TF-IDF vectorization is shown in Figure 4.

The supervised learning approach is generally taken when there is a clear definition of the dependent and independent variables. This tool then uses this defined input-output pair to build a model using the training set and predicts the output pairs on the testing set. Supervised learning approach was carried out with many classifiers listed in Table 1 (Bishop, 2006). Average F-1 scores, for 100 random 20-80 splits of data are then tabulated in the subsequent sections.

$$W_{x,y} = tf_{x,y} \times (1 + \log(N+1/df_x+1))$$

TF-IDF
Term x within document y

$tf_{x,y}$ = frequency of x in y
df_x = number of documents containing x
N = number of document containing c

Before:

Document ID	Text
0	Tom's family includes 5 kids 2 dogs and 1 cat
1	The dogs are friendly The cat is beautiful
2	The dog is 11 years old
3	Tom lives in the United States of America

After: Out of 22 uni-grams the table below shows for 9 of them

Features → / Document - ID ↓	11	america	and	are	beautiful	cat	dog	includes	family
0	0	0	0.412	0	0	0.325	0	0.412	0.412
1	0	0	0	0.392	0.392	0.309	0	0	0
2	0.445	0	0	0	0	0	0.445	0	0
3	0	0.377	0	0	0	0	0	0	0

The TF-IDF vectorizer in sklearn normalises the IDF scores in the fashion as shown below to smoothen the weights.

$$\text{Normalized value of '11'} = \frac{idf(11)}{\sqrt{idf(\text{the}) + idf(\text{dog}) + idf(\text{is}) + idf(11) + idf(\text{years}) + idf(\text{old})}}$$

Normalised values of 11 = 0.445

Figure 4 Visual representation of TF-IDF vectorization of sample text

Once the F-1 scores have been computed, the cause of wrong predictions by the model needs to be identified through detailed error analysis. The wrongly predicted observations from the SVM (just as an example) classifier was compiled and the observations (587) along with the labels were manually analyzed, independently, by the first and the second authors, to find the reason behind the wrong predictions. The primary objective of error-analysis was to classify the wrongly predicted observations into four categories - "Mislabelled", "Wrong Prediction", "Doubtful", and "Inconclusive". Mislabelled observations denote the observations for which the label assigned by the worker itself is wrong. The Wrong Prediction observations denote the observations for which our classifier failed to predict the correct label. Doubtful observations are the observations for which the authors are unable to provide a suitable classification. The inconclusive category refers to the observations for which the description was either incomplete or was vague for authors to understand the context. Results of the error analysis then help the authors to identify take future decisions to improve the F-1 score. Naturally, error analysis is a subjective process. In order to minimize the biases, the study always adopts check by multiple authors independently and based on thorough communication between the authors.

4. RESULTS

Distributions of F1 scores for all the classifiers used in this study, for 100 random stratified samples, for each of the categories UA, UC, GO and for the Total Score are shown in Figure 5. Results in Figure 5 demonstrate the robustness of mean F1 scores summarized in Table 5, as the overall F1 score do not vary much.

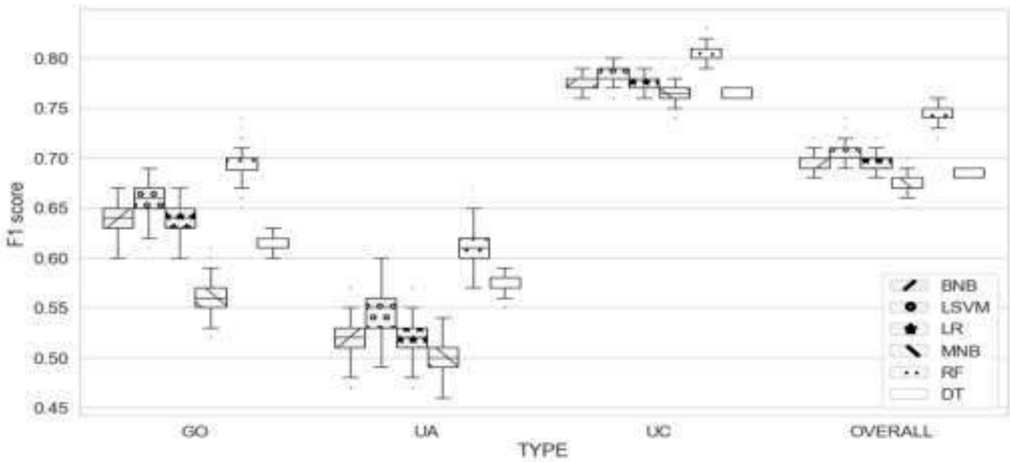


Figure 5 Box whisker plot for 100 repetitions of random stratified sampling (Base-case)

Comparatively, high variation is observed in the UA category of all the classifiers. Potential reasons for the same are then discussed in the error analysis. In the original data, approximately 54% of the observations are labelled as UC, explaining the high accuracy in its prediction. Although the proportion of data available for GO and UA are approximately the same, GOs are relatively easy to classify due to certain positive features that are repetitive (refer error analysis).

The analysis suggests that MNB classifier ranked the least, and RF classifier ranked highest in all the categories. In contrast, results from Goh and Ubeynarayana (2017) had reported a high accuracy with Linear SVM model for accident data, with a highly sophisticated underlying neural network. Developing such a neural network for the large volume of data used in this study will have several practical limitations related to computational requirements. Hence, LSVM model in our study may not have performed as better.

Overall, RF classifier gives an average prediction accuracy of approximately 74%. Such a result is also consistent with the F1-scores reported in previous studies for similar contexts relying on only automatic classification schemes (Goh and Ubeynarayana, 2017; Marucci-Wellman et al., 2017). Hence, an ML-based technique could prove to be a promising practical tool for analyzing the large volume of SOs obtained directly from the site.

Table 5 Average F1 scores for the base case

Classifier	GO	UA	UC	OVERALL
BNB	0.64	0.52	0.78	0.70
MNB	0.56	0.50	0.76	0.68
RF	**0.70**	**0.61**	**0.81**	**0.74**
LR	0.63	0.52	0.77	0.69
L SVM	0.66	0.55	0.78	0.71
DT	0.61	0.57	0.76	0.69

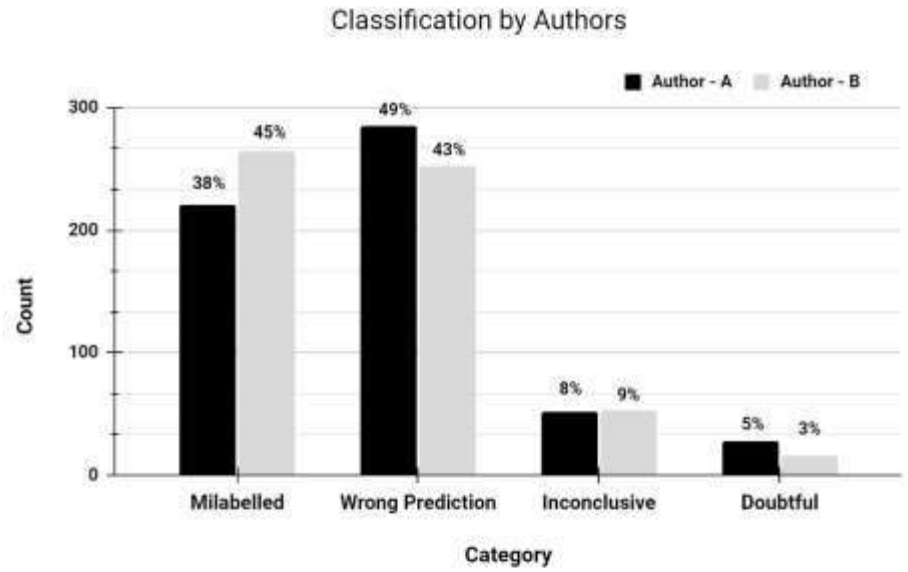
4.1 Error analysis and subsequent modifications

The results from the error analysis, along with a few example cases have been summarized in Figure 6. A major proportion i.e., approximately 46% of the errors were classified to be "Wrong Prediction", by the two authors. Upon an in-depth examination of these observations in detail, authors realized the issues relating to the exclusion of certain important words, as part of the stop-word removal process. Such exclusion of certain stop-words could affect the meaning of certain observations. For example, upon removal of stop-word "No", the issue of having no-sign board at the site, changed to the presence of a signboard at the site. Such an observation could have then been wrongly classified as the GO by the classifier, instead of the original UC (See Figure 6). Hence, a need to refine the selection of stop-words was deemed necessary to improve the F-1 score. A list of excluded stop-words, compared to list of commonly used stop-words even in previous applications, is summarized in Appendix A. The F1 scores of all the classifiers after modifying the stop-words are shown in Table 6.

Table 6 Average F1 scores after excluding some stop words

Classifier	***GO***	***UA***	***UC***	***OVERALL***
BNB	0.74***	0.54***	0.79***	0.73***
MNB	0.60***	0.51***	0.77***	0.69***
RF	**0.77*** **	**0.62*** **	**0.82*** **	**0.77*** **
LR	0.74***	0.54***	0.79***	0.73***
L SVM	0.76***	0.56***	0.80***	0.74***
DT	0.72***	0.57	0.77***	0.72***
**** p< 0.0001 (t-test, compared to the base case)*				

The results from the modified list of stop-words suggest that there was an improvement of about 2-3 percentage points in the F1 scores when compared to the base case. Such an improvement was also found to be statistically significant, suggesting that indeed the careful selection of the stop-words could be beneficial for further improving the efficiency of the ML classifiers. The results also suggest that a generic set of stop-words may not be suitable for all applications of ML, and more construction-specific stop-words, distinguishing between UA, GO and UC may need to be developed. It is important to note that, despite the exclusion of several stop-words, the F-1 scores are still in the mid-efficiency range and not on high-efficiency, as reported by a few studies, and several data quality-related issues could be the reason for such.



OBSERVATION (before)	OBSERVATION (Ater Cleaning)	Worker label	Predicted label	Category
No sign board at hydro test area.	sign board hydro test area	UC	GO	Wrong Prediction
safe access siganges to be provided in col 9 of U-151	safe access siganges provided col u	UC	GO	Wrong Prediction
Observe seobon crew maintain and following swp of excavation safety.	observe seobon crew maintain following swap excavation safety	UC	GO	Mislabelled
As heat is raising there is a need of supply of ors to the workers	heat raising need supply worker	GO	UC	Mislabelled
While debling after hydro test vaccum tanker shoulder be available for sucking oily water while deblinding called vaccum tanker.	dealing hydro test vacuum tanker shoulder available sucking oily water deblinding called vacuum tanker	UA	UC	Inconclusive
Found hot work area. Fire both not maintained properly. Grinding flying particles going out side booth.	found hot work area fire not maintained properly grinding flying particle going side booth	UA	UC	Doubtful

Figure 6 Result of Error Analysis

5. DISCUSSION AND FUTURE WORK

The discussions here focus on providing practical recommendations on how the ML-based report classifications can be assimilated at the project sites to optimize the work for project managers. The study discusses whether the practice of SOs classification by worker's themselves, a relatively inexpensive method, can be continued at the given site or inputs from safety experts, a rather costly approach, is necessary to enhance the efficiency of the ML classifiers. The results here demonstrate that despite having considerable problems related to data quality (such as the grammatical/ spelling issues in the description provided by workers, not having high familiarity with the English language), reasonable prediction efficiency could be obtained by a variety of ML classifiers on the site data. This is particularly relevant to the developing country context, where site documentation is often present in the form of written documents, and software systems are rarely put to extensive use. In this context, our results show that projects managers can still rely on data analytics and ML to improve safety performance on sites. Certainly, a large volume of information helped in enhancing the prediction efficiency. Such a result then highlights the value-addition of adopting ML/AI tools for automatic classification of the observations in a short span of time and demonstrates the potential of such tools to be adopted in safety management practices.

On the other hand, prediction efficiency could be further enhanced. The current study demonstrated the possibility of improvement, through suitable selection of "stop-words". Such results also highlight, that generalized lexicons, commonly used in ML applications, may not be suitable as-is for their applications in the classification of different types of SOs. Particular attention must be given for developing lexicons which can differentiate between seemingly "positive" SOs from that of "negative" SOs. The recent safety-theories have also emphasized on learning not only from "what went wrong", but also to learn from "what goes right" despite their potential of going wrong, in a complex system such as construction (Hollnagel, 2012). Hence, such an improvement in the lexicon, will also help bring the current ML practices in alignment, with the state-of-the-art safety theories.

In addition, through error analysis, our study finds that approximately 41% of the error observations could also be attributed to being mislabelled. At this site, worker's themselves are responsible for providing a classification of the report. From a manager's perspective, such a practice could be resource effective. However, our study suggests that it could have an effect on the data quality, and therefore on the prediction efficiency. At this stage, a rough estimate suggests that a further increase of about ten percentage points could be achieved in F1 scores, once the issues of mislabelling could be rectified. However, it requires significant resources on behalf of the analysts. Hence, as a future study, authors are aiming to correct the labels of the GOs.

6. CONCLUSION

The study presents a quantitative evaluation of the classification prediction efficiency of different types of ML classifiers, for near-miss SOs obtained from a real construction site. Further, it demonstrates the steps that could be taken to enhance the efficiency of the classifiers. The novelty of the study lies in its attempt to utilize the ML approaches for automatic classification for a “real” data on near misses, obtained directly from a construction site. Despite the potential limitations to prediction efficiency due to data quality issues, such as the grammatically incorrect descriptions, site-specific abbreviations etc., the study demonstrates a prediction efficiency of about 70%, which is at par with other previously reported numbers even for the data obtained from standardized datasets. Such results demonstrate that ML techniques hold significant potential to further enhance pro-active safety management at construction sites. The study also demonstrates that through suitable modifications in the stop-words, the prediction efficiency can be enhanced. The results of the study could be greatly affected by some of the data quality issues such as the mislabelling in the original data, and in future, such mislabels should be corrected. Future studies could also focus on increasing the proportion of test-data in the overall split, to assure the robustness of the results. The usage of ML techniques could be further improved to synthesize more details from the valuable information that has been gathered from real-site about the near-misses.

APPENDIX A

The stop words excluded in the study

"no", “wouldn't", "during", “didn't”, "above", "below", "did", "shouldn't", "before", "after", "had", "have", "will",” against

REFERENCES

Bird, S., Klein, E., Loper, E. (2009), "Natural language processing with Python: analyzing text with the natural language toolkit." *O’Reilly Media, Inc.*

Bishop, C.M. (2006), *Pattern recognition and machine learning.* Springer.

Goh, Y.M., Ubeynarayana, C.U. (2017), "Construction accident narrative classification: An evaluation of text mining techniques." *Accid. Anal. Prev.* 108, 122–130.

Hollnagel, E., (2012), *FRAM, the functional resonance analysis method: modelling complex socio-technical systems*. Ashgate Publishing, Ltd.

Marucci-Wellman, H.R., Corns, H.L., Lehto, M.R., (2017), "Classifying injury narratives of large administrative databases for surveillance—a practical approach combining machine learning ensembles and human review." *Accid. Anal. Prev.* 98, 359–371.

Oswald, D., Sherratt, F., Smith, S. (2018), "Problems with safety observation reporting: A construction industry case study." *Saf. Sci.* 107, 35–45.

Pedregosa, F., Varoquaux, G., Gramfort, A., Michel, V., Thirion, B., Grisel, O., Blondel, M., Prettenhofer, P., Weiss, R., Dubourg, V. (2011), "Scikit-learn: Machine learning in Python." *J. Mach. Learn. Res.* 12, 2825–2830.

Peng, T., Liu, L., Zuo, W., (2014), "PU text classification enhanced by term frequency–inverse document frequency-improved weighting. Concurr." *Comput. Pract. Exp*. 26, 728–741.

Sarkar, S., Maiti, J. (2020), "Machine learning in occupational accident analysis: a review using science mapping approach with citation network analysis." *Saf. Sci.* 131, 104900.

Tixier, A.J.-P., Hallowell, M.R., Rajagopalan, B., Bowman, D. (2017), "Construction safety clash detection: identifying safety incompatibilities among fundamental attributes using data mining." *Autom. Constr.* 74, 39–54.

Tixier, A.J.-P., Hallowell, M.R., Rajagopalan, B., Bowman, D. (2016a), "Application of machine learning to construction injury prediction." *Autom. Constr.* 69, 102–114.

Tixier, A.J.-P., Hallowell, M.R., Rajagopalan, B., Bowman, D. (2016b), "Automated content analysis for construction safety: A natural language processing system to extract precursors and outcomes from unstructured injury reports." *Autom. Constr.* 62, 45–56.

Wang, X., Huang, X., Luo, Y., Pei, J., Xu, M. (2018), "Improving workplace hazard identification performance using data mining." *J. Constr. Eng. Manag*. 144, 4018068.

Yan, H., Yang, N., Peng, Y., Ren, Y. (2020), "Data mining in the construction industry: Present status, opportunities, and future trends." *Autom. Constr.* 119, 103331.

Blockchain Technology in Project Management

K.C. IYER[1] and Purva GUPTA[2]

Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi, India;
email: kciyer@civil.iitd.ac.in [1]
Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi, India;
email: purvagupta2010@gmail.com [2]

ABSTRACT

Advancement in technology and rapid digitization have resulted in a fast-changing landscape for the construction sector and are all set to bring a paradigm shift in how we manage and execute construction projects. Blockchain, a type of Distributed ledger technology (DLT), is becoming increasingly main-stream in the corporate world. The aim of this research is towards automation of the contractual processes, performance and administration using blockchain and smart contracts. The paper explains the key concepts underpinning DLT and smart contracts; looks into the application of this technology in construction sector; presents a semi-automated contractual framework with underlying blockchain technology for construction contract management, and identifies the platform most suitable for this purpose. The intention is to provide a more collaborative, transparent and faster contractual framework which addresses administrative and governance challenges in project execution, streamlines the implementation of construction contracts, simplifies the contract execution, identifies and automates certain bottlenecks in the process, all keeping in view the cultural mindset of the stakeholders and technological expertise available.

KEYWORDS

Blockchain, Digitization, Automation, Construction Contracts

INTRODUCTION

The advent of the Fourth Industrial Revolution (Industry 4.0) has opened an entirely new outlook on how businesses work. Industry 4.0 comprises of various upcoming disrupting technologies like Artificial Intelligence, Machine Learning, Blockchain Technology, etc. with the potential to reshape the business practices. It has already fundamentally altered the working of various industries from finance to healthcare (Schwab, 2016). Covid 19 pandemic has made us re-think on making our industry and businesses more robust and resilient. It has fast-tracked the process of digitization and automation across the world.

One of the biggest industries in the world is the construction industry. It constitutes 13 percent of global GDP but has seen a meager productivity growth of 1 percent annually for the past two decades, which is even outside of the crises. Most of the projects suffer from time and cost overruns, and overall earnings before interest and taxes (EBIT) are only around 5 percent despite the presence of significant risk in the industry (McKinsey, 2020). Industry 4.0 has the potential to revamp the Construction Industry to what we can call as Construction 4.0 (Sawhney, 2020; Winfield, 2020). Blockchain Technology is one of the key technologies in the process of trustworthy digitization. It started with cryptocurrencies and is spreading into a myriad of other sectors from healthcare to construction. In this paper, we explore its application in construction project management using the following tools: Intelligent and collaborative contracting, decentralization of the databases, transparency of transactions, and smart asset management (McNamara and Sepasgozar, 2020). This will enable greater collaboration, better efficiency, cost and time savings, and bring more transparency on board.

LITERATURE REVIEW

In this section, we present a review of literature pertaining to construction management, construction contracts, blockchain technology and smart legal contracts, and how they fit together combining construction with computation.

Construction Contract Management

Management of contracts in the construction sector is a long and tedious process governed by a multitude of stakeholders, processes, and procedures that involve a large number of third parties and intermediaries. The process involves decision making at various levels from the preparation of the contract, bidding and award of contract, design and execution to commissioning and handover of the project. The multi-contractual links and involvement of multiple stakeholders make the process of contract administration and the time needed for each stage of the process extremely onerous (McNamara and Sepasgozar, 2020).

The level of collaboration across the value chain is low with the tendency to risk aversion and blame culture. This results in a siloed ecosystem with huge frictions at risk interfaces. There is a reluctance to share information with employees of different divisions in the same company, or different companies in the same consortium working on a common project. Misaligned contractual structures with failure to read, understand or operate construction contracts as intended is a major cause of global construction disputes which remain unresolved for decades (Arcadis, 2019)**.** The owner's or the contractor's attitudes to distort the language of the contracts with their adamant and rigid attitude in going by the 'content' of the contract rather than 'intent' of the contract is seen as the main source of dispute in the construction sector (Iyer, Kalidindi and Ganesh, 2002). However, this fragmented landscape has the potential to change if the cultural fundamentals and contract management practices are reformed.

Blockchain introduces 'smart contracts', (also called chaincode) enabling real-time coordination of activities in real-world conditions by streamlining and automating the contract administration process which in turn could save the industry an attractive percentage of project costs (Cardeira, 2015). Before we explore the application of Blockchain within the field of Construction and Contract Management, we first look into the current state of the technology and the key concepts linked with it.

Distributed Ledger Technology (DLT) and Blockchain

A distributed ledger technology (DLT) enables a decentralized network in which each participant can interact or transact with one another in a peer-to-peer manner without intermediaries and the ledger is updated simultaneously and is available with each one of them. Blockchain is an advanced version of DLT with immutability and higher security achieved using cryptographic hash-linked blocks in a sequential chain. Blockchain was the underlying technology behind Bitcoin which was first introduced in the Bitcoin whitepaper by Satoshi Nakamoto (Nakamoto, 2008). It intended to remove the need for trust in third party or bank to process payments using an electronic money transfer system based on cryptographic proof (Turk and Klinc, 2017).

Core Features of Blockchain

The main features of Blockchain technology are its **distributed and digital nature** where information is stored chronologically and can be viewed/accessed by a community of users in **real-time** (Thomson Reuters, 2018). It is **immutable** so that the information once published on the blockchain, cannot be changed or tampered with. It is **decentralized** that is not managed by a central authority rather available to all the stakeholders (Li *et al.*, 2019). Blockchain has the potential to automate away the middle man **(disintermediation)** without affecting the workers on the ground (Balint, 2018). In nutshell, we can say that "Instead of putting the taxi driver out of a job, Blockchain puts Uber out of a job and lets the taxi drivers work with the customer directly" (Savelyev, 2017). It resolves the so-called 'trust problem' in the construction industry (Mathews, Bowe and Robles, 2017).

Smart Contracts and Intelligent Contracts

The term 'smart contract' was coined in 1994 by Nick Szabo, a cryptographer who defined it as "A computerized transaction protocol that executes the terms of a contract" (Szabo, 1994). Vitalik Buterin released a white paper in 2013 on Ethereum, which proposed a system through which blockchain technology could be used in applications beyond Bitcoin and cryptocurrencies using 'Smart Contracts' (Buterin, 2013). Smart contracts are **digital programs**, based on the **blockchain consensus**, which will s**elf-execute** when the terms of the agreement are met, and due to their decentralized structure are also self-enforcing and tamper-proof (Fig.1). A smart contract functions as the business logic of a blockchain application. There can be many smart contracts running concurrently on the blockchain network.

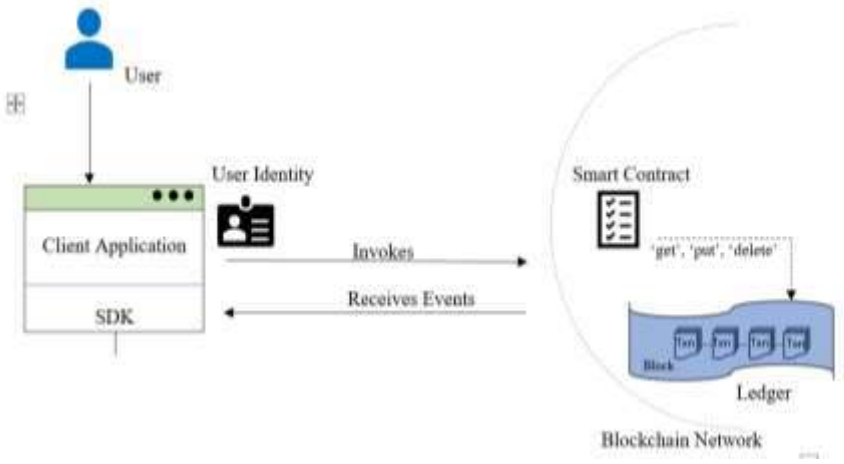


Figure 1 Smart Contract and Blockchain

Intelligent Contracts or **Smart Legal Contracts** are partially automated contracts comprising of automated 'smart clauses', which are self-executing with clear functionality. These clauses are written in both legal language as well as their respective coding. This makes them interpretable by both human and machine. Jim Mason defines Intelligent contract as "software code to implement human intentions by dynamically carrying out instructions associated with a contract, rather than relying on legal texts interpreted by courts, regulatory bodies or other legal institutions” (Mason, 2017; 2019).

The control of data and assets, as well as defining of smart clauses happen at the time of drafting of the contract. It has pre-defined conditions which once met, can trigger execution of payment or obligation of payment, thereby allowing contracting parties to operate beyond boundaries of trust (De Filippi and Hassan, 2016).

RESEARCH METHODOLOGY

Based on the extensive literature review of academic research papers and industrial initiatives, it is understood that in order to realize the full potential of digitization and automation in construction industry on ground level, the construction contracting and administrative process needs to be revamped. However, little research is found in this area. This paper looks into the drawbacks in the traditional contracting system and how they can be resolved using an Intelligent semi-automated contract administration and performance system with attributes of Blockchain Technology and Smart legal contracts (summarized in Table 1).

With this background, we propose an Intelligent Contracting System (ICS) using a permissioned and private blockchain network with the potential to solve various open issues in traditional construction contracting and project management. This system would not only automate and digitize the construction contracts but would also bring a fundamental disruption and shift to the current approach by leveraging the benefits of blockchain technology into the traditional contracting process.

The Blockchain platform identified for this purpose is **Hyperledger Fabric V2.0 by Linux.** Given the nature of construction contracts and projects, the need for privacy of data in the contracting system along with varied access controls to different stakeholders was identified as the key requirement to implement the system. Permissioned Blockchain ensures this privacy and security. Hyperledger Fabric is an enterprise-grade, distributed ledger platform that offers modularity, confidentiality and versatility needed to accommodate the complexity and details across construction business (Nawari and Ravindran, 2019).

Table 1: Traditional Contracting System: Drawbacks and Potential Solution

Drawbacks in traditional contracting system	**Blockchain Feature**	**Potential solutions in the proposed Intelligent Contracting System**
• On-field project progress and on-paper project progress vary. • Time and cost over-run • Manual claims due to market price or design variations, etc.	Near Real-Time	• Real-time status • Well-defined and updated project timeline. (Wang et al., 2020) • Simultaneous project evaluation, monitoring and cost optimization • Contract terms adjust to the physical world in real-time
• Silo mentality • Information gap • Different interpretation of contract clauses by parties leading to disputes.	Distributed and De -centralized	• Improved collaboration • Better trust • All stakeholders have access to the ledger of transactions without discrepancy • Smart legal contracts enable more clarity, automation and better contract adherence
• Lack of accountability • Improper risk allocation	Transparent and Traceable	• Certain and verifiable record of every payment, transaction, business interaction and execution done with due consensus. • Transparent and followable contracting process.
• Payment held ups for contractors and sub-contractors.	Digital Transaction	• Real-time automated payments based on the work or activities completed as per pre-defined contract conditions (Hamledari and Fischer, 2020; Luo et al., 2019)
• Poor record keeping i.e., Certain records incomplete or not found. • Double spending or frauds in digital transactions • Digital rights and policies on 3 D and 4D models unclear	Immutable, secure and Reliable	• Immutable record • Contract Audit trail sharing and managing lifecycle of the contract. • Improvised governance • Past transactions cannot be tampered with thereby alleviating risk of double spending, fraud and manipulation • Digital data and intellectual property protection
• A long and tedious administrative process	Dis - intermediation	• Reduced administrative and overhead costs of the project

The ICS Framework

The proposed semi-automated framework for Intelligent Contracting System comprising all stages of the contracting process is shown in Fig. 2. The areas where automation and digitization of the process can save time and cost, and improve efficiency are identified and included in the process.

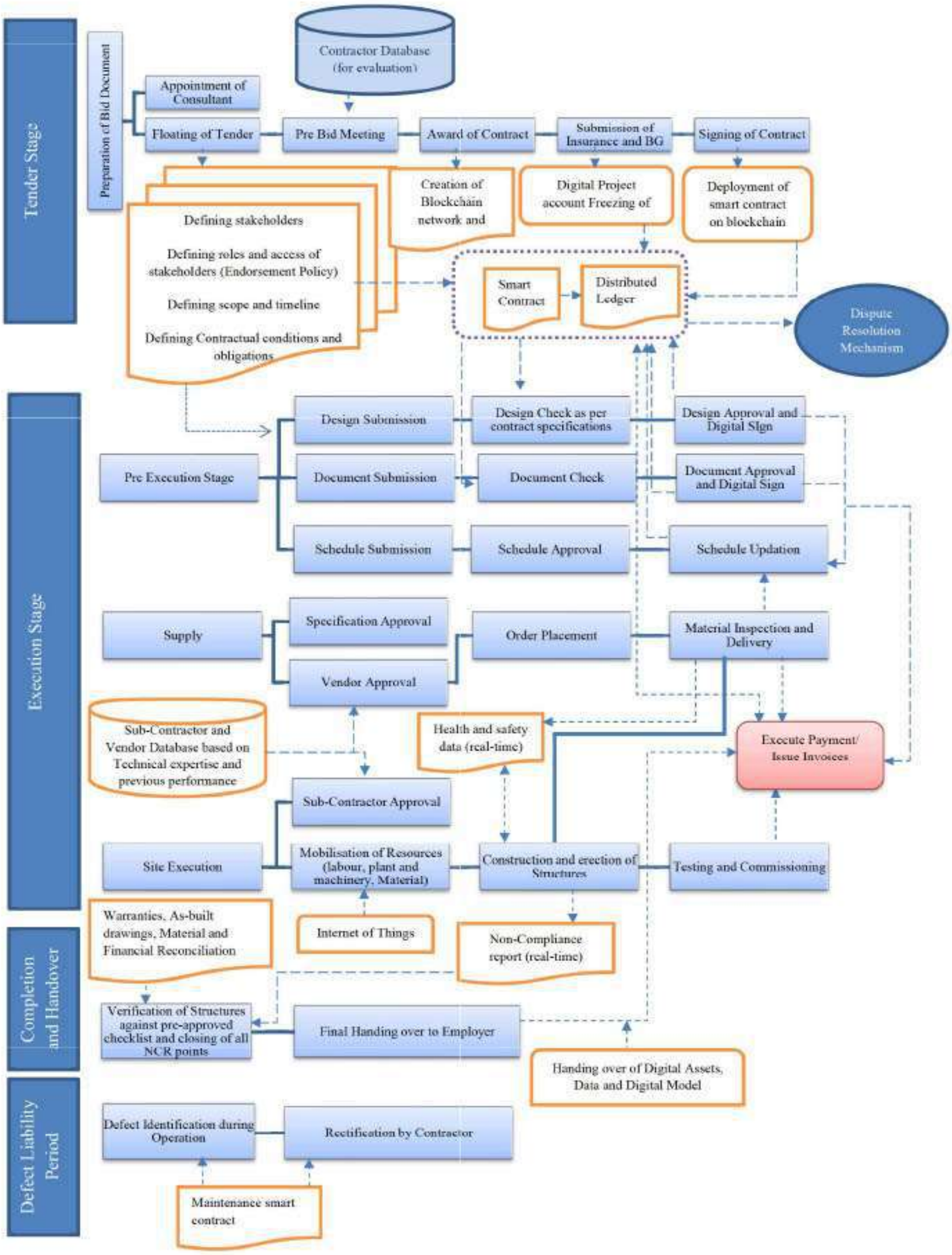


Figure 2 Intelligent Contracting System

The proposed Blockchain-based system engages every stakeholder in a collaborative manner as compared to the central management of the main contractor in traditional system. The exchange of information is transparent and real-time among all stakeholders. ICS encourages thorough contract management giving better cost control, faster payment mechanisms and effective project delivery. Furthermore, incorporation of intelligent smart contracts would reduce repetitive claims, ensure better delay accountability, and save cost and time lost in dispute resolution.

DISCUSSION AND FUTURE WORK

'We tend to overestimate the effect of technology in the short run and underestimate the effect in long run' - Roy Amara, President of the Institute of Future.

Blockchain is a promising technology with the potential to longstanding accountability and efficiency issues in our industry. Still, like any other new and upcoming technology, it has its own challenges. Not just the technological proficiency, but a strong cultural shift is needed to overcome the barriers of reliability and interoperability. Also, wide-scale adoption of the technology needs workable solutions for storage and compatibility issues (Li et al., 2019). Till the technology and the mindset mature, a semi-automated approach is preferred to make widespread adoption achievable and acceptable.

The paper proposes a contract management framework with intelligent legal contracts at the heart of the semi-automated framework. The research provides a foundation on which further work can be done in terms of identifying suitable smart clauses whose automation would leverage maximum benefit and prevent disagreements thereby improving efficiency and transparency of the contract and project management process with incremental and need-basis coding.

REFERENCES

Arcadis (2019), *Global construction disputes report 2019*. Available at:

Balint, P. (2018), *Blockchain Technology in the Construction Industry, ICE*.

Buterin, V. (2013). "A Next-Generation Smart Contract and Decentralized Application Platform, Ethereum Whitepaper".

Cardeira, H. (2015). "Smart contracts and possible applications to the construction industry", *New Perspectives in Construction Law Conference*.

De Filippi, P. and Hassan, S. (2016). "Blockchain technology as a regulatory technology: From code is law to law is code", *First Monday*, 21(12).

Hamledari H., and Fischer, M. (2020). "Role of blockchain-enabled smart contracts in automating construction progress payments", *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 13(1).

Hyperledger (2020), *hyperledger-fabricdocs Documentation Release master*.

Iyer, K. C., S. N. Kalidindi, and L. S. Ganesh (2002). "Dispute prone contract clauses: A basis for operational flexibility in contract administration", *Global J. Flexible Syst. Manage*. 3 (4): 39–51.

Li, J., Greenwood, D. and Kassem, M. (2019). "Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases", *Automation in Construction*, 102(March), pp. 288–307.

Luo, H., Das, M., Wang, J., Cheng, J. C.P. (2019). "Construction payment automation through smart contract-based blockchain framework", *Proceedings of the 36th ISARC 2019*, pp. 1254–1260.

Mason, J. (2017). "Intelligent contracts and the construction industry", *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 9(3).

Mason, J. (2019). "BIM Fork: Are smart contracts in construction more likely to prosper with or without BIM?", *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 11(4), pp. 1–5.

Mathews, M., Bowe, B. and Robles, D. (2017). "BIM+Blockchain: A solution to the trust problem in collaboration? | Enhanced Reader", *CITA BIM Gathering 2017*.

Mckinsey & Company (2020), *The next normal in construction*.

McNamara, A. J. and Sepasgozar, S. M. E. (2020). "Developing a theoretical framework for intelligent contract acceptance", *Construction Innovation*, 20(3).

Nakamoto, S. (2008). "Bitcoin: A peer-to-peer electronic cash system".

Nawari, N. O. and Ravindran, S. (2019). "Blockchain and the built environment: Potentials and limitations", *Journal of Building Engineering*, 25(October 2018).

Savelyev, A. (2017). "Contract Law 2.0: Smart contracts as the beginning of the end of classic contract law", *SSRN Electronic Journal*.

Sawhney, A., Riley, M. and Irizarry, J. (2020), *Construction 4.0: An innovation platform for the built environment*. London: Taylor & Francis (Routledge).

Schwab, K. (2016), *The fourth industrial revolution*. Geneva: WEF.

Szabo, N. (1994) *Smart Contracts*.

Thomson Reuters (2018). "Blockchain for construction/real estate", pp. 1–12.

Turk, Ž. and Klinc, R. (2017). "Potentials of blockchain technology for construction management", *Procedia Engineering*, 196(June), pp. 638–645.

Wang, Z., Wang, T., Hu, H., Gong, J., Ren, X. and Xiao, Q. (2020). "Blockchain-based framework for improving supply chain traceability and information sharing in precast construction", *Automation in Construction*, 111, p.103063.

Winfield, M. (2020). "Construction 4.0 and ISO 19650: a panacea for the digital revolution?", *Proceedings of the ICE - Management, Procurement and Law*, pp. 1–7.

Section II

ADVANCED CONSTRUCTION PROJECT MANAGEMENT

Editor's Note

Construction projects contribute to the nation's growth, and advanced techniques to manage those needs special attention. This section describes about six papers that discuss advanced techniques in construction project management. For instance, Kapoor and Sharma emphasises on reducing the commonly occurring biases in decision making process involved in long gestation projects while recommending the suitable project management tools and techniques to achieve the same. The paper mainly addresses cause and effect of the cognitive, framing, and emotional biases that unmasks at different stages of the project life cycle. It also highlights the remedies for all these biases across project life cycle which helps in establishing a sound decision-making process in an organisation.

Having known that power transmission is a significant part of power projects, Ghatak and Garg investigates on the key factors responsible for the success of power transmission projects. With a questionnaire-based survey conducted among experts across countries and a structured data sampling, the authors quantify the relationship between the critical factors known to lead way to power transmission success.

Meanwhile, Kumar and Trivedi developed an integrated framework attempting to reduce the vulnerability of equipment management system in construction projects. The study ends with the business model and implementation plan for successful product delivery. Similarly, a research was carried out by Jacab and Dave to classify various applications for UAVs in the construction field, and established a set of guidelines for the use of UAVs in construction using a design science analysis methodology. Likewise, the main objective of the study by Patel et al. is to understand the advantages of automation in construction by comparing the different modern tools available in the market.

Enhancing Decision Quality to Manage Risks in Complex Long Gestation Projects

Dr. G Srikantha SHARMA[1] and Ms. Suparna KAPOOR[2]

General Manager; email: halseaking@gmail.com [1]
Dy. General Manager; email: suparna_kapoor@hotmail.com [2]

ABSTRACT

Decision making in long gestation project is complex since the context in which decision is made is different from the context in which it is executed. The VUCA (Volatile, Uncertain, Complex, and Ambiguous) environment necessitates the project manager to undertake decisions with limited amount of data. Behavioural economics theory reveals that under conditions of ambiguity and where decision making has to be quick, managers use the System 1 thinking pattern for decision making. Since System 1 is prone to heuristics, fallacies and biases, Project Managers have to be wary of its influence while taking decisions under such conditions. This paper specifically deals with biases which impact decision making and hence Project outcomes. The three categories of biases being explored are cognitive biases, frame biases and emotional biases. Typical situations and cases of such biases in each of the stages of the project are discussed. It is also proposed that the influence of these biases can be minimised by use of specific Project management tools and techniques. The paper discusses some of these tools and techniques and advocates the institutionalisation of these tools in the project management systems and structure of the organisation so as to reduce Project risks due to biases.

KEY WORDS

Biases, Decision making, Long Gestation, Project Life Cycle, Tools and Techniques

INTRODUCTION

Over the past couple of decades, the complexity and uncertainty in projects has increased exponentially due to globalization, technology, disruptions, climate change etc. In such an environment the capabilities of the Project Manager are tested at every crucial stage and phase of Project decision making. The decisions, made in the current context, have an impact that is noticed and judged at a later point in time. In long gestation projects like infrastructure, aviation, ship building etc., the time gap between decision making and execution may sometimes be between 2-4 years. Long gestation projects normally need high upfront commitment and investment in capital equipment, machinery, freezing of specifications etc. Considering the size of the program and the gestation period, it is very much plausible that the Project Manager who takes the decision is different from the Project Manager who executes the decision. The business environment in which the decision was made itself undergoes changes.

Typical of projects is the uniqueness of the product, service or result. Accordingly, the processes are new and have to be developed for each project. There are not many existing rules and protocols to be followed for decision making. The Project Manager has to use his intuitive abilities, experiential understanding and personal judgement while making decisions. Such discretionary decision making may be influenced by the past experiences and biases which the Project Manager uses for taking decisions thus making it highly subjective in nature. Further, in Complex projects with multiple stakeholders, it is required to tackle the inputs of the primary stakeholders and obtain the approval of the key stakeholders while formalising any decision. Hence, effective, structured and logical decision-making process is paramount for long gestation projects to achieve decision quality.

The quality of a decision is generally evaluated in terms of the impact or the result of the decision made. If the outcome becomes favourable the quality of the decision is lauded while if the outcome is not so desirable, the project manager who made the decision faces flak. However, it is to be borne in mind that uncertainties are inherent in any project however well it is conceived or executed. The outcome is influenced by various Enterprise Environmental factors outside the reasonable control of the Project Manager. Hence it is vital to judge the quality of the decision based on the process adopted to arrive at the decision rather than on the outcome thereupon. A well framed structured decision-making process is more probable to yield better outputs when practised consistently.

Henry Mintzberg the great Management Thinker has said "Organizational effectiveness does not lie in that narrow minded concept called rationality. It lies in the blend of clearheaded logic and powerful intuition". Since data collection is difficult and time consuming in each and every situation many short and long term decisions are made based on "gut instinct". The Project Manager has to optimally blend the logical thinking process with the intuitive thinking process. This paper examines the two types of thinking processes propounded by Daniel Kahneman in the context of decision making for long duration projects and proposes adoption of structured tools & processes for decision making so as to improve decision quality.

LITERATURE REVIEW

System 1 and System 2 thinking:

Daniel Kahneman (2011) has undertaken extensive research in the field of behavioural economics and how economic decisions are not purely rational but influenced by cognitive dissonance and emotional constructs. He won the Nobel Prize in Economics in 2002 for his ground breaking work in applying psychological insights to economic theory, especially in the field of decision making under uncertainty.

Kahneman (2011) attributes the decision making anomalies to behavioural fallacies of the human brain. In his seminal book "Thinking Fast Thinking Slow" Kahneman identifies two different systems operating in the human brain: The System 1 thinking and the System 2 thinking. Commenting on the book, Mark Looi (2019) states that System 1 is the intuitive system and is always functioning and cannot be switched off. It makes decisions fast by neglecting ambiguity and supressing doubt. It frames decision processes narrowly and in isolation of one another. Whenever a project manager has to give quick decisions or take decisions under a lot of uncertainty, he resorts to System 1 thinking. By contrast, System 2 thinking involves more about of logic, judgement, quantitative reasoning and attention to effortful mental activities. While System 2 thinking is more likely to give consistently favourable outcomes, a Project Manager may not always be able to apply it fully due to insufficiency of information, uncertainty, complexity and ambiguity inherent in a project environment. Especially in large gestation projects, the level of lack of adequate information in the long time frame necessitates the project Manager to go in for System 1 decision making. This may lead to the creeping in of biases which the project Manager needs to address while taking decisions. Considering that project decisions many a times are restricted by time and have to be made with limited information, especially in long gestation projects, there is a tendency System 1 based decisions (what is called the 'gut') and unless supported by tools and techniques of System 2, chances of falling into the trap of biases and fallacies is enhanced. The characteristics of System 1 and System 2 are given in the Figure 1.

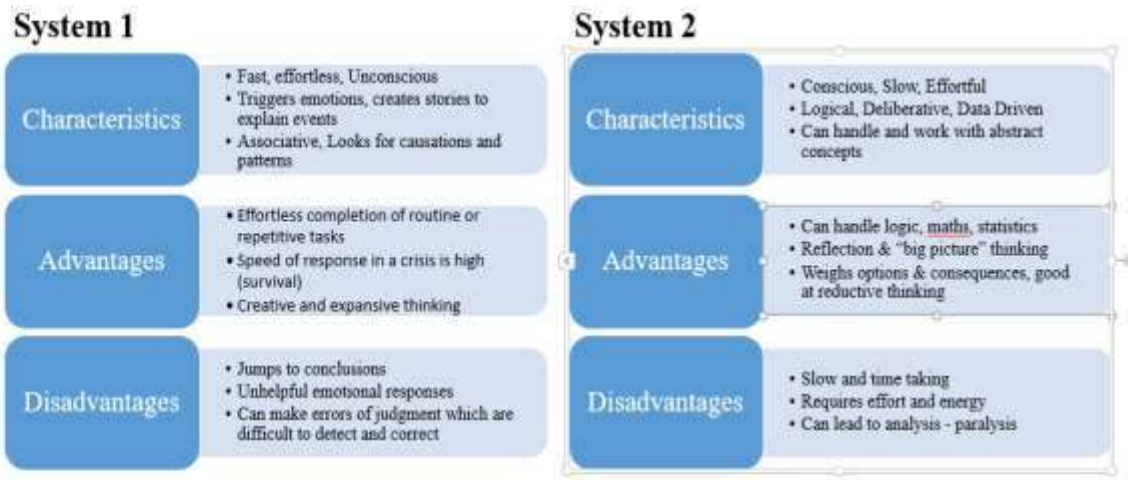


Figure 1: System 1 and System 2 thinking

Prospect Theory

Kahneman and Tversky (2013) have provided a critique of traditional utility theory to decision making which propounds that project managers make decisions purely rationally to maximise utility of the investment to the project. They proposed an alternative model – the Prospect theory, which says that choices of decision making under risk are influenced by several intuitive, cognitive and emotional factors which the classical economic theories cannot explain. This has an import on the decision-making process in Projects with respect to risk management. Prospect theory brings out that faced with a risky choice leading to gains, Project Managers are risk averse preferring solutions that have lower expected utility but higher certainty. By contrast, faced with a risky choice leading to gains, Project Managers are risk seeking preferring solutions that lead to a lower expected utility but with a potential to avoid losses. In-line with the above, the prospect theory implies that Project Managers might attribute excessive weight to events with a low probability and conversely attribute lesser weight to events with high probability. This skews the decision making when using the Probability - Impact Matrix approach. It also leads to Project Managers trying to adopt mitigation strategies for low-risk events while ignoring high risk events.

Biases in Decision making

Biases in decision making is a tendency to make decisions which may not have any rational justification or have been taken in the absence of sufficient supporting evidence and based on implicit assumptions. Biases occur either due to overdependence on system 1 thinking approach or a flawed input to the system 2 thinking approach. March & Simon (1993) bring out that project Managers when confounded with limited data and fast decision requirement tend to reduce problems into simpler constructs and use information selectively based on their beliefs, assumptions, metamodels and preferences. With the result they create solutions which reflect their experiences and support and preserve their beliefs.

Biases can broadly be classified into three categories based on their origin:

a) Cognitive
b) Framing
c) Emotional

Cognitive bias is defined by Amor Tversky & Kahneman (1972) as a systematic error in thinking which occurs when people processing and interpreting information in the world around them tend to simplify information processing based on their past experiences and beliefs and arrive at decision with relative speed. The Project Manager having a cognitive bias creates his own subjective reality from his perception of the input leading to distortion and inaccurate judgement. His perception is clouded by his experiences and beliefs about their own self, the business context, stakeholders and the project being handled. Cognitive biases include optimism bias, confirmation bias, planning fallacy, to name a few. A further discussion on these cognitive biases and use of structured project management tools and techniques to overcome the same will be discussed in subsequent paragraphs.

Framing bias refers to the observation that the manner in which data or information is presented affects the decision-making process as opposed to the facts themselves. The options are worded differently either by the presenter or by the decision maker himself so that it appeals to his/her preconceived notions or expected outcomes. The decision maker interprets the decision according to a decision frame chosen by him/her based on their subjective opinion. Narrowly framed problems or situations lead to looking for data or interpreting data selectively to confirm the assumptions of the frame overlooking important alternatives to the frame. Anchoring, optimism bias and sunk cost bias are three frames that will be discussed in this paper which affects decision making at various phases of the project life cycle. Martinsuo (2014) has identified the need to reframe biases in the context of managing uncertainties in projects in a systematic manner.

Emotional biases are spontaneous impulsive responses of a project Manager based on his personal feelings at the time the decision is made. It may be backed by a background of experience in similar situations and the effects thereupon. Emotional decisions are not based on sound reasoning or judgement. It is held very firm by the decision maker and it takes effort to acknowledge and then to review such decisions. Hence emotional biases are more difficult to address as compared to cognitive biases and framing biases. It is not possible to delineate emotions completely from the decision making process but being aware of the biases it creates may prompt the Project Manager to seek additional data or rationality to the situation. Some of the emotional biases which a project Manager may come across include loss aversion or endowment effect, illusion of progress, halo effect, overconfidence bias etc. It may be necessary for the Project Manager to obtain views from different persons so as to avoid his individual emotions affecting the decision process. Alternately tools may be adopted or systems put in place to provide alternate propositions for the Project Manager to take rational decisions. These will be discussed in the subsequent paragraphs.

Project Life cycle

Project Management Body of Knowledge (PMBOK) has adopted a life cycle approach to describe various tools and techniques used in project management. The project life cycle is divided into five phases: initiation, planning, execution, monitoring & control and the closing stages, refer Figure 2. Each of these stages comprise of various processes across ten knowledge areas. The processes involve deployment of specific tools and techniques following the ITTO (Input, Tools & Techniques, and Output) framework of PMBOK.

The Project Manager along with his project team takes various decisions across the project life cycle. The decisions in the initiation stage focuses on project appraisal, contract formulation, establishing of rough order baselines and milestone identification. The decisions in the planning phase include resource allocation, time estimation, scheduling, risk identification and evaluation of alternatives among others. During monitoring & control, execution and closing phases, the project manager takes decisions with regard to expediting, foreclosure, trigger point reviews and resource re-allocation. Long gestation projects, like those in Aerospace, have two unique characteristics. Firstly, the Project Manager who takes decisions during the planning phase may be different from the project manager who takes decisions in the execution phase due to the elongated timelines of the project. Secondly, organisations involved in long gestation projects have a functional organisation structure where the planning group does the planning, the contracts group does the contract finalisation and separate execution groups execute portions of the project. All these necessitate that structured approach to decision making is vital so that the information flows seamless across the project life cycle and no undue risks crop up over the timeline.

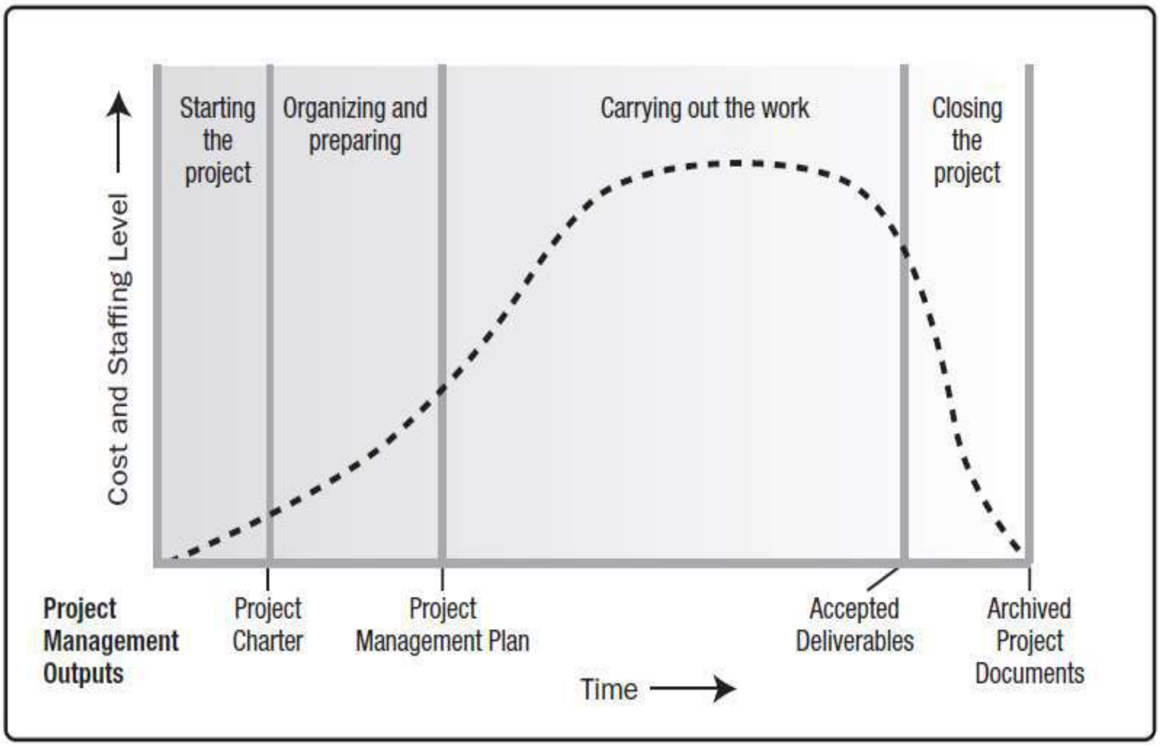


Figure 2: Project Life cycle stages

PMBOK Guide – 6th Edition

ENHANCING DECISION QUALITY TO REDUCE PROJECT RISKS

The Project Manager makes different types of decisions in different stages of the project life cycle. Accordingly, the nature of biases affecting the decision making process vary based on the stage of the project in the life cycle. We shall analyse the biases under the three categories defined in para 2.3 and discuss use of specific tools and techniques of Project Management described in the PMBOK which can be used to mitigate the risks due to improper decision making in the succeeding paragraphs. A summary of the types of biases being discussed is provided in Table 1:

The table has been developed based on the authors experience in managing projects as well as their interaction with various levels of Project Managers as part of Learning and Development initiatives within the organization. The proposed approaches, tools are techniques are based on phenomenological research methodology. The project names and other details have not been stated due to reasons of confidentiality.

Table 1: Summary of biases and their remedies across the project life cycle

Biases/Stage of Project	**Initiation phase**	**Planning phase**	**Execution , M & C phase**
Cognitive Biases	**Optimism Bias** *Probabilistic thinking, Scenario building, Back casting method*	**Planning Fallacy** *Contingency planning, PERT methodology, Planning bias uplift*	**Confirmation Bias** *Internal audits, Expert consultation, Devil's advocate method*
Framing Biases	**Availability Bias** *Assumption validation, Lessons learnt document, Risk register archives*	**Anchoring** *Bottoms up estimating, Cross validating with historical evidence, Avoid benchmark trap*	**Sunk Cost bias** *Defined Kill point, Phase gate approaches, Residual ROI approach, PMO intervention*
Emotional Biases	**Halo effect** *Delphi method , Murder board , Sociocracy technique*	**Loss aversion bias** *Decision Tree methodology, Price cum incentive contracts*	**Illusion of progress** *Earned value methodology, Milestone slip chart, Use of Gantt chart dash board*

Biases in Initiation Phase:

Optimism Bias:

Optimism bias is defined as the difference in the expectations of a Manager and the actual outcome. This is a cognitive bias reflected in the overestimation of the likelihood of getting a positive outcome and underplaying the chances of a negative outcome. (Sharot, 2011). The reason for undue optimism among Project managers is self enhancement, self-preservation and perceived self-control. Both experienced project managers as well as fresh project managers fall prey to this bias, albeit for different underlying factors. An experienced Project Manager recalls instances of success in taking risks selectively and estimates that the current decision will also lead to successful outcomes. A fresh Project Manager, in his enthusiasm to perform under strict control limits over estimates the capacity of the project team and situations and underplays the risks involved.

Optimism bias is prevalent in projects needing technical expertise like design projects, those linked to market retention like new product launch and social welfare projects like road construction. In long gestation projects, the very distance of completion date makes the Project manager callous compounded by the probability that it may be a different person leading the project in that phase. A desperate bid to grab the project by all means during the pre-initiation stage of the project makes the Project Manager to quote lesser cost and timelines for the project which then gets carried into the Project Charter.

Optimism bias can be reduced by carrying out a scenario analysis during the initiation stage of the project in a brain storming session. This will enable assessing multiple options before taking a decision. Scenario analysis will then to be followed by a back-casting exercise to identify the gap between the existing state and the deliverables required for the project. Use of probabilistic methods to arrive at time baseline and cost baseline will reduce the risks due to optimism bias. The project Team should have a balanced composition with at least one member playing the role of devil's advocate so that the decision is put to rigorous test before implementation and risks, if any come to the fore early on in the project.

Use of scenario analysis and probabilistic thinking to avoid optimism bias has been demonstrated in the naval medium lift helicopter indigenisation project. The customer projected a time period of three months to operationalise the project. The project analysis was carried out using the PERT methodology. It comprised four major activities of fault diagnosis, spares availability, snag rectification and flight testing. Since each was a new activity, a three point estimating technique was adopted to obtain an expected time frame of 150 days. Further planning was carried out using back casting method. By avoiding the optimism bias, it was possible to plan helicopter deployment activity and base readiness realistically and ensure operational effectiveness.

Availability bias (Recency effect):

Availability bias or recency effect refers to the mental shortcut that relies on immediate examples that comes readily to the mind while taking decisions. The ease of recall may be either because it had happened recently or because one felt very emotional about it. The availability heuristic is a framing bias that gives more importance to events in a fame of recent past than for events in the distant past. It operates on the presumption that if an event can be recalled easily, it must be more important than the ones that are not recalled easily.

Accordingly, project managers assess probability by giving more weight to current or easily recalled information instead of processing all information. For example, while estimating the cost or time required for a project, the project manager accesses information of the immediate past projects or the projects he was intensely involved and arrives at a decision. While selecting a particular equipment or capita item or software to be used for a project, exemplars come into play. Exemplars are solutions which come immediately to mind by availability heuristics. Advertisements, frequent discussion on a particular product leads to exemplars coming to mind more often while taking decisions.

There are two Project management tools to address this bias. One is assumption analysis. While the scope statement is being prepared, all the assumptions have to be documented as an assumptions log. These have to be then analysed for validity with a presentation to the sponsor or customer. Organisations need to systematise the process of lessons learnt document for every project so that whenever a new project is being initiated, the lessons learnt from projects across the time spectrum can be used for better prediction of time and cost estimates. Archives of risk registers should also form part of the lessons learnt document so that it provides a reality check the perception of the project manager can be compared with the actual record of what has happened in the past.

The availability bias was noticed in the twin engine helicopter prototyping project. The organisation had full-fledged manufacturing facilities for a single engine helicopter project which was in operation for more than two decades. When the prototyping of the twin engine helicopter project was taken up, it was assumed that the existing machinery and equipment will cater to the prototyping project and no further investment is required. Accordingly, manufacturing of the 2500 critical components were launched. Mid-way through the project it was realised that some of the gear grinding capabilities, 3-D milling machinery and co-ordinate measuring metrological facilities were not available. A thorough assumption validation at the beginning of the project could have avoided the delay in the project of six months and cost overruns due to emergency equipment purchases and outsourcing to Proprietary firms.

Halo effect:

Halo effect is an emotional bias in which one tends to give more importance to a person’s opinions in all fields just because he is proficient in one domain of knowledge or is occupying an important position in the Project hierarchy. Edward Thorndike (1920) first coined the term to describe the constant error in psychological ratings on all characteristics of a person based on one or few of his characteristic. For instance, a designer proficient in embedded systems is also assumed to have in-depth knowledge in aviation systems as well and his opinions are valued unduly high in project cost estimation. The report of a technical consultant firm incorporating a footnote on organisational structure recommendation for your project may receive more than required importance just because it has come from a specialised agency. Another example is to attach more importance to the suggestions of an influencing member or team leader or sponsor without subjecting it to analytical dissection. The Design Director set up an estimate of 36 months for drawing board to tarmac of a trainer aircraft. Just because the estimate came from a Design head, it became the baseline for the project. Later the project had an overrun up to 60 months leading to loss of potential orders. Another example is the estimate given for developing a Vaccine for Covid given by a popular leader politician against which the country’s laboratories were working on.

There are many structured brain storming techniques in Project Management to overcome the Halo effect bias depending on the culture and openness to discussion in the team. If the proposer is a senior person, Delphi technique can be adopted. Since this is a blind evaluation approach, the halo of the proposer does not come in the way of objective evaluation. If the culture provides a little openness, the murder board method can be used in which the proposal will be subject to intense scrutiny and the proposer will have a chance to give his justification. The proposal can be accepted if it passes the scrutiny. Where consensus forming is essential for project success sociocracy technique may be preferred. Each of the team member has a voting right by lifting the appropriate number of fingers of his right hand (from 0 – 5) to indicate the level of acceptance. An average of 3 from all members will be required for the proposal to be incorporated in the project. By these methods the bias due to halo can be minimised.

Planning stage

Planning fallacy:

The planning fallacy refers to a prediction phenomenon, wherein Managers underestimate the time it will take to complete a future task, despite knowledge that previous tasks have generally taken longer than planned. The tendency to overpromise and under deliver is known as planning fallacy. It occurs in both time estimates as well as cost estimates. One explanation for planning fallacy is "focalism": that is the Project Manager tends to focus on the future task and do not consider similar task in the past which took longer time to complete. Planning fallacy results in students' syndrome during execution stage. With the result, activities start getting delayed assuming they still have time to complete the same.

There are four sequential steps to be adopted to avoid planning fallacy. Each of these four steps are described in the PMBOK. The first step is a comprehensive Work Breakdown Structure broken down to sufficient detail that the time and cost can be estimated to a greater degree of precision When the project team has to estimate durations for a higher order of activity set, the errors will be more than when the tasks are subdivided into smaller pieces for which standard rates can be applied. The second step is to have early team buy-in during estimating resources for each element of the activity. Subject matter experts can give more realistic estimates, especially with a fully differentiated WBS. Use of the PERT methodology for project time estimates following a beta distribution will ensure that optimistic time estimates are moderated by the most likely and pessimistic values also. The contingency reserves can be added after accounting for this.

When time and cost estimates have to be carried out at a macro level and a detailed work breakdown structure cannot be prepared at that point in the project, Kahnemann and Lovallo (2003) propose to develop a reference class of similar projects and establish a probability distribution for the parameter being estimated. Flyvberg (2008) takes this further to propose what he terms as "Planning bias uplift". Under this method, similar projects are studied with respect to estimated costs (or time) and actual costs (or time) and the average factor of actual to estimate is determined for that class of projects. This factor is then used to give an uplift to the planning estimates to arrive at more realistic figures. Of course, this method is applicable for similar projects in complexity, time domain, geography etc.

Anchoring effect:

Anchoring is a framing bias when the project manager tends to rely too heavily on the first piece of information (Anchor) he receives about a subject, holds on to it and makes adjustments about the first piece of data. Once an anchor is established, all subsequent decisions and negotiations will centre and be informed by the initial suggestion. There will be a bias to interpret subsequent data around the anchor. M Lorko(2019) suggests that such relatively uninformed suggestions or expectations play a role in the estimation of project resources. Self-anchoring effect is the process in which future estimates of a Project Manager are anchored around his own first estimates. Mc Gray et al (2002) go on to further state that no amount of subsequently generated data will do little to offset the initial anchor.

This phenomenon is more in long gestation projects where the planning cell may be different from the execution cell. The results of the deviation from the planned estimates to the actuals are rarely communicated back to the planner that in the next project the planner again holds on to his anchor without realising that the estimate was negated in the previous project. It is necessary to provide feedback to the planners on the estimation accuracy so that they can recalibrate their anchors.

Another method of avoiding anchoring bias is to undertake bottoms up estimating for the project phase using templates drawn from the organisational process assets and validate the same using historical data. Halkjelsvik & Jørgensen (2012) bring out that the planning group should isolate itself from the expectations of the customers or the higher management while carrying out the estimating activity. Illustrating the effect of anchoring, the rough order initial time lines for developing a turbo prop engine was pegged at 36 months. After initial go ahead the project team carried out a detailed work breakdown structure and bottoms up estimate revealing that the project could take up to 50 months. However, the sponsors were anchored onto the initial value of 36 months (3 years) and continued to monitor against the initial time frame resulting in improper control efforts and the project was 60 % complete at the end of 50 months.

Loss Aversion bias:

Given multiple options, Project Managers tend to choose that alternative which minimises their risk rather than that option which maximises their profits (Schindler & Pfattheicher, 2016). Losses hurt more than their equivalent gains (Kahneman & Tversky, 1979).This is known as loss aversion bias. The pain of losing is about twice that of the pleasure of gaining an equivalent amount. Hence Project Managers expect to have twice the returns to venture into an innovation project than a safer routine project. Another manifestation of loss aversion is in risk management planning where the project manager tries to address risks even with low PI values leading to unnecessary expenditure on Annual maintenance contract, insurance premium, redundancy etc.,.

Loss aversion leads to risk aversion and is more predominant in long gestation projects executed by bureaucratic organisations. Swalm (1966) attributes this to the corporate incentives and control processes in large projects that actively discourages taking risks on behalf of the corporation. This means that the Project Manager needs to rationalise and prove to a degree higher than in his individual capacity the choice of a risky project.

Hullet (2006) proposes the widespread use of the decision tree approach to put on paper the multiple options, evaluate each and present pictorially to the stakeholders the rationale behind the choice. This approach uses the concept of Expected Monetary Value (EMV) of each approach and factors the probability of success of each approach. Organisations with slightly lesser risk appetites may use the expected Utility (E(U)) in place of the Expected Monetary Value (EMV) for arriving at decisions.

Adoption of Price Plus Incentive Contracts instead of fixed rate contracts will enable the Project team to reap the benefit of positive risks, incentivise the contractor to perform effectively and also reduce the high prices inbuilt in a fixed price contract.

A typical example of loss aversion bias is the training campus project planned at Rs. 70 crores with 2 years' time frame for completion. However, even after 5 years the project had not moved from planning to execution phase. When finally, the contract was awarded for execution, half way into the project, the contractor refused to further the work quoting cost over runs due to delay in award of contract. Since lot of money had already been invested into the project, the organisation was forced to put in another Rs. 27 crores and the project was completed in 7 years. During this period, the utilisation envisaged for the campus was no more existing resulting in a sub optimal use of project deliverable. A timely contract award along with a price cum incentive contract could have salvaged the project to some extent.

Execution Phase:

Confirmation Bias:

Nickerson (1998) defines confirmation bias as the tendency of seeking or interpreting evidence in ways that is consistent with the existing belief, expectation or hypothesis in hand. The Project Manager seeks information and data to reinforce held perceptions and ignores contrary information which tend to imply otherwise. With the result they maintain their stand even when confronted with information that should take them to a new decision. This can lead to systemic errors in decision making process where more effort is made to seek information that confirms previous preference

Confirmation bias can happen either at the individual level or at the group level. In order to overcome this, it is necessary to constitute Audit Committees and Project Review Boards with multiple stakeholders to review the progress of the project. Audit committees utilise check lists and templates to ensure that biases do not enter into the evaluation process. Project Review Board will have stakeholders with different points of view for a 360-degree assessment of project progress. Carrying out periodic project review with one or more team member playing the role of devil's advocate will enable bringing onto the table issues which otherwise tend to get hidden during the project execution.

Customer sponsored aerospace projects have a robust inbuilt mechanism of Program Management Group (PMG) to eliminate confirmation biases. Domain experts like designers and developers look for evidence to support their strongly held ideas while ignoring contra indications. Regulatory bodies, with limited implicit interest in the project further aid this process. Having a cross functional project Management group, for the Advanced helicopter program for instance with representatives from manufacturing, sponsors and pilots ensured that performance characteristics emanating from prototype trials were not ignored but methodically addressed leading to successful certification of the helicopter deliverables.

Sunk Cost Bias:

Sunk cost bias is defined by Olivola (2018) as the general tendency for pursuing an inferior alternative merely because of previously invested significant but non recoverable resources in it. Rationally this investment may not be justifiable and if the situation would have been related to similar investment is a new project, the decision would have been different. Sunk cost bias is significant in long gestation projects because a lot of resources including time would already have been invested irrevocably in the project and it would be difficult to abandon the project at this late stage. Further, where multiple project managers come and go in long gestation projects, the incumbent project Manager would not want to take the blame of pulling the project down but would rather keep funding the same in the glimmering hope that it may eventually complete. The effect of Sunk cost bias is that the project team continues riding dead horses potentially wasting money and blocking resources, which are not available to other, strategically more important projects, and leading people into a frustration over not really moving forward.

It would be prudent to have predefine kill points at various stages of the project in consultation with the sponsor, so that the project does not cross the stage gate without due evaluation and decision making. At the phase gate, a few high level risks would have become certainties resulting in no further business justification to continue treading the path. At these kill points, alternate strategies to salvage the project may be deliberated. One method is the use of Residual Return on Investment appraisal (RROI). If the project return on investment is more than the additional resources that need to be expended to complete the project, it may still be viable to go ahead with the project since it would at least salvage image of the company, but if the additional investment is not recoverable, it would be prudent to kill the project.

The decision on continuing or otherwise of the project phase has to be taken by the Program Management Office (PMO) based on a portfolio level perspective. The PMO review can carry out a due diligence analysis along with the project team, owners, sponsors and other stakeholders still identifying with the project. The PMO review will enable eliminating the sunk cost bias, release resources to more strategic projects and serve as a good example to other running projects to be evaluated on factual criteria and not on individual emotions.

Examples of legacy design projects continuing to be funded and manned long after its utility has been eroded are seen in large multi project organisations. For example, the aircraft design division of an organisation continued to put in resources for an unmanned aerial vehicle and unmanned combat aircraft project even though the deliverables were nowhere in sight since already a substantial fund had been sunk into the project.

Illusion of Progress:

Project Managers sometimes ignore structured tools and techniques and go by the rule of the thumb method to monitor and control projects. They rely on their expertise, experience and gut instincts to understand the progress of the project. As long as machines are clattering and people are moving and team members appear busy, the project Manager gets a wrong sense of progress. However, even though work is being done, the right work may not be being carried out or the work may not be adding value to the project. To get a sense of the track of the project, Project Managers use colourful dash boards displaying various numbers and graphs and they get an illusion of progress; but it is essential to identify the right metric for measuring the progress of the project. For example, using percentage completion may not give idea of completion of significant milestone which results in stage payments.

One way to avoid the illusion of progress is the use of Earned Value Methodology (EVM) to track the progress of the project. The Project Manager can monitor the value generated against the baselines and can make meaningful conclusions. Generating the "S" curve achieved against baseline enables the Project manager know the trend of progress of the project. Use of Critical Path Methodology enables tracking whether critical activities are being progressed or only easy but subcritical activities are being undertaken. Linking progress to milestones and milestone slip charts will clearly reveal progress against committed deadlines. Use of Gantt chart is another pictorial method to track progress of project on a continuous basis without getting affected by the illusion of progress.

A successful example of utilising Gantt charts to have visible display of project progress and critical delaying activities has been in the turbo trainer project. Methodical use of Gantt charts coupled with critical path methodology enabled unearth the effect of engine delivery delay likely to cause project delay resulting in proactive back up plan initiation and execution mitigating project delays.

CONCLUSION:

With increasing expectations of customers, complexity of projects are increasing. Long gestation projects need decisions to be taken in the present context which will have impact at a later point in time. The Project Manager who has taken the decision in one phase of the project will not be there in another stage of the project. In the wake of uncertainty, when Project Managers take decisions with limited data, biases tend to creep in. It is essential for the Project

Manager to be aware of the various biases that can cloud the decision-making process in various phases of the project. Use of structured tools and techniques as discussed in the paper will minimise the adverse effect of decision biases, more so in a VUCA environment. The paper has identified specific tools and techniques to be adopted to overcome specific types of biases and at various phases of the project. This paper serves as a checklist for a Project management practises audit to be undertaken by the PMO to ensure sound decision-making processes in the organisation.

REFERENCES:

Folkes, V. S. (1988). *The availability heuristic and perceived risk,.* Journal of Consumer research, 15(1), 13-23.

Hulett, D. T. (2006). *Decision tree analysis for the risk averse organization*. Paper presented at PMI® Global Congress 2006—EMEA, Madrid, Spain. Newtown Square, PA: Project Management Institute.

Jørgensen, M., Halkjelsvik, T., & Kitchenham, B. (2012). "*How does project size affect cost estimation error? Statistical artefacts and methodological challenges",* International Journal of Project Management, 30(7), 839-849.

Kahnemann, D., & Tversky, A. (1979). *Prospect Theory: a decision making under risk,* Econometrica, *47,* 263-292.

Kahnemann, D. (2011). *Thinking, fast and slow,* Allen Lane Paperback, 2011. *Kapitel*, *11*, 119-128.

Lorko, M., Servátka, M., & Zhang, L. (2019). *Anchoring in project duration estimation,* Journal of Economic Behavior & Organization, 162, 49-65.

McCray, G. E., Purvis, R. L., & McCray, C. G. (2002). *Project management under uncertainty: The impact of heuristics and biases,* Project Management Journal, 33(1), 49-57.

Mintzberg, H. (1989). *Mintzberg on management: Inside our strange world of organizations*. Simon and Schuster.

Nickerson, R. S. (1998). *Confirmation bias: A ubiquitous phenomenon in many guises,* Review of general psychology, *2*(2), 175-220.

Olivola, C. Y. (2018). *The interpersonal sunk-cost effect,* Psychological science, 29(7), 1072-1083.

Sharot, T. (2011). *The optimism bias,* Current biology, *21*(23), R941-R945.

Schindler, S., & Pfattheicher, S. (2017). *The frame of the game: Loss-framing increases dishonest behaviour*, Journal of Experimental Social Psychology, 69, 172-177.

Swalm, R. O. (1966). *Utility theory-insights into risk taking*, Harvard Business Review, 44(6), 123-136.

Thorndike, E. L. (1920). *The Constant Error in Psychological Ratings*, Journal of Applied Psychology, 4,25-29

Success Traits of Power Projects: Empirical Analysis

Achintya GHATAK[1] and Adarsh GARG[2]
CG Power and Industrial Solutions limited; achintya.ghatak@gmail.com and
Galgotias University; adarsh.15@hotmail.com

ABSTRACT

Power Transmission constitutes an essential part of power projects, which, in turn, are more like construction projects. Thus, power projects' success becomes a significant concern with the increased boundary and volume of the power transmission sector in the recent decade, especially in India. This study emphasizes the need to investigate and comprehend the success traits of power transmission projects. The research objective is to identify power transmission projects' critical characteristics and study their relationship with project success. This study discusses a set of 43 variables into six groups of factors vis-a-vis Strategy, Risk, Supply Chain, Information Communication Technology, Environment, and Project Success. The research tool comprises a survey questionnaire, and personal interviews with experts of power transmission projects actively involved in the projects at various levels, and 414 valid responses are received. The statistical analysis comprehends that all five critical factors significantly affect the Power Transmission Project Success. These findings are likely to contribute significantly to achieving the project's success in management and social perspective to the Indian power transmission industry.

KEY WORDS

Critical Success Factors (CSFs); Strategy; Information Communication Technology (ICT); Power Transmission (PT)**.**

1. **INTRODUCTION**

The power sector contains three areas: power generation, power transmission (lines & substations), and power distribution. Power Transmission, a vital part of the power transport value chain, dissipates power from the generating stations to its delivery to the load centers. So, more transmission power projects need in India. The power transmission project characteristics are quite similar to the construction projects, and the primary concern of the project team is on project success. Substation in PT projects activities such as control building, pump house, drain, road, dormitory is similar to a non-power construction project. PT project and other infrastructure projects like road projects, oil and Gas projects face similar challenges: ROW problem, land acquisition, and land development. Over the most recent five years, the India transmission segment has indicated robust growth. Essentially, the state, center, and the private utilities' rule the power transmission segment, while long before, private utilities had control of just 3-4 percent on the power transmission area. According to Center Electricity Authority (CEA), a two lakh sixty thousand (2.6 lakh) crore venture would occur in the power transmission segment from FY18 to FY22, shown in Table-1.

Table-1: Projected Investment in Power Transmission sector in India between FY 18-22

Total Investment	2.6 lakh crore
Transmission Line	100000 Circuit KM
Substation: Transformer Capacity	200000 MVA

Source: Central Electricity Authority, India, 2018

In terms of GDP and power consumption, India is now among the fastest-growing countries in the world. The challenge is to address the energy needs of around 1.3 billion people with fast economic growth and electricity use. To ensure reliable, accessible, uninterruptible (24x7) and quality power for all, effectiveness, organized, affordable and stable electricity system is necessary for the smooth supply of power from the generating station to the load centers (as per the Electricity Act, 2003) and for the optimal utilization of resources. India has set a 9 percent target growth rate that would put it on a track to become a USD 5 trillion economy by 2024-25, making it the world's fastest-growing large economy. Sustained economic growth in India puts a massive pressure on its energy resources, energy systems, and infrastructure.

The PT project area's significance necessitates recognizing CSFs and their effect on India's PT projects venture accomplishment. Various researchers have estimated the capability of the power sector in India. However, their examination is constrained to potential, arrangement, difficulties, and possibilities of the power division. Some factors are identified for reducing power shortage, which is including Properties, reduction of losses in distribution and transmission, supply - site management by maximum electric energy efficiency, policy shifts in pricing models, switch and focus on renewable energy for power generation, total energy systems, latest energy storage devices (Kumar, et.al., 2014). It is decoupled, and open up to private entrepreneurs for involvement, with the prerequisite of investing heavily and in order to provide competitiveness in the overall structure. Therefore, it has opened the way for business opportunities to be used for investment (Mukhopadhyay, 2004).

1.1 Research Objectives

This research aims

- To identify critical success factors (CSFs) for power transmission projects in India.
- To study the relation and impact of all those CSFs to project success for PT projects in India.

1.2 Organization of The Study

The study has organized as following manner:

- Introduction
- Literature Review
- Research Methodology
- Result and Discussion
- Conclusion and Recommendation

2. LITERATURE REVIEW

This piece of the exploration subtleties analyzes the past literature in critical success factors (CSFs), strengthening the present study to discover the CSFs for the power transmission projects.

2.1 Project Success

For the last numerous years, researchers concentrated on achieving the iron triangle targets (time, cost, and quality). The achievement of the project is frequently shifted among various partners. The project, within time and cost, are dealt with, has failed on the likelihood that it does not accomplish the organization's vital goals (Frefer, 2018, & Cooke-Davies, 2002), and it is referred to that project achievement which has three diverse gatherings of goals, i.e.

- Project objective (the iron triangle of cost, time, and scope).
- Business objectives (Owner's expectation) and

- Social and Environmental objectives (local community's expectation)

2.2 Finding Critical Success Factors

Critical Success Factors (CSFs) are mainly those that demonstrate an indispensable activity in achieving an association through the project. The possibility of "success factors" is created in 1961 by D. Ronald Daniel of McKinsey and Company. It is refined into critical success factors in1981 by John F Rockart. From that point forward, numerous creators have distributed arrangements of "CSFs."

After a comprehensive literature audit, it is essential to explore the success traits of PT projects to view the potential of and expenditure on PT projects in India. The primary success traits are proposed for power transmission projects in India, as Strategy, Risk, Supply Chain, Information Communication Technology, and Environment.

The past literature and current study discuss the following factors in power sector projects in Table-2.

Table-2: Critical Factors in Power Sector Projects

S. No	Author	Location	Research Variable/CSFs	Current Study Variable Identified
1	Aziz, (2013)	Egypt	1) consultant, 2) contractor, 3) design, 4) equipment, 5) external, 6) labor, 7) material, and 8) project	**Strategy:** nine (9) sub-factors which include :1) Leadership strategy(S-CSF1), 2) Bidding strategy(S-CSF2), 3) Strategy of addressing risk(S-CSF3), 4) Clear Objectives and understanding(S-CSF4), 5) Cohesive procurement strategy(S-CSF5), 6) Strategy of effective communication(S-CSF6), 7) market intelligence strategy(S-CSF7), 8)
2	Bhattacharyya and Dey (2007)	India	1) political, 2) financial, 3) economic, 4) legal and regulatory framework, 5) management failure	

<table>
<tr><td>3</td><td>Choudhury (2014)</td><td>India</td><td>1) conception and feasibility studies, 2) project planning,3) bidding and contracting 4) project implementations</td><td rowspan="7">Strategic execution plan align with project scope(S-CSF8), and 9) Human resource strategy (S-CSF9).

Risk: nine (9) sub-factors for risk factor dimension include: 1) fund flow of client(R-CSF1), 2) control of scope creeping(R-CSF2), 3) team conflict resolution(R-CSF3), 4) timely subcontractor payment(R-CSF4), 5) clear and unambiguity scope(R-CSF5), 6) Justified penalty clause(R-CSF6), 7) timely document and drawing approval(R-CSF7), 8) price variation clause(R-CSF8) and 9) test list with less frequency(R-CSF9).

Supply Chain: six (6) sub-factors dimension are: 1) early assortment of supplier (SC-CSF1), 2) selection of appropriate vendor (SC-CSF2), 3) clear responsibility matrix between supplier and purchaser (SC-CSF3), 4) relationship with suppliers & client (SC-CSF4), 5) proper co-ordination between supplier and client (SC-CSF5), and 6) clear terms & condition (SC-CSF6).

Information Communication technology: five (5) sub-factors for information communication technology are; 1) e-tendering (ICT-CSF1); 2) improve design</td></tr>
<tr><td>4</td><td>Doloi, et. al., (2012)</td><td>India</td><td>1) project, 2) site, 3) process-related, 4) human, 5) authority and (6) technical</td></tr>
<tr><td>5</td><td>Hermawati and Rosaira (2017)</td><td>Indonesia</td><td>1) Planning, 2) community 3) communication and beneficiaries, 4) technology, 5) project management, 6) stakeholders support and network development.</td></tr>
<tr><td>6</td><td>Mohan, A., and Topp, K., (2018)</td><td>Pakistan</td><td>1) communication factor, 2) team factors, 3) technical factor, 4) organizational factor, and 5) environmental factor</td></tr>
<tr><td>7</td><td>Maqbool, et al. (2018)</td><td>Pakistan</td><td>1) communication, 2) team, 3) technical, 4) organizational, 5) environmental</td></tr>
<tr><td>8</td><td>Nundwe, and Mulenga (2017)</td><td>Zambia</td><td>1) late advance payments, 2) financial mismanagement by the contractor, and 3) irregular payments to sub-contractors</td></tr>
<tr><td>9</td><td>Pall et al. (2016)</td><td>Not Specified</td><td>1)administrative, 2) employer 3) servicer, 4) advisor, 5) sketch, 6) material, 7) apparatus, 8) worker, 9) miscellaneous</td></tr>
</table>

10	Tsiga, et. al., 2016	Not Specified	1) External Challenge, 2) Client knowledge and experience, 3) Top management support; 4) Institutional factors, 5) Project characteristics, 6) Project manager competence; 7) Project organization, 8) Contractual aspect, 9) Project team competence, 10) Project Risk Management; 11) Requirements Management	(ICT-CSF2); 3) planning & monitoring software (ICT-CSF3); 4) integration of project activities (ICT-CSF4) and 5) standardization of process (ICT-CSF5). **Environment**: six (6) sub-factors for environment and third-party factor include: 1) available encumbrance free land (E-CSF1), 2) accessibility of site (E-CSF2), 3) environment clearance and obtain permit (E-CSF3), 4) stable government (E-CSF4), 5) availability of construction material (E-CSF5), and 6) safety measure at site (E-CSF6).
11	Zhao et al. (2010)	China	1) viability, 2) set-up, 3) company, 4) servicer, 5) suppliers	

2.3 Research Gap

The analysis of literature identified the significant gap as given below:

- In the past literature, the success of PT projects has not been studied concerning Strategy, Risk, Supply Chain, Information Communication Technology and Environment as the CSFs.
- There is no study on PT projects in India.
- There is no holistic framework for PT projects, which can be considered standard.

2.4 Hypotheses

The above writing sets up five significant traits as the success factors for power transmission projects: strategy factors, risk factors, supply chain factors, information communication technology factors, and environmental factors. Thus, the researcher proposed the following hypotheses for this study to be tested here:

H_1: Strategy factor effect Project success.

H_2: Risk factors effect Project success.

H_3: Supply chain effect Project success.

H_4: Information communication technology effects Project success.

H_5: Environment effects project success.

3. RESEARCH METHODOLOGY

A logical approach is drawn for a robust research design that contains new empirical evidence along-with the prevailing theory. A questionnaire survey design is used to collect quantitative data in a random sample of project management team members, forming a wide range of respondents to achieve the derived theory's extensive analysis. The research method for the present study is given in Figure-1.

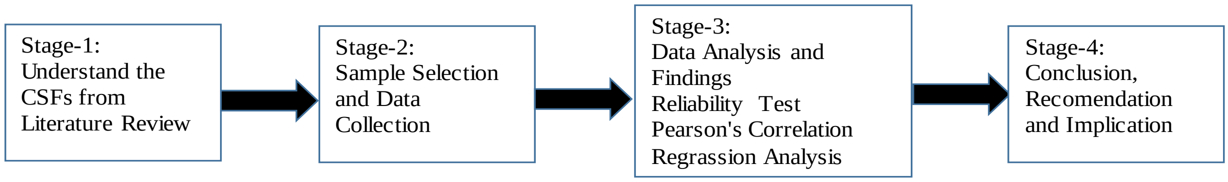


Figure-1: Research Methodology

Source: Self Design of Author

3.1. Questionnaire development

Identifying of critical success factors for the study and development of a questionnaire is a significant step for the research's conclusion. In the present study, six variables are being studied, which comprise of one dependent factor, i.e., project success, and five independent factors, namely: 1) Strategy, 2) Risk, 3) Supply Chain, 4) Information Communication Technology, and 5) Environment. The questionnaire is based on five-point Likert Scale, with ‘1’ as "no impact," ‘2’ as "negligible impact," ‘3’ as "marginal impact," ‘4’ as "moderate impact," and ‘5’ as "major impact".

3.2. Population, and sampling technique

The project team members include project managers and top management of various organizations taking power sector projects in India, is the "unit of investigation" for this exploration. Table-3 shows a concise portrayal of respondents' profiles regarding experience, function, and company (Public & private) who partook in this study. An aggregate of 485 surveys was sent out, of which got 414 substantial responses with a response rate of approximately 85 percent. Different techniques, such as email, web, and telephonic conversations, are used to gather specialist's data.

Table-3: Respondents Profile

Characteristics	Category	No. of respondents	In Percentage (%)
Experience	1-5 years	35	8
	6-10 years	52	13
	11-15 years	74	18
	16-20 Years	85	21
	21-25 years	102	25
	Above 25 years	66	16
Function	Strategy	135	33
	Operation	279	67
Company	Private	339	82
	Public	75	18

Source: Authors Own

4.RESULTS AND DISCUSSION

4.1 Mathematical validity of factor analysis

Utilizing the statistical tool SPSS-25, ascertaining the Pearson correlation, the researcher evaluated the relationship among different variables. Pearson correlation is given in Table-4. It is found that the Pearson bivariate correlation is more prominent than 0.4 in the vast majority of the cases among various variables in all the factors. These outcomes show that factors structured in factor analysis contain most related variables.

Table-4: Correlation matrix for the Success Traits

Factor I: Project Success

	PSCSF 1	PSCSF 2	PSCSF 3	PSCSF 4	PSCSF 5	PSCSF 6	PSCSF 7	PSCSF 8
PSCSF1	1							
PSCSF2	.374**	1						
PSCSF3	.597**	.428**	1					
PSCSF4	.376**	.486**	.479**	1				
PSCSF5	.479**	.572**	.540**	.465**	1			
PSCSF6	.510**	.450**	.414**	.408**	.356**	1		
PSCSF7	.501**	.489**	.539**	.448**	.398**	.458**	1	
PSCSF8	.445**	.392**	.505**	.520**	.556**	.300**	.403**	1

Factor II: Strategy

	SCSF1	SCSF2	SCSF3	SCSF4	SCSF5	SCSF6	SCSF7	SCSF8	SCSF9
SCSF1	1								
SCSF2	.332**	1							
SCSF3	.484**	.347**	1						
SCSF4	.354**	.430**	.383**	1					
SCSF5	.492**	.472**	.546**	.527**	1				
SCSF6	.431**	.376**	.395**	.522**	.412**	1			
SCSF7	.379**	.444**	.362**	.460**	.470**	.367**	1		
SCSF8	.384**	.443**	.392**	.438**	.543**	.426**	.375**	1	
SCSF9	.354**	.417**	.406**	.426**	.379**	.517**	.456**	.462**	1

Factor-III: Risk

	RCS F1	RCSF2	RCSF3	RCSF 4	RCSF 5	RCSF6	RCSF 7	RCS F8	RCS F9
RCSF1	1								
RCSF2	.300**	1							
RCSF3	.449**	.315**	1						
RCSF4	.462**	.448**	.487**	1					
RCSF5	.393**	.420**	.325**	.322**	1				
RCSF6	.487**	.458**	.492**	.416**	.400**	1			
RCSF7	.312**	.365**	.479**	.428**	.438**	.398**	1		
RCSF8	.386**	.485**	.314**	.351**	.379**	.422**	.350**	1	
RCSF9	.450**	.302**	.462**	.435**	.442**	.493**	.366**	.390**	1

Factor IV: Supply Chain

	SCCSF1	SCCSF2	SCCSF3	SCSCF4	SCCSF 5	SCCSF 6
SCCS F1	1					
SCCS F2	.487**	1				
SCCS F3	.531**	.452**	1			
SCSC F4	.472**	.484**	.506**	1		
SCCS F5	.525**	.427**	.537**	.478**	1	
SCCS F6	.569**	.593**	.498**	.529**	.523**	1

Factor V: Information Communication Technology

	ICTCSF1	ICTCS F2	ICTCSF3	ICTCS F4	ICTCS F5
ICTCSF1	1				
ICTCSF2	.475**	1			
ICTCSF3	.473**	.535**	1		
ICTCSF4	.523**	.549**	.588**	1	
ICTCSF5	.467**	.568**	.527**	.524**	1

Factor VI: Environment

	ECSF1	ECSF2	ECSF3	ECSF4	ECSF5	ECSF6
ECSF1	1					
ECSF2	.391**	1				
ECSF3	.504**	.594**	1			
ECSF4	.524**	.441**	.460**	1		
ECSF5	.480**	.533**	.564**	.495**	1	
ECSF6	.428**	.562**	.612**	.459**	.526**	1

As thumb rule applies to most situations with the following ranges: Cα>0.9 indicates excellent, 0.9>Cα>0.8 as good, 0.8>Cα>0.7 as acceptable, 0.7>Cα>0.6 as questionable, 0.6>Cα>0.5 as low, and 0.5>Cα denotes unacceptable (Doloi, et. al., 2012). The value of Cα for all variables are greater than 0.8 as shown in Table-5.

Table-5: Reliability Cronbach's Alpha for the Factors

Factors		**Cronbach's alpha (Cα)**
Project Success	Factor I	0.872
Strategy	Factor II	0.871
Risk	Factor III	0.81
Supply Chain	Factor IV	0.86
Information Communication Technology	Factor V	0.846
Environment	Factor VI	0.86
All Factors Are Selected		0.947

Source: Authors Own

4.2 Regression analysis

The independent variables (Strategy, Risk, Supply Chain, Information Communication Technology, and Environment) and dependent variable (Project Success) used are the factors that resulted from the factor analysis, as shown in Table 4. These factors are entered into a regression model stepwise as categorical variables are shown in Table-6. In this way, can communicate the regression model framed to measure the overall impact of project success by singular traits part as:

$$Y = a + b_1X_1 + b_2X_2 + ... b_nX_n + e \text{ -------------- } (1)$$

Table-6: Regression Model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson	
1	.642[a]	0.413	0.406	0.5641	2.18	
		Sum of Squares	Df	Mean Square	F	Sig.
Source			**Coefficient(β)**	**Std. Error**	**t**	**Sig.**
Intercept			1.183	0.186	6.369	0.000
Strategy			0.166	0.049	3.355	0.001
Risk			0.19	0.053	3.574	0.000
Supply chain			0.12	0.045	2.664	0.008
Information communication technology			0.147	0.043	3.432	0.001
Environment			0.138	0.046	3.022	0.003

Source: Authors Own

The proposed regression model for impact of success can be explained as:

Impact of Success = (+1.183)

Strategy(X_1) = (+0.166)

Risk(X_2) = (+0.190)

Supply Chain (X_3) = (+0.120)

Information Communication Technology(X_4) = (+0.147)

Environment(X_5) = (+0.138)

Error (e) = (+0.186)

From the above it was derived the following equation:

$Y=1.183+0.166X_1+0.190X_2+0.120X_3+0.147X_4+0.138X_5+0.186$ ---------- (2)

From this result of regression analysis, independent variables; Strategy, Risk, Supply Chain, Information Communication Technology, and Environment all put together have a 41.30 percent impact on India's power transmission project success. One-unit change of project success happens by change 0.166-unit Strategy, 0.190-unit Risk, 0.120-unit Supply Chain, 0.147-unit Information Communication Technology, and 0.138-unit Environment.

4.3 Hypotheses

From Table-6 below hypotheses are drawn;

H_1: Strategy factor has significant ($p=0.001<0.05$ and $t=3.355$) affect Project success.
H_2: Risk factor has significant ($p=0.000<0.05$ and $t=3.574$) effect on Project success.
H_3: Supply chain factor has significant ($p=0.008<0.05$ and $t=2.664$) affect Project success.
H_4: Information communication technology factor has significant ($p=0.001<0.05$ and $t=3.432$) effect Project success.
H_5: Environment factor has significant ($p=0.003<0.05$ and $t=3.002$) affect project success.

5. CONCLUSION AND RECOMMENDATIONS

This study has identified 43 sub-factors into 6 groups and shown the relationship between CSFs and project success in India's power transmission project. The proposed model of this study claims the idea of project success with the support of CSFs in PT projects, which scarcely investigated in the existing published literature. The present study would enhance the CSFs information base by enriching the research conclusions concerning their impact on transmission power projects' success. PT project management practitioners can use this model to generate efficient results in terms of organizational and business goals.

REFERENCE:

Aziz, R. F., (2013), "Ranking of Delay Factors in Construction Projects After Egyptian Revolution", Alexandria Engineering Journal, 52(3), 387–406.

Bhattacharyya, S. C. and Dey, P K, (2007), "Managing Risk in A Large Rural Electrification Programme In India", Impact Assessment and Project Appraisal, 25(1), 15-26.

Choudhury, D. K., (2014), "Project Management Information System for Construction of Thermal Power Plant: A Case Study with Special Reference to National Thermal Power Corporation Limited, India", International Journal of Engineering Research & Technology (IJERT), 3(3), 2352-2377.

Cooke-Davies, T., (2002), "The ''real'' success factors on projects", International Journal of Project Management, 20, 185–190.

Doloi, H., Sawhney, A., Iyer, K. C., and Rentala, S., (2012), "Analyzing Factors Affecting Delays in Indian Construction Projects", International Journal of Project Management, 30(4), 479–489.

Frefer, A. A. Mahmoud M.; Haleema, H.; and Almamlook, R., (2018)," Overview Success Criteria and Critical Success Factors in Project Management", Industrial Engineering & Management, Vol. 7, No. 1, pp 1-6.

Hermawati, W.; and Rosaira, I., (2017) "Key Success Factors of Renewable Energy Projects Implementation in Rural Areas of Indonesia", Journal of STI Policy and Management, 2(2), 111–125.

Kumar, S., Bhattacharyya, B., and Gupta, V. K. (2014), "Present and Future Energy Scenario in India", The Institution of Engineers (India).

Mohan, A., and Topp, K., (2018), "India's Energy Future: Contested Narratives of Change", Energy Research & Social Science, 44, 75–82.

Maqbool, R., Rashid, Y., Sultana, S., and Sudong, Y., (2018), "Identifying the Critical Performance Factors and Their Relevant Aspects for Renewable Energy Projects; An Empirical Perspective", Journal of Civil Engineering and Management, 24(3),223–237.

Maqbool, R., Sudong, Y., Manzoor, N., & Rashid, Y., (2017), "The Impact of Emotional intelligence, Project Managers' Competencies, and Transformational Leadership on project Success", Project Management Journal, 48(3), 58–75.

Mukhopadhyay, S., (2004), "Power Generation and Transmission Planning In India – Methodology, Problems And Investments", IEEE Power Engineering Society General Meeting.

Nundwe, M. and Mulenga, M. N. (2017), "Delays in Construction of Electrical Power Transmission Lines in Zambia", American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS), 30(1), 82-96.

Pall, G. K., Bridge, A J., Skitmore, M., and Gray, J., (2016), "Comprehensive Review of Delays in Power Transmission Projects", IET Generation Transmission & Distribution, 10(14), 3393 – 3404.

Tsiga, Z.; Emes, M.; and Smith, A., (2016)," Critical Success Factors for the Construction Industry", PM World Journal, V(VIII), 1-12.

Zhao, Z. Y., Zuo, J., Zillante, G., Wang, X. W (2010), "Critical Success Factors for BOT Electric Power Projects in China: Thermal Power Versus Wind Power", Renewable Energy, 35(6), 1283-1291.

Developing an Integrated Framework for Heavy Construction Equipment Management Platform

Nandan KUMAR[1] and Jyoti TRIVEDI[2]
CEPT University, Ahmedabad; email: nandannda@gmail.com [1]
CEPT University, Ahmedabad; email: jyoti@cept.ac.in[2]

ABSTRACT

There is growing need for better project management techniques within the disciplines of engineering, business, and technology. With the advent of industrialization, the projects of humankind took on increasing complexity. To keep pace with advances in information technology and business processes, the organizations must change their strategy of traditional work management, which will enhance project productivity. Contractor's organization always suffers of productivity issues. Significant contributions of issues are from the equipment department, due to ineffective management. By emphasizing practical applications, the study targets the ultimate purpose of project management: to unify and integrate the interests, resources, and work efforts of many stakeholders to accomplish the overall project goal. There is a need of centralized solution to manage the equipment. A literature study extracts the factors which have a direct influence on EMS. To know the absence of factors in the study, a comparison study is made between factors of literature review and factors of commercially available EMS's. It leads to generate a framework to include and combine all the factors which are missing in existing standalone EMS's. The problem is around the real-world practice, a constructive based design-science research method is adopted for the research. A top construction company in India is shortlisted for the case study to extract the factors and incorporation of the EMS in the company. The research outcome is used in creation of an integrated framework for EMS, which is a set of guidelines that include, required inputs for EMS, visualization framework, user interface design, implementation plan, incorporating innovative ideas in the proposed framework.

KEYWRODS

Equipment Management System (EMS), Information Technology, BIM (Building Information Modelling, GA (Genetic Algorithm)

INTRODUCTION

A contractor company in the construction industry strives for the efficiency of the tasks. Equipment in construction companies is always prone to ineffective utilization. Half of the success is achieved by effective management of equipment during the life cycle. The information technology is developed in such a way that the projects are being executed rely heavily on the asset management system of the company. The research is focused on the integration of available technologies and equipment management platforms during the operational phase of the equipment. The manual errors could be reduced by integrating the available technologies. The Objectives of the research are: Identification of problems in Standalone EMS tools. Identification of factors responsible for operation of existing EMS. Development of a framework to show information flow. Implementation plan for EMS as a product delivery. The Scope of the research work is choosing a Case study to check the evolved level of EMS in the organization and the presence of factors as per literature review. Study of heavy construction equipment used, and the research is limited to two shortlisted factors.

LITERATURE REVIEW

Equipment in the construction industry plays a very important role in finishing the tasks in given constraints viz. budget, time, quality, safety environment etc. 36% of the construction costs are of equipment costs. (Hadikusumo & Prasertrungruang, 2016). The equipment management system in a contractor company is governed by following factors: *Information***:** Updated and accurate information availability of equipment in organization, like serial number, date of purchase, Service life, vale of the equipment etc. (Tavakoli et al., 1990). *Tracking:* Tracking of equipment and its tasks. *Planning:* Equipment planning based on its tasks. *Maintenance:* Periodic maintenance of the equipment. *Equipment management platform:* Modern and user-friendly EMS will be a better solution to manage the equipment in a contractor company. (Room, 2019)(Tatari & Skibniewski, 2006). The equipment management system in the contractor company is an important asset for efficient management of operations of equipment. The productivity of the project team and time would be saved by equipment sharing between two contractors within the project.(Liu et al., 2018). *Existing Integrated Platforms and Frameworks:* (Ren et al., 2017) Efficient utilization of equipment will happen from effective equipment management. (Niu et al., 2017) proposed data management system architecture for construction equipment management. *Methods of data analysis* : (Sharma, 2013) explains and demonstrates the role of the genetic algorithm in different domains of computer science. Working with GA aims to get a better solution from the number of available solutions. (Thengade & Dondal, 2012) said the working of GA is depended on the following major operators viz. selection, crossover, mutation.

Factors in Equipment Management System

The factors are building blocks of EMS, each factor is constituent of equipment, associated task and manpower which is associated with the task. Its denoted as following: Equipment (E), Task(T) and Manpower (M) The uses of factors are explained based on whether its related to Equipment, Task or Manpower as explained in Figure 1. Finding all the factors which are responsible for operation of EMS in literature review.

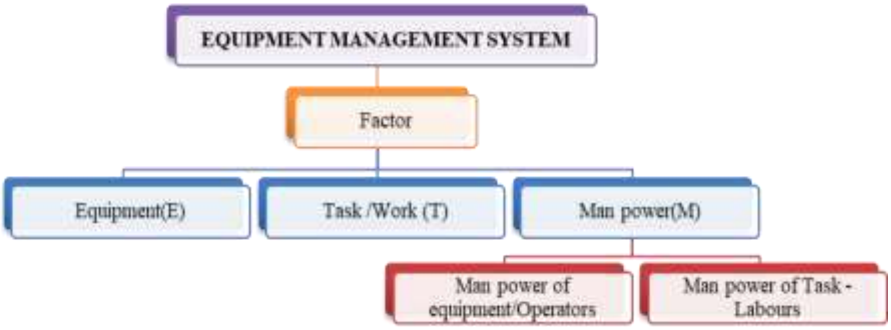


Figure 1 Factor configuration in EMS

If 'Location tracking' is a factor, if task information is related to equipment then, suffix is **E** (Real time location), likewise **M** (Labors associated with equipment) and **T** (Tracking of assigned task) are marked. As per the usage five different categories of factors are made. A) Information Category: Description, Cost, Efficiency, Manuals. Research Gap: BIM Based integrated manuals. B) Planning Category: Projections, Equipment planning. C)Tracking Category: Location tracking, Detection, Positioning & orientation, Equipment Statistics, Task based monitoring, Operating assistant system, Equipment operation, Automation in works. *Research Gap: Tracking of task's location with BIM visualization is not completely developed, Realtime data entry vs task progression, Live data of equipment failure*. D)Maintenance Category: Performance surveillance, Energy optimization, Periodic maintenance and insurance data. *Research Gap: This information should be kept in the server for faster access and immediate action and resolution plan.* E) Safety Category: Accident prevention / Equipment break down prevention system, Hazard energy monitoring system. *Research Gap: Alert to get* *alternative equipment which is available nearby – Equipment sharing platform within the project.*

RESEARCH METHODOLOGY

Constructive based design science research method is chosen, as research is around the real-world practices and problems. Understanding of the topic using a case-based project & using literature review. Collecting the data from case study and literature review and analyzing the data to arrive at a framework in terms of guidelines. Creating a framework includes a set of guidelines which are needed for creating an IOT & cloud-based product development. It integrates available platforms or ERP's.

DATA COLLECTION

The data collection from the case study was required to find out the benchmark of the integration of the existing standalone software. The information regarding technologies used in current EMS will be known. Available factors in EMS in the selected project in comparison with factors that are found out in the literature review is found. There was dedicated plant & machinery division and establishment of software which was used to track and monitor all the equipment at the site. All the information in the company was tracked and maintained in 8 divisions of *SAP-HANA1709*.

DATA ANALYSIS

Two factors are shortlisted for further data analysis. Viz. *Equipment statistics, Task based monitoring.* The shortlisted factors are from Tracking Category as per literature review. An excavator is shortlisted to carry out the analysis for the shortlisted factors.

Required Data Input

The Required data input for *equipment statistics* and *task-based monitoring*, which is to be loaded for the successful working of integrated equipment platform for equipment statistics. In the case study, all the data is not loaded in Realtime. By end of the day data is collected and synched in the central server. The cost and time impact from the data input which is qualitatively analyzed. Texts in Italics shows the desired solution vs current practice. As per the case study,

Equipment Statistics: Equipment distance was tracked offline through odometer. *Sensor and Realtime synchronizations of data with the platform.* Location tracked manually. *GPS trackers* *will avoid De routing of the equipment.* Productivity tracking was manual. *Sensors which tracks the current productivity.* Manual fuel tracking through empharical methods. *Sensors synced with the central platform to avoid fuel thefts*.

Task-Based Monitoring**:** Description of the work was conveyed verbally at site. *Automatic integration of project schedule. Task details on equipment operator's dashboard.* Work hours were tracked manually. *Realtime tracking of the equipment.* Human resource integration with work was manually tracked. *Automated workers entry in the server through mobile/tablet platform.* Task based assistant system was not present. *The platform should be able to guide automatically to workforce. Reduces communication errors.*

Visualization Framework

As shown in Figure 2 Visualization framework, It consists of following main components: *Access Medium:* The medium of information accessibility, it can be mobile app, web portal or desktop application. *Data cloud:* The data cloud is pool of information where the data is retrieved from the cloud based on the query. The type of information is segregated and fetched based on the following division: Preconstruction, Realtime data, Post construction data. The data cloud is interlinked with other main components. *Site input:* This component is for retrieval of information from the site and it is decided by the interference. There are mainly three types of information retrieval are: 1) Equipment data, 2) Operator data, 3) Workforce data.

Results: Results are real-time data or Prediction. *Output:* The output will be in the form of Visualization, Charts, analytics & Reports. *Hardware and software:* There are various types of hardware & software which will help in connecting all the components, for smooth run of the main product. As the product designed in different components, the solution can be applied to any plants & equipment at the organization. The software can be customized for both existing and new equipment.

Query Example

Requirement of information like *"Fuel Status",* Conventionally the project manager asks site manager via phone call then the reply will be given via call/ text messages/ mail. Usually the process takes around 1- 24 hrs. If they use SAP severs (case study) to send the data, takes up to 24 hrs. to give the complete information. The concerned factor for this information is *"Equipment statistics".* The main challenges in the conventional methods are: Manual errors due to human interventions and Unavailability of right person during the information exchange. As per the software solution it will take seconds to address the query including predictive analysis. *Additional results of the solution:* 1) The solution gives the fuel tank health: It will be helpful in knowing till when does fuel lasts based on the type of work it involved. 2)Upcoming task and fuel requirement can be predicted, so scheduled fuel filling can be known by background calculations. Nearby fuel station or method of filling can be predicted by syncing the productivity and nearby location analysis.

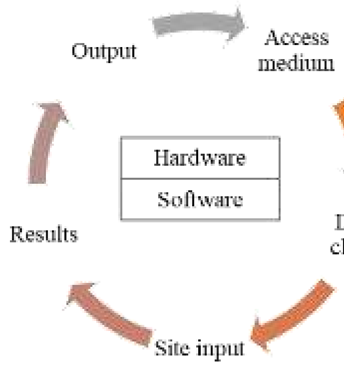


Figure 2: Visualization framework

Predictive Analysis

The fuel factor is considered for the predictive analysis. The related data is collected from 334 excavators from the case study. 4 aspects are considered for the analysis i.e. fuel issued quantity in liters, work done in cum, total working time and idle time in hrs.

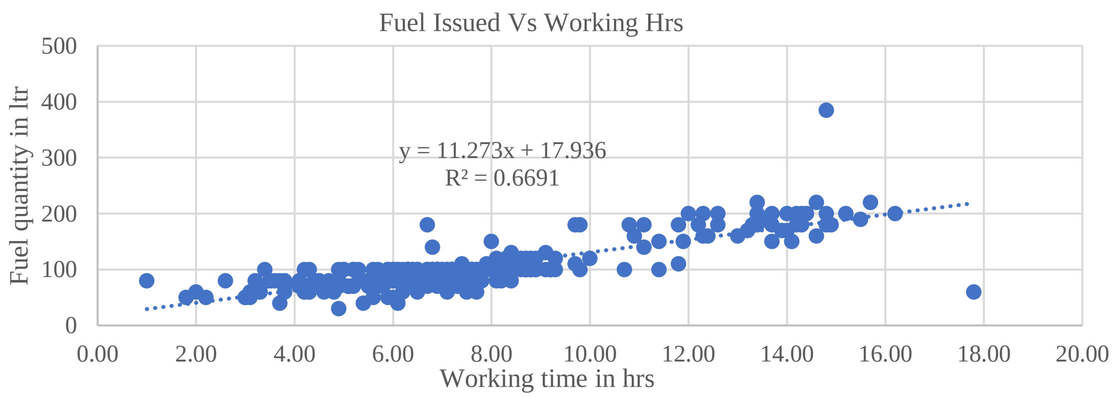


Figure 3 Fuel vs Working hrs. correlation

As shown in Figure 3, the fuel issued quantity is directly proportional to the working hours with r^2 value being 0.66, fuel quantity which is issued is dependent on the working hrs of the excavator in the data set considered. Similarly, the fuel issued quantity is directly proportional to the work done of the excavator with r^2 value being 0.14 and its directly proportional to idle time of the excavator with r^2 value 0.18. The genetic algorithm is used to find the alternative for given factor using the given constraints. *Optimization and Analysis:* As per the first factor 'Equipment statistics', the 'Fuel factor' must be minimized using the working hours, work done and idle time as constraints.

As per the second factor 'Task-based monitoring', the 'work done' must be maximized by using fuel consumed, working hours and idle time as constrains. To optimize the factors 'GA Optimization for Excel-Version 1.2' is used as part of the genetic algorithm analysis. (Schreyer, 2006)(Trivedi et al., 2012). *Optimization - Fuel Minimization***:** The objective function for applying in GA is given by *"Eq (1)"*

$$Y = a0 + a1 (X1) + a2 (X2) - a3(X3) \qquad (1)$$

Where, Y = Fuel consumed in ltr and a0, a1, a2, a3 are constants. X1 = Working hours in hrs, X2 = Work done in cum, X3 = Idle time in hrs. Its solved using multi linear regression (MLR) with the help of built-in add on of MS excel data analysis tool pack. The resulted data is substituted in *"Eq (1)",*

$$Y = 16.50 + 10.24 (X1) + 0.01 (X2) - 2.53 (X3) \qquad (2)$$

$R^2 = 0.68$, which implies dependent values can be explained by the regression model. *"Eq (2)"* is used in addon, GA software in excel as mentioned earlier to get optimized values. Dependent variables considered 1 unit. The minimization function is processed for independent value that is **fuel consumption**.

Table 1 Optimized values vs Site values

Sl	Variables	Site values (As per MLR)	Predicted values
1.	Fuel consumed in ltrs	24.22	355.96
2.	Working time in hrs	10.24	42.95
3.	Work done in cum	0.01	320.09
4.	Idle time in hrs	2.53	23.59

Optimization - Work done Maximization: The objective function for applying in GA is given by,

$$Y= b0 + b1 (X1) + b2 (X2) - b3(X3) \qquad (3)$$

Where, Y = Work done in cum and b0, b1, b2, b3 are constants, X1 = Working hours in hrs, X2 = Fuel consumed in ltr, X3 = Idle time in hrs. Using MLR, the coefficients are generated. The resulted data is substituted in *"Eq (3)"*

$$Y= 121.40+ 19.46 (X1) + 0.60 (X2) - 0.85 (X3) \qquad (4)$$

$R^2 = 0.17$, very smaller number of depended variables can be explained in regression model. *"Eq (4)"* is used for maximization function for work done by excavator.

Table 2 Optimized values vs Site values factor 2

Sl	Variables	Site values (As per MLR)	Predicted values
1.	Work done in cum	140.61	1814.36
2.	Working time in hrs	19.46	692.97
3.	Fuel consumed in ltrs	0.6	1000
4.	Idle time in hrs	0.85	0.01

All the predictive analysis happens in background when the integrated EMS is fully functional.

User Interface and User Experience

Where the scheduled is synced in server, the operator gets notified in the interface provided to them. Figure 4, shows the description of various fields that are planned in the interface, where operator access multiple real-time information. *"Simulation field"* helps in clarifying the doubts and shows work related videos. For some of the tasks, the method statements are kept in the internal sever in video format or doc for specific task. *"Scan field"* is to scan the QR codes in the designated work fronts before or after the completion of the works so that the process and course of completion of the work will automatically synced in the server. The *"Translation field"* is dedicated for the language translation for operator.

Figure 4: Equipment Operator user interface

Implementation Plan

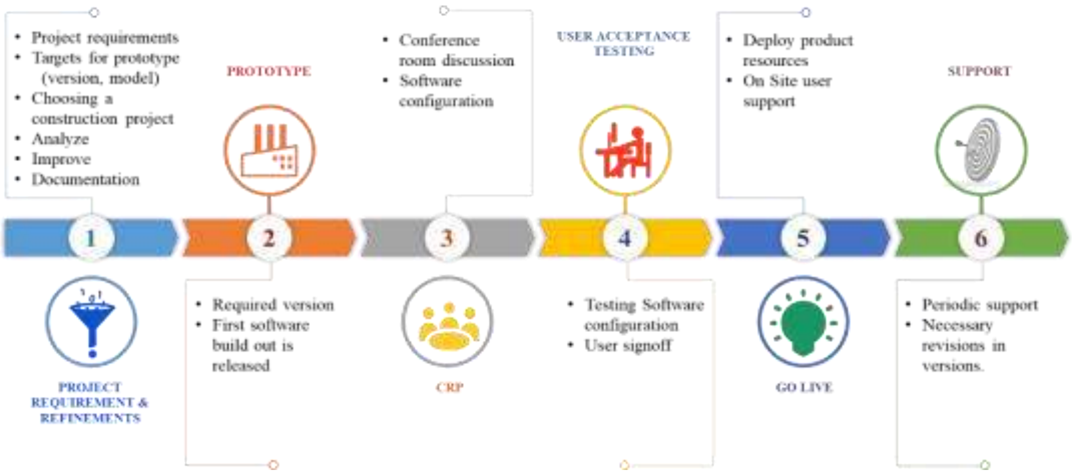


Figure 5: Implementation plan of the integrated EMS

Figure 5 shows the implementation plan for the integrated software from the stage of the project start. Initially the processes are refined by functional team and technical team. After the first build out, reviewing of the product in front of the board panel (CRP) Conference Room Pilot will be completed. The issues are addressed, and CRP's are conducted to completely develop the issue free product before it goes onto the field. The product is helpful in reporting an issue at the site. Risk is reduced by ensuring right person present at the right Workfront and time. It analyses the accidents, near misses by reporting it to ensure safety of workforce and reduces future accidents. Mitigates the risk of over allocation or under allocation of resources. *Creating a value chain:* The solution helps in creating a value chain to other related businesses like maintenance, service sector, parts manufacturers, sub-contractors through proper analytics.

CONCLUSION

The research outcome is used to provide a better solution to the vulnerability of efficient EMS. There will be reduction of manual interventions in decision making, operation management and advancement in managerial thinking. Maximization of productivity and utilization of equipment. Predictive analysis that will help in knowing the additional results which are profitable. A query example is considered to show the way of working of these components, and its results. The optimization is used for the predictive analysis of the integrated equipment management platform. This is a background process which can run in the future software, where it will be helpful in predicting the values. An app-based interface for worker and end labour is designed, which shows the incorporation of the drawings and simulation or BIM models with labour to ease the speed of work and communication. The product not only benefits the equipment owner, it creates value chain among subsidiary businesses. The Implementation plan is made for the successful delivery of the product. The data analysis is carried out considering only two factors i.e. Equipment statistics and Task based analysis. *Future scope:* One of the small jobs is taken up and a basic user interface is prepared for testing purpose at the site. The product is used for one specific project to check the credibility of the product. Applied to varied type of the equipment within the project to check all types of analysis and its results.

REFERENCES

Hadikusumo, B. H. W., & Prasertrungruang, T. (2016). *Study of Factors Influencing the Efficient Management and Downtime Consequences of Highway Construction Equipment in Thailand*. *9364*(August 2009), 2–11. https://doi.org/10.1061/(ASCE)0733-9364(2009)135

Liu, Z., Wang, H., & Li, H. (2018). Model of Equipment Sharing between Contractors on Construction Projects. *Journal of Construction Engineering and Management*, *144*(6), 1–11. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001485

Niu, Y., Lu, W., Liu, D., Chen, K., & Xue, F. (2017). A Smart Construction Object (SCO)-Enabled Proactive Data Management System for Construction Equipment Management. *Congress on Computing in Civil Engineering, Proceedings*, *2017-June*(June), 130–138. https://doi.org/10.1061/9780784480830.017

Ren, X., Zhu, Z., Germain, C., Belair, R., & Chen, Z. (2017). Automated Monitoring of the Utilization Rate of Onsite Construction Equipment. *1Department of Building, Civil, and Environmental Engineering, Concordia University, Montreal,*. https://www.researchgate.net/publication/317577977_Automated_Monitoring_of_the_Utilization_Rate_of_Onsite_Construction_Equipment

Room, C. (2019). *Equipment management*. https://www.cheqroom.com/blog/tips-efficient-equipment-inventory-management/

Schreyer, A. (2006). *GA Optimization for Excel*. 1–8.

Sharma, M. (2013). Role and Working of Genetic Algorithm in Computer Science Role and Working of Genetic Algorithm in Computer Science. *International Journal of Computer Applications & Information Technology*, *2*(1), 27–32.

Tatari, O., & Skibniewski, M. (2006). Integrated agent-based construction equipment management: Conceptual design. *Journal of Civil Engineering and Management*, *12*(3), 231–236. https://doi.org/10.1080/13923730.2006.9636397

Tavakoli, A., Collyard, C., & Masehi, J. (1990). Equipment management system. *Jornal*, *6*(2), 211–220. https://doi.org/10.1061/(ASCE)9742-597X(1990)6

Thengade, A., & Dondal, R. (2012). Genetic Algorithm – Survey Paper. *MPGI National Multi Conference International Journal of Computer Applications®, January 2012*, 975–8887.

Trivedi, J., Nair, S., & Iyyunni, C. (2012). *Optimum Utilization of Fly Ash for Stabilization of Sub- Grade Soil using Genetic Algorithm*.

Development of a Feasibility Study Framework for UAVs in the Indian Construction Industry

Georgie JACOB[1] and Bhargav DAVE[2]
CEPT University, Ahmedabad; email: georgie.pooyappally@gmail.com [1]
VisiLean, Ahmedabad; email: bhargav@visilean.com [2]

ABSTRACT

Civilian applications of Unmanned Aerial Vehicles (UAVs) started very recently. Exploring the applications of UAVs in the construction industry has been of importance ever since. Finding the feasibility of UAVs in the Indian construction industry has been relatively unexplored. In this regard, a study has been carried out to find out different applications of UAVs in the construction industry, to find out the feasibility of UAVs in the Indian construction industry, and to develop a set of guidelines and a framework to use UAVs in construction. Design science research methodology was adopted for this study as the method is very rigorous in testing the solution. Semi-structured interviews were conducted with professionals who are closely related to this field. Different applications of UAVs in construction were identified from interviews and literature studies. Interview data were analysed using thematic analysis and a deductive approach was used to find out different factors for the development of the framework and guidelines. The guidelines were integrated with the framework to make it handy and robust. The feasibility of UAVs in the Indian construction industry was established by analysing different factors such as legal and financial aspects in India considering the current scenario. It was inferred that the UAV enabled method is feasible when the scope of the project is very large or when the time is a constraint. The study explored the benefits of UAVs in construction. Major benefits include visualization and ease in decision making in different stages of a project. Real-time visualization using UAVs helps in monitoring different aspects of a project like safety and quality inspections, progress monitoring, 3D mapping, volumetric estimations, material tracking, and even helpful in tendering purposes. This enhances the decision making capability of top management in a project without physically accessing the site. UAVs can save considerable amount of time, manpower, and money which ultimately leads to better project management. The framework can guide a professional through the financial, legal, and operational feasibility for adopting UAVs in construction which helps in choosing or declining the use of UAVs in a project considering the characteristics or purpose of the project. The *checklists incorporated will ease the burden of the professionals as well as the operators in performing UAV operations.*

KEYWRODS

Unmanned aerial vehicle, Fesibility of UAVs, Application of UAVs, Visualiztion and Decision making

INTRODUCTION

Unmanned Aerial Vehicles (UAVs), commonly termed drones were used only in military operations in the earlier days. Recently, people started using this technology for civilian applications. Although legal constraints in each country restricts the use of UAVs up to an extent, researches are going on regarding the applications of UAVs in different sectors. In accordance with this, a few studies have been carried out regarding the applications of UAVs in construction industry. These studies have listed several applications such as construction monitoring, job site logistics, safety conditions, quality inspections, building inspections, damage assessment, site surveying, 3D mapping and other technical aspects (Irizarry & Costa, 2016; Zhou & Gheisari, 2018). All these applications use visual data generated by UAVs for review and analysis according to the respective application which is chosen in the particular study. The effectiveness of UAVs in these applications will depend upon the technology used in the UAVs in terms of automated computer systems with digital automation of data process and integration of visual tools. This study aims to explore the applications of UAVs in construction industry, to check the feasibility of UAVs in the Indian context, and to develop a framework and a set of guidelines for using UAVs in construction.

LITERATURE REVIEW

Many studies have explored the applications of UAVs in construction. UAVs are small aircrafts which do not need human operators on board for operation. UAVs are mainly divided into three types; Fixed wing, Vertical Take-off and Landing (VTOL) vehicles, and Rotorcrafts. Fixed-wing is similar to a traditional aero plane and are more effective in covering large areas. Rotorcrafts have propellers attached directly to its body or individually to the arms which are extended from the body which helps in vertical take-off and landing, hold its position, rotate in its position, and have flexible mobility. These types of UAVs can thus be used for applications which require precise vehicle placement and mapping complex three-dimensional features. VTOL UAVs are a mix of Fixed-wing and Rotorcraft. That is, it can take-off and land vertically, but horizontal movement will be like a fixed-wing UAV (Greenwood et al., 2019).

UAVs are unlocking a lot of challenges in the construction industry and practitioners are still testing the limits of this technology. Major applications explored in this regard are construction progress monitoring, 3D mapping, inspections, crack detection and volumetric estimations.

Visual documentation of the entire construction site which has major progress deviations, limited visibility of images due to static and dynamic obstructions, and incomplete documentation at the site are the major challenges for progress monitoring (J. Lin et al., 2015). Automated progress monitoring using UAVs is an innovative way to tackle this challenge. In one of the literature, geometry and appearance based reasoning methods used to track the progress from an aligned BIM-3D point cloud model detected more than 90% BIM elements. Geometry based reasoning detected the BIM elements and appearance based reasoning detected the materials used (Han et al., 2018). In another literature, superimposing systematically updated 4D BIM information on a 3D point cloud generated by UAVs at a particular stage of construction monitored the progress of project efficiently and tracked the deviations (Álvares & Costa, 2019).

UAVs have been used in mapping 3D models from UAV imagery which can provide a 3D view of the site to enhance the construction management tasks (Álvares et al., 2018). Inspections using UAVs have also been a major research area. The application of UAVs in safety provided a visualization on safety inspections and increased the effectiveness of safety inspections (Costa et al., 2016). Liu et al. (2016) used UAVs for inspection of curtain walls of a commercial building. Lei et al. (2018) developed a method for crack detection using UAVs called Crack Central Point Method which could reduce the noise of the images effectively and accurately extract the cracks from the collected images. Digital Terrain Models (DTMs) derived from UAVs were tested for its accuracy by stock pile volume estimation. This study concluded that large projects having massive stockpiles may need LiDAR or camera mounted UAVs as the physical survey may not be possible because of the size or shape of the stockpile (Hugenholtz et al., 2015).

RESEARCH METHODOLOGY

This research used Design Science Research (DSR) method as the research strategy which follows the constructive approach of research. For research problems which talks about practical problems, using conventional qualitative methods like interviews or surveys exclusively will give unsatisfactory or low results. The organizations may not get much benefit for giving their efforts in participating in the research. This may lead to poor participation from the organization level which subsequently leads to unsatisfactory results. Thus, DSR method is the right strategy to adopt as the study requires practical functioning of the solution.

This method attempts to develop an artefact followed by implementing the artefact for testing its applicability. The developed artefact is iterated in a loop till the desired artefact is generated and thus giving a practical solution to the problem as well as theoretical contribution to the study. This helps in reducing the gap between research and practice (Lukka, 2003). Figure 1 shows the process flow for the research methodology structured to meet the objectives of this study.

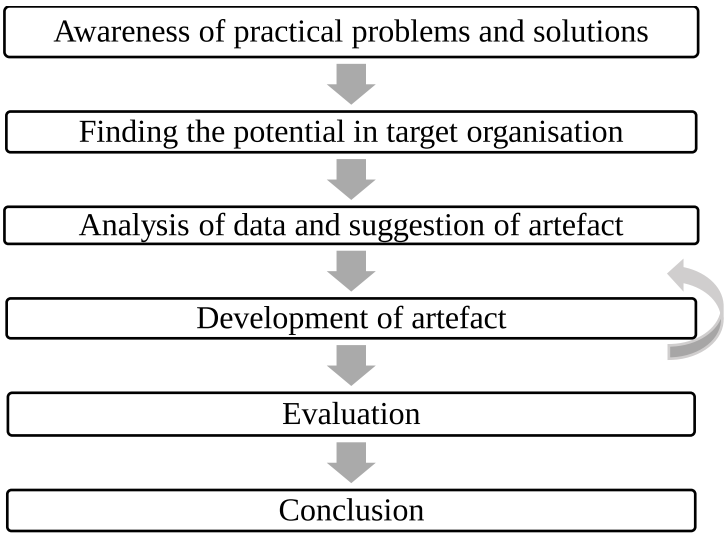


Figure 1. Methodology adopted

- ***Awareness of practical problems and solutions:*** Literature study on the applications of UAVs in construction industry as well as semi-structured interviews targeted on construction industry professionals which helps in finding the problems and solutions.
- ***Finding the potential in target organization:*** Finding an organisation with a practical problem which can be solved using one of the applications of UAVs to test the final framework.

- ***Analysis of data and suggestion of artefact:*** Data is analysed using thematic analysis and based on this, the artefact is suggested. In this study, suggested artefact is the framework and a set of guidelines for using UAVs in construction.
- ***Development of Artefact:*** Developing the framework and the guidelines based on the data analysis.
- ***Evaluation:*** Validation of the framework and guidelines with construction industry professionals in an iterative manner. The suggestions were incorporated and it was revalidated again.
- ***Conclusion:*** Stepping back from the empirical work and documenting the learning process. The results were interpreted and conclusions were derived. The framework and guidelines were formalized in this stage.

DATA COLLECTION

The first part of data collection involved semi-structured interviews which were targeted on two types of people. One being the project specific personnel who have used UAVs and the other being the people who work in organizations giving UAV services for construction related applications. As a part of data collection, 11 persons were interviewed. The details of the interviewee are mentioned in table 1.

Table 1. Details of interviewee

Name	Designation	Type of Organization	City
Project Specific			
A	Project Manager	Contractor	Gandhinagar
B	Construction Professional	Project Management Consultant	Ahmedabad
C	Director and Founder	Project Management Consultant	Ahmedabad
D	Manager	BIM Consultant	Pune
E	Planning Manager	Contractor	Mumbai
Organizations Providing UAV Services			
F	Manager - Operations	UAV Consultants	Ahmedabad
G	Assistant General Manager	Geo Spatial Consultants	Bangalore
H	CEO and Founder	BIM Consultants	Gandhinagar
I	Director	UAV Consultants	Ahmedabad
J	Owner and Director	UAV Consultants	Ahmedabad
K	Owner and Director	Geo Spatial Consultants	New Delhi

Efforts were taken to find a target organisation for testing the framework. As a part of this, a discussion was held on the corporate office of organization A. Researcher presented his findings to the senior officials of the company. The company never used UAVs for any construction related applications in the past and was positive minded in exploring new technologies and incorporating it in their projects.

One of the ongoing projects under the company was a slum rehabilitation project near Ahmedabad. Majority of the people have been temporarily relocated. But one of the plots was still not relocated because of the resistance from residents. This plot was not surveyed due to this reason. This was considered an opportunity for both the company and the researcher to test the framework. Figure 2 shows the existing survey map for the project.

The highlighted area in the survey map shows the incomplete survey details of the plot mentioned above. It was decided to do an aerial survey and map the entire area. Organization F agreed to do the survey for organization A. After a meeting with the Directors of both the companies, the requirements from the contractor was finalised and the commercial aspects were approved after negotiations. Documents were submitted to the local police authority for permission. But, unfortunately at this stage, COVID 19 pandemic happened and the researcher was not able to do the survey during the research period.

Figure 2. Existing survey map

ANALYSIS AND FINDINGS

Thematic analysis approach was adopted in this study for data analysis. Interview transcripts were coded and a deductive approach was used for the analysis. The findings are given below.

Applications of UAVs

A total of 24 applications were identified in this study. The applications were segregated based on the output needed from UAVs and the use of each output. Of the total 24 applications, 8 applications were identified exclusively from interviews and 2 exclusively from literature study. The applications are listed in table 2.

Table 2. Applications of UAVs

Output	Uses	Applications
Orthomosaic	2 D Measurements	*(1) Alignment and planning of roads, railway corridors and metro projects *(2) Encroachment Measuring *(3) Counting and detection of objects *(4) Site inspection for tendering (5) Mining Surveillance *(6) Tax Collection *(7) Change Detection #(8) Jobsite logistics
	Surveying	(9) Land Survey
Digital Terrain Model/ Digital Surface Model	Volumetric estimations and Contour mapping	*(10) Storm water management (11) Stock pile measurements/ Material Tracking (12) Earthwork estimations
3D point cloud	Mapping	(13) 3D mapping (14) Land Mapping (15) Heritage Mapping
	Progress Monitoring of buildings, road and infrastructure	(16) Progress monitoring without BIM (16) BIM integrated automatic progress monitoring
Images/ Videos	Progress monitoring	(16) Progress monitoring with images/videos

Output	Uses	Applications
		(17) Site Monitoring
	Inspections	(18) Safety Inspections
		(19) Façade Inspections
		(20) Crack detection
Thermal images		(21) Bridge Inspections
	Inspections	*(22) Solar inspection
Ultrasonic waves,		(23) Quality inspections
LiDAR sensors		#(24) Structural Damage Assessment

The applications marked * are exclusively from interviews and # are from literature review. Applications without any mark were identified both in interview and literature review.

Regulatory Environment in India

As per Indian regulations, UAVs are categorized in accordance to its weight into Nano (<=250 g), Micro (250 g to 2 kg), Small (2 kg to 25 kg), Medium (25 kg to 250 kg) and Large (> 250 kg). Nano can be used only till 15 m from ground level and Micro till 60 m from ground level. No UAVs are allowed to fly more than 120 m height from ground level for civilian purposes. The major requirements for UAV operations are,

- Unique Identification Number (UIN) from Directorate General of Civil Aviation (DGCA). The UIN should be affixed on the UAV. Permission from Digital Sky Platform before undertaking any flight operations. (Exception – Nano category)
- Flying operations are permitted only on daylight.
- No UAV operations should be performed in the restricted areas mentioned by DGCA.
- Operators should have an Unmanned Aircraft Operator Permit (UAOP) to operate the UAVs for commercial operations. Digital Sky No Permission No Take-off (NPNT) compliant. (Exception – Nano and Micro category)
- Local police permission is required for all the UAV operations.

The fee for issue of UIN is INR 1000 and for UAOP, it is INR 25,000. Fee for renewal of UAOP is INR 10,000 (Office of the Director General of Civil Aviation, 2018).

Feasibility of UAVs in the Indian Construction Industry

Establishing the feasibility of a technology mainly depends on the feasibility of alternate technologies as well. The following are the main reasons why UAV technology was chosen over other alternate methods.

- Accuracy requirement is much higher
- Project is not having the liberty of time and manpower
- Surveying of very big land parcels in square kilometre range where normal surveying methods are much tedious and time consuming
- Better visualizations needed for the top management

In the current scenario, the Indian construction industry is unaware of different outcomes of UAV based survey. But, a few companies are well updated on these technologies and are using advanced applications like 5D BIM integrated automated construction progress monitoring. Other than just visualisation and top management reviews, this method helps to reduce considerable amount of human effort in documentation. Mapping huge land parcels using UAVs are 2 to 3 times faster than the conventional surveying methods.

Financial Feasibility

The cost of services range from INR 3000 to INR 3,00,000 per sq.km. The cost will depend on the type of output and the level of accuracy required. The initial investments needed for buying UAVs may depend on the process adopted for survey. The two major technologies adopted, are Post Process Kinematic (PPK) and Real Time Kinematic (RTK). In PPK, the data is collected with Global Positioning System (GPS) tagging and then processed to get the required output. RTK is much more advanced and have capabilities of real time processing in cloud while data is being collected. High quality PPK drones cost INR 2 to 3 lakhs whereas RTK drones costs INR 8 to 10 lakhs. Based on this, the insurance covers approximately ranges between INR 50,000 to INR 1,75,000 for the entire system per year.

Preferring UAV mapping for small land parcels may not be feasible as the cost may not reduce proportionately corresponding to the decrease in area. Considering a UAV can cover 3 sq.km per day, mapping a land parcel less than 3 sq.km also costs the same as the resources and manpower used are the same. If the area to be surveyed is considerably larger than 3 sq.km, the cost per square kilometre may get reduced. The rough cost ranges of different outputs of

UAVs are given in table 3. The cost may vary with respect to the economy and future developments of the technology.

Table 3. Rough cost ranges

Sl. No.	Applications	Cost Range
1	Progress Monitoring	INR 20,000 to 80,000 per day
2	Land mapping	INR 20,000 to 1,20,000 per day
3	Images and videos with annotations	INR 3,000 to 4,500 per sq.km
4	Detailed orthomosaic and 3D point cloud	INR 20,000 to 1,30,000 per sq.km
5	Detailed analysis with engineering drawings and 3D models	up to INR 3,00,000 per sq.km

Legal Feasibility

The regulations for UAVs in India are liberal in the current scenario. Most of the regulations are applicable from 'small' UAV category to 'large' UAV category. Nano UAVs are exempted from almost all the regulations and Micro UAVs from some of the regulations. It is understood from the interviews that the specific UAV model Phantom 4 Pro of DJI series can be considered as a bench mark for almost all the applications identified in this study. This UAV weighs 1388 grams which makes it fall under Micro UAV category. Micro UAVs have the following relaxations of laws which are (i) No requirement of UAOP if the UAV is operating below 60 m, (ii) No need to file flight plan 24 hours before operations, (iii) The equipment capability features needed are lesser compared to other categories, (iv) Age restriction (18 years) and academic qualification (10^{th} pass in English) requirement for the operator is not applicable (v) Ground training from DGCA approved flying training operation is not mandatory. Most of the relaxations are favourable for the Indian construction industry and thus the legal aspects in India in the current scenario are highly feasible for construction.

Comparison with Alternate Methods

For establishing the feasibility of UAVs, checking and comparing the feasibility of alternate methods are also a major concern. Most of the applications of UAVs are related to surveying and mapping. Total station surveying and satellite image processing are the major alternate technologies in this field. The suitability of these technologies may highly depend on the accuracy required, area to be surveyed and the time with which the survey have to be completed. For surveying small land parcels with very high accuracy, total station is preferred as it has an accuracy of 1.5 mm. For large area in the range of square kilometres, UAVs can be used, and for much larger area like covering an entire city in a short span of time, satellite images can be used. Table 4 given below shows a comparison of these three methods in terms of accuracy, area covered, time for processing and cost.

Although total station is highly accurate, the cost is higher, area covered is much lesser and the time for processing is much greater. Satellite image processing can be carried out in very less cost and huge areas can be covered in a very short time. But the accuracy is highly compromised. All parameters of UAV are in an optimum range.

Table 4. Comparison with alternate methods

Parameters	**Total Station**	**Satellite Image Processing**	**UAV Survey**
Accuracy (mm)	1.5	Greater than 500	10 to 30
Area covered/day (sq.km)	0.1 to 0.2	-	3
Time for processing (hrs/sq.km)	30	1.5 to 2	3
Cost (INR/sq.km)	1,00,000 to 2,50,000	2000 to 3000	30,000 to 1,20,000

Framework and Guidelines

The final framework is divided into two phases. The first phase is the planning phase where the UAV method is checked for its feasibility and then the initial requirements of the survey are finalised. The second phase is the data collection and processing phase which describes the requirements needed to be fulfilled during UAV operation and further stages. The framework is shown in figure 3, 4 and 5. The guidelines are an integral part of the framework developed in this study. The guidelines are linked to each stage of the framework. The factors to be looked-upon for each guideline is given in table 5. The serial numbers referred in table 5 are corresponding to the guideline numbers given in the framework. 5 checklists were developed and linked to the required stages of the framework to make it more reliable. Checklist 1 is a list of locations in India were UAV operations are restricted which is adopted from DGCA's guidelines. Checklist 2 should be referred for on-site reconnaissance where the site to be surveyed is inspected in prior for proper flight planning. Checklists 3, 4 and 5 should be referred at the time of site visit before starting the UAV operations at site. Checklist 2 is given in table 6 and checklist 3, 4, 5 are given in table 7, 8 and 9 respectively.

Phase 1 – Planning

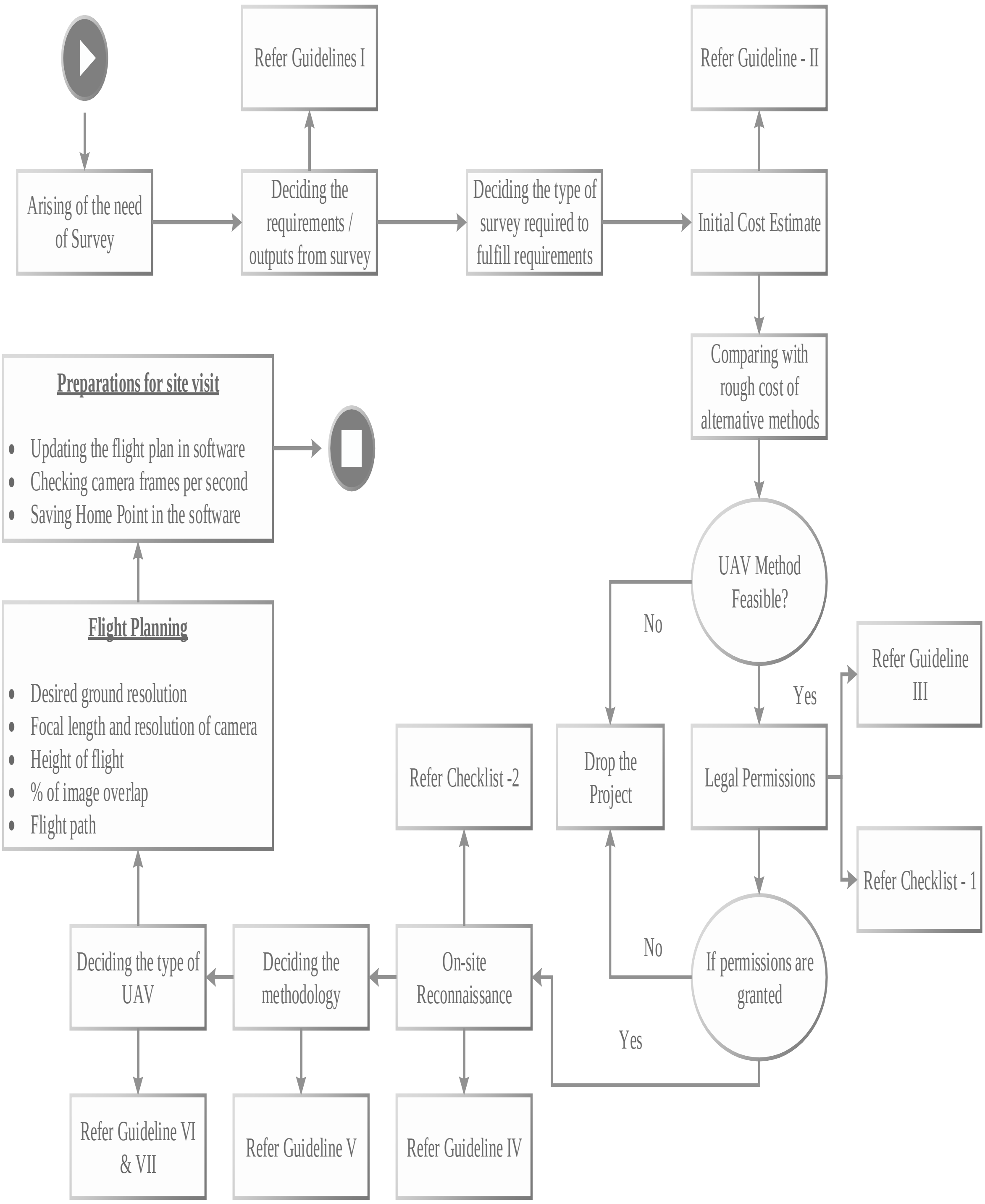


Figure 3. Framework: Planning Stage

Phase 2 – Data Collection and Processing

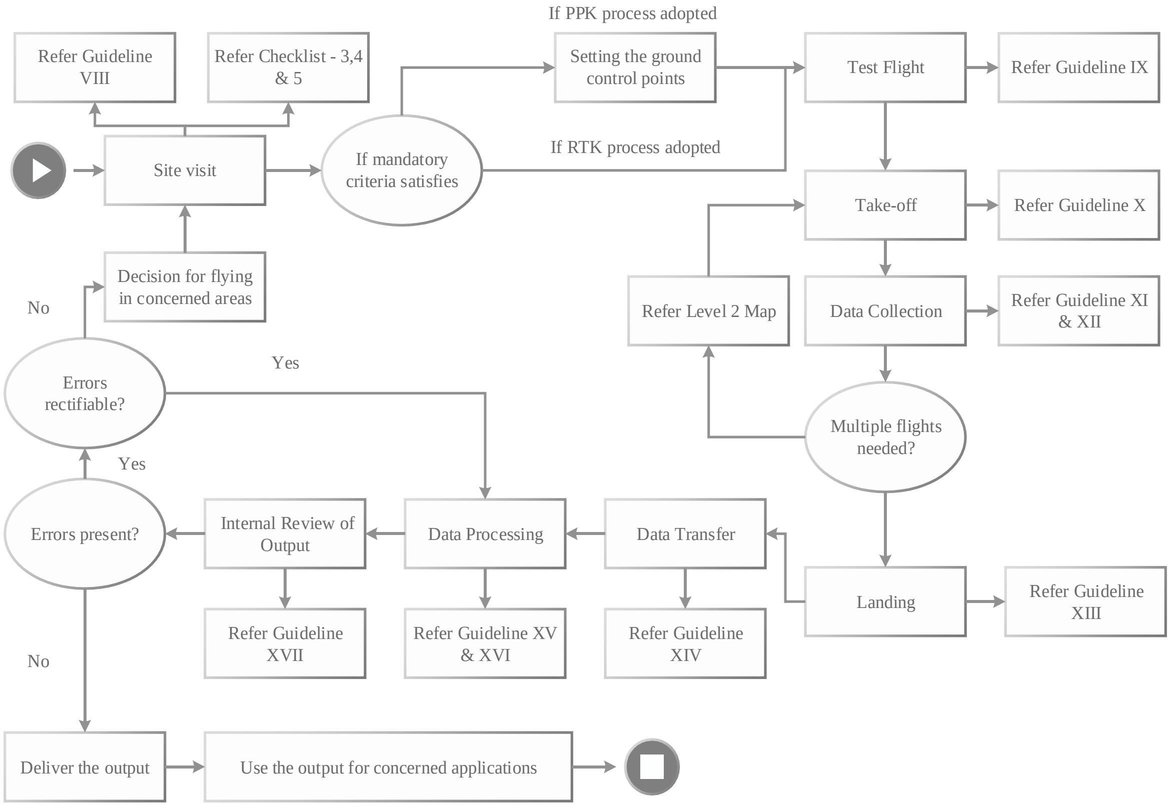


Figure 4. Framework: Data collection phase

In the data collection stage, if one flight is not enough because of the larger area to be covered, then the UAV may have to be landed in between to change the battery. This is referred in level 2 map below.

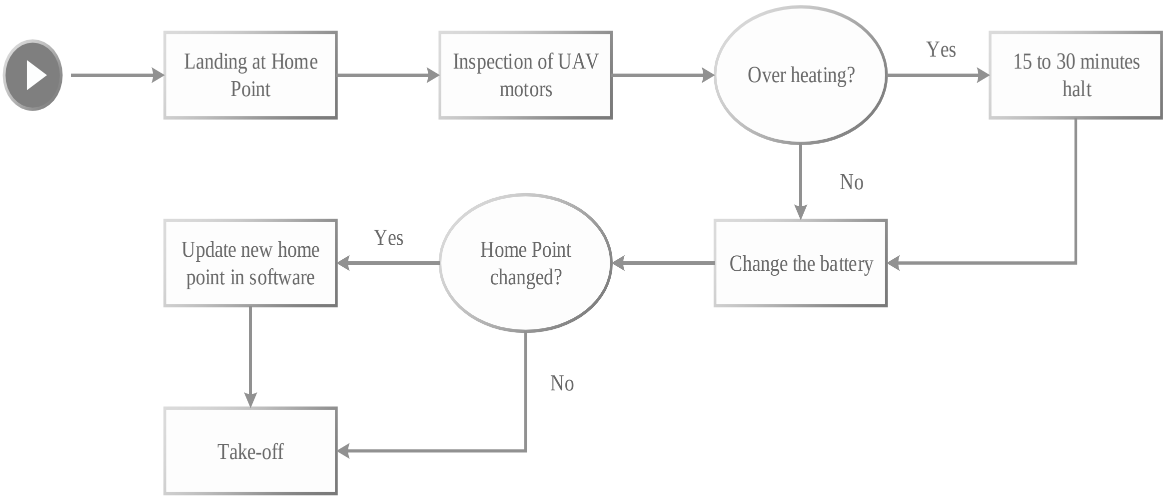


Figure 5. Framework: Level 2 Map

Table 5. Guidelines

Sl. No.	Guideline	Factors
I	Applications of UAVs	Refer Table 2
II	Factors affecting cost of services	Accuracy required, Level of detailing, Duration, Scope of work, Area of delivery, Type of solution required, Urgency of work, Solution or output required, Type of process used (PPK/RTK), Type of location.
III	Legal compliances	Permission from Digital Sky platform (except Nano), UIN affixed in UAV (except Nano), UAOP handy during operations (except Nano and Micro), Digital Sky NPNT compliance (except Nano and Micro), Flying operations only on daylight, No operations in the restricted areas, Local police permission for all operations.
IV	On-site Reconnaissance	Open central location for take-off and landing, Identifying obstructions in site for safe flight planning.
V	Factors for selecting methodology of survey	Initial cost of UAV and operating system, remote range, Ground Control Points(GCP), processing method, accuracy, time taken for survey, cost
VI	Factors for UAV selection	Accuracy required, Flight stability, Type of survey to be done, Level of detailing of output required, Area of survey, Type of camera or sensor required, Weight of camera/ sensor to be mounted, Weight of UAV, Vertical take-off and landing, Flight duration, Ability of system to mount sensors
VII	Sensors / Equipment Used	RGB Camera – Orthographic models, LiDAR Sensors – Forestry, 3D mapping, Thermal radiometric sensor – Solar inspection, Crack detection
VIII	Safety precautions	Workers should be made aware of UAV operation in advance, Preferred when workers are not present at site or when they are having a break, Detailed SOP to be provided the client (Contractor/PMC) before operations, Risk assessment and mitigation plan, Space for take-off and landing (minimum 3m x 3m), Follow safety features instructed by DGCA.
IX	Test flight	Manual mode of operation preferred, Test the radio interference and secure communication between RC transmitter and UAV, Flight should be operated along the planned flight path, Identifying the nearest and safest emergency landing sites.

Sl. No.	Guideline	Factors
X	Factors to check before take-off	Saving home point before take-off, Turn on SRT file logging option for saving GPS to data collected, In between the survey, Changing home point in case of landing in a new location.
XI	Challenges faced during time of flight	Obstructions in land, Inability of getting live feed for inspections at in-accessible places, Electromagnetic fluctuations due to presence of metallic objects, Battery Limitations, Battery problems in winter, Reflective surfaces in ground (eg: water bodies), Heating problems in high temperature (summer), Moving objects in flight path, Accessibility constraints, Signal losses due to limitation of range or network issues, Flying in a circular path , Adverse weather, conditions like precipitation or high wind
XII	Risks at time of flight	Power failure, Circuit failure, Crashing, Bird hitting, Collision with any incoming object in flight path, Collision with workers/people, Privacy invasion, Connection between UAV and control system lost, Interference of UAV in project activities, Distractions while working
XIII	Factors to check before landing	Minimum battery requirement to land at the home point, Identification of emergency landing points in case of insufficient battery, Runway space needed in case of Fixed wing UAVs.
XIV	Data transfer	High capacity memory card takes more time for data transfer which results in heating issues of memory card as well as card reader. 64 GB memory card is preferred for data transfer. If the memory card gets corrupted or data is lost, it’s preferred that no other data is copied in memory card till the lost data is retrieved.
XV	Software used	Pix-4D, Agisoft Photoscan, Drone Deploy, Bentley Context Capture 3D, Autodesk ReCap, 3DF Zephyr, Precision Hawk, Agisoft Metashape, Open Drone Map, PhotoModeler, Map Made Easy Simactive Correlator3D™
XVI	Factors affecting processing time	Number of images collected / Volume of the data, Computer specifications, Size of the data, Type of survey, Area of survey, Level of detailing, Resolution needed to achieve
XVII	Possible errors in output	No GPS values in data, Wrong GPS values in data, Camera might not have clicked. Glitches or patches if the flight path is not well defined, Blurry images, Sufficient ground control points not available, Insufficient amount of images, Errors due to issues in flight
XVIII	Benefits achieved	Predicting Site Conditions, Easier documentation, Real time information to the higher authority, Creates more clarity while decision making, Time saving, More accurate than satellite images, Economic in large surveying projects, Better visualization, Cost of man power is saved, Economic Progress monitoring method in case of big projects

Table 6. Checklist 2: On-site reconnaissance

Sl. No.	**Criteria**	**Yes/No**	**Remarks**
1	Obstructions at site? (trees, power lines, buildings)		The flight path should be clear from obstructions while flight planning.
2	Electromagnetic equipment or HT lines at site?		UAV should be selected accordingly. (e.g.: DJI Matrice 210 RTK can be used near HT lines)
3	Reflective surfaces at site? (materials or water bodies)		If yes, then processed images might have errors because of reflections. The operations preferred only if there is no requirement of data processing.
4	Site having any accessibility issues?		The home point of UAVs should be an accessible point and the other areas of survey should be in visual line of site from home point.
5	Site having excessive high wind conditions?		UAV manual contains the specifications for the amount of wind it can withstand. Select UAVs accordingly.
6	Site situated under any geo-fenced area?		Permissions should be taken to open the geo-fence in the area to be surveyed from the concerned authority
7	Continuous bird movements/ Site a migratory bird zone?		UAV operations in migratory bird seasons should be avoided if possible. Sounding alarms should be used to keep the birds away.
8	Minimum 3m x 3m clear space for take-off and landing at site?		If no, by taking permissions from the concerned person, space should be identified outside the site and the operations should be in visual line of site.

Table 7. Checklist 3: Regulations

Sl. No.	Criteria	Yes/No	Remarks
1	Local police authority permission taken for drone activity?		If no, then the UAV operations should be stopped till the required permissions are granted.
2	All concerned authority permissions taken (If applicable)?		
3	UAV having a valid UIN (For UAVs not under Nano category)?		If no, then that specific UAV cannot be used for any operations until the UIN is issued by DGCA.
4	Operator having a valid UAOP (For UAVs not under Nano/Micro category)?		If no, then the operator should be switched with a person who is having the license.
5	Height of flight greater than 15 m? (requirement for Nano category)		If yes, then the relaxation of regulations for Nano and Micro category will no longer be applicable. The specific UAV should have all the requirements mentioned by DGCA before flight operations.
6	Height of flight greater than 60 m? (requirement for Micro category)		

Table 8. Checklist 4: Weather conditions

Sl. No.	Criteria	Yes/No	Remarks
1	Is it raining?		If yes, then the operations should be stopped till the rain is over.
2	Site having sufficient daylight?		Sufficient day light is needed for operations. Additionally, the quality of data collected may badly affect due to insufficient day light.
3	Site having high wind conditions above the specification of the UAV?		If yes, then the UAV operations should be stopped.
4	Is there a minimum ground visibility of 5 km?		This is a preferred criterion. If this is not satisfied, then sufficient safety precautions should be taken at the time of planning and in terms of identifying emergency landing sites.
5	Is the cloud ceiling greater than 450 m?		This criterion is preferred for identifying other aircrafts in the air space. If the cloud ceiling is lesser, the height of operations should also be lesser according to the weather conditions.

Table 9. Checklist 5: Safety

Sl. No.	Criteria	Yes/No	Remarks
1	Are the workers (if any) moving around in site?		Operations in the absence of labours or when all labours are inside the building or during intervals is preferred.
2	Are the workers (if any) made aware of the UAV operations?		If no, then workers should be made aware of the UAV operations.
3	SOP of UAV operation provided to client?		It is preferred that SOP should be provided before the operations so that the client can have better understanding about the methodology carried out.
4	Flight path planned and assigned in the software (if manual flying is not required)?		This is preferred to be done before carrying out the operations.
5	Is there any other aircraft movement nearby?		If yes, then the operations should be immediately stopped. No two UAVs should be operated in the same area. Manned aircrafts should be always given priority during the operations.
6	UAV battery fully charged?		Preferred for more flight duration.
7	Extra set of battery and blades taken?		In case of emergency, extra pair is preferred.
8	Is the height of flight decided?		Preferred in case of automatic flight operations. Accuracy can change according to height variations.
9	Is the height of flight greater than 120 m?		The maximum height limit for civilian operations is 120 m. Permissions needed for operation at further heights.
10	All GCPs set (if required)?		Depends on the technology adopted. GCPs are necessary for accuracy of the output.
12	Radio, command and control link working?		If no, then operations should be stopped

CONCLUSIONS

The applications of UAVs are considerably increasing in the construction industry. The research identified 24 applications of UAVs in construction from literature review and semi-structured interviews. From interviews, it was found that, majority of the applications in India were based on photogrammetric technique where images taken from UAV platforms were merged using this technique to form an orthomosaic and then further processed to get DSM/DTM or a 3D point cloud.

Interviews with professionals in this field helped in establishing the feasibility of UAVs in Indian construction industry partially. The feasibility was explored by analysing the financial as well as legal aspects in the Indian context. Regulations in India are found favourable for adopting UAVs in construction industry as there were some relaxations in regulations for the Nano and Micro category of UAVs. From the feasibility study, it was inferred that this method is feasible when the scope of project is very large or the time is a constraint.

A framework and a set of guidelines were developed for using UAVs in construction industry and the guidelines were integrated to this framework. The framework can guide a professional through the financial, legal and operational feasibility for adopting UAVs in construction. The checklists incorporated will ease the burden of the professionals as well as the UAV operators. The guidelines and framework were validated with professionals in the industry and are found to be effective in guiding professionals who wish to integrate UAVs in construction and give a standard and safe methodology to follow which complies with all major regulations in India.

REFERENCES

Álvares, J. S., & Costa, D. B. (2019). Construction Progress Monitoring Using Unmanned Aerial System and 4D BIM. *Proc. 27th Annual Conference of the International Group for Lean Construction (IGLC)*, 1445–1456. https://doi.org/10.24928/2019/0165

Álvares, J. S., Costa, D. B., & Melo, R. R. S. de. (2018). Exploratory study of using unmanned aerial system imagery for construction site 3D mapping. *Construction Innovation*, *18*(3), 301–320. https://doi.org/10.1108/CI-05-2017-0049

Costa, D. B., De Melo, R. R. S., Álvares, J. S., & Bello, A. A. (2016). Evaluating the performance of unmanned aerial vehicles for safety inspection. *IGLC 2016 - 24th Annual*

Conference of the International Group for Lean Construction, 23–32.

Greenwood, W. W., Lynch, J. P., & Zekkos, D. (2019). Applications of UAVs in civil infrastructure. *Journal of Infrastructure Systems*, *25*(2), 1–21. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000464

Han, K., Degol, J., & Golparvar-Fard, M. (2018). Geometry- and Appearance-Based Reasoning of Construction Progress Monitoring. *Journal of Construction Engineering and Management*, *144*(2), 1–12. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001428

Hugenholtz, C. H., Walker, J., Brown, O., & Myshak, S. (2015). Earthwork volumetrics with an unmanned aerial vehicle and softcopy photogrammetry. *Journal of Surveying Engineering*, *141*(1), 1–5. https://doi.org/10.1061/(ASCE)SU.1943-5428.0000138

Irizarry, J., & Costa, D. B. (2016). Exploratory Study of Potential Applications of Unmanned Aerial Systems for Construction Management Tasks. *Journal of Management in Engineering*, *32*(3), 1–10. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000422

J. Lin, J., Kevin, K. H., & Golparvar-Fard, M. (2015). A Framework for Model-Driven Acquisition and Analysis of Visual Data Using UAVs for Automated Progress Monitoring. *Journal of Construction Engineering and Management*, 156–164. https://doi.org/10.1061/9780784479247.083

Lei, B., Wang, N., Xu, P., & Song, G. (2018). New Crack Detection Method for Bridge Inspection Using UAV Incorporating Image Processing. *Journal of Aerospace Engineering*, *31*(5), 1–13. https://doi.org/10.1061/(ASCE)AS.1943-5525.0000879

Liu, J., Jennesse, M., & Holley, P. (2016). Utilizing Light Unmanned Aerial Vehicles for the Inspection of Curtain Walls: A Case Study. *Construction Research Congress 2016: Old and New Construction Technologies Converge in Historic San Juan - Proceedings of the 2016 Construction Research Congress, CRC 2016*, 2651–2659. https://doi.org/10.1061/9780784479827.264

Lukka, K. (2003). The Constructive Research Approach. *In: Case Study Research in Logistics, Series B*, 83–101.

Office of the Director General of Civil Aviation. (2018). *Requirements for Operation of Civil Remotely Piloted Aircraft System (RPS)* (pp. 1–37). Government of India. http://dgca.nic.in/rules/car-ind.htm

Zhou, S., & Gheisari, M. (2018). Unmanned aerial system applications in construction: a systematic review. *Construction Innovation*, *18*(4), 453–468. https://doi.org/10.1108/CI-02-2018-0010

Role of Modern Tools in Construction Projects

Dhruv PATEL[1], Rohan JAIN[2] and Dr. J.S. SUDARSAN[3]
NICMAR Pune; dp24597@gmail.com[1]
NICMAR Pune; rohanjain05121996@gmail.com[2]
NICMAR Pune; ssudarsan@nicmar.ac.in[3]

ABSTRACT

The Construction Real Estate Infrastructure and planning (CRIP) sector is a prominent sector among the industries worldwide. It plays a vital role in contributing to any country's economy. *Mainly several sub-sectors of the CRIP sector that contributes to country's economy are highways, railways, airways, waterways, irrigation, power generation, government buildings, residential buildings, etc. Many public sector projects add a push towards the development of CRIP sector in India. In this CRIP sector the project activities also involve multi-tasking and multi-activity with different types of people at different levels. Mostly, exchange of inter-departmental information utilizes vast amounts of data throughout the construction project activities. The efficiency of transformation of data depends on several factors. Mainly the outcome of the efficiency depends on the way in which data was handled, data was transferred and data was communicated and also the timely information transfer between different stages, and participants involved in a project. So, the influence of factors plays a predominant role in delivering the efficiency of the crucial data amongst the team players involved in the construction projects. This efficiency can be improved by implementing modern tools like automation – Internet of Things framework, mobile application, computer software, etc. In this research study, an initiative was taken to look into the role of automation tool in improving the efficiency of the construction project activity like quality, safety, etc. Among the different automation tool, the most familiar and most common tool used in several developed countries are mobile applications. Even though several mobile applications are in practice all the applications are not performing with full outcome. Many applications are lagging with data security, user friendliness, training intensity, etc. The main objective of this research study is to understand the benefits of automation compare various modern tools available in the market and examine those modern tools to check if they rectify negative impacts of automation. This was achieved by performing a qualitative analysis among selected mobile applications. By carrying out the performance analysis best suitable modern tool can be ascertained. It was*

inferred from this research study the adoption and integration of automation technologies in the construction activities will prove beneficial in enhancing efficiency and productivity along with profits.

KEYWORDS- Construction Project Activities, Automation, Mobile Applications, Project Efficiency.

1. INTRODUCTION

The role of CRIP sector in infrastructure development of any country is highly significant. Especially in developing countries like India. It plays a vital role in nation building and also it is one of the sectors contributing to country's economy. Based on the recent survey conducted by India Construction Industry Analysis by Construction Type (Residential, Non-Residential and Infrastructure) & COVID-19 Impact with Market Outlook 2017-2030, it is said that the construction industry contributes 8% to India's GDP [11]. However, looking at the current pandemic scenario the construction industry along with other industries has been affected drastically. It is high time to look in to issues in CRIP sector finding out suitable strategy or mechanism to overcome the crisis. It can be ensured by effective project accomplishment needs a coordinated work among construction workers, supervisors, architects, managers and even with external parties in the communication process [5]. This can be achieved through better project planning, management, improved execution, new financial policies, adoption of new technologies, automation, etc. Automation is one such strategy that promises better planning, coordination & communication with the team, improved quality, better safety, more accuracy, forecasting of risks, data analysis, etc [1,2,3]. There are various ways to implement the automation strategy in different sectors of construction activities such as autonomous machines on site, drones to perform surveying, robotics in concrete works, internet of things (IOT) framework using sensors, mobile applications, computer software, mobile/cloud BIM technology, virtual reality technology, etc [13]. Among the different automation tool, the most familiar and most common tool used in several developed countries are mobile applications [4,6,7]. Mobile information systems and cloud computing offer solutions to the delivery of fast and real time information and services in project management. [8, 9, 10] They will increase the effectiveness of collaboration and the reliability of the information whilst reducing information delays [11, 12,]. Several research studies pertaining to CRIP sector among the workers community in developing countries highlights that usage of modern tools like mobile app among workers is very poor and more than 60% of workers were unaware of mobile applications and also lack of knowledge in using the mobile application. [4]. In this digital era, it is mandatory that automation tool must be implemented in the CRIP sector and it is going to dominate entire sector in near future [20]. So, it is high time to find an effective strategy to overcome lapses with respect to modern tools needs to be identified [21]. This research study examined the role of mobile technologies in improving the communication support for the construction project site of CRIP sector and to increase efficiency and productivity in the project execution process and also to identify the better strategy for the same [14,15,16,17]. The main aim of this study is to understand the benefits of digitalization for effective on-site communication, to compare various mobile applications available in the industry, to rectify the negative impacts of digitalization in the construction project site of CRIP sector [11,12]. Tools adopted to achieve the objective are by floating the questionnaire among the CRIP sector community. Based on the questionnaire outcome both positive and negative aspect was inferred with respect to automation and the qualitative analysis of data was carried out with the help of a qualitative data analyzing software called NVivo [4, 5, 16]. The outcome of the research study was mainly based on a live case-study of Pune based construction firm.

2. METHODOLOGY

To achieve the objective and to procure suitable data to perceive the conclusion, a questionnaire was floated [4,9,13]. The detailed methodology adopted in order to carry out the research to fulfill the end goal was stipulated in **figure 1** below:

3. RESULTS AND DISCUSSION

To ascertain the impact of automation among the construction community a questionnaire was floated. This was done to get a clear understanding of what role does automation play and how its implementation affects construction projects. Respondents to the questionnaire belonged to the CRIP sector community such as construction professionals, construction managers, employees working at different designations and interns. Following statements were stated in the questionnaire to which the participants responded on a scale from strongly disagree to strongly agree:

- Modern technology increases productivity & efficiency of work.
- Modern technology has a complex interface.
- Modern technology proves to be cost beneficial.

- Modern technology proves to be time saving.
- Modern technology requires a lot of training to get adapted to it.
- Modern technology proves to be effective on-site communication.
- Modern technology proves to useful in Quality Control.
- Modern technology proves to be useful in Health Safety Environment (HSE).
- Regular input is given by user while using Mobile Applications.
- Modern technology increase stress among workers.
- Do you think digitalization or automation has negative impacts? If yes, then give reasons based on your experience.

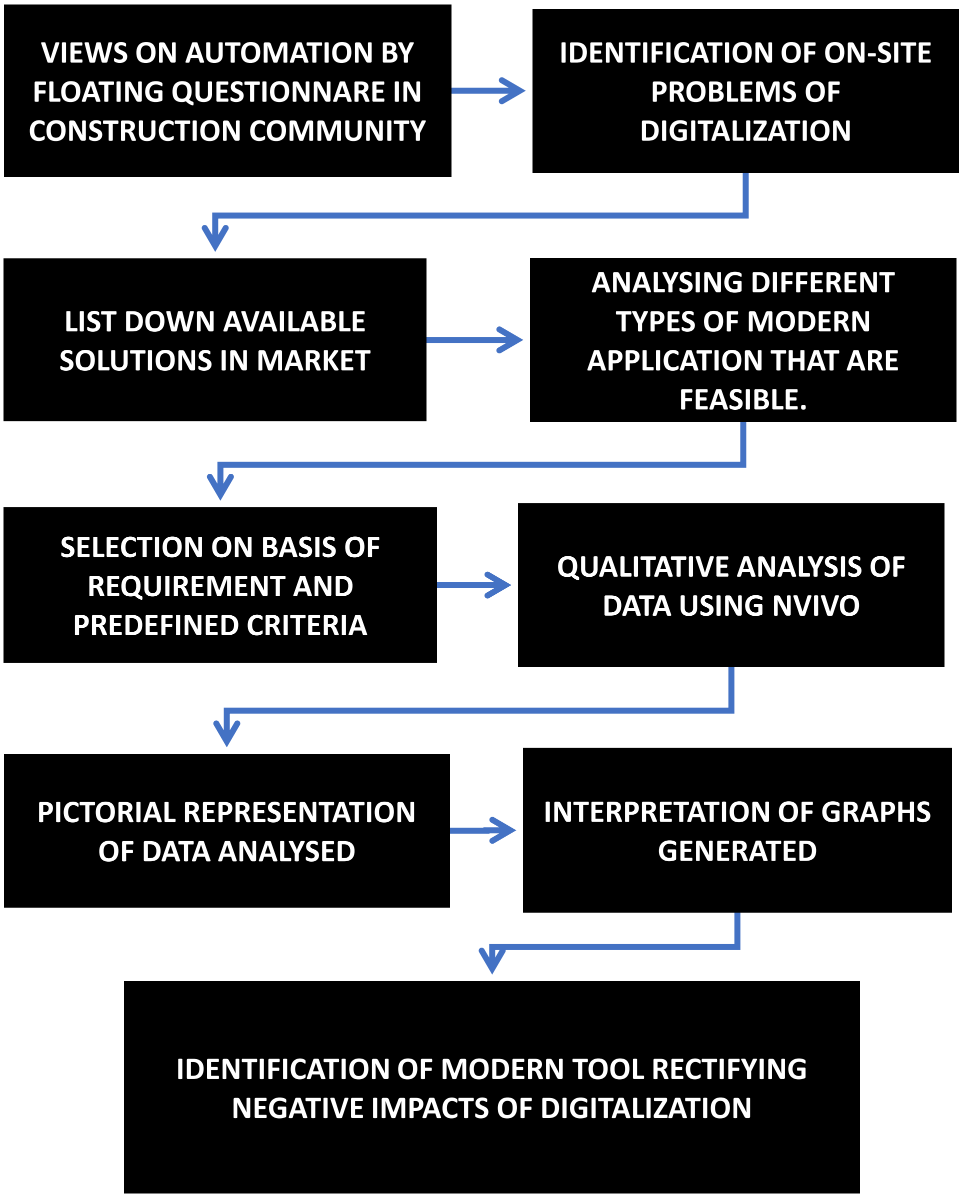


Figure 1: Methodology Adopted

Based on the questionnaire floated, responses were received and the output of the questionnaire has been replicated in the following numbers. 58.6% agree that automation increases productivity and efficiency of work, 49.5% agree that it proves to be time saving, 51.1% agree it provides effective on-site communication and 49.5% agree it proves to be useful in Quality control and Health Safety & Environment. From the above numbers it can be understood that automation is advantageous which will help in development of construction industry.

The outcome of the questionnaire was then substantiated by means of a case study based on a Pune based well established real-estate company. Experiencing the current pandemic scenario, this real-estate company wanted to adopt digitalization on their 400-acre township project being executed. The company wanted to digitalize its construction processes of quality department in order to achieve better quality control [6,18]. Keeping this case-study in mind, this research outcome talks about how mobile applications and software solutions as mentioned in **table 1** with respect to quality management, checklists and inspections in achieving improved productivity, ensuring safety etc., also analyzed.

3.1 Mobile applications

The software was scrutinized based on the methodology are listed below in the table: -

Table 1: List of Software

Mobile Application	**ERP/SAP/Customized IT Sol ^{n}**
P	A
Q	B
R	C
S	D

NOTE:

- Here, **P**, **Q**, **R** & **S** are construction mobile applications and in context of construction **A**, **B**, **C** & **D** are construction software solutions such as ERP, SAP or customizable IT solutions.
- The mobile applications and construction software solutions are renamed as alphabetical letters to maintain its **confidentiality.**

Out of the solutions identified, **A** & **B** (ERPs and SAPs respectively) were eliminated from the quantitative and qualitative analysis to be carried out. The reason behind doing this was that maximum construction firms are using ERPs or SAPs for accounting, material procurement or other such departments. Finding another ERP or SAP solution just for quality management will require the firm either to adopt two different ERP or SAP solution or move on to a completely new ERP or SAP solution to manage all their departments. Software developers such as **C** & **D** that provide customized IT solutions were also eliminated. This was done because getting a customized product after multiple discussions and meetings with the developers would be time consuming. Therefore, ready to use mobile applications like **P**, **Q**, **R** & **S** are preferred and required so that users could be created, upload basic data and commence using them in order to save time.

3.2 Parameters to measure efficiency

The parameters represented in **figure 1** and discussed in **table 2** & **3** were used to measure efficiency of mobile applications. The user interface of the mobile application must be simple or user friendly and smooth. The application must not crash and lag. The application should be compatible both with Mobile and PC. The application should be secured (i.e., no data theft). It must possess analytical dashboard (most preferably hyperlinked). It would be better if pre-installed checklists are provided. The report generated must be in pdf or excel. Intimating system is a must through the application (i.e., intimate by email via app and app notification). The application must not be expensive.

The following **tables 2 & 3** gives out information associated to different parameters of all four mobile applications. This material was gathered after receiving demonstrations from their developers: -

3.3 Outcome of Quantitative Analysis

To select the most effective mobile application and to meet with the objective, it was decided to prepare a ranking matrix as represented in **table 4**. Different mobile applications were rated on common parameters to measure their efficiency. Ratings were provided on the basis of interface observed and information collected during the demonstration delivered. Total sum of all average score was calculated for every mobile application on the basis of which they were finally ranked.

Table 2: Information of app P and Q

S. No	Particulars		P	Q
1	Notification		Mobile Push Notification + Email Intimation	Email Intimation
2	Dashboard	Real time update	Available	Available
		Analytics	Analytical Dashboard with varied filters	Non-Analytic Dashboard
3	User Experience		Complex to adapt and intense training required	User friendly, Simple interface and works smoothly
4	Additional Features		1) 3D model viewer and walk though 2) Isolate items 3) Upload drawings & attach links to it 4) Dimension measurement, area calculation.	1) Separate comment box is provided at the end of checklist for caption 2) Responses available - Yes, No.
5	Available Modules		Plan viewer, Task Manager, Schedule, BIM viewer, Punch-list and Inspection.	Quality Assurance, Non-Conformance, Material Module, Work Done Confirmation
6	Available Platform		Android & iOS	Android
7	Reports		PDF, PDF detailed & CSV	Excel, Web console report
8	Subscription		User Based	Tower Based
9	Cost		Rs. 2175 / user / month (Business Plan)	Rs. 5000 / tower / month

Table 3: Information of app R and S

S. No	Particulars		R	S
1	Notification		Mobile Push Notification + Email Intimation	Mobile Push Notification + Email Intimation
2	Dashboard	Real time update	Available	Available
		Analytics	Analytical Hyperlinked Dashboard	Analytical Dashboard
3	User Experience		UI is good and app runs smoothly	Too complex to adapt and understand
4	Additional Features		1) Time taken to fill a checklist by user and their location can be tracked via in-built GPS.	1) Reminders on late items schedule automatically 2) Pre-loaded Checklists 3) Offline Mode

S. No	Particulars	R	S
		2) Users will get notified in prior to their upcoming inspections 3) Offline mode	
5	Available Modules	Inspections, Schedule, Actions, Sensors and Incidents	Inspections, Punch-list, Reports, RFIs & NCRs, Performance & Task Management
6	Available Platforms	Android & iOS	Android & iOS
7	Reports	PDF, CSV, JSON, DOC & Web reports	Excel (.cvc) only
8	Subscription	User Based	User Based
9	Cost	Rs. 975 / user / month	Rs. 1683 / user / month (Professional Plan)

Table 7: Ranking Matrix based on the parameter's outcome

No	Category	Particulars	P	Q	R	S
			Score Card (1=lowest; 4=highest)			
1	**Client base**		4	2	3	4
2	**Cost**		1	4	3	2
3	**Dashboard**		2	3	4	1
4	**User Interface**	**User Experience**	2	4	3	3
		Training Required	1	4	3	1
		Interface Smoothness	3	3	4	3
5	**Modules**		3	2	4	4
6	**Security**		4	2	4	4
7	**Customization**		3	4	3	3
8	**Additional Features**	**Offline Mode Available**	4	4	4	4
		Other Modules	4	2	3	3
9	**Total Sum of all Average Score**		**2.81**	**3.1**	**3.45**	**2.9**
Final Position			**4th**	**2nd**	**1st**	**3rd**

Effective outcome of the qualitative analysis was interpreted using qualitative analyzing software called NVivo. The analysis was carried out by coding the parameters to measure efficiency based on the ranking. The outcome of the ranking was represented in the form of histograms as stipulated in **figure. 2**, **3**, **4** & **5**.

3.4 Interpretation of qualitative analysis outcome

The interpretation of the histograms was done as follows. The x-axis represented parameters that highlight efficiency. Values '1' and '0' of a particular parameter in the y-axis signified either 'yes' or 'no' respectively. For instance, the 'iOS' parameter stipulated in f**igure. 2**, **4** & **5** showed '1' on the y-axis which signified **P**, **R** & **S** are available on iOS platform whereas **figure. 3** showed '0'which signified **Q** is not. Similarly, the 'Features' parameter that had values greater than '1' on the y-axis stipulated in **figure 2**, **4** & **5** showed that application **P**, **Q**, **R** & **S** possessed 5, 5, 9 & 6 major technological features respectively.

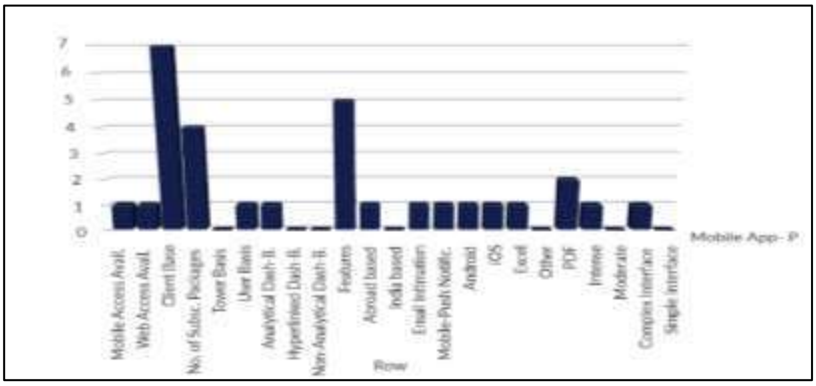


Figure 2: Pictorial Representation of Parameters of Mobile Application P

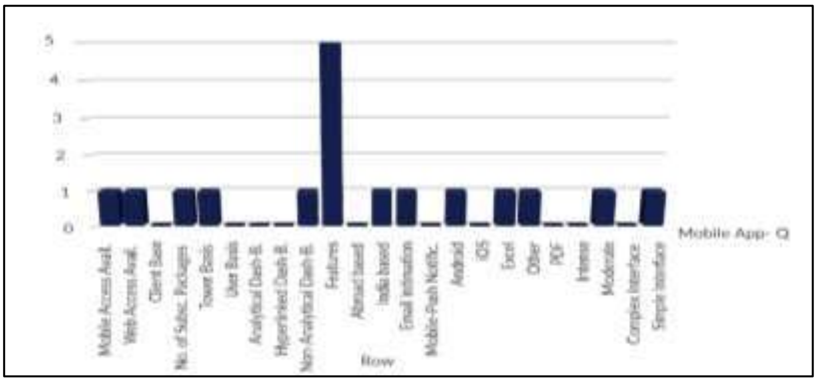


Figure 3 : Pictorial Representation of Parameters of Mobile Application Q

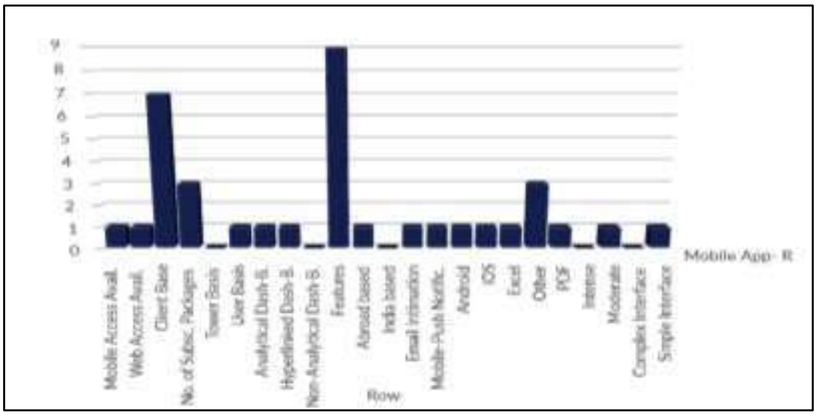


Figure 4: Pictorial Representation of Parameters of Mobile Application R

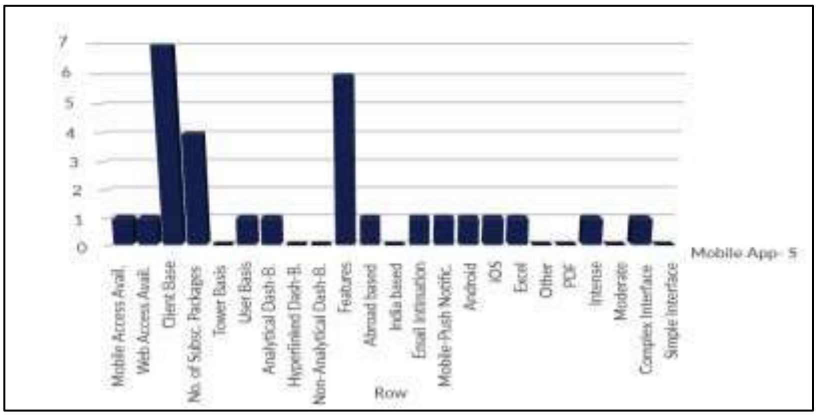


Figure 5: Pictorial Representation of Parameters of Mobile Application S

Based on the interpretation of **figure 2**, the following information has been arrived from the quantitative analysis. For example, let us consider for mobile application P.

- It can be accessed through a mobile-phone as well as a web-console.
- It has a client base of 7 major construction companies.
- There are 4 different subscription packages offered by the developer having different costs and benefits.
- The client is charged on user basis and not on tower basis by the developer for the subscription package they select (i.e., cost / user).
- The mobile application possesses an analytical dashboard. It is analytical only and not hyperlinked.
- It has 5 major technological features that make it attractive to use.
- The developer company is based in abroad and not in India.
- The users on the platform can be intimated through both email and mobile-push

notification.

- The application is available on both android and iOS platform.
- The report system of the application generates PDF format reports and no other formats.
- Intense training is required to get adapted to the application since the interface is complex.

Similarly, the information was interpreted for mobile application **Q**, **R & S** as represented in **figure 3, 4 & 5**.

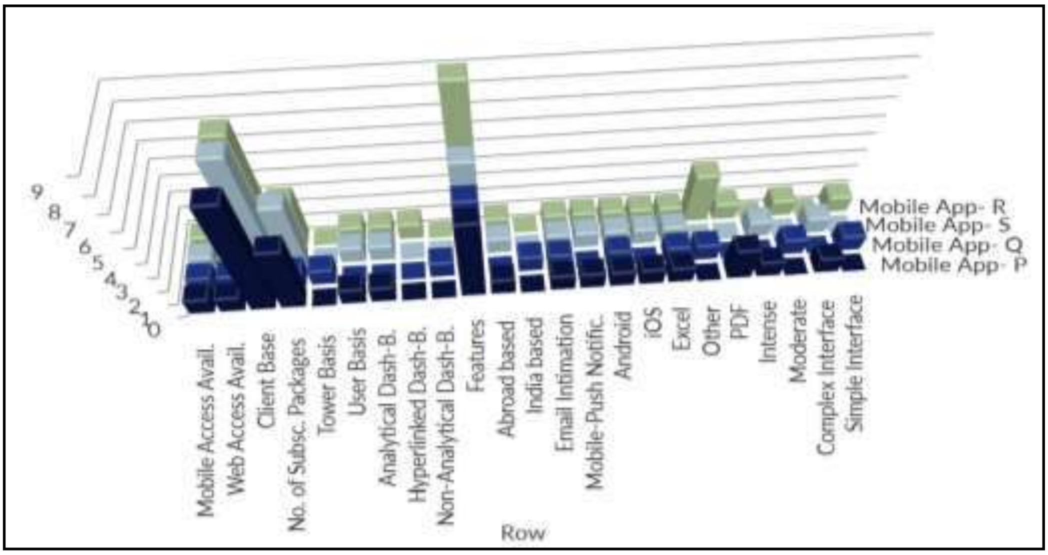


Figure 6: Cumulative Result of all applications

3.5 Discussion

The main outcome of the study was arrived by comparing all four mobile applications and the same was represented in 3D as stipulated in **figure 6,** for better decision making and interpretation. It can be clearly seen that all four applications can be accessed via Mobile and PC. Application **R** possess both analytical and hyperlinked dashboard whereas **P** & **S** possess only an analytical dashboard. Application **Q** has a non-analytical dashboard. Major technological features offered by application **R** are maximum as compared to **P**, **Q** & **S**. Intimation system for application **P**, **R** & **S** consists of both email intimation and mobile-push notification whereas its only email intimation for **Q** [12]. Similarly, applications **P**, **R** & **S** are available on both android and iOS whereas **Q** is only available on android [15]. The report system of application **R** looks the best amongst others because it provides reports in different formats such as PDF, Excel, etc. Applications **Q** & **R** would be easier to use since they have a simple interface which will require moderate training to get adapted to in compariso n to **P** & **S** [19]. Thus, the 4 applications have been compared and interpreted to learn more about their functionalities highlighted according to the parameters.

4. CONCLUSION

It was identified that with respect to quality management, checklists and inspections there are many solutions like **A**, **B**, **C**, **D**, **P**, **Q**, **R** & **S** which are available in the market. The challenge is to find the most suitable, easy to use, simple and economical application for your construction project. After performing a detailed quantitative and qualitative analysis on applications **P**, **Q**, **R** & **S** it can clearly be seen that the application **R** stands out and the same has been ranked 1st in the ranking matrix. The following are the advantages of application **R:**

- It helps in improving co-ordination and communication by bringing all the team members on the same platform.
- Its analytical-hyperlinked dashboard will help track project and employee performance.
- Users will not miss out on their tasks since features like 'schedule' and 'mobile-push notification' will intimate them in prior.
- In-built GPS location and time tracking system will increase accuracy of work.
- Its flexible reporting system will help exchange digital reports in multiple formats on both android and iOS devices.
- Above all the most important advantage is that the application has a simple interface which will require minimal training to get adapted and is cost-beneficial.

In order to increase the efficiency and productivity of construction projects it is mandatory to adopt the automation (mobile application) criteria like **R** which possess several advantages.

5. ACKNOWLEDGEMENT

Authors are thankful to National Institute of Construction Management and Research (NICMAR), Pune for providing facility and support to do this research work.

6. REFERENCES

Chen Y. and Kamara M. J. (2005). The Use of Mobile Computing in Construction Information Management, 581-583.

Sattineni A., Schmidt T. (2015) Implementation of mobile devices on Jobsites in the construction Industry, 488-490.

G.A. Yakubu, O. E. Ogunsanmi and A. O. Yakubu (2015) Influences of communication problems on project performance in Nigeria, 74-75.

Ekow Y. J., Kofi O.G. (2016) Awareness and Utilization of Construction Related Smart Mobile Device Applications in the Construction Industry, 1-3.

Djajalaksana M.L., Zekavat P.R. and Moon S. (2017). Effectiveness of On-Site Communication in Residential Housing Projects, 1-6.

Kumar A. (2014) Study of Quality Management in Construction Industry, 37-39.

Hussain Z. Md. and Hossain S. A. 2017, Real-time Supervision through ICT in Construction Quality Management and Monitoring System in Bangladesh", 148-149

Sinda N, Roja S. Y., (2017) Quality Control and Safety Assurance in Construction Building, 310.

Oke A., Aigbavboa C., and Mabena S., (2017) Effects of Automation on Construction Industry Performance, 370-371.

Lee N. and Kim Y., (2018) A Conceptual Framework for Effective Communication in Construction Management: Information Processing and Visual Communication, 2018, 534.

Olanrewaju A., Tan S. Y. and Kwan L. F., (2017) Roles of communication on performance, 763-764.

Hussain M. A., Othman Ayman A.E., Gabr H. S. And Aziz T. A., (2018) Causes and Impacts of Poor Communication in the Construction Industry, 1-3.

F.H. Abanda, D. Mzyece, A.H. Oti and M.B. Manjia, (2018). A Study of the Potential of Cloud/Mobile BIM for the Management of Construction Projects, 2-5.

McMeel D. and Gonzalez V. (2019) Review of Digital Technologies to Improve Productivity of New Zealand Construction Industry, 570-579.

Venkatraman S. and Yoong P., (2019) Role of mobile technology in the construction Industry, 1-16.

Sudharsan K and Priyadharshni P, (2019) Study on the Development of a Mobile Application for the ease of Communication for Construction Site Management, 1-3.

Rawal N. Md., Fathi Md. S. and Abedi Md., (2019) Mobile Application for Sustainable Construction Management, 1-3.

Salvi S. S. and Kerkar S. S., (2020) Quality Assurance and Quality Control for Project Effectiveness in Construction and Management, 26-29.

Azhar S., Jackson A. and Sattineni A., (2013) Construction Apps: A Critical Review and Analysis, 1-7.

Cline R. C. and Davis K. A., (2013) Using Mobile Technology in a Construction Management "Hands-On" Laboratory, 2-3.

Clancy T., Woo J. H., and Wyszkowski P., (2012) Cost-Effective Mobile Application Strategies in a Competitive and Economically Challenged Industry, 718-719.

Section III

ICT IN CONSTRUCTION MANAGEMENT

Editor's Note

This section comprises of studies in the domain of Information and Communication Technologies and related technical innovations in the construction sector. Srinivas and Dixit used the Delphi approach to gather expert opinions on the application of digital technologies in Indian building industry. Technology Organization Environment (TOE) Model is used to classify the variables influencing the implementation of technologies in AEC Industry, and DEMATEL technique is used to segregate the relevant cause and effect factors.

Similarly, Hire et al. examined BIM's existing adoption primarily for construction to eliminate on-site collisions. A systematic review of current literature is carried out, and it is found out that BIM will help to manage the safety of construction in different ways, consisting of planning for site protection, detection of hazards prior to construction, familiarity with working conditions by visualisation, coordination and co-ordination, protection design, and automatic on-site security checking,

Likewise, the goal of the study by Anand et al. is twofold: firstly, to understand how to simulate BIM and energy modelling early in design and secondly, to understand how to optimize the design in terms of cost, safety and energy. The results demonstrate the advantages of the green building construction technique. Similarly, Malla et al. developed a Lean Agile Based Construction System through a questionnaire, and this model is projected to improve the organizational work efficiency. Similarly, the goal of the paper by Kunjam and Jayakumar is to provide a framework for optimally managing assets during the time of service, and to build a database to support future maintenance and repair work decisions.

Integration of Project Management in Construction Industry 4.0 Framework

A V S S Surya SRINIVAS[1], Vijaya DIXIT[2]
[1]Research Scholar, [2]Assistant Professor, Indian Institute of Management, Ranchi

ABSTRACT

The current Industrial revolution with main and prime emphasis on digitalization influences all industries which includes Architectural Engineering and Construction (AEC) Industry. Construction Industry 4.0 (CI4), which is synonymous with Industry 4.0 (I4) framework, is proposed by some researchers to explore digital implementation possibilities in AEC Industry. The project Management framework is already established and available which guides and manages various projects which includes AEC projects. However, during current I4 revolution, it is necessary for Integration of both Project Management framework with CI4 framework. The current paper reviewed the literature pertains to technology advancements and its suitability to construction industry. Authors used Delphi technique to collect expert opinions on implementation of digital technologies in construction industry in Indian scenario. Technology Organization Environment (TOE) Model identified through literature was used in identifying the factors influencing the implementation of technologies in AEC Industry and DEMATEL technique was used to segregate the causal and effect factors. Considered few project sites of one of the big construction conglomerates of India as case study and expert opinions were collected and discussed regarding implementation of digital technologies in AEC Industry.

KEYWORDS:

Project Management, Construction Industry 4.0, CI4, Technology Organization Environment Model

INTRODUCTION

Industrial Revolution 4.0 (or) Industry 4.0, emphasizes on digitization, advancement, production customization, robotic automation and human-machine interaction are being implemented in almost all industries and has picked up momentum since 2014. Architecture Engineering and Construction (AEC) Industry which normally adapt improvements from Manufacturing Industry, is currently in the process of implementing Industry 4.0 standards, which attracts researchers to explore the research possibilities to formulate Construction Industry 4.0 Framework.

Construction Project Management is vast which starts from Conceptualization stage to Commissioning stage of any construction project. PMI's PMBOK specified and elaborated ten knowledge areas which covers entire Project Management Framework. Current research focuses on Integration of all ten knowledge areas of Project Management into Construction Industry 4.0 framework. Current state of the art of the technologies in construction associated with the notion of Industry 4.0 (e.g., BIM, virtual reality, augmented reality, Drone, etc.) is explored through extensive literature studies. The proposed framework incorporates current technological advancement related to construction industry and applies to construction project management through improved value chain and productivity.

Motivation for the Study

Currently many construction companies in AEC Industry are adopting ERP (Enterprise Resource Planning) Software like EIP, SAP etc, are basically databases which integrates all functionalities of project management for managing Projects, Programs & Portfolios. However, these ERPs are limited to data recording and usage for future reference and minimal analysis for decision making. These ERPs have a maximum manual intervention for capturing the data which is laborious and time-consuming. However, due to fast growing world scenario, it is very much essential to capture the real-time data as well as real-time analysis for quick decision making. These ERPs are also generating huge & BIG data. However, proper data analysis using advanced statistics & data mining techniques are missing. Hence, with this view in backdrop motivated to study on Integration of all knowledge areas of Project Management with Digital applications for effective Project Management by capturing real-time data and analyzing the same for effective & quick decision making.

Literature Review

From the literature review done so far, Artificial Intelligence (AI) & Machine Learning (ML) applications in structural design was first studied during 1985 to 1988 and subsequently extended to construction safety. Tomasz A & Mumtaz U (1993) applied "AI & ML applications to learn about the accidents and measures to prevent the same using theory of rough sets. The use of AI is growing across many industries. Bernstein (2017) focuses on the evolving role of an architect of the intersection of design & constructions, including subject such as alternative delivery systems & value generations. AI clouds help the construction industry work faster and keep its workforce accident free (Woyke, 2018). In her article she tagged important key words viz: Big data, wearable technology, data science, analytics, future work, jobs. Bharadwaj (2018) classified the major applications for AI in construction & building. These are; (i) Planning & Design (ii) Safety (iii) Autonomous equipment, & (iv) Monitoring & maintenance. Wadlow (2018) explained importance of planning stages, construction underway, after construction, BIM & Virtual Assistant as key categories of AI in the CI. Ilter and Dikbas (2018) reviewed application of the AI in construction, dispute resolution. In his paper, he analyzed and categorized in to three groups as settlement oriented system method, selected oriented system & dispute evaluative oriented systems. Gayatri (2019), reviewed the application of Robotics, AI, and the Internet of Things can reduce building costs by up to 20 percent. AI is being used to track the real-time interactions of workers, machinery, and objects on the site and alert supervisors of potential safety issues, construction errors, and productivity issues. Aslam & Abid (2019), opinioned that implementing the Industry 4.0 digital standards in construction will benefit the construction industry in achieving the higher productivity. Literature survey was done on Industry 4.0 technology implementation in construction industry by various researchers such as Flávio Craveiro et.al (2019), Robert Klinc & Ziga Turk (2019), Farah Salwati Binti Ibrahim et.al (2019), Christopher J. Turner et.al (2019), Omoseni Oyindamola Adepoju & Clinton Ohis Aigbavboa (2020), Zhijia You & Lingjun Feng (2020), Nathalie Perrier et.al (2020)". It is found that research focus is more on identifying the various digital technologies from other industries in Industry 4.0 framework and mapping them into Construction 4.0, identifying the challenges & opportunities.

Authors also checked the literature and found that Davis et.al (1989), "developed technology acceptance model (TAM) based on the Theory of Reasoned Action (TRA). The same model was developed shifty with inclusion of various factors at various instances. Later on, with inclusion of social influence processes, cognitive instrumental processes and a detailed account of key forces underlying judgement of perceived usefulness and behavioral intention, TAM was expanded to TAM2 by Venkatesh and Davis (2000). Later in 2003, Venkatesh et al. (2003) identified and discussed eight models related to behavioral intention to use information technology and proposed the Unified Theory of Acceptance and Use of Technology (UTAUT). TAM3 was proposed by Venkatesh and Bala (2008) based on TAM2 with an inclusion of the effects of trust and perceived risk on system use. X. Qin et al. (2019) proposed TAM-TOE model for BIM acceptance based on the Technology Acceptance Model (TAM) and the Technology-Organization-Environment (TOM) framework". An Interval DEMATEL method was applied to analyze the relationships between a set of factors and their influencing levels to each other.

In view of literature survey done so far, Out of all emerging technology hitting the market today, AI is a new technology that is on track to revolutionize the construction industry. Hence, in the current study, proposed to use AI & ML Applications in Project Management in Construction Projects. Although significant research studies exist on Project Management in Construction, there exists a gap in exploration & implementation of Technology driven Advanced Applications (TdAa) in effective implementation of Project Management in Construction organizations in Industry 4.0 Framework.

The authors propose three fold objectives: Firstly to review the Digital applications in Construction Project Management from the existing literature related to AEC Industry. Secondly, to identify the influencing factors through Technology Organization Environment (TOE) Model and to identify Cause & Effect Variables. Thirdly, to develop an "Digital Application based conceptual framework for Integration of all ten knowledge areas of Project Management with Industry 4.0" using Technology Acceptance Model (TAM).

Research Methodology

The research methodology includes the content analysis from relevant literature to identify the various digital applications & related technological advancements in the proposed area and specific to construction domain. A structured questionnaire-based survey (quantitative study) was be floated to the construction industry experts to identify the effect of factors influencing technological advancements in AEC industry as well as the effect of digital technologies already implemented and their interactions with ERPs. With the identified applications from the Literature and first round of questionnaire survey, expert opinions, a second level of structured questionnaire-based survey will be floated to the construction industry and academic professionals and the identified technological advancements shall be analyzed using various statistical & machine learning tools to create a digital application based conceptual framework.

Expert opinion survey on Implementation of Digital Technologies (Case Study)

Authors contacted few experts preferably planning managers and project managers belongs to various construction projects of one of the big construction conglomerate in Indian AEC Industry, which has implemented some digital initiatives in their organization. These digital initiatives were linked to their existing ERP system. The projects belongs to various sectors such as construction of buildings, factories, transmission lines and water treatment plants.

It is observed on an outset from the respondents that the implementation of digital technologies into AEC industry indeed a very good move which actually has positive impact on both schedule as well as on cost parameters. For example, electronic document management system linked with the cloud server and accessible to all stake holders helps in identifying the latest revision of the drawing. The system also provides real time alerts whenever there is an updation in the deliverable list, which enables the stakeholders to access to the latest updates immediately. This will helps in avoiding miscommunication and keeping all stakeholders in same platform always.

Another respondent opinioned that, point of sale concept was introduced in their store management system which helps them in real time stock status of the material at any point of time. This helps them in real time material reconciliation and effective inventory planning. The store management system is already available in ERP, however it takes time in getting real picture due to manual intervention in updating the details of already issued material. Construction sites being dynamic, it is highly difficult to have real time stock status with manual intervention in updating the required details in ERP. Hence, integrating the ERP system with point of sale concept helps in getting the real time stock status.

Mobile app implemented for quality control is found useful as per some other respondent. It reduces the effort in updating the status in excel daily. All the details of inspection, engineers comments etc are being recorded in real time through mobile app and status report can be generated at any point of the time from the app itself. This helps in minimizing effort duplication, real time status monitoring can be done by any stakeholder.

Convolutional Neural Network algorithm based app is being used to ensure compliance to PPEs by all people on site. Surveillance cameras were linked to Safety app, which identifies and sends alert to all stakeholders if any workmen is not wearing any required PPE such as Helmet, Safety Shoes etc. This will help in strict compliance and more surveillance to ensure implementation of EHS standards.

CI4 technologies mapping to Project Management Framework

Based on the observations from the case studies, identified some CI4 technologies which are being used and mapped to project management framework which are as indicated in the table 1 below. However, extensive survey needs to be done with big sample size across various organizations in AEC Industry to identify the technologies being used as well as suggestions to implement various other technologies.

Table 1 CI4 Technologies Mapping to PM Framework

<table>
<tr><th>PM Knowledge Area</th><th>CI4 Technologies</th></tr>
<tr><td>Project Procurement Management</td><td>Radio frequency identification (RFID)
Barcode
Global positioning system (GPS)</td></tr>
<tr><td>Project Resource Management</td><td rowspan="2">Mixed reality/Virtual reality (MR/VR)
Internet of Things (IOT)
Radio frequency identification (RFID)</td></tr>
<tr><td>Project Communication Management</td></tr>
<tr><td>Project Risk Management</td><td>Machine learning</td></tr>
</table>

Technology Organization Environment Model

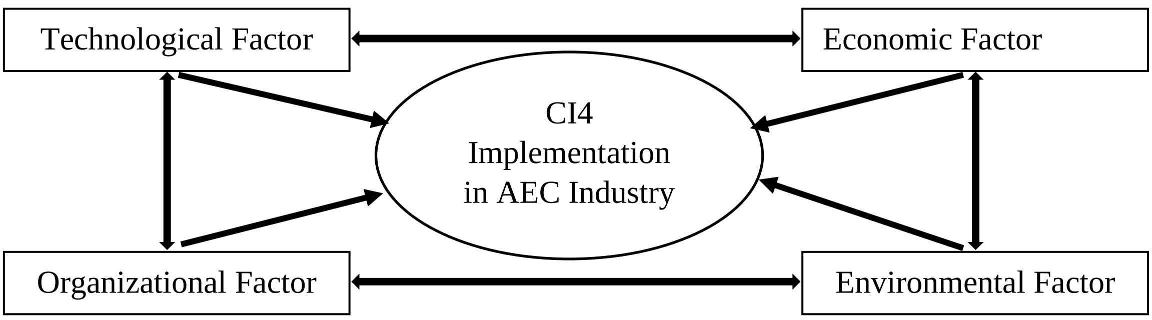


Figure 1: TOE Model for CI4 Implementation in AEC Industry (From Paper X.Qin., et.al., (2020))

X.Qin., et.al., (2020) used the TAM-TOE model in BIM Implementation. From his work it is understood that, The Technology-Organization-Environment model (TOE) was proposed by Tornatzky and Fleischer (1990) which models the influences of technological, the organizational and the environmental context in the process of adopting and implementing technological innovations by a firm (Drazin,1991). The technological context refers to internal (ERP System which an Organization is being used) and external technologies (CI4 technologies) that are currently applied by the organization and those available in the market but not yet used by the company. The organizational context refers to the company size, organizational structure and human resource and the environmental context covers factors outside the control of the organization such as competition, partners and the industry environment. Songer et al. (2001) suggested to introduce economic factors into the technology adoption framework, as the fourth dimension of factors for the TOE-based framework of BIM technology (Figure 1). The influencing factors were identified through literature was finally chalked down to 15 factors using Delphi technique and the same was tabulated in Table 3 below. These factors were again circulated to Industry experts and responses were collected to identify the relation among these factors. DEMATEL Technique was used for analyzing the responses received from the experts.

Table 2. Influence levels and respective interval numbers (From Paper X.Qin., et.al., (2020))

Influence Level	No Influence	Very Low	Low	High	Very High
Value	[0,0]	[0,1]	[1,2]	[2,3]	[3,4]

Data Analysis & Results, Discussions

The DEMATEL (Decision Making Trial and Evaluation) method quantifies the independent views of the helps respondents such that it can be measured and analysed. It can be used to describe the causal relationship model between the variables and the effects exerted by the factors. The benefit of this technique is that experts can communicate their views on the effects (direction and intensity of effects) between variables more fluently.

1:Direct relation matrix generation.

Direct relation matrix A is generated.

$$A = \begin{bmatrix} 0 & \cdots & a_{n1} \\ \vdots & \ddots & \vdots \\ a_{1n} & \cdots & 0 \end{bmatrix}$$

The table 4 shows the direct relation matrix, which is the same as pairwise comparison matrix of the experts.

2: Normalized direct-relation matrix computation

$$p = max\left\{ max \sum_{j=1}^{n} a_{ij}, \sum_{i=1}^{n} a_{ij} \right\} \qquad N = \frac{1}{p} * A$$

3: Total relation matrix computation

"After calculating the normalized matrix, the fuzzy total-relation matrix can be computed as follows":

$$T = \lim_{k \to +\infty} (N^1 + N^2 + \cdots + N^k)$$

$T = N \times (I - N)^{-1}$"

4: Set the threshold value

In this study, the threshold value is equal to 0.646. All the values in matrix T which are smaller than 0.646 are set to zero, that is, the causal relation mentioned above is not considered. The model of significant relations is presented in the table 7.

5: Final output and create a causal diagram

"The next step is to find out the sum of each row and each column of T (in step 3). The sum of rows (D) and columns (R) can be calculated as follows:

$D = \sum_{j=1}^{n} T_{ij}$ $R = \sum_{i=1}^{n} T_{ij}$

Then, the values of D+R and D-R can be calculated by D and R, where D+R represent the degree of importance of factor i in the entire system and D-R represent net effects that factor *i* contributes to the system."

The table 8 below shows the final output.

Table 3. Influential Factors Identified through Literature and categorized into TOE Framework

Code	**Category**	**Factor**
Criteria 1	Technological	Non-physicality (without human physical presence)
Criteria 2	Environmental	First Mover Advantage / Implementation of technology by competitors
Criteria 3	Environmental	Demand for technology in market
Criteria 4	Economic	Technological Benefits (Reducing coordination problems / increased collaboration, increased productivity, etc.)
Criteria 5	Organizational	Top management support / Push by top management
Criteria 6	Technological	IT involvement in technology
Criteria 7	Organizational	Employees, stakeholders(subcontractors & vendors) adaptability and knowledge level to new technology, change management, skill gap assessment & re-skilling, Raising organizational challenges through implementation of new technologies in business operations
Criteria 8	Technological	Decision-support aiding tools in O&M
Criteria 9	Technological	Technology modifications through in-house capability enhancement / Support for technology provider, Timely discovery of potential problems through increased detail and information
Criteria 10	Environmental	Information management (Interoperability) between all stakeholders and single point of trust
Criteria 11	Economic	Effective in Life Cycle Cost incl. investment cost
Criteria 12	Economic	Better valuation / Brand Image with use of technology
Criteria 13	Environmental	Policy formulation towards industry academia collaboration for technological knowledge updates
Criteria 14	Environmental	Standardisation/ Regulatory laws
Criteria 15	Technological	Data Security, Protection & Fraud Resistance

*Note: For Ease, further we name Criteria 1 as C1, Criteria 2 as C2 and so on., Criteria15 as C15.

Table 4 Direct relation matrix

.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	0.0	1.2	3.2	3.2	2.8	4.0	2.8	2.8	2.6	3.0	3.0	3.2	2.6	2.6	2.8
C2	0.0	0.0	3.2	1.2	4.0	3.8	2.2	2.0	3.0	2.0	3.0	3.8	2.4	1.4	2.2
C3	2.2	2.8	0.0	2.4	3.0	3.6	2.4	3.0	3.0	3.0	2.8	3.0	2.4	2.4	3.0
C4	2.8	2.2	3.0	0.0	3.0	3.4	2.8	3.2	2.8	3.2	2.8	3.6	2.2	2.6	2.8
C5	2.8	3.2	2.6	3.0	0.0	3.2	3.0	2.6	2.4	2.2	2.4	3.2	2.2	2.4	2.4
C6	2.8	2.8	3.2	3.4	2.2	0.0	2.4	2.4	2.8	2.6	2.6	2.6	2.6	2.2	3.2
C7	1.2	1.6	2.0	3.2	3.2	2.8	0.0	3.0	2.2	2.6	2.4	2.6	1.8	2.6	2.4
C8	2.6	2.4	2.6	3.4	2.6	3.0	2.2	0.0	2.4	2.4	3.0	2.6	2.4	2.8	1.8
C9	1.6	2.6	2.8	3.6	2.6	3.0	2.4	2.2	0.0	2.4	2.4	2.6	2.8	2.6	2.8
C10	1.2	2.2	2.8	3.2	2.2	2.8	2.4	2.4	2.6	0.0	2.2	2.6	2.2	2.8	3.2
C11	1.0	2.8	2.8	3.0	2.4	3.0	2.4	2.6	3.0	2.2	0.0	3.0	2.0	2.2	2.6
C12	2.6	3.2	3.4	3.0	3.2	2.4	2.6	2.6	2.8	2.4	3.0	0.0	2.8	2.0	2.0
C13	2.6	2.6	3.2	2.6	2.4	2.6	2.2	2.0	3.0	2.6	2.0	3.0	0.0	3.0	2.2
C14	1.8	2.4	3.2	2.4	2.4	2.2	2.6	2.4	2.8	2.6	2.2	2.4	2.8	0.0	2.0
C15	2.0	2.8	3.0	2.8	2.4	2.6	2.6	2.6	2.8	2.8	2.2	2.6	2.0	2.4	0.0

Table 5 The normalized direct-relation matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	0	0.030	0.079	0.079	0.069	0.099	0.069	0.069	0.064	0.074	0.074	0.079	0.064	0.064	0.069
C2	0	0	0.079	0.030	0.099	0.094	0.054	0.050	0.074	0.050	0.074	0.094	0.059	0.035	0.054
C3	0.054	0.069	0	0.059	0.074	0.089	0.059	0.074	0.074	0.074	0.069	0.074	0.059	0.059	0.074
C4	0.069	0.054	0.074	0	0.074	0.084	0.069	0.079	0.069	0.079	0.069	0.089	0.054	0.064	0.069
C5	0.069	0.079	0.064	0.074	0	0.079	0.074	0.064	0.059	0.054	0.059	0.079	0.054	0.059	0.059
C6	0.069	0.069	0.079	0.084	0.054	0	0.059	0.059	0.069	0.064	0.064	0.064	0.064	0.054	0.079
C7	0.030	0.040	0.050	0.079	0.079	0.069	0	0.074	0.054	0.064	0.059	0.064	0.045	0.064	0.059
C8	0.064	0.059	0.064	0.084	0.064	0.074	0.054	0	0.059	0.059	0.074	0.064	0.059	0.069	0.045
C9	0.040	0.064	0.069	0.089	0.064	0.074	0.059	0.054	0	0.059	0.059	0.064	0.069	0.064	0.069
C10	0.030	0.054	0.069	0.079	0.054	0.069	0.059	0.059	0.064	0	0.054	0.064	0.054	0.069	0.079
C11	0.025	0.069	0.069	0.074	0.059	0.074	0.059	0.064	0.074	0.054	0	0.074	0.050	0.054	0.064
C12	0.064	0.079	0.084	0.074	0.079	0.059	0.064	0.064	0.069	0.059	0.074	0	0.069	0.050	0.050
C13	0.064	0.064	0.079	0.064	0.059	0.064	0.054	0.050	0.074	0.064	0.050	0.074	0	0.074	0.054
C14	0.045	0.059	0.079	0.059	0.059	0.054	0.064	0.059	0.069	0.064	0.054	0.059	0.069	0	0.050
C15	0.050	0.069	0.074	0.069	0.059	0.064	0.064	0.064	0.069	0.069	0.054	0.064	0.050	0.059	0

Table 6 The total relation matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	0.491	0.647	0.785	0.778	0.733	0.823	0.678	0.693	0.727	0.699	0.700	0.781	0.644	0.656	0.688
C2	0.425	0.536	0.686	0.636	0.668	0.717	0.580	0.588	0.644	0.589	0.613	0.697	0.559	0.546	0.588
C3	0.529	0.668	0.695	0.743	0.722	0.797	0.655	0.682	0.720	0.683	0.681	0.760	0.626	0.636	0.677
C4	0.560	0.677	0.789	0.712	0.746	0.818	0.685	0.709	0.739	0.710	0.703	0.798	0.643	0.662	0.694
C5	0.527	0.657	0.733	0.733	0.634	0.766	0.649	0.654	0.686	0.647	0.653	0.743	0.604	0.618	0.644
C6	0.530	0.652	0.750	0.746	0.689	0.697	0.639	0.654	0.699	0.660	0.661	0.734	0.616	0.617	0.666
C7	0.446	0.564	0.651	0.671	0.642	0.686	0.521	0.603	0.618	0.595	0.592	0.661	0.539	0.566	0.584
C8	0.508	0.620	0.711	0.720	0.672	0.739	0.612	0.574	0.665	0.631	0.646	0.708	0.590	0.608	0.611
C9	0.487	0.627	0.717	0.726	0.674	0.740	0.618	0.627	0.611	0.633	0.634	0.710	0.600	0.606	0.635
C10	0.459	0.594	0.689	0.690	0.639	0.707	0.594	0.607	0.645	0.552	0.605	0.681	0.564	0.587	0.619
C11	0.456	0.611	0.692	0.689	0.647	0.715	0.597	0.614	0.657	0.607	0.556	0.694	0.562	0.576	0.609
C12	0.527	0.664	0.757	0.740	0.714	0.757	0.646	0.660	0.702	0.657	0.672	0.677	0.623	0.615	0.642
C13	0.504	0.621	0.720	0.698	0.664	0.725	0.608	0.617	0.675	0.632	0.620	0.712	0.531	0.609	0.617
C14	0.464	0.589	0.687	0.662	0.634	0.683	0.589	0.597	0.640	0.603	0.595	0.667	0.569	0.513	0.584
C15	0.485	0.619	0.707	0.695	0.656	0.717	0.610	0.623	0.662	0.629	0.617	0.695	0.571	0.589	0.558

Table 7 The total- relationships matrix by considering the threshold value

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	0	0.647	0.785	0.778	0.733	0.823	0.678	0.693	0.727	0.699	0.700	0.781	0	0.656	0.688
C2	0	0	0.686	0	0.668	0.717	0	0	0	0	0	0.697	0	0	0
C3	0	0.668	0.695	0.743	0.722	0.797	0.655	0.682	0.720	0.683	0.681	0.760	0	0	0.677
C4	0	0.677	0.789	0.712	0.746	0.818	0.685	0.709	0.739	0.710	0.703	0.798	0	0.662	0.694
C5	0	0.657	0.733	0.733	0	0.766	0.649	0.654	0.686	0.647	0.653	0.743	0	0	0
C6	0	0.652	0.750	0.746	0.689	0.697	0	0.654	0.699	0.660	0.661	0.734	0	0	0.666
C7	0	0	0.651	0.671	0	0.686	0	0	0	0	0	0.661	0	0	0
C8	0	0	0.711	0.720	0.672	0.739	0	0	0.665	0	0	0.708	0	0	0
C9	0	0	0.717	0.726	0.674	0.740	0	0	0	0	0	0.710	0	0	0
C10	0	0	0.689	0.690	0	0.707	0	0	0	0	0	0.681	0	0	0
C11	0	0	0.692	0.689	0.647	0.715	0	0	0.657	0	0	0.694	0	0	0
C12	0	0.664	0.757	0.740	0.714	0.757	0.646	0.66	0.702	0.657	0.672	0.677	0	0	0
C13	0	0	0.720	0.698	0.664	0.725	0	0	0.675	0	0	0.712	0	0	0
C14	0	0	0.687	0.662	0	0.683	0	0	0	0	0	0.667	0	0	0
C15	0	0	0.707	0.695	0.656	0.717	0	0	0.662	0	0	0.695	0	0	0

Table 8 The final output

	R	D	D+R	D-R
C1	7.400	10.523	17.923	3.123
C2	9.345	9.070	18.415	-0.275
C3	10.769	10.274	21.042	-0.495
C4	10.639	10.645	21.284	0.006
C5	10.133	9.949	20.081	-0.184
C6	11.088	10.010	21.099	-1.078
C7	9.283	8.939	18.222	-0.344
C8	9.502	9.614	19.116	0.112
C9	10.091	9.647	19.738	-0.444
C10	9.530	9.231	18.760	-0.299
C11	9.546	9.282	18.828	-0.264
C12	10.717	10.053	20.769	-0.664
C13	8.839	9.553	18.392	0.714
C14	9.004	9.077	18.081	0.074
C15	9.416	9.434	18.850	0.017

The following figure 2 shows the model of significant relations. This model can be represented as a diagram in which the values of (D+R) are placed on the horizontal axis and the values of (D-R) on the vertical axis. The position and interaction of each factor with a point in the coordinates (D + R, D-R) are determined by coordinate system.

6: Interpret the results

According to the figure 2 and table 7 above, each factor can be assessed based on the following aspects:

Horizontal vector (D + R) represents the degree of importance between each factor plays in the entire system. In other words, (D + R) indicates both factor i’s impact on the whole system and other system factors’ impact on the factor, in terms of degree of importance, C4 is ranked in first place and C6, C3, C12, C5, C9, C8, C15, C11, C10, C2, C13, C7, C14 and C1, are ranked in the next places.

The vertical vector (D-R) represents the degree of a factor’s influence on system. In general, the positive value of D-R represents a causal variable, and the negative value of D-R represents an effect. In this study, criterion1, criterion4, criterion8, criterion13, criterion14, criterion15 are considered to be as a causal variable, criterion2, criterion3, criterion5, criterion6, criterion7, criterion9, criterion10, criterion11, criterion12 are regarded as an effect.

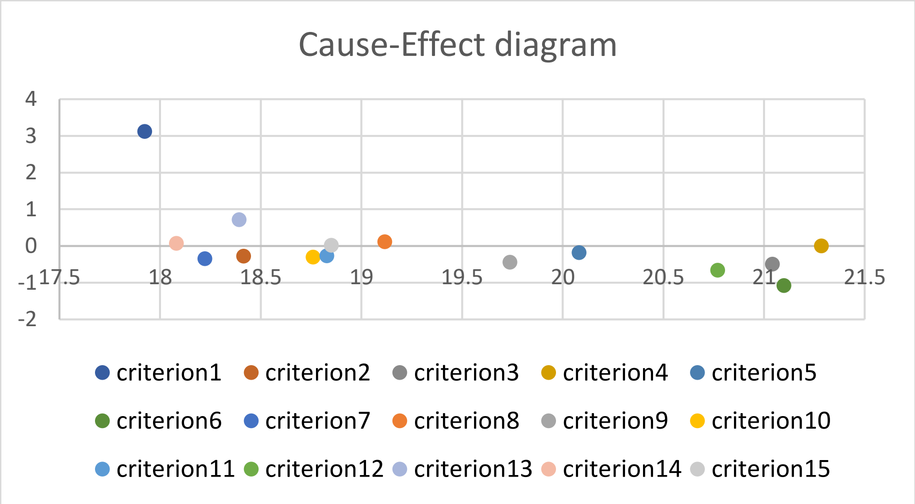


Figure 2 Cause-Effect diagram

Interpretations & Inferences from DEMATAL Results in Implementation CI4 Technology

The study resulted in 6 causal factors and out of the same the most driving factors are "Non physicality(without human intervention)(C1)", followed by "Policy formulation towards industry academia collaboration for technology updates(C13)". The other causal factors are Decision-support aiding tools(C8), Standardisation/ Regulatory laws(14), Data Security, Protection & Fraud Resistance (C15), and Technological Benefits(C4). These causal factors influence the remaining factors and effect the strategic elements of an organisation. Apart from that, this study resulted in 9 effect factors, out of which the first four factors which are having higher degree of importance are "IT Involvement in Technology (C6)", "Better valuation/Brand Image with use of technology(C12)", "Demand for Technology in Market(C3)", "Technology modifications through in-house capability enhancement(C9)".

The driving factors mentioned above needs to be pushed by top management of organizations such that new technology viz., CI4 technology adaptability shall be increased which shall result in enhancement of brand image, increased involvement of IT, in-house technology upgradation and capability enhancement. The implementation of CI4 technologies by an organization will also have first mover advantage as the organization showcases the benefits of usage of CI4 technologies such as improvements in time, cost & productivity. From the case study it is observed that the Organization which has already implemented the CI4 technology has involved the client intervention in their quality control app where there is a provision for client/consultant approval. This initiative will affect the stakeholder adaptability to the CI4 technologies and shall make client/consultant groups aware of CI4 technologies and their benefits. Use of CI4 technologies also affect Life cycle cost of the project as well as enhances the demand for new technologies in the market.

Conclusions & scope for further research

Authors tried to achieve all the objectives chalked out in the current research. However, in depth and rigorous study is required by collecting more responses to the questionnaires. Various CI4 technologies already implemented in Indian AEC Industry was mapped in PM Framework based on expert opinion survey done. However, the expert opinion survey needs to be extended to all AEC organizations in India which helps in better Integrating Project Management with CI4 Framework as well as in understanding the Integration of ERP with CI4 Technologies. Due to time constraint, current study is based on Delphi technique with minimum experts. DEMATEL Results may vary when the sample size increases. Current study is an outline and as indicated above sufficient time needs to be spent to collect responses from all possible stakeholders of AEC Industry in India rather than contacting few specific experts or few project sites pertains to a single organization. Authors linked the Factors identified and mapped in TOE framework to the CI4 Technologies Implementation in AEC Industry. TOE framework analyzed using DEMATEL technique needs to be extended to TAM-TOE framework for further analysis.

References

Perrier, N., Bled, A., Bourgault, M., Cousin, N., Danjou, C., Pellerin, R., & Roland, T. (2020). Construction 4.0: A survey of research trends. *Journal of Information Technology in Construction*, *25*(September), 416–437. https://doi.org/10.36680/J.ITCON.2020.024

Adepoju, O. O., & Aigbavboa, C. O. (2020). Implementation of Construction 4.0 in Nigeria: Evaluating the Opportunities and Threats on the Workforce. *Academic Journal of Interdisciplinary Studies*, *9*(5), 254–264. https://doi.org/10.36941/ajis-2020-0102

Turner, C., Oyekan, J., Stergioulas, L., & Griffin, D. (2020). Utilizing Industry 4.0 on the Construction Site: Challenges and opportunities. *IEEE Transactions on Industrial Informatics*, *Figure 1*, 1–1. https://doi.org/10.1109/tii.2020.3002197

Adepoju, O. O., & Aigbavboa, C. O. (2020). Assessing knowledge and skills gap for construction 4.0 in a developing economy. *Journal of Public Affairs*, *July*, 1–10. https://doi.org/10.1002/pa.2264

You, Z., & Feng, L. (2020). Integration of Industry 4.0 Related Technologies in Construction Industry: A Framework of Cyber-Physical System. *IEEE Access*, *8*, 122908–122922. https://doi.org/10.1109/ACCESS.2020.3007206

Qin, X., Shi, Y., Lyu, K., & Mo, Y. (2020). Using a Tam-Toe Model To Explore Factors of Building Information Modelling (Bim) Adoption in the Construction Industry. *Journal of Civil Engineering and Management*, *26*(3), 259–277. https://doi.org/10.3846/jcem.2020.12176

Hossain, M. A., & Nadeem, A. (2019). Towards digitizing the construction industry: State of the art of construction 4.0. *ISEC 2019 - 10th International Structural Engineering and Construction Conference*, *July*, 0–6. https://doi.org/10.14455/isec.res.2019.184

Ibrahim, F. S. B., Esa, M. B., & Kamal, E. B. M. (2019). Towards construction 4.0: Empowering bim skilled talents in malaysia. *International Journal of Scientific and Technology Research*, *8*(10), 1694–1700.

Craveiro, F., Duarte, J. P., Bartolo, H., & Bartolo, P. J. (2019). Additive manufacturing as an enabling technology for digital construction: A perspective on Construction 4.0. *Automation in Construction*, *103*(October 2018), 251–267. https://doi.org/10.1016/j.autcon.2019.03.011

Oztemel, E., & Gursev, S. (2020). Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*, *31*(1), 127–182. https://doi.org/10.1007/s10845-018-1433-8

Turk, Ž. (2019). *Construction 4.0 – Digital Transformation of One of the Oldest Industries*. *21*(3). https://doi.org/10.15458/ebr.92

Gayatri Patil (2019): "Applications of Artificial Intelligence in Construction Management", Volume 9, Special Issue, March 2019, 6th National Conference On Technology & Innovation: Disrupting Businesses, Transforming Market, Jalgaon, India.

Wadlow, T., (2018) Feature: How Artificial Intelligence Supports the Construction Industry. https://www.constructionglobal.com/equipment-and-it/feature-how-artificial-intelligence-supports-construction-industry

Md Ben Daya, Elkafi Hassini, Zied Bahroun (2017):"Internet of things and supply chain management: a literature review", International Journal of Production Research, pp. 4719-4742.

Yi Liu, He Wang, JunyuWang, Kan Qian, Ning Kong, Kaijiang Wang, Lirong Zheng, Yiwei Shi, and DanielW. Engels (2015): "Enterprise-Oriented IoT Name Service for Agricultural Product Supply Chain Management", International Journal of Distributed Sensor Networks, Volume 2015, pp.1-12.

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences*, *39*(2), 273–315. https://doi.org/10.1111/j.1540-5915.2008.00192.x

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly: Management Information Systems*, *27*(3), 425–478. https://doi.org/10.2307/30036540

Venkatesh, V., & Davis, F. D. (2000). Theoretical extension of the Technology Acceptance Model: Four longitudinal field studies. *Management Science*, *46*(2), 186–204. https://doi.org/10.1287/mnsc.46.2.186.11926

Tomasz A & Mumtaz U (1993): "Application of Machine Learning to Construction Safety", Conference proceeding on Management of Information Technology for Construction, Singapore 1993.

A Critical Review on BIM for Construction Safety Management

Shalaka HIRE[1] Kirti RUIKAR[2] Sayali SANDBHOR[3] Amarnath CB[4]
Civil Engineering Department, Symbiosis Institute of Technology (SIT), Symbiosis International (Deemed University)(SIU), Lavale, Pune, Maharashtra, India; shalaka.hire@sitpune.edu.in[1]
School of Architecture, Building and Civil Engineering, Loughborough University, UK; K.D.Ruikar@lboro.ac.uk[2]
Civil Engineering Department, Symbiosis Institute of Technology (SIT), Symbiosis International (Deemed University)(SIU), Lavale, Pune, Maharashtra, India; sayali.sandbhor@sitpune.edu.in[3]
President, India BIM Association, L and T, India; amarnathcb@lntecc.com[4]

ABSTRACT

The earlier so-called "brick and mortar" industry is entering the digital era. Digitization in the construction industry gives efficient and effective ways to manage several construction aspects such as scheduling, cost, quality, information, and documentation leading to improved productivity. Along with these aspects, safety management also needs special attention in terms of digitalization, for a safer, more efficient, and productive work environment on construction sites. The Indian construction industry is known as labour intensive industry, which employs approximately 32 million of labour. The cost spent on the labour is 30% to 50% of the total project cost. Still, the labours are given the least attention in the construction sector. The bar of onsite construction accidents in India is rising at a rapid pace and it shows that current safety practices are insufficient. To manage the smooth and safer working of labour force and to reduce on-site accidents, conventional safety practices need to be replaced with advanced and digitalized safety practices. Building Information Modeling (BIM) is believed as the most prominent process that is supported by various tools, technologies for digital representations of physical and functional characteristics of a construction project. This study explores the comprehensive review of existing literature in the line of work of utilization of BIM for site safety. For the selection of literature, a well-defined methodology is adopted. It includes scientometric analysis followed by screening of the obtained results to review the most relevant literature in BIM for safety. Outcome of undertaking an extensive review would help to understand potentials of BIM for safety management, prerequisites needed to implement BIM for safety, its adoption process and also identify areas where additional research will benefit the future integration of BIM and site safety

KEYWRODS:

BIM, Construction, Safety, Hazards, and Accidents

INTRODUCTION

Construction safety is one of the most critical parameters which affect the overall construction productivity. Despite being an important parameter, it is still one of the highly ignored areas in construction project management. Nowadays, automation has been observed in several construction aspects such as for effective cost management, time management, quality management; but automation for safety management is the least priority by many construction firms. Construction accidents are the most widespread issue faced by construction industries of both developing and developed countries. However, developed countries are adopting advanced technologies for reducing the rate of construction accidents. Considering developing countries like India, the rate of construction accidents is rapid. OSHA estimated that every year one in ten construction site employees get injured. The OSHA also says falling hazards are the leading cause of injury at building sites. According to the Bureau of Labor Statistics, around 150,000 injuries from construction sites occur every year. These statistics are increasing and witness insufficient traditional safety practices.

Nowadays, BIM has been considered as the most flourishing technology in the construction sector. BIM, according to the worldwide authority (http://buildingsmart.org/) stands for "A digital representation of a facility's physical and functional features (Joblot et al. 2017) Different construction phases can be procured with the utilization of BIM, such as stages of programming, design, preconstruction, development, and post-construction (Azhar, Khalfan, and Maqsood 2012).

The wide applications of BIM with dimensions ranging from 3D to nD include visual representation, clash detection, scheduling, cost management, energy consumption, collaboration and communication, facility management, safety management and to name a few (Bongiorno et al. 2019). Most of the surveys conducted for BIM awareness and adoption reported that Indian construction firms have not fully explored the potential benefits of BIM (Ahuja et al. 2020). It is also reported that the adoption of BIM in India is limited to design purposes only (CB 2020). Hence for the understanding of how BIM can be utilized for safety management, an extensive literature review is carried out. This review examines worldwide studies in the area of BIM adoption for safety management, its statistics such as leading countries, leading authors, and also summarizes with a critical review of these publications.

To recognize the functions and novelties of BIM for construction safety management, this study aims to examine recent research on the exploitation of BIM to enhance the safety of construction. The outcome of undertaking an extensive review help to understand the potentials of BIM for safety management, prerequisites needed to implement BIM for safety, integration of other technologies with BIM for safety, and its adoption process. This research also discusses areas where the potential integration of BIM and site safety will benefit from additional research.

METHODOLOGY

A significant body of literature on the subject of the application of BIM for construction safety has been reviewed. Various online platforms are used for the collection of the most relevant papers in the selected domain. Along with this, the Scopus database has been used to keep the search precise and limiting only to safety and BIM. For this search, four different keywords namely "BIM" OR "BIM" AND "Construction" AND "Safety" were used and results are refined to get the most relevant papers in the field [Figure 1]. This study includes the most recent literature on the subject published in top-ranked construction management journals. To obtain the most recent research in the field, the review time frame was limited to five years (2015 to 2021) of publication.

SCIENTOMETRIC ANALYSIS OF RESULTS

The search process resulted in the most relevant documents in the selected domain. This study not only reviews the literature based on BIM for safety but also studies the scientometric analysis for resulted literature. The scientometric analysis helps to understand leading countries, leading authors, top journals in the selected domain. It examines past areas covered in the selected field and also signifies the need and scope for research in the selected domain

Leading countries in BIM and safety-based publications: A total of 120 documents are observed in the area of BIM adoption for safety management. Leading countries in this domain are the United States, China followed by the United Kingdom [Figure 2]. On the other hand a developing country such as India is in 17th position with only 3 publications. It shows that Indian researchers have a huge scope for studying the research domain under consideration.

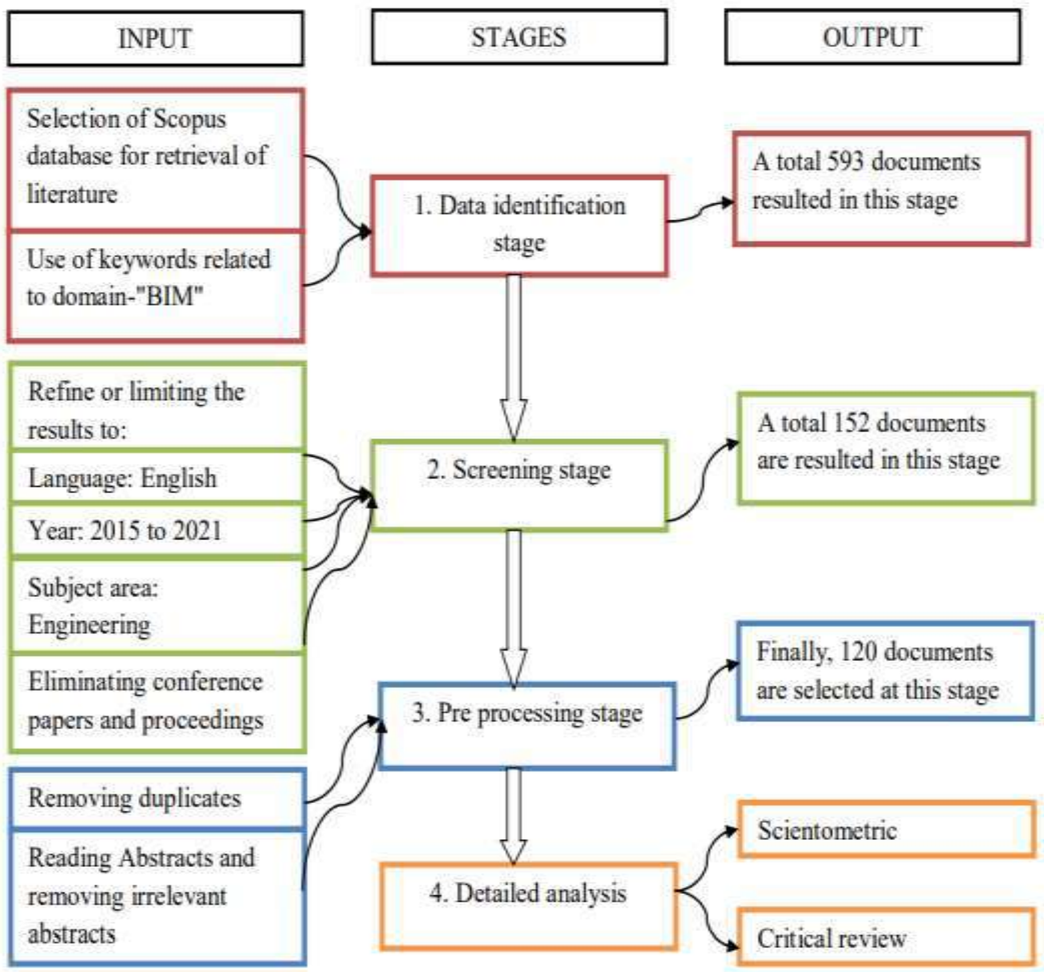


Figure 1: Methodology for selection of literature or research papers

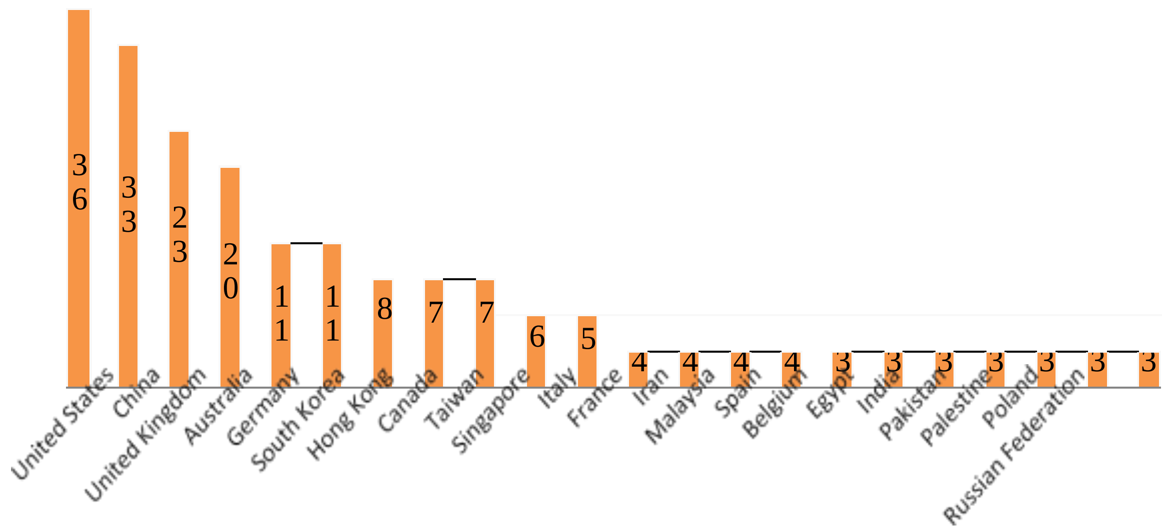


Figure 2: Country-wise publications in the BIM for safety domain (Information source: www.scopus.com)

Leading journals in BIM and Safety publications: Journals are the platforms for publishing research and are widely accessible over the internet. Papers published in peer- reviewed journals are likely to remain a very critical way of communicating research findings. This analysis also helps in identifying the productive journals that have published documents on construction safety. A network diagram is prepared for journals using tool VOSviewer [Figure 3]. Journals that appear with bigger font sizes are likely to have a maximum number of publications as compared with journals with lesser font sizes and the topmost journals can be quickly assessed by visual inspection of the changing font size. Figure 3 illustrates that 'Automation in Construction' has been observed as the topmost journal with the highest i.e. 38 number of publications. Further, the 'Safety Science' journal is in second-highest position followed by 'Engineering Construction and Architectural Management' with 13 and 08 publications. Citation wise 'Automation in Construction' journal remains on the first rank with 1135 citations followed by 'Engineering Construction and Architectural Management' and 'Safety Science' with 638 and 71 citations.

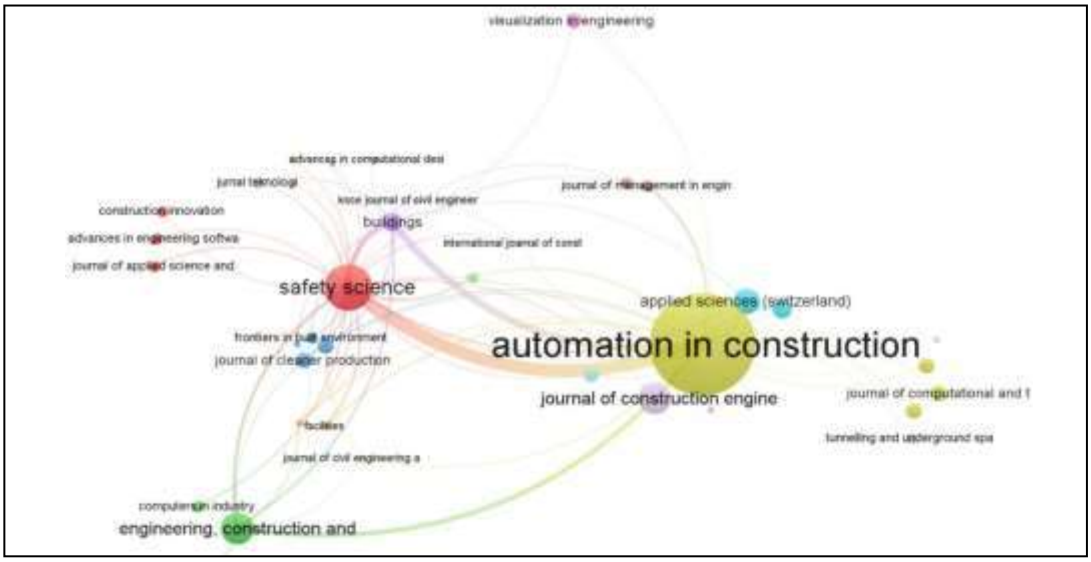


Figure 3: Network of journals that publish research on BIM for construction safety

Leading authors in BIM and safety-based publications: Researchers play an important role in leading research and some have more prominence in a subject area than others. Visualization of authors in the proposed domain is shown in Figure 4. Author names that appear with bigger font sizes are likely to have the maximum number of publications as compared with author names with lesser font sizes. Teizer has been observed as a leading author with 08 publications followed by Zhang & Kim with 06 and 05 publications. However, this list does not consider the co-authorship between these publications. Some of the documents may be co-authored by authors appearing in the same figure. In such cases, these common publications appear as individual documents for each author. For example, out of the 06 publications by Zhang and 03 publications by Eastman, 02 documents are common and jointly co-authored by Zhang and Eastman. Thus, two common publications appear in search results (by the number of documents) of Zhang as well as Eastman, as their publications. These authors have explored the adoption of BIM for safety (some with the co-authorship).

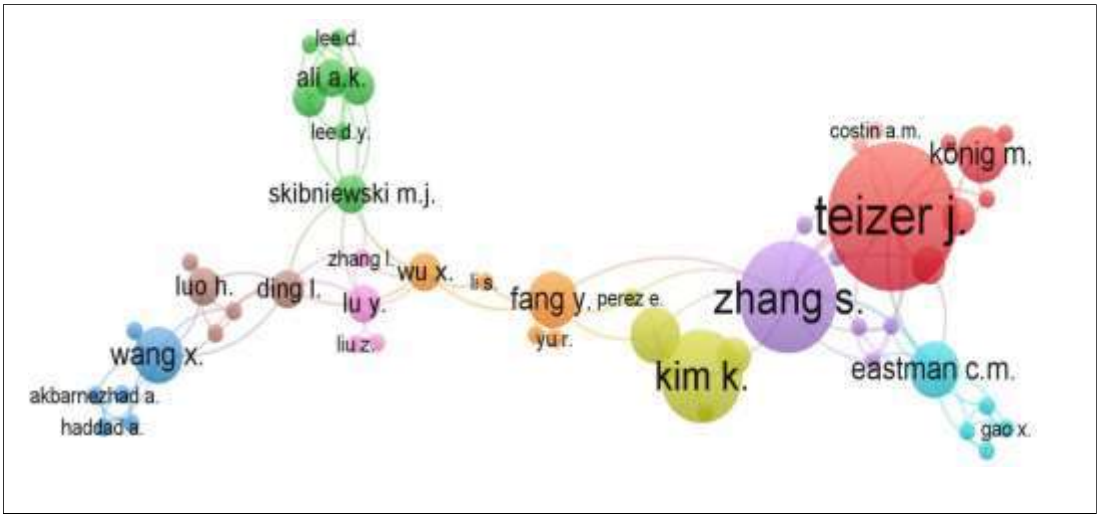


Figure 4: Network of authors name in the research of BIM for construction safety

CRITICAL REVIEW OF BIM AND SAFETY LITERATURE

BIM has been adopted widely around the globe for different construction activities. The very first publication of general adoption of BIM is observed in the year 2004 (www. scopus.com). Further, publication on the adoption of BIM for safety is firstly observed in the year 2007 (www. scopus.com). For this particular study, documents ranging from the year 2015 to date are considered. Literature retrieved from scopus database is examined and categorized according to its application. For instance, BIM for overall risk assessment, fire safety, fall safety, workspace planning, workers behavior & tracking, and also the review & survey studies. The studies show that all the categories are somehow interlinked with each other.

BIM for fall safety: Every year, as per OSHA, the largest number of deaths in the construction industry are consistently accounted for by falls. Falls also includes a variety of variables, including uneven working surfaces, misuse or inability to use fall safety systems and human error. The most frequent causes of falls from height are fallen from scaffolding (Smolarz 2019). Improper placement of scaffolding, incompetent supervisor, unsound, and insufficient scaffolds to carry their weight can lead to failure of scaffolds. With automated design, planning and drawing of scaffolding systems for building, BIM may solve these problems (Hara et al. 2019). The design method includes precise amounts of scaffold materials which helps to reduce the design effort and the cost estimating processes. Kim et al. 2018 establish a scaffolding decision-making process that produces stable scaffolding tactics with no unnecessary physical effort and compromises for other critical construction objectives, such as cost and time. This framework produces multiple scaffolding tactics automatically and assesses them in terms of protection, expense, and duration quantitatively. Kim et al. 2016 with the incorporation of job series and provisional structures into safety planning, created BIM-based automated scaffolding-related hazard detection and prevention. The algorithms were introduced as a plug-in and tested with a real-world construction project in a commercially available BIM app. Further, Zhang et al. 2015 suggested a BIM-based method of detection and avoidance of fall hazards for building safety planning. This study investigates latent fall risks that are naively introduced into the construction schedule can be recognized and prevented in the planning phase. Next, there is a discussion of a study of studies on building security and BIM. A system involving automated BIM security rule-checking algorithms were then developed. BIM-based construction safety management of buildings can analyze the problems that appeared in the management of progress early warning. Combine with the case study, the BIM constructs a visual safety management platform, 4D construction simulation, and collision detection technology. Dynamically rehearse construction progress and manage the hidden dangers such as falling and collision during actual construction progress (Xiong and Tang 2017). Excavations are also a major cause for falls on site. These falls happen due to a lack of safety warning signs around the trench or lack of barricades around the trench. To avoid these excavation hazards, Khan et al. 2019 developed a series of rules-based algorithms using a visual programming language (VPL) in commercially available software, this automatically creates geometric conditions in BIM and visualizes the construction, along with their take-off quantity and optimized positions of possible risks and security tools.

BIM for fire safety: Fires present an extreme threat to human safety, and over the past few years, several dramatic fires have been reported in under-built buildings. The majority of construction sites rely only on fire extinguishers, as there is no everlasting fire safety system in under-built buildings. A reasoned approach to preparing the installation of firefighting equipment on the construction site is missing in conventional safety planning. Fires can spread rapidly during construction. A BIM-based automated code-checking technique for fire protection in tall timber construction is developed and on the real project onset of fire regulations, it is validated (Kincelova et al. 2020). Shi et al. 2019 conducted a study on Industry Foundation Classes (IFC)-And Fire Dynamics Simulator (FDS)-based knowledge sharing for building fire safety. A quick and accurate approach to data distribution between BIM functions and broadly used fire simulation tool for fire safety research has been successfully implemented. A visual language solution implemented for the conversion of rules and a multi-agent simulation of fire safety preparation for construction. This technique has the potential to benefit designers through its simplicity and ease, although it may be beneficial for practical use in the field (Khan et al. 2020). Using a simulation of fire dynamics and agent-based modeling, Mirahadi, et al. 2019 developed an IFC-centric performance- based assessment of construction evacuations, which provides a more comprehensive measurement of safety success compared to the existing safety indices and measures of the industry.

BIM for struck by an object hazard: Around 25 percent of all fatal building workplace incidents in many developing countries contribute to the unnecessary proximity of pedestrian workers to construction machinery or hazardous materials. Golovina et al. 2019 developed advanced positioning technology that records trajectory data, while computational algorithms produce preceding inaccessible information automatically to near-miss events. The determined data is set in improved mathematical data models that can be recuperated, effectively deciphered, and adjusted by clients on a building site in current preventive risk recognizable proof and control measures.

BIM for seismic hazards: Ground damage risks from earthquakes pose a major risk to infrastructure, lifelines, and houses. To be able to reduce the risk of earthquakes, hazard detection, awareness, vulnerability, and risk assessment, mitigation and preparedness are critical. Vitiello et al. 2019 suggested a BIM-based approach to cost-optimizing existing structures with seismic retrofit strategies. A disentangled system based on a quasi-probabilistic methodology is modified in a BIM model to determine the monetary yield and financial misfortunes of a framework faced with seismic risk. BIM has likewise utilized seismic harm to building roofs and furniture for the virtual scene plan (Xu et al. 2019). First, for the consequent structural Time-History Analysis (THA) and scene building, a modeling system is developed based on BIM to construct compatible structural and scene models. The result of this study offers all-around established seismic harm scenes for indoor non-structural segments for virtual quake wellbeing drills to be led.

BIM for workers behavior-based hazards and tracking: Existing studies indicate that hazardous activities of worker movement are one of the key causes for fatalities in construction sites resulting in severe collisions with site objects and machinery (Arslan, Cruz, and Ginhac 2019). The need to enforce the construction protocol is becoming more important as construction worksites become larger and more complex. Getting a real-time monitoring system installed on a job site for materials, equipment and staff will help project managers improve safety, safety, quality control, worker logistics, and maintain a construction project's local regulations. A real-time tracking system is used to identify potentially dangerous areas by comparing workers' current paths to their optimal paths (Costin et al. 2015). Using a Real-Time Position Tracking System (RTLS) based on RFID, where RFID tags are placed on staff's hard hats, location tracking is performed (Asadzadeh et al. 2020). Lee et al., 2019 sets up a checklist for Behavior-based Safety (BBS) observation and tracks the unsafe conduct of employees. Similarly, Arslan, Cruz, and Ginhac 2019 researched BBS for worker protection by visualizing intrusions in complex building environments. The building locations where there have been intrusions using the BIM system are demonstrated. The developed framework provides a combination of systems from the data attainment stage to the simulation of hazardous job activities in the analysis of superior employee movements. Intrusion, which is unauthorized entry to unsafe areas on a building site, is one of the most significant rule-breaking practices (Shuang et al. 2019). This research examined how age and gender have an effect on different types of construction site intrusion behaviors. The study shows that male site workers were more resistant than females to intrusion. Middle-aged workers had substantially greater intrusion frequency for both genders than younger and older employees.

BIM for workspace planning: Due to congested site conditions, safety and productivity performances are often low. Parn et al. 2019 researched the digitization of work safety management in enclosed spaces. The goal of this paper is to report on the further creation of a BIM-entitled confined space security monitoring framework plug-in for a hybrid Application Programming Interface (API). Further, Zhang, et al. 2015 presented a model with workplace position monitoring to visualize and evaluate workplace specifications in BIM. This approach uses remote sensing and workspace modeling technologies to create automated workspace visualization in BIM and is an important component of building safety planning. The hard hats of a work crew building cast-in-place concrete columns were connected to the Global Positioning System (GPS) data loggers. By simulating a building process using both interactive virtual reality and BIM technologies, BIM has also been adopted for building workspace planning (Getuli et al. 2020).

BIM for safety risk management: Risk management is the recognition, measurement and choice for risk reduction (Reddy 2015). Considering safety, the earliest detection of hazards will minimize loss of life, property, and save time and expense as well. Before commencement of construction, risks can be recognized, primarily through the planning and design phase (Li, Yu, and Liu 2018). Kim, et al. 2020 for automating construction site risk assessment, developed a methodology for BIM-based hazard identification and evaluation. This research analyses the stage-wise tasks needed for more automated BIM-based construction safety planning. Many of the associated hazards are identified in the risk analysis stage and the associated risks are analyzed and quantified. The identification of risk can be through the design as well (Yuan et al. 2019). The concept of Prevention through Design (PtD) helps to focus onthe safety of the workers in the life cycle during the project's design phase. Documentation, construction unsafe conditions and their pre-control steps were identified and gathered in a PtD knowledge base about current safety laws. Similarly, during the design process, Jin et al. 2019 , built a system for evaluating construction risks using 4D BIM. This approach has the potential to determine the safety risk and forecasts the safety risk in a particular period, workspace, and mission before construction for an entire high rise project. It allows designers to conduct risk assessments and select alternatives for safety-related architecture. Cortés-Pérez, et al. 2020 developed the methodology for integration in the design process in compliance with the criteria stipulated by the Spanish health and safety regulations.

BIM for safety training, inspection and monitoring: Safety education and training are vital tools for training individuals and managers about workplace risks and controls so that they can function more quickly and more effectively. However, another role for education and training is to give employees a better understanding of the safety and health program itself, so that they can contribute to its growth and implementation. Training with advanced teaching methods such as visualization and simulation will allow employees to better understand danger conditions than conventional teaching methods (Clevenger, et al. 2015). Ahn et al. 2020 examined two unlike types of safety training methods, representing the actual site's hazard status. It was stated that employees trained through BIM simulation showed a greater degree of understanding than the group of employees who were conventionally trained. To recognize hazardous conditions and protect workers from possible injuries and catastrophic events, sites need to be constantly monitored in light of safety inspection and surveillance. BIM can regulate the safety of construction sites (Wu, Lu, and Hsiung 2015). In the construction site performance evaluation, integrated systems with Bluetooth Low-Energy (BLE)-based position tracking technology, BIM-based hazard identification and a cloud-based communication network will assist and potentially improve site safety (Park, Kim, and Cho 2017). Similarly, the Wireless Sensor Network (WSN) and BIM have been implemented as a ground breaking feature that enables the construction site to visually control the safety status via a visual, coloured interface and remove any dangerous gas automatically (Cheung et al., 2018). Along with this, Unmanned Arial Vehicles (UAV) and BIM can also used for safety monitoring on different construction projects (Alizadehsalehi et al. 2018)

Review and survey based studies on BIM adoption for safety: This category describes the review studies and surveys held in the domain of BIM for safety. Review papers are very significant in terms of research as it helps to understand past studies available, different methodologies and approaches adopted by various authors, need and scope for the study in the domain in single research paper. In this context. Fargnoli et al., 2020 reviewed different literature available in the proposed domain and categorized it into knowledge-based systems, automated safety regulation, safety design, information scheduling, resolution of overlaps and disputes, safety preparation, as well as expectations of stakeholders.Similarly, a science mapping approach (R. Jin et al. 2019; Akram et al. 2019; Sadeghi et al. 2016) was adopted for exploring the review of BIM for construction safety. To gain a deeper understanding of research advances in safety initiatives. Martínez et al., 2018 studied a systematic review in the proposed domain. It has also conducted a scientometric analysis followed by review of available studies. Available studies were categorized according to their utilization in different construction phases [Figure 5]. Maximum study, mainly in the construction process, was documented to concentrate on the adoption of BIM for protection. The key results suggest that the rising introduction of BIM in the AEC sector is changing the approach to defense. It is possible to automatically classify potential safety hazards and use an automated approach to implement appropriate preventive methods.

As explained in the section of BIM for risk management, risk can be identified through design. In this context, Hossain et al. 2018 conducted a systematic review of studies on design-for-Safety knowledge library for BIM-integrated safety. Similarly, on BIM and BIM-related technologies for risk management, Zou, et al., 2017 conducted a systematic review. It offers an overview of traditional risk management and a detailed and systematic review of published literature on existing risk management strategies using technologies such as BIM, automated control of regulations, knowledge-based systems, information technology-based reactive and proactive security systems. The search tool used for this research indicates that a large number of studies are based on the survey questionnaire. These studies collect perceptions of stakeholders, employees(Han et al. 2019), students (Swallow and Zulu 2019b) and various construction professionals on applications, barriers, benefits and awareness of BIM for safety in different countries (Marefat, Toosi, and Mahmoudi Hasankhanlo 2019; Swallow and Zulu 2019 . Enshassi, et al., 2016 , conducted a survey in the Gaza strip on the adoption of BIM for the improvement of construction security, including its visibility, applications and barriers. In order to improve safety, the scarcity of widespread use in the construction industry and the insufficient availability of training are the main obstacles to the implementation of BIM in construction.

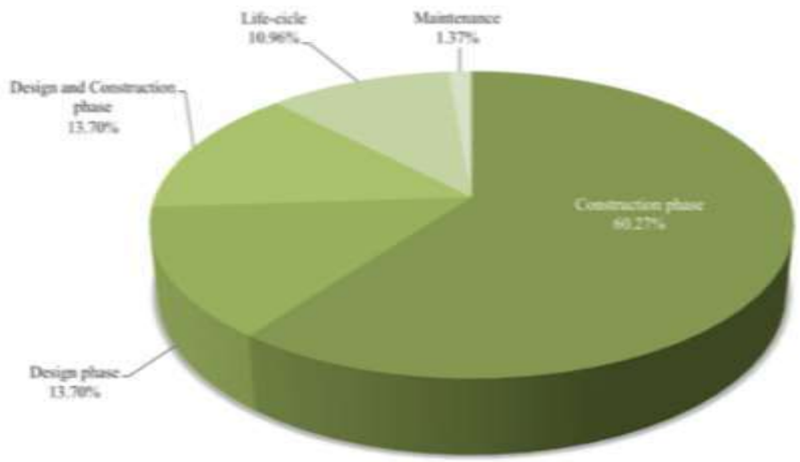


Figure 5: Percentage of publications of adoption of BIM for safety as per project phases

CONCLUSION AND FUTURE SCOPE:

This review study adopted a scientometric approach to identify the most relevant researches in the field of utilization of BIM for safety. According to the review of literature, it can be stated that BIM can be used for construction safety management with a variety of applications in different kind of hazards such as for fall safety, fire safety, struck by an object hazard, seismic hazards, workers behavior-based hazards and tracking, workspace planning, overall safety risk management including identification of risk at the design stage, safety training, inspection, and monitoring. This study also examined past reviews and survey-based studies on BIM adoption for safety. It can be stated that BIM has the capability for identification of hazards, automatic safety checking, simulation, and information management, and to name a few. One of the major advantages of BIM for safety is that it can identify the hazards at the design stage, i.e. before construction. It saves time and cost also reduces rework. It has all the capabilities that cover the insufficiencies of traditional practices. It is a single platform for information management which is most critical for sharing the risk information to different people involved in the process. With its collaboration and communication applicability, it helps for better decision making. It is also observed that various technologies such as GPS, GIS, sensor-based technologies, safety rules have been integrated with BIM for construction safety management. One of the benefits of these integrations is that with a combination of two or more different technologies, a single system can be formed that can provide better safety solutions on a common platform.

Looking at the scientometric data from Scopus, it is observed that very negligible studies are available in India for the utilization of BIM for safety. Despite having major applications for safety, it's not fully explored in India. Indian construction firms have adopted BIM majorly for design and drawing purposes only, and need to take a step forward in implementing BIM for safety as well. It can be reported that there are a need and scope for Indian authors to research in the domain. This need is not only limited to conducting research but also implementing it practically to the sites to reduce the number of construction accidents.

Falls being the major cause of accidents on construction site, majority of the studies on BIM-based safety planning are focused on fall safety management. It is necessary to utilize BIM benefits for other types of accidents occurring on a typical construction site. For effective life cycle management, application of BIM-based safety planning should not be limited to the pre-construction phase only. It should be adopted for construction as well as post-construction phase. For future work, designing BIM-based safety solutions for real-time accidents can be considered.

Most of the review studies also show that lack of awareness of BIM benefits along with return on investments, lack of expertise, lack of training, and lack of BIM standards are the barriers in BIM adoption as well as practicing safety using BIM applications. Indian firms require standard guidelines and mandates by the government that can majorly contribute to successful BIM adoption. The study also revealed that more realistic BIM implementations are required, with a focus on safety training and education in particular. It should be noted that the current review is constrained to selected literature published in the Scopus database and that only

English journal papers in the final publication phase were included. Any recent research conducted in other languages or other forms of papers, such as conference proceedings may theoretically be removed.

REFERENCES

Ahn, Sungjin, Taehui Kim, Young Jun Park, and Ji Myong Kim. 2020. "Improving Effectiveness of Safety Training at Construction Worksite Using 3D BIM Simulation." Advances in Civil Engineering 2020. https://doi.org/10.1155/2020/2473138.

Ahuja, Ritu, Anil Sawhney, Megha Jain, Mohammed Arif, and Samya Rakshit. 2020. "Factors Influencing BIM Adoption in Emerging Markets – the Case of India." International Journal of Construction Management 20 (1): 65–76. https://doi.org/10.1080/15623599.2018.1462445.

Akram, Ramsha, Muhammad Jamaluddin Thaheem, Abdur Rehman Nasir, Tauha Hussain Ali, and Shamraiza Khan. 2019. "Exploring the Role of Building Information Modeling in Construction Safety through Science Mapping." Safety Science 120 (August): 456–70. https://doi.org/10.1016/j.ssci.2019.07.036.

Alizadehsalehi, Sepehr, Ibrahim Yitmen, Tolga Celik, and David Arditi. 2018. "The Effectiveness of an Integrated BIM/UAV Model in Managing Safety on Construction Sites." International Journal of Occupational Safety and Ergonomics 0 (0): 1–16. https://doi.org/10.1080/10803548.2018.1504487.

Arslan, Muhammad, Christophe Cruz, and Dominique Ginhac. 2019a. "Semantic Trajectory Insights for Worker Safety in Dynamic Environments." Automation in Construction 106 (March): 102854. https://doi.org/10.1016/j.autcon.2019.102854.

———. 2019b. "Visualizing Intrusions in Dynamic Building Environments for Worker Safety." Safety Science 120 (July): 428–46. https://doi.org/10.1016/j.ssci.2019.07.020.

Asadzadeh, Amin, Mehrdad Arashpour, Heng Li, Tuan Ngo, Alireza Bab-Hadiashar, and Ali Rashidi. 2020. "Sensor-Based Safety Management." Automation in Construction 113 (February). https://doi.org/10.1016/j.autcon.2020.103128.

Azhar, Salman, Malik Khalfan, and Tayyab Maqsood. 2012. "Building Information Modeling (BIM): Now and Beyond." Australasian Journal of Construction Economics and Building 12 (4): 15–28. https://doi.org/10.5130/ajceb.v12i4.3032.

Bongiorno, Nicola, Gaetano Bosurgi, Federico Carbone, Orazio Pellegrino, and Giuseppe Sollazzo. 2019. "Potentialities of a Highway Alignment Optimization Method in an I-Bim Environment." Periodica Polytechnica Civil Engineering 63 (2): 352–61. https://doi.org/10.3311/PPci.12220.

CB, Amarnath. 2020. "India Building Information Modelling Association (R .) BIM Implementation in India India Building Information Modelling Association (R .)," 1–10.

Clevenger, Caroline, Carla López del Puerto, and Scott Glick. 2015. "Advances in Engineering Education Interactive BIM-Enabled Safety Training Piloted Construction Education AND." Advances in Engineering Education, 1–14.

Cortés-Pérez, Juan Pedro, Alfonso Cortés-Pérez, and Paloma Prieto-Muriel. 2020. "BIM-Integrated Management of Occupational Hazards in Building Construction and Maintenance." Automation in Construction 113 (May). https://doi.org/10.1016/j.autcon.2020.103115.

Costin, Aaron M, Jochen Teizer, Bernd Schoner, and Trimble Thingmagic. 2015. "RFID AND BIM-ENABLED WORKER LOCATION TRACKING TO SUPPORT REAL-TIME BUILDING PROTOCOL CONTROL AND DATA VISUALIZATION" 20 (January): 495–517.

Enshassi, Adnan, Abed Ayyash, and Rafiq M. Choudhry. 2016. "BIM for Construction Safety Improvement in Gaza Strip: Awareness, Applications and Barriers." International Journal of Construction Management 16 (3): 249–65. https://doi.org/10.1080/15623599.2016.1167367.

Fargnoli, Mario, and Mara Lombardi. 2020. "Building Information Modelling (BIM) to Enhance Occupational Safety in Construction Activities: Research Trends Emerging from One Decade of Studies." Buildings 10 (6). https://doi.org/10.3390/BUILDINGS10060098.

Getuli, Vito, Pietro Capone, Alessandro Bruttini, and Shabtai Isaac. 2020. "BIM-Based Immersive Virtual Reality for Construction Workspace Planning: A Safety-Oriented Approach." Automation in Construction 114 (November 2019): 103160. https://doi.org/10.1016/j.autcon.2020.103160.

Golovina, Olga, Manuel Perschewski, Jochen Teizer, and Markus König. 2019. "Automation in Construction Algorithm for Quantitative Analysis of Close Call Events and Personalized Feedback in Construction Safety." Automation in Construction 99 (October 2018): 206–22. https://doi.org/10.1016/j.autcon.2018.11.014.

Han, Yu, Zhida Feng, Jingjie Zhang, Ruoyu Jin, and Emmanuel Aboagye-Nimo. 2019. "Employees' Safety Perceptions of Site Hazard and Accident Scenes." Journal of Construction Engineering and Management 145 (1). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001590.

Hara, Takashi, Katsukiyo Shimomura, Keita Hamano, and Shoko Miyake. 2019. "Automatic Design, Planning and Drawing of Scaffolding System for Constructions." Advances in Computational Design 4 (2): 179–96. https://doi.org/10.12989/acd.2019.4.2.179.

Hossain, Md Aslam, Ernest L.S. Abbott, David K.H. Chua, Thi Qui Nguyen, and Yang Miang Goh. 2018. "Design-for-Safety Knowledge Library for BIM-Integrated Safety Risk Reviews." Automation in Construction 94 (June): 290–302. https://doi.org/10.1016/j.autcon.2018.07.010.

Jin, Ruoyu, Patrick X.W. Zou, Poorang Piroozfar, Hannah Wood, Yang Yang, Libo Yan, and Yu Han. 2019. "A Science Mapping Approach Based Review of Construction Safety Research." Safety Science 113 (December 2018): 285–97. https://doi.org/10.1016/j.ssci.2018.12.006.

Jin, Ziyu, John Gambatese, Ding Liu, and Vineeth Dharmapalan. 2019. "Using 4D BIM to Assess Construction Risks during the Design Phase." Engineering, Construction and Architectural Management 26 (11): 2637–54. https://doi.org/10.1108/ECAM-09-2018-0379.

Joblot, L., T. Paviot, D. Deneux, and S. Lamouri. 2017. "Literature Review of Building Information Modeling (BIM) Intended for the Purpose of Renovation Projects." IFAC-PapersOnLine 50 (1): 10518–25. https://doi.org/10.1016/j.ifacol.2017.08.1298.

Khan, Numan, Ahmad K. Ali, Miroslaw J. Skibniewski, Do Yeop Lee, and Chansik Park. 2019. "Excavation Safety Modeling Approach Using BIM and VPL." Advances in Civil Engineering 2019. https://doi.org/10.1155/2019/1515808.

Khan, Numan, Ahmed Khairadeen Ali, Si Van Tien Tran, Doyeop Lee, and Chansik Park. 2020. "Visual Language-Aided Construction Fire Safety Planning Approach in Building Information Modeling." Applied Sciences (Switzerland) 10 (5). https://doi.org/10.3390/app10051704.

Kim, Inhan, Yongha Lee, and Jungsik Choi. 2020. "BIM-Based Hazard Recognition and Evaluation Methodology for Automating Construction Site Risk Assessment." Applied Sciences (Switzerland) 10 (7). https://doi.org/10.3390/app10072335.

Kim, Kyungki, Yong Cho, and Kinam Kim. 2018. "BIM-Driven Automated Decision Support System for Safety Planning of Temporary Structures." Journal of Construction Engineering and Management 144 (8): 1–11. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001519.

Kim, Kyungki, Yong Cho, and Sijie Zhang. 2016. "Integrating Work Sequences and Temporary Structures into Safety Planning: Automated Scaffolding-Related Safety Hazard Identification and Prevention in BIM." Automation in Construction 70: 128–42. https://doi.org/10.1016/j.autcon.2016.06.012.

Kincelova, Kristina, Conrad Boton, Pierre Blanchet, and Christian Dagenais. 2020. "Fire Safety in Tall Timber Building: A BIM-Based Automated Code-Checking Approach." Buildings 10 (10): 1–24. https://doi.org/10.3390/BUILDINGS10070121.

Lee, Pin-chan, Junhao Wei, Hsin-i Ting, Tzu-ping Lo, Danbing Long, and Lun-maan Chang. 2019. "Dynamic Analysis of Construction Safety Risk and Visual Tracking of Key Factors Based on Behavior-Based Safety and Building Information Modeling." https://doi.org/10.1007/s12205-019-0283-z.

Li, Meng, Hongliang Yu, and Ping Liu. 2018. "An Automated Safety Risk Recognition Mechanism for Underground Construction at the Pre-Construction Stage Based on BIM." Automation in Construction 91 (February): 284–92. https://doi.org/10.1016/j.autcon.2018.03.013.

Marefat, Akbar, Hossein Toosi, and Reza Mahmoudi Hasankhanlo. 2019. "A BIM Approach for Construction Safety: Applications, Barriers and Solutions." Engineering, Construction and Architectural Management 26 (9): 1855–77. https://doi.org/10.1108/ECAM-01-2017-0011.

Martínez-Aires, María D., Mónica López-Alonso, and María Martínez-Rojas. 2018. "Building Information Modeling and Safety Management: A Systematic Review." Safety Science 101 (January): 11–18. https://doi.org/10.1016/j.ssci.2017.08.015.

Mirahadi, Farid, Brenda McCabe, and Arash Shahi. 2019. "IFC-Centric Performance-Based Evaluation of Building Evacuations Using Fire Dynamics Simulation and Agent-Based Modeling." Automation in Construction 101 (March 2018): 1–16. https://doi.org/10.1016/j.autcon.2019.01.007.

Park, Jeewoong, Kyungki Kim, and Yong K. Cho. 2017. "Framework of Automated Construction-Safety Monitoring Using Cloud-Enabled BIM and BLE Mobile Tracking Sensors." Journal of Construction Engineering and Management 143 (2). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001223.

Parn, Erika A., David Edwards, Zainab Riaz, Fahad Mehmood, and Joseph Lai. 2019. "Engineering-out Hazards: Digitising the Management Working Safety in Confined Spaces." Facilities 37 (3–4): 196–215. https://doi.org/10.1108/F-03-2018-0039.

Reddy, A Suchith. 2015. "Risk Management in Construction Industry-A Case Study." International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297 (February). https://doi.org/10.15680/IJIRSET.2015.0410052.

Sadeghi, Haleh, Saeed Reza Mohandes, Abdul Rahim Abdul Hamid, Christopher Preece, Ali Hedayati, and Bachan Singh. 2016. "Reviewing the Usefulness of BIM Adoption in Improving Safety Environment of Construction Projects." Jurnal Teknologi 78 (10): 175–86. https://doi.org/10.11113/jt.v78.5866.

Shi, Jianyong, Jicao Dao, Liu Jiang, and Zeyu Pan. 2019. "Research on IFC- And FDS-Based Information Sharing for Building Fire Safety Analysis." Advances in Civil Engineering 2019. https://doi.org/10.1155/2019/3604369.

Shuang, Dong, Li Heng, Martin Skitmore, and Yin Qin. 2019. "An Experimental Study of Intrusion Behaviors on Construction Sites: The Role of Age and Gender." Safety Science 115 (March): 425–34. https://doi.org/10.1016/j.ssci.2019.02.035.

Smolarz, Anna. 2019. "Analysis of Accidents in Construction in 2015-2017." Civil and Environmental Engineering Reports 29 (4): 149–56. https://doi.org/10.2478/ceer-2019-0051.

Swallow, Mark, and Sam Zulu. 2019a. "Benefits and Barriers to the Adoption of 4d Modeling for Site Health and Safety Management." Frontiers in Built Environment 4 (January). https://doi.org/10.3389/fbuil.2018.00086.

Swallow, Mark, and Sambo Zulu. 2019b. "Students' Awareness and Perception of the Value of BIM and 4D for Site Health and Safety Management." Journal of Engineering, Design and Technology 18 (2): 414–30. https://doi.org/10.1108/JEDT-07-2019-0174.

Vitiello, U., V. Ciotta, A. Salzano, D. Asprone, G. Manfredi, and E. Cosenza. 2019. "BIM-Based Approach for the Cost-Optimization of Seismic Retrofit Strategies on Existing Buildings." Automation in Construction 98 (November): 90–101. https://doi.org/10.1016/j.autcon.2018.10.023.

Wu, I. Chen, Siang Rou Lu, and Bin Chen Hsiung. 2015. "A BIM-Based Monitoring System for Urban Deep Excavation Projects." Visualization in Engineering 3 (1). https://doi.org/10.1186/s40327-014-0015-x.

Xiong, Na, and Jian Tang. 2017. "Research on Construction Safety Management Based on BIM -- Taking the Direction of Construction Engineering as an Example" 156 (Meici): 739–42. https://doi.org/10.2991/meici-17.2017.147.

Xu, Zhen, Huazhen Zhang, Wei Wei, and Zhebiao Yang. 2019. "Virtual Scene Construction for Seismic Damage of Building Ceilings and Furniture." Applied Sciences (Switzerland) 9 (17). https://doi.org/10.3390/app9173465.

Yuan, Jingfeng, Xuewei Li, Xiaer Xiahou, Nicholas Tymvios, Zhipeng Zhou, and Qiming Li. 2019. "Accident Prevention through Design (PtD): Integration of Building Information Modeling and PtD Knowledge Base." Automation in Construction 102 (February): 86–104. https://doi.org/10.1016/j.autcon.2019.02.015.

Zhang, Sijie, Kristiina Sulankivi, Markku Kiviniemi, Ilkka Romo, Charles M. Eastman, and Jochen Teizer. 2015. "BIM-Based Fall Hazard Identification and Prevention in Construction Safety Planning." Safety Science 72: 31–45. https://doi.org/10.1016/j.ssci.2014.08.001.

Zhang, Sijie, Jochen Teizer, Nipesh Pradhananga, and Charles M. Eastman. 2015. "Workforce Location Tracking to Model, Visualize and Analyze Workspace Requirements in Building Information Models for Construction Safety Planning." Automation in Construction 60: 74–86. https://doi.org/10.1016/j.autcon.2015.09.009.

Zou, Yang, Arto Kiviniemi, and Stephen W. Jones. 2017. "A Review of Risk Management through BIM and BIM-Related Technologies." Safety Science 97 (August): 88–98. https://doi.org/10.1016/j.ssci.2015.12.027.

An Experimental Study Integrating BIM And Green Building Concepts For A Residential Project

Ankita ANAND[1], Shobha RAMALINGAM[2], Dhiraj R.K SHARMA[3], Akshita PATEL[3], Mohit KUMAR[3], Vaibhav KUMAR[3]

Affiliation; email: ankita.anand0906@gmail.com 1
Affiliation; email: sramalingam@ms.nicmar.ac.in 2

ABSTRACT

BIM and Green Building concepts are taking stride in the AEC industry in order to deliver sustainable projects. A review reveals that different researchers have adopted different methods to integrate them and perceive its benefits or limitations. That apart, there are also limited studies within the country to explicate its application methodology. To this end, a hypothetical BIM 3D model using Autodesk Revit Architecture was built for a housing society consisting of 60 flats along with associated amenities. An energy analysis of the model was carried out by integrating with Autodesk Green Building Studio. The objective of the study was two-fold: foremost, to understand how BIM and energy modelling could be simulated early in design and second, to understand, how to optimize the design with respect to cost, safety and energy consumption in order to achieve an energy-efficient facility. The results demonstrate the ease of integration of BIM with green building concepts using the above said tools and the apparent benefits on the economics of the project that include energy cost savings, apart from application of green principles to the selection of materials. This study, though preliminary, is expected to lend a stepping stone for practitioners to simulate energy analysis using BIM early in design to deliver positive energy buildings.

KEYWORDS -

Building information modelling, Energy analysis, Green rating, Sustainable construction.

1. INTRODUCTION

Adoption of Building Information Modelling (BIM) has surged in the construction industry due to the several benefits that the platform offers for various stakeholders including visualization needs, ability to detect clashes prior to construction, simulated structural analysis and so on that in turn can minimize rework costs and enhance project performance. Several nations world- wide have therefore mandated the implementation of BIM in projects over the years including UK, Europe and the USA. India is still in its nascent stage of BIM adoption and has not mandated the process in contracts. Few stakeholders have taken the lead in implementing BIM in their projects due to the potential benefits perceived in other countries. Implementation of BIM in the project lifecycle starts with the production of an astute 3D model and empowers documentation, coordination, and simulation during the whole lifecycle of a project including planning, designing, building operations and maintenance (Rui, 2019). While BIM allows stakeholders to collaborate for various simulating needs in the design and execution phase of projects, developers and engineers are also demanding sustainable building solutions due to several climatic concern's world over. Researchers including Abdelalim and Aboelsoud (2019), highlight the demand for sustainable facilities that produce less impact on the environment and stress on the need to integrate sustainability checks in the BIM project delivery through simulations during the design phase of the projects. This triggers our interest to understand the use of collaborative tools to support sustainable construction.

A review of literature in this direction shows the interest in the Architecture, Engineering and Construction (AEC) industry to integrate the two diverse yet promising techniques: BIM and Green building concepts - for better project performance and long-term benefits in projects (Ahuja et al. 2017, Schlueter and Thesseling 2009). The parametric properties of BIM, allows rapid modification and alteration in the design and enhances sustainability. BIM has traversed along several dimensions. For instance, the 4th and 5th dimension of BIM helps to track the construction schedule and manage cost along the project life-cycle, more efficiently. However, going further beyond, there is ambiguity on what the 6th dimension connotes. While the National Building Specification (NBS) associates it with facility management, several authors have associated it differently in literature. For instance, it is allocated to safety (Zhou and Azar, 2019), health, safety and contract information (Ding et al., 2012; Park and Cai, 2017); facilities management (McPartland, 2017); sustainability and energy performance (Yung and Wang, 2014). Alternatively, authors have related facility management to 6D and sustainability to 7D (Harrison and Thurnell, 2015). Further, Montiel-Santiago et al. (2020) have correlated the 6th and 7th dimension to sustainability and facility management respectively. Thus, it is clear that there exists an ambiguity in what the dimensions connote and this lack of clarity from 6D and onwards has led to a lack of development of appropriate standards or its application through a consistent approach or methodology as also voiced by Montiel-Santiago et al. (2020).

Studies show that buildings are the prime energy consumers in modern cities as opposed to automobiles (as generally perceived) and account for 40% to 45% of energy consumption and the global building sector accounts for 33% of energy-related carbon-di-oxide emissions (Tathagat and Dod 2015). BIM as a collaborative tool allows simulating the energy analysis on the built form along with the material and its properties. With this energy model, the real behaviour of the building can be simulated, allowing to make optimal decisions on the design and the usage of resources to achieve a nearly Zero-Energy Building (ZEB) as set by the European Union (EU) Energy performance building directives, 2010 on energy efficient buildings (Li et al., 2013). This includes the Green building certification process; a focus on reducing carbon footprint, reduction of emissions and new standards for energy efficiency. The EU nation's energy targets for 2020 included a 20% reduction in energy consumption, 20% reduction in greenhouse gas emission and 20% increase in the use of renewable energy and for 2030 include achieving 27% in all these areas respectively. Buildings that produce more energy compared to its emission are today connoted as 'positive energy buildings' (Harputlugil, 2017; EU directive, 2012). All these have led to an urgency to address energy consumption and emissions from buildings (Scherer et al., 2016).

The question then arises, how BIM supports the implementation of the Green Building Certification processes (GBC's) such as the Leadership in Energy and Environmental Design (LEED) developed in the USA and Building Research Establishment Environmental Assessment Methodology (BREEAM) developed in the UK (Zane, 2009). In India, Green Rating Integrated Habitat Assessment, commonly known as GRIHA is formulated to take in account the regional climatic conditions of the country for all building types (MNRE, 2010). There are several certification levels and categories under each of these rating systems. For instance, 100 base points can be possibly achieved across six major categories in LEED v2009 that include: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality and innovation in design. Digital tools have further developed to enable the green rating system certification process and legislations have further supported it. For instance, Crawley et al. (2005)'s study compares around twenty major building energy simulation tools including: BLAST, ECOTECT, EnergyPlus, eQUEST, TRACE and TRNSYS, to name a few. All of these are independent analytical tools and do not corroborate with BIM. However, recently few researchers have discussed integrating the green rating system with BIM. For example, (Nguyen et al., 2016) stress the need to integrate and develop new parameters within BIM to assess LEED credits for optimizing material selection and documentation process. Incidentally, (Montiel-Santiago et al., 2020) demonstrates compliance to LEED credits through the usage of the REVIT INSIGHT tool in the BIM platform and (Stumpf et al., 2011) discuss the feasibility of the usage of Autodesk® Green Building Studio®, a cloud-based service using a DOE-2 simulation engine to support energy modeling early in design through gbXML (Green Building Extensible Markup Language) data exchange standards.

To this end, it is evident that BIM provides the possibility of generating various design alternatives for achieving energy efficient buildings. Despite its perceived benefits, there is lack of information to understand how the tool can be efficiently utilized for energy modelling and which platform allows for ease of integration. Motivated by these insights and testing through the design of a hypothetical residential project, this study explores to understand: "*How green building concepts can be integrated with BIM and how can the energy efficiency of the building be simulated early in design and optimized for sustainable project delivery?*

2. CASE SETTING AND EXPERIMENT METHODOLOGY

This study was carried out as an experimental hypothetical study. The proposed residential building was assumed to be situated in Pune city. The residential building comprises G+5 storeys with a total site area of 36.5 acres and associated amenities. It housed six wings and 3 bungalows with a swimming pool, clubhouse, and a garden with parking facilities. Based on the site location, the wind flow direction was determined as south-west. Each wing consisted of 10 flats with parking at the ground floor level. The carpet area of a singular bungalow was planned to be 176m^2 and of a 2BHK flat to be around 100m^2. Overall plot dimensions on the four sides were assumed to span: 135m*101m*136*120m. In this study, Autodesk® Revit software, v2020 was foremost used to build a 3-dimensional building model of the proposed project and then exported to Autodesk® Green Building Studio® (GBS) for an energy analysis. We chose to work with GBS as it is a powerful and accurate tool that enables architects and designers to optimize energy consumption and work toward carbon-neutrality. Further, we also wanted to investigate the feasibility of data exchange and transfer of information through the gbXML file format within Autodesk products. The goal was to assess the applicability of this integration early in design in order to identify energy saving measures in the project. The methodology included:

- Creating a 3D model using the Autodesk Revit software (v2020)
- Exporting it to the gbXML format for further analysis in GBS software.
- Estimating the energy efficiency of the building and generating various scenarios to understand the optimal solution.

3. RESULTS AND FINDINGS

This section is divided into three parts. 3.1 shows the output from the Revit model. 3.2 discuss simulated energy analysis. 3.3 compares the results with the green rating system.

3.1 Revit 3D model

Foremost, a 3D model was generated in Autodesk Revit software with 2-D floor plans created in AutoCAD. Figures 1 to 7 show the various features and aspects of the residential project generated in Revit energy analysis

Figure 1: Site Elevation

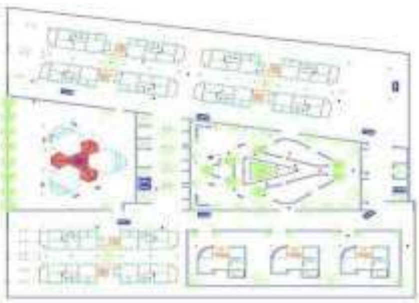


Figure 2: Site Plan

Figure 3: Landscape View

Figure 4: Aerial View

igure 5: Individual Villas

Figure 6: North- East View with Amenities

Figure 7: Club house

3.2 Energy analysis using Green Building Studio

The BIM 3D model was exported into GBS through the gbXML file format for an A project was created in the "My Project" segment, and the details regarding the project such as location (Pune, India), building type/usage (residential) and whether the project was for actual ongoing or purely for academic purpose were entered. The utility rates for electricity consumption were set as Rs.7/unit and for fuel consumption was set at Rs. 75/litre to carry out the base run. GBS uses default standards based on ASHRAE 90.1, 2007.

The uploaded gbXML file in the project then created the base run with the following results. The result showcased the consumption of electricity fuel and its cost. i.e 951,048 kWh, 4,688,227 MJ and Rs. 9989965. The Charts further display in detail the annual energy consumed, CO2 emission, lifecycle cost, etc. Alternative options could also be done for the analysis where the HVAC details, the roof construction details, the type of lighting used, walls glazing etc could be changed to produce nearly perfect energy-efficient building. We therefore explored some of the options in this study and explained the results below.

Figure 8 shows the results from the energy analysis. The table contains a base-run along with two alternative scenarios generated by varying specific parameters such as the material used and its cost. The results showed the CO_2 emission level and annual energy produced.

	BASE RUN	ALTERNATIVE RUN I	ALTERNATIVE RUN II
ENERGY, CARBON & COST SUMMARY	**Energy, Carbon and Cost Summary**	**Estimated Energy & Cost Summary**	**Estimated Energy & Cost Summary**
	Annual Energy Cost [illegible]	Annual Energy Cost [illegible]	Annual Energy Cost [illegible]
	Lifecycle Cost [illegible]	Lifecycle Cost [illegible]	Lifecycle Cost [illegible]
	Annual CO_2 Emissions	**Annual CO_2 Emissions**	**Annual CO_2 Emissions**
	Electric 0.0 Mg	Electric 0.0 Mg	Electric 0.0 Mg
	Onsite Fuel 330.8 Mg	Onsite Fuel 188.5 Mg	Onsite Fuel 183.0 Mg
	Large SUV Equivalent 23.4 SUVs / Year	Large SUV Equivalent 16.9 SUVs / Year	Large SUV Equivalent 18.4 SUVs / Year
	Annual Energy	**Annual Energy**	**Annual Energy**
	Energy Use Intensity (EUI) 1,388 MJ / m² / year	Energy Use Intensity (EUI) 1,089 MJ / m² / year	Energy Use Intensity (EUI) 1,189 MJ / m² / year
	Electric 951,048 kWh	Electric 709,237 kWh	Electric 865,405 kWh
	Fuel 4,608,227 MJ	Fuel 3,779,343 MJ	Fuel 3,885,947 MJ
	Annual Peak Demand 289.8 kW	Annual Peak Demand 307.2 kW	Annual Peak Demand 244.4 kW
	Lifecycle Energy	**Lifecycle Energy**	**Lifecycle Energy**
	Electric 28,531,452 kW	Electric 22,717,288 kW	Electric 26,562,273 kW
	Fuel 140,646,810 MJ	Fuel 113,380,298 MJ	Fuel 116,659,410 MJ

Figure 8: Results from the energy analysis

a) Cost summary

In the base run, the annual energy cost (both fuel and Lighting) for the building was Rs. 99,90,668. The lifecycle cost for both energy, fuel and Lighting was Rs.136,072,901. For alternative 1, the annual energy cost (both fuel and Lighting) for the building was Rs.8,001,769. The lifecycle cost for both energy, fuel and Lighting was Rs.108,984,095. For alternative 2, the annual energy cost (both fuel and Lighting) for the building was Rs.9,030,559. The lifecycle cost for both energy, fuel and Lighting are Rs.122,996,210 which is the cost for about 30 years.

b) Annual CO2 emission

Various aspects are responsible for CO2 emission from the electricity; it was about 0.0Mg. Due to onsite fuel, it showed as 233.8Mg for the base run, for alternative 1, it was about 0.0Mg, and due to onsite fuel, it was 188.5Mg, and for alternative 2, it was about 0.0Mg, and due to onsite fuel, it showed as 193.8 Mg.

c) Annual energy

For the proposed project, it consumes about 951,048kWh electricity annually, and the fuel consumed was approximately expected to be 4,688,227MJ annually. The energy use intensity was expected to be 1,356MJ/m2/year and also the peak demand estimated was about 259.8kW. For alternative 1,759,237kWh electricity annually, and the fuel consumed was approximately 3,779,343MJ annually and the energy use intensity was of 1,089MJ/m2/year and also the peak demand estimated was about 207.2kW. For alternative 2, 895,409kWh electricity annually, and the fuel consumed was approximately 3,885,647 MJ annually and the energy use intensity was 1,189 MJ/m2/year and also the peak demand estimated was about 244.4kW.

d) Life cycle energy

The amount of electric energy that was consumed for about 30 years was 28,531,452kW, and fuel was 140,646,810MJ for base run. For alternative 1 electric energy was 22,777,098kW and fuel showed as 113,380,290MJ. For alternative 2, electric energy was 26,862,273kW and the fuel showed as 116,569,410MJ.

Figure 9 shows the other results from the analysis for the base run and two alternatives that include cost and energy summary, energy usage intensity, natural ventilation potential, annual electric and fuel use.

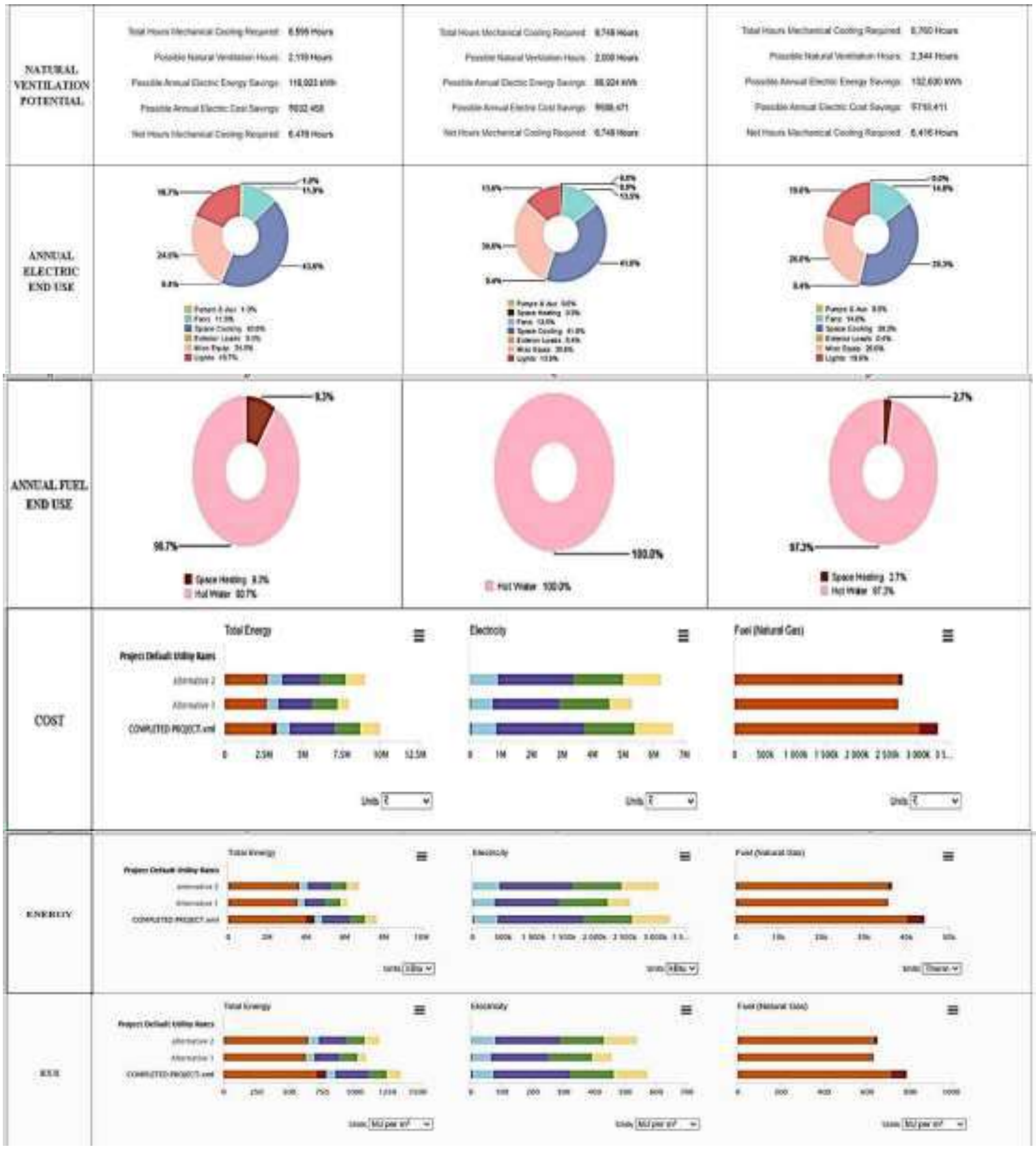


Figure 9: Results from the analysis

For the alternative run 1, i.e., we used Residential 17 SEER/9.6 HSPF Split HP <5.5 ton for HVAC, Insulated Blue Reflective Low-e for the walls and reduced LPD value by 30%. With this, we could obtain a 24.86% decrease in total annual cost, decrease in total annual energy consumption by 24.25%, decrease in energy use intensity by24.56% from base run and hence this design solution was preferable. In the alternative run 2, i.e., we used residential 17 SEER/0.85 AFUE Split/Pkgd <5.5 ton for HVAC, Insulated Blue Low-e for walls and by rotating the building by 180 degree and increasing LPD value by 30%, we could obtain 10.63% decrease in total annual cost, decrease in total annual energy consumption by 17.95%, decrease in energy use intensity by 14.10% from base run. Hence, this design solution was also preferable. However, a cross- comparison between alternative 1 and 2 shows that alternative 1 was more energy and cost efficient as alternative 1 consumed 5.34% less annual energy than alternative 2 and also the annual cost of alternative 1 was 13.004% less than alternative 2. Hence, we suggest alternative 1 for our model.

3.3 LEED credits in GBS

We opted for a LEED green rating system for the designed 3D BIM model. Thus, we further analysed the feasibility of GBS with LEED rating system. GBS evaluated and gave LEED points to the project with LEED daylight and water efficiency. Some of the results are explained below.

a) Water usage as per LEED assessment

As shown in Figure 10, the water usage per annum was 37,096,756 L and Rs.318,211 was the total cost per annum.

Total:	**37,096,756 L / yr**	**रु318,211 / yr**
Indoor:	36,268,647 L / yr	रु314,096 / yr
Outdoor:	828,109 L / yr	रु4,115 / yr
Net Utility:	**35,641,582 L / yr**	रु317,161 / yr

Figure 10: Water usage cost for the project

b) Water Efficiency

Based on the water usage, the total efficiency saving for indoor use was 9.1% and annual cost saving was Rs.32,390. Total net-zero savings showed as 1,881,967 L and Rs.15,344 per annum, as evident from Figures 11 and 12

	Total	Male	Female	Employee Only	Efficiency	Percent of Indoor Usage (%)	Gallons per Year	Annual Cost Savings (₹)
Toilets:	126	63	63	0	Standard	0	0	0
Urinals:	0	00		0	Standard	0	0	0
Sinks:	66	33	33	0	Hands-Free	1.9	773,586	6,900
Showers:	126	63	63		Low-Flow	7.2	2,857,576	25,490
Clothes Washers:	63				Standard	0	0	0
Dishwashers:	0				Standard	0	0	0
Cooling Towers:	0				Standard	0	0	0
Include cooling tower blowdown in sewer costs					Total Efficiency Savings:	9.1%	3,631,162	₹32,390

Figure 11: Building summary and efficiency savings for the project

		Annual Rainfall (mm)*	Catchment Area (m²)	Surface Type	Liters per Year	Annual Cost Savings (₹)
Rainwater Harvesting:	Yes	763	1870	Gravel/Tar	1,141,448	9,132
Native Vegetation Landscaping:	Yes				426,793	3,414
Greywater Reclamation:	Yes				313,726	2,798
Site Potable Water Sources:	No	Yield:	50	L / day	0	0
*Source: National Climatic Data Center #CLIM81				Total Net-Zero Savings:	1,881,967	₹15,344

Figure 12: Net-zero measures and savings for the project

c) Photovoltaic Potential

As shown in Figure 13, we used single-crystalline panels (13.8% efficient) in our building for an area of 1,893m^3. The total expenditure was Rs.2,091,528.59 and actual production was at 421,107kWh which helped us save Rs.2,947,746.56 annually. Wind energy helped us generate an annual electric generation of 1,048kWh. Possible annual electric energy savings due to natural ventilation was then 118,923kWh which led to annual electric cost Savings of Rs.832,458.

Photovoltaic Potential (more details)	
Annual Energy Savings:	421,107 kWh
Total Installed Panel Cost:	₹2,091,529
Nominal Rated Power:	261 kW
Total Panel Area:	1,893 m²
Maximum Payback Period:	1 years @ ₹7.00 / kWh

Wind Energy Potential	
Annual Electric Generation:	1,048 kWh

Figure 13: Photovoltaic potential and wind energy potential for the project

CONCLUSION

This study elucidates the importance of sustainable development in projects through the integration of BIM with green building concepts. The BIM-Energy analysis approach supports cost effective decision-making during construction and allows project teams to make energy conscious decisions early in design.

A hypothetical residential project was modelled using Autodesk Revit 2020. Foremost, the benefits of 3D models in BIM were perceived. BIM helped us visualize a building and all its components and systems. Modelling in Revit allowed us to see potential problem areas and fix them before the error was committed. This information allowed for better planning and design and lowered the need for expensive rework and revision. Second, this 3D model was integrated with Autodesk Green Building Studio for a simulated energy analysis. Here, we perceived the ease of integration of the BIM model with Autodesk Green Building Studio for a simulated energy analysis without recreating the building geometry, window placement, etc. for input into the energy analysis tool. It took less than a minute to export a gbXML file from a correctly built BIM model. In general, the main exterior walls, windows, roofs, floors and interior partitions separating the building's thermal zones are all that is needed in the BIM model for energy analysis.

Two scenarios with alternative materials were generated to compare with the base results for energy analysis. Alternative 2 was preferable with the materials selected and the orientation of the building along with the openings. The results could also be integrated with the LEED rating system in GBS. Thus, it is evident that Revit Architecture when linked with Green Building Studio provides more efficient results by giving quick feedback on green design alternatives and enables green rating certification process. The experimental study was made realistic by assuming real site data with inputs provided by project developers. The results were discussed with the developers and validated. However, the study has its limitations due to a single hypothetical case studied and with limited opportunity for endorsement. It is therefore recommended that future research could be carried out on a project site of this scale and results validated. Though the results are preliminary, we affirm that such studies would propel project managers to take informed decisions in project execution, observing that project performance predominantly is poor not only due to time and cost overrun but also due to poor decisions made on projects. This study has therefore shown the importance of collaborative tools like BIM in the design phase and the integration of the same for simulating energy analysis early in projects that provides project managers with a rationale for sound decision making.

REFERENCES

Abdelalim, A.M., Abo.elsoud, Y. (2019). "Integrating BIM-based simulation technique for sustainable building design." *In: Shehata M., Rodrigues F. (eds) Project Management and BIM for Sustainable Modern Cities, Sustainable Civil Infrastructures. Springer, Cham*.

Ahuja, Sawhney and Arif (2017). "Driving lean and green project outcomes using BIM: A qualitative comparative analysis." *International journal of sustainable built environment*, Vol. 6, 69–80.

Crawley, D. B., Hand, J. W., Kummert, M., and Griffith, B. T. (2005). “Contrasting the capabilities of building energy performance simulation programs.” *Building and environment,* 43(4), 661-673.

Ding, L. Y., Zhou, Y., Luo, H. B. and Wu, X. G. (2012). “Using nd technology to develop an integrated construction management system for city rail transit construction.” *Automation in Construction*, 21, 64–73.

EU Directive (2012). “European parliament and of the council of 25 October 2012 on energy efficiency.” *Amending directives 2009/125/EC and 2010/30/EU and repealing directives 2004/8/EC and 2006/32/E,* Chapter 12, 004, 202-257.

Harputlugil (2017). “Energy efficient building design development: A Retrospective approach.” *International Symposium on Energy Efficiency in Buildings, Ankara, Turkey*, 296-303.

Harrison and Thurnell (2015). “BIM implementation in a New Zealand consulting quantity surveying practice”. *International Journal of Construction Supply Chain Management,* 5(51), 1- 15.

Li, D.H.; Yang, L.; Lam, J.C. (2013). “Zero energy buildings and sustainable development implications.” *A review, Energy,* 54, 1–10.

McPartland (2017). BIM dimensions - 3D, 4D, 5D, 6D BIM explained, NBS, NSB. <https://www.thenbs.com/knowledge/bim-dimensions-3d-4d-5d-6d-bim-explained>.

Ministry of New and Renewable Energy, Government of India; the Energy and Resources Institute (2010). “Green Rating Integrated Habitat Assessment, GRIHA.” *published by Teri Press, New Delhi.*

Montiel-Santiago, F.J.; Hermoso-Orzáez, M.J.; Terrados-Cepeda, J.; (2020) “Sustainability and energy efficiency: BIM 6D.” *Study of BIM methodology applied to hospital buildings, value of interior lighting and daylight in energy simulation, Sustainability*, 12, 5731.

Nguyen, T.H., Toroghi, S.H. and Jacobs, F. (2016). “Automated green building rating system for building designs.” *ASCE journal of architecture engineering* 22(4), A4015001 1- 10.

Park J & Cai H (2017). “WBS-based dynamic multi-dimensional BIM database for total construction as-built documentation.” *Automation in Construction*, Vol. 77, 15-23.

Rui, (2019). “Review of building information modelling (BIM) - application in construction industry.” *IJITEE,* (6C2).

Scherer, R.J.; Katranuschkov, P.; Baumgartel, K. (2016). “Open e BIM platform for energy-efficient building design, in ework and ebusiness in architecture, engineering and construction.” *Proceedings of the 11th European conference on product and process modelling (ECPPM)*, Limassol, Cyprus, 7–9, eBook ISBN 9781315386904,387–395, Christodoulou, S.E., Scherer, R.,Eds.; CRC Press: London, UK.

Schlueter, A., and Thesseling, F. (2009). “Building information model-based energy performance assessment in early design stages.” *Automation in construction,* Volume 18, Issue 2, 153-16.

Stumpf, Annette & Kim, Hyunjoo & Jenicek, Elisabeth, (2011). "Early design energy analysis using building information modeling technology." *Installation technology transfer program*, ERDC/CERL TR-11-41.

Tathagat, D; Dod, R, D. (2015). "Role of green buildings in sustainable construction - need, challenges and scope in the Indian scenario". *IOSR journal of mechanical and civil engineering (IOSR-JMCE)* e-ISSN: 2278-1684, p-ISSN: 2320-334X, 12(2), 01-09.

Yung, P and Wang, X (2014). "A 6D CAD model for the automatic assessment of building sustainability." *International journal of advanced robotic systems*, 11, 531-540.

Zane (2009). "Green building: tech brief." *The national environmental services center*, *West Virginia university,* 8(4).

Zhou, H., Azar E.R (2019). "BIM-based energy consumption assessment of the on-site construction of building structural systems." *Built environment project assessment management* 9, 2–14.

Modelling Interactions of Lean-Agile Enablers in Construction Project Management using Interpretive Structural Modeling (ISM)

Vijayeta MALLA[1], Saniya Faiyaz PATHARWAT[2], Ravindranadh K.CHOWDARY[3]
[1] Assistant Professor, NICMAR Hyderabad, vmalla@nicmar.ac.in
[2] Student, NICMAR Hyderabad, saniya.sami625@gmail.com
[1] Assistant Professor, NICMAR Hyderabad, kravindranadh@nicmar.ac.in

ABSTRACT

The endless fluctuating customer demands, swift project deliveries and technological advancements amidst volatile market conditions is pressurizing the construction professionals to adapt to Flexible Construction Systems(FCS).Conventional Water fall methods are deficient in implanting project complexities and flexibilities, which necessitates a hybrid philosophy like Lean and Agile to be integrated with the Construction Project Management. Agile values and its tenets facilitate the changing customer requirements, condensed schedules and cost to the market under V.U.C.A (Volatile, Uncertain, Complex and Ambiguous) environment. For the transformation from Waterfall based Construction process to Lean-Agile enabled Construction System (LACS), there exist few enablers that drive the implementation of LACS. The paramount necessity calls for thorough analysis of the behaviour of these enablers for efficient implementation of LACS. Substantial researchers studied the critical factors affecting Lean-Agile adoption using questionnaires or literature survey as the groundwork for further research. However, a lacuna of holistic perspective was observed in determining interactive associations between these enabling factors. Therefore, this paper addressed the interdependencies among the final set of ten factors of Lean-Agile enabled Construction System (LACS) through questionnaire of 101 respondents. Interpretive Structural Modelling(ISM) and MICMAC analysis was deployed to capture interdependencies from sixteen experts and then categorised LACS enablers as dependent and independent. 'Collaborated Working and Distributed Management' and 'Process Transparency' are the key dependent LACS enablers from this study. The outcomes of this study presents a cluster of enablers possessing maximum driving power and minimum dependence which depicts the high attention seeking enablers and those of strategic importance. The classification provides the construction project managers to distinguish between the dependent and independent variables with their associations which would aid them in only focusing those critical enablers that are vital for forming an effective implementation of LACS.

KEYWORDS:

Construction Management; Lean Construction; Agile; Interpretive Structural Modelling; MICMAC Analysis; Continuous Improvement; Agile Project Management

1. INTRODUCTION

A significant component to framework of any nation's economic development is its construction industry. According to Statista research department, Global expenditure on the construction industry amounted to a whopping USD 11.4 trillion in 2018 and is expected to grow to about USD 14 trillion by 2025. However, over the years, with the boom of investment from the private sector towards the construction and infrastructure, the projects complexities have gone on increasing. This leads to the failure of the projects in the fronts of the deliverables with respect to the project triangle. Projects experience time & cost overruns,scope creeps and quality breaches along with lowered stakeholder satisfaction increasingly. Studies on these failure aspects attribute it to the underlying conventional waterfall theory of the project management which proves to be inadequate. (Thomas V. A. & Sudhakumar J., 2014; AlSehaimi A. & Koskela L., 2008). The endless fluctuating customer demands, swift project deliveries and technological advancements amidst volatile market conditions is pressurizing the construction professionals to adapt to Flexible Construction Systems (FCS).

The journey of Lean Methodology in Construction started with the research that suggested that construction, in itself, is a unique kind of production and hence it is applicable to be adopted in the construction. As per Koskela (1997), the purpose of Lean ideology is waste minimisation in converting the physical input into output during production process Additionally, lean construction approach in design and development phase for built environment leads to limiting of wastage efforts, resources and resulting in value improvement (Koskela et al., 2002; Koskela, 2004). Project management should recognisethe project as a phenomenon that is complex and dynamic which resides in a non-linear and complex setting. (Bertelsen S. and Koskela L., 2004). Further, the lean methodology was developed and set into practical frameworks, such as the Last Planner System® created in 1992 by Ballard and Howell emphasized minimisation of the meek uncertain factors that hinder the flow of the work process which was disregarded in traditional waterfall project management (Ballard and Howell, 2003). These frameworks center on the reduction of wastes in the process of construction as a whole and strive for continuous improvement through the learnings acquired.

As far as the Agile Methodology is concerned, it has its origins in the software development and the term was coined by the Agile manifesto. It gave the principles for the agile systems including customer involvement, dynamic change management, iterative and incremental plans, and working software as a metrics over comprehensive documentations. (Beck et. al., 2001). Over the years, this methodology developed and gave great success in the software development. Although construction and information systems are perceived to be a lot different in terms of project management, there are many similarities in the sectors, like need of the requirements definition, realisation of value in the usage phase. (Owen & Koskela, 2006). This prompted the implementation of agile methodology to the construction field. Agile project management proves to be beneficial while managements of projectsdistinguished by uncertainty and complexity with adaptability and responsiveness. (Fernandez & Fernandez, 2009). Agile Project Management fits well in the design phase, owing to the cultural inertia in the construction organisation and the casual nature of most workforce, it is difficult to implement in the execution phase as the activities go on getting interdependent. (Owen et. al., 2006) Agility, which encourages flexibility and embraces changes in the project, makes it more resistant to deviations from the plan originally agreed upon with increased flexibility. (Han F., 2013)

1.1 Emerging Research and Empirical Evidence Connecting Lean and Agile Methodology

Studies suggest that the synergy of lean with agile methodologies help develop a mechanism which both, focuses on the waste reduction and process optimization, while also welcoming changes and making the process more flexible. Few facets of the Last Planner System and agile framework exhibit similarities. Kanban has been found to be the probable missing link between lean and agile and it is believed to have the capacity bind the two methodologies together into a LeAgile or Lean Agile Enabled Construction System (LACS). (Iqbal S., 2015)

Implicit use of lean tenets and agile methodologies lessen the project complex attributes aiding in overcoming the shortfalls observed in lean construction alone (Sohi et. al., 2016). Acase study in Poland on column concreting, when applied a synergy of lean and agilemanagement, streamlined the process and helped achieve significant results with respect to time and cost reduction. (Nowotarski & Paslawski, 2016) Also, a hospital building project in the UK, used lean blended agile system for the disciplinary works like Mechanical and installation, paving way for improved health and safety onsite, better ergonomics, reduction in onsite labour, improved quality, refined productivity due to the elimination of wastes. It led to having a notable enhancement in the on-time delivery and cost savings of the project (Court et. al., 2009). Limited empirical studies investigated the interactions and power analysis of enablers to integrated tenets of Lean blended Agile philosophies in built environment. In this context, this study investigates to comprehend the following research questions, which leads to the formation of the research objectives: (1) What could be the crucial enablers to the implementation of Lean blended Agile system in the construction? (2) How should the enablers be prioritized towards effective implementation?

The objectives have been categorised in twofold; firstly, to understand pairwise critical enabler's interactions of Lean-Agile enabled Construction System (LACS) and second objective is to identify the driving enablers and dependent enablers.

2. RESEARCH METHODOLOGY

To achieve the objectives, a hybrid methodology consisting of five steps will be utilised in the research

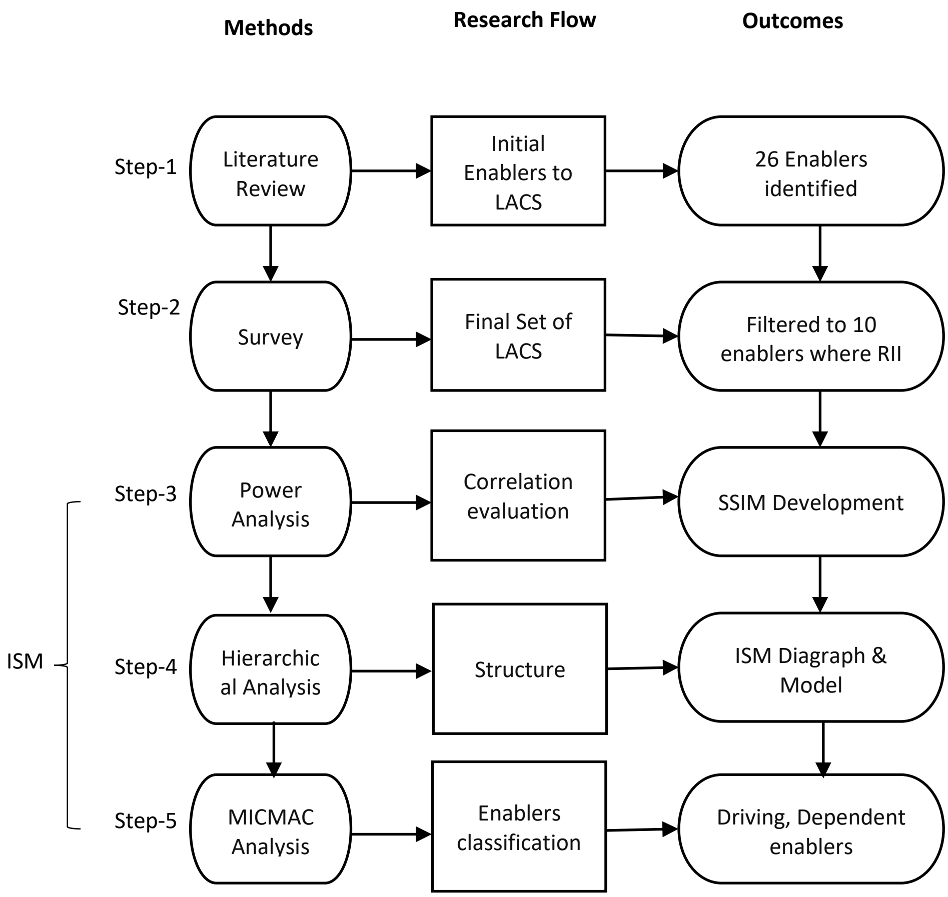


Figure 1. Research Methodology

As evident from Figure 1 the first step involves identification of enablers that effect the implementation of LACS through literature and subject matter experts.

The second step comprises of floating the questionnaire survey to the construction industry professionals through E-mail and personal interviews in the establishment of relative pairwise association among these enablers. The aggregated collective expert opinions form the basis for developing the Initial Reachability Matrix (IRM).

The third step is power analysis where the Final Reachability Matrix (FRM) is arrived after calculating the transitivity checks. The fourth step encompasseshierarchical analysis of these enablers, where these enablers are decomposed to numerous hierarchical levels. The final step includes the classification of these enablers into driving powers and dependent powers through an analysis called a Cross-Impact Matrix Multiplication Applied to Classification (MICMAC).

2.1 Initial Identification of Enabling Factors

The authors gathered preliminary data consisting of enabling factors driving execution process in relation to Lean-Agile enabled Construction System (LACS). The literaturereview was carried out by searching and critically examining the various research journals, conference proceedings, theses etc. by the usage of keywords such as "Lean", "Agile, "Construction", "LeAgile", "Agilean", "Enabler", etc.

2.2 Selection of Final factors for (LACS).

Prior to the ISM analysis, previously identified preliminary enablers were further downsized to form the final crucial Lean Agile Enabled Construction System (LACS) Enablers in the construction industry. The authors chose to downscale final enablers on the basis of the threshold value of RII greater than 0.85, which is derived from the responses of structured questionnaire of the identified preliminary enablers. Hence, ten enablers have met the chosen criteria (where RII >0.85) for conducting the ISM method. The reason for selecting top ten factors based on relative importance index is that the complexity of conducting ISM analysis gets compounded when the chosen factors increase which was also mentioned by (Attri et al., 2013).

For downsizing the enablers, a structured questionnaire survey was administered for gathering expert opinions from 16 construction industry professionals and academia whose average work experience is 14 years. The participants were requested to mark the importance of each LACS enabler for construction industry application on a Likert Scale of one to seven, i.e., Least

Important to Most Important; valued as 1 to 7. A total of 225 questionnaires were givenout, to finally obtain 101 valid responses (rate of response as 44.89%). The reliability and internal consistency of questions was checked using SPSS tool where Cronbach's alpha valueis 0.97 and level of significance is 0.0001 and within the limits

Table 1. Key Enablers of the Lean Agile Enabled Construction System

No.	Name of the Enabler	RII Score	Ranking as per RII score
E13	Learning Organisation	0.884	1
E4	Continuous Improvement	0.879	2
E2	Project Management and Drafting tool Usage	0.875	3
E32	Flexibility of Organisation	0.874	4
E19	Team Training & Education	0.872	5
E6	Standardization & Bench-marking	0.868	6
E25	Continuous proactive adaptation to changes	0.864	7
E24	Concurrent effecting of Design & Construction phases	0.858	8
E16	Collaborative working & Distributed Management	0.858	9
E11	Process transparency	0.858	10

The respondents belong to various organisations in the Indian Construction Industry. Their designations range in various planning, billing, inspection, managing profiles, etc. The responses of this structure questionnaire survey from practitioners and academia was exported to Microsoft excel spread sheet for the Relative Importance Index analysis of the importance of each enabler factor. The ten enablers with maximum scores among all, indicated the severity of impact on LACS relatively, were screened and shortlisted as illustrated in Table 1.

3. ISM METHODOLOGY

To analyse the interactions among factors in a complex system, there exists ample multi criteria decision making (MCDM) tools like, Analytical Network Process (ANP), Analytical Hierarchy Process (AHP), Decision evaluation making and trial laboratory (DEMATEL) etc. However, the above-mentioned methods fail to capture dependencies, hierarchical structured mode of depiction of factors and power analysis. Specifically, while incorporating ANP, it lacks incorporation of dependencies between factors which hinders interactions among the factors (Wu, 2008). Emergent philosophy like agile being applied to construction apart from integrating lean principles lead to complex milieu. And, as ISM methodology involves empowering expert knowledge in evaluating the interrelationships and solves complex systems by considering dependencies among the factors, this ISM framework aids in resolving the complex web of hybrid integrated enablers of lean and agile. Hence, the authors chose the application of Interpretive Structural Modelling (ISM) which suits to the achievement of objectives for the current study. ISM investigates the direct and indirect interrelationships among the factors in a complex framework which was pioneered by Warfield in 1974.

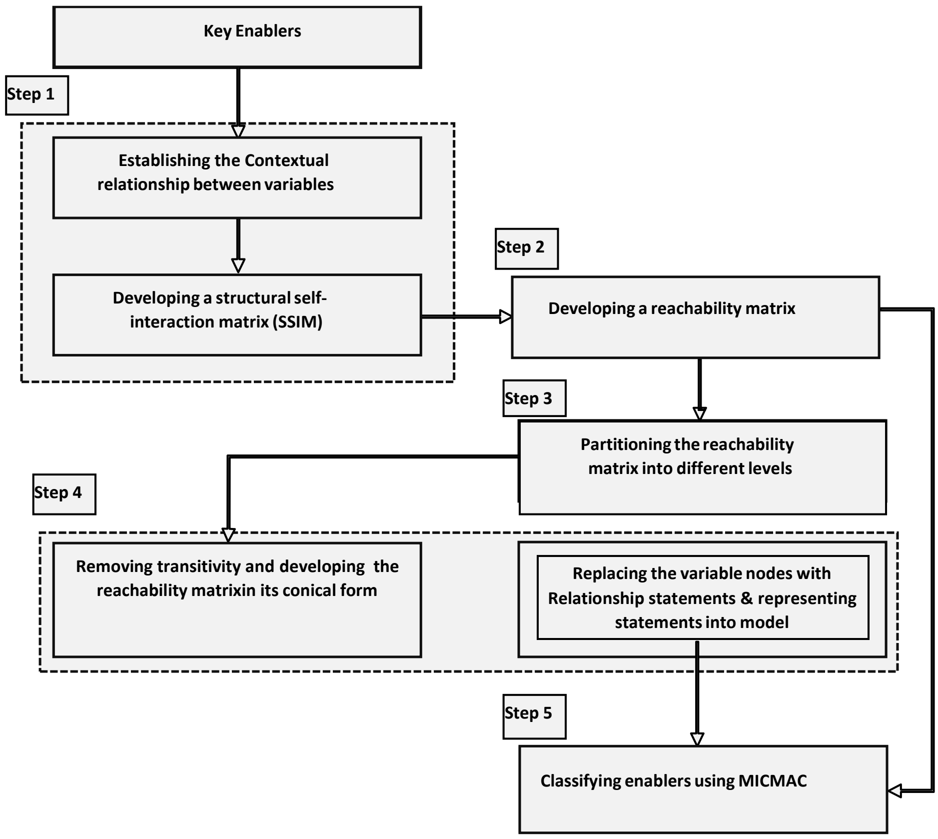


Figure 2. ISM Methodology Process in this study

ISM empowers expert knowledge being embedment in the direct and indirect association among varied factors in ranking and providing direction (Thakkar et al., 2005; Attri et al., 2013). ISM methodology has been utilised in construction management domain to assessing the influential factors of worker's productivity (Sandbhor and Botre, 2014) and risk assessment factors during design stage of built environment projects (Etemadinia and Tavakolan, 2018). Also, ISM has been used to study the barriers in implementing BIM for prefabricated construction in China (Tan et. al., 2019). This study uses the ISM Methodology to structurally model the intricate interconnections among the enablers of LACS.

3.1 Establishment of Correlation between the enablers

After downsizing to ten enablers (after combining two common factors from ten shortlisted factors), another questionnaire survey was administered to capture the opinions of the experts in establishing the mutual relationships among these enablers. Theauthors approached to 16 experts relevant to their experience related to Lean and Agile understanding through LinkedIn and email.

Table 2. Structural Self-Interaction Matrix

		Enabler j									
Enabler i		**E13**	**E4**	**E2**	**E32**	**E19**	**E6**	**E25**	**E24**	**E16**	**E11**
	E13		V	V	V	O	A	V	A	V	V
	E4			A	V	V	V	V	A	V	V
	E2				X	O	A	O	X	V	V
	E32					O	A	V	A	V	V
	E19						A	V	A	V	V
	E6							V	X	V	V
	E25								A	V	V
	E24									V	V
	E16										A
	E11										

Also, the experts' composition consisted few from the research community who possess sound knowledge and practical exposure to Lean supported research projects. All sixteen experts were requested to fill a matrix centering the relationship between each two enablers. The input results obtained from exhibit the contextual interrelationships among the enablers and the same was developed into a Structural Self-Interaction Matrix (SSIM) as shown in Table 2. The interrelationships among enablers i and j were represented with notations as follows:

a. V = Enabler i will help to achieve Enabler j

b. A = Enabler j will help to achieve Enabler i

c. X = Enabler i and j will help to achieve / alleviate each other

4. O = Enabler i and j are unrelated

In scenarios where difference of opinion existed, the experts distinctive decision in assessing the relationship between two enabler was on the basis of, "minority gives way to the majority" judgment (Gan, X et. Al., 2018, Shen, L et.al., 2016) was utilised for final decision in regards to the interrelationships.

Accordingly, the construction of contextual relationships among the ten enablers was done on the basis of evaluation of the association between variables given by the experts, (see Table 2).

Table 3. Final Reachability Matrix

	Enabler j											**Dependence Power**
Enabler i		**E13**	**E4**	**E2**	**E32**	**E19**	**E6**	**E25**	**E24**	**E16**	**E11**	
	E13	1	1	1	1	1	1	1	1	1	1	10
	E4	1	1	1	1	1	1	1	1	1	1	10
	E2	1	1	1	1	1	1	1	1	1	1	10
	E32	1	1	1	1	1	1	1	1	1	1	10
	E19	0	0	0	0	1	0	1	0	1	1	4
	E6	1	1	1	1	1	1	1	1	1	1	10
	E25	0	0	0	0	0	0	1	0	1	1	3
	E24	1	1	1	1	1	1	1	1	1	1	10
	E16	0	0	0	0	0	0	0	0	1	0	1
	E11									1	1	2
Driving Power		6	6	6	6	7	6	8	6	10	9	

3.2 Level Partitioning and Formation of ISM Based Model

As per the ISM process, initial reachability matrix (IRM) and final reachability matrices (FRM)were determined (as shown in Table 3). Then from the developed FRM generation of reachability set and antecedent set of every enabler was conducted to form level partitioning as depicted in Table 4. The reachability set involves every particular enabler and any other enablers it might prompt, ought to there be any, while the antecedent set contains every particular enabler and other enablers, again ought to there be any, that may result. After that, the convergence of the reachability and antecedent sets is inferred for all enablers. The enablers for which the antecedent set and the intersecting points are the equivalent, take up the top level of the ISM hierarchy, showing that these enablers would probably be influenced by other enablers. Once the enabler at the top level is established, it will be eliminated from the reachability set of other enablers. Afterwards, this process is repeated to get enablers at the following level and won't stop until all enablers are set in the ISM hierarchy

Table 4. Level Partition for the enablers

Enablers	Reachability Set	Antecedent Set	Intersection Set	Levels
E16	E16	E2,E4,E6,E11,E13,E16,E19,E24,E25, E32	E16	1
E11	E11	E2,E4,E6,E11,E13,E19,E24,E25, E32	E11	2
E25	E25	E2,E4,E6,E13,E19,E24,E25, E32	E25	3
E19	E19	E2,E4,E6,E13,E19,E24, E32	E19	4
E2	E2,E4,E6,E32, E13,E24	E2,E4,E6,E32,E13,E24	E2,E4,E6,E32,E13,E24	5
E6	E2,E4,E6,E32, E13,E24	E2,E4,E6,E32,E13,E24	E2,E4,E6,E32,E13,E24	5
E32	E2,E4,E6,E32, E13,E24	E2,E4,E6,E32,E13,E24	E2,E4,E6,E32,E13,E24	5
E24	E2,E4,E6,E32, E13,E24	E2,E4,E6,E32,E13,E24	E2,E4,E6,E32,E13,E24	5
E13	E2,E4,E6,E32, E13,E24	E2,E4,E6,E32,E13,E24	E2,E4,E6,E32,E13,E24	5
E4	E2,E4,E6,E32, E13,E24	E2,E4,E6,E32,E13,E24	E2,E4,E6,E32,E13,E24	5

. **3.3 Formation of ISM Diagraph and Model**

On the basis of the results of level partitions, the ten key enablers were placed in the initial diagraph to demonstrate of enablers‟ chain of influence.

An arrow signals from enabler i to enabler j, presents that enabler i can result in enabler j, and a two-way arrow symbolizes a mutual influence. These relationships of inter- influence among enablers are expressed by transitivity; both direct and indirect transitivity links are included in the diagram. Then, by changing the nodes with statements, the diagraph was transferred to the ISM. The tenenablers were separated into five levels of the ISM model.

3.4 Classification of Enablers

These ten enablers are classified by transforming the reachability matrix (see Table 3) into a MICMAC diagram that was first presented by Godet in 1986, helps to calculate thedriving and dependence powers of enablers. This researched focuses on recognizing the main enablers that drive the model in an assortment of classes. In general, an enabler witha higher dependence power signals that several other enablers need to be addressed beforethis enabler can be addressed.

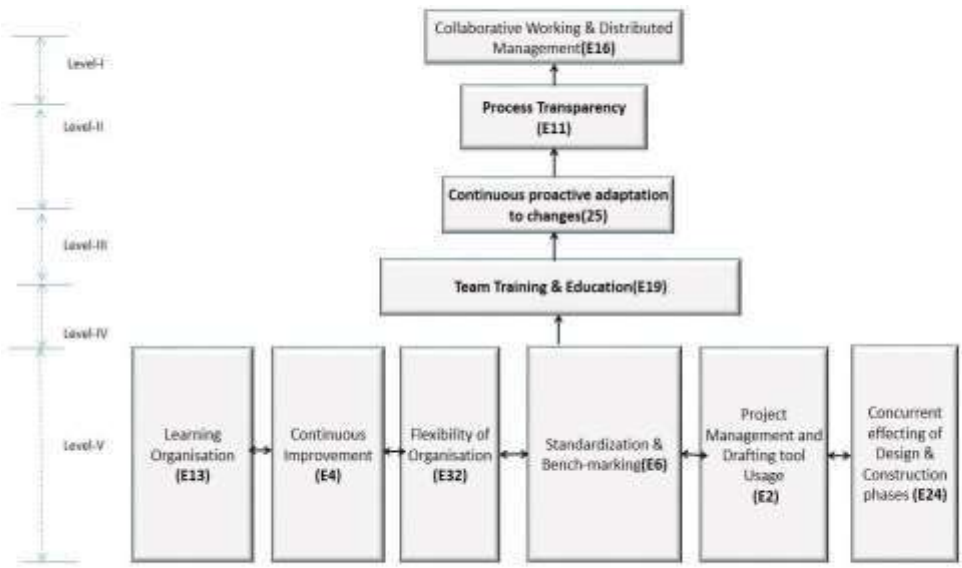


Figure 3. ISM model of enablers to LACS

An enabler with a higher driving power indicates that its achievement allows the attainment of several other enablers (Attri et al., 2013). Followingthe classification that was adopted by previous researchers (Mandal and Deshmukh, 1994), the enablers are classified into four groups, namely,

a. Autonomous enablers in which both, dependence and driving powers are low;

b. Dependent enablers where dependence power is high but driving power is low;

c. Independent enablers where dependence power is low driving power is high;

5. Linkage enablers where both dependence and driving powers are high.

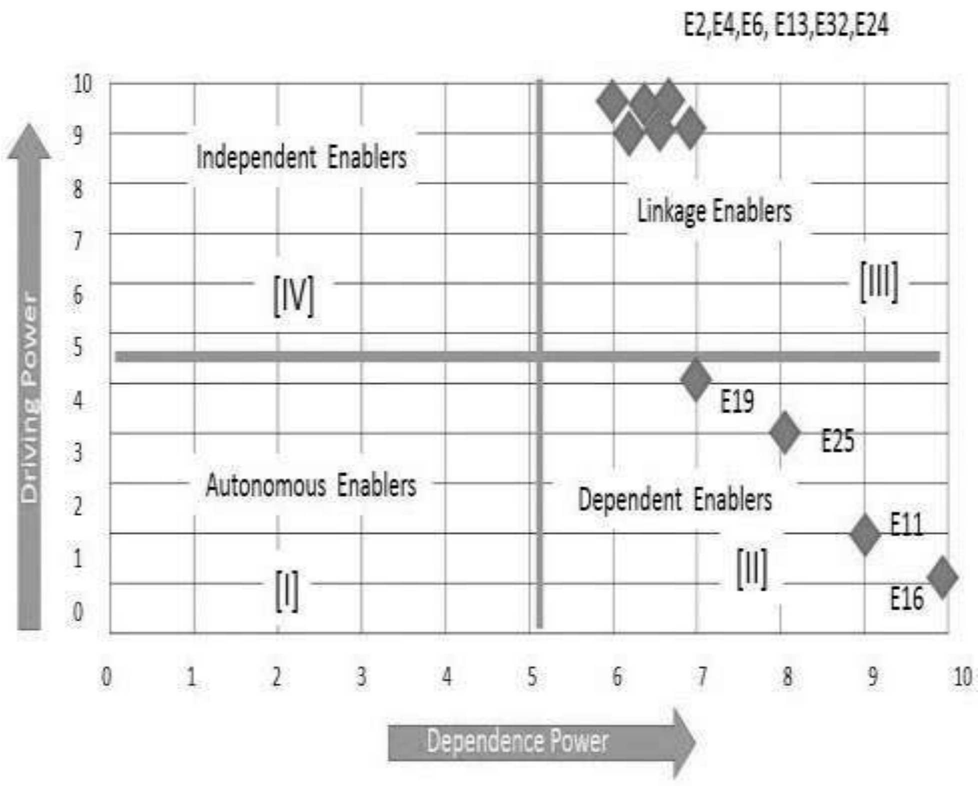


Figure 4. MICMAC Analysis of Enablers to LACS

Figure 4 and Table 3 shows the results from the MICMAC analysis

4.0 FINDINGS AND ANALYSIS

Following are few findings from the ISM Model of the study:

- Results depicted in the Table 3 and Figure 3 clearly depict that the enablers most needed to be achieved towards implementation of a Lean Agile Enabled Construction System (LACS) are E13 (Learning Organisation), E04 (Continuous Improvement), E32 (Flexibility of Organisation), E06(Standardisation and Bench-marking), E02 (Project Management and Drafting Tools Usage) and E24(Concurrent effecting of Design & Construction phases).
- This finding suggests that framework of operations within the organisation and organisational attitude in terms of setting up processes and ability to develop focus and innovate gradually and continually as an organisation are the most crucial enablers.
- Additionally, E19(Team Training and Education) and E25 (Continuous Proactive adaptation to changes) reside at Level IV and Level III respectively, relating towards

building teams trained and equipped to incorporate changes welcomingly within the organisation as a part of creating a working operational strategy for LACS.

- Finally, the enablers, E11(Process Transparency) and E16(Collaborated Working and Distributed Management) placed in the top two levels, that is Level II and Level I respectively, indicate the need of change to how information is being disseminated across the organisation and to the project stakeholders, while also enabling them to be work in a more collaborated and integrated way, ultimately having a framework in place for effective utilization of LACS.

General observations concerning the classification of enablers from the MICMAC Analysis are as follows:

- Based on the analysis, there are no observable barriers in the quadrant [I] of autonomous enablers. It shows that none of the identified barriers have weak dependence and driving powers, hinting that all the barriers are relatively linked to each other.
- E16(Collaborated Working and Distributed Management) has the least driver nature however has the maximum dependent characteristic as is clearly indicated by it in the corner-most part of quadrant [II]. Therefore, this enabler can be judged as the outcome of other enablers.
- Also, other enablers in the quadrant [II] are E19(Team Training and Education), E25 (Continuous Proactive adaptation to changes) and E11(Process Transparency). They have a low driving power yet a high dependence power, meaning that they areinfluence by other factors but don't have the ability to influence others.
- In quadrant [III], we can find the enablers E02 (Project Management and Drafting Tools Usage), E04 (Continuous Improvement), E06(Standardisation and Benchmarking), E13 (Learning Organisation), E32 (Flexibility of Organisation) and E24(Concurrent effecting of Design & Construction phases). These enablers can said to be unstable, that is, any action directed towards these six enablers might effect the other enablers apart from generating self-assessment from the effects among these variables. They are the connecting links among enablers.
- No enabler is identified to be an independent factor, that is present in quadrant [IV], which indicates that no enabler is dominant and may be impacted by other enablers.

The identified interrelationships among the ten enablers mentioned help to put forth a three-level strategy to encourage a Lean Agile Enabled Construction System (LACS).

At the rudimentary and first level, the strategic focus should emphasize on the enablers in Level V of the ISM Model. Efforts need to be directed towards the utilising project management and drafting tools for planning and scheduling of project. Standardisation of repeatable aspects of construction such as processes and setting benchmarks attributable to quality and consistency should be developed. At the same time, given the unpredictability of global environment for construction, the organisation should be flexible to adapt and find a way around such volatile factors of the environment which may hamper the project progress. The phases of design and construction should be coordinated in a concurrent manner in value delivering iterations. The organisation should embrace an attitude and practice of developing systems for organisational learning and applying the same to continually improve. The focus here in this level are directed towards transforming the organisation and how it handles projects and processes. This level needs top management commitment as it needs transformation in the attitude and practices followed. Since the enablers on this level are linked, they set a pathway for the materialisation of the second level of this strategy.

At the second level, the strategy aims to attend to the enablers on levels IV and III of the ISM. The team involved in the project should be trained on the procedures to be adopted and education should be imparted touching on the aspects of these new methodologies. In addition, the team should have a welcoming proactive approach towards changes throughout the project life continuously.

At the final and third level, the strategic focus should concentrate on the top two levels of the ISM. At this level, one should keep in mind that the process transparency to its stakeholders is an important factor that would enable a LACS. Besides, members of this team will need to work in a highly collaborative manner in order to have repeated feedbacks and reducing interfaces. The management or decision-making power should be distributed across the team so as to empower them and result in effective decision making in case when predicaments are encountered. These steps put together, sequentially, may help achieve a functional and effective LACS.

5.0 DISCUSSION AND CONCLUSIONS

A Lean Agile Enabled Construction System (LACS) can prove to be an efficient system to bridge the gap of shortcomings of the traditional waterfall project management framework in the construction as many studies have already suggested. Also, this framework proves to be beneficial while addressing both, the standardisation aspect of construction as well as the volatilefactors of changing requirements and condition when Lean and Agile Methodologies are put together to work instead of having their independent use which has been observed to have shortcomings in the practical applications in the construction industry. This study aimed towards the objective of coming forward with a model towards the development of a practically applicable framework of LACS. Wherefore, an ISM Model was developed in consonance with opinions of experts for the top ten factors which were selected in agreement with their relative importance index from questionnaire survey proceeding from construction industry professionals.

The findings from this research present evidence that many of the key enablers pertaining to team and process characteristics are have a highly interdependent mutual relationship and upon achieving them can an organisation progress towards applying the organisational level enablers.

The results from the analysis are an endeavour to shed a light on the interrelationships and interdependencies between the key enablers of LACS to the academia and professionals. There exists a limited research towards such a system for the construction industry application, as compared to same in other industries and hence this study could add to the knowledge base for the same.

6.0 Research Limitations / Implications

Significant as it is, the present research still has a few implications that should not be overpassed and thus lays down directives for further research. The first major implication is pertaining to the base of the proposed model that depends upon experts‟ subjective opinions and it was not tested practically to reinforce the discoveries of the work. The opinions may tend to have a certain level of biasness within them. Also, the model falls short to attribute the level of significance of interrelationships between the enabling variables so as to know the weak or strong relationships. These could be addressed by further research by incorporating tools like confirmatory factor analysis and validation of the same by practicalimplementation and Structural Equation Modelling (SEM).

REFERENCES

Hofacker, B. Fernandes de Oliveir, F. Gehbauer, M. d. Carmo Duarte Fr eitas, R. Mendes Jr, A. Santos, J. Kirsch (2008) Rapid Lean Construction-Quality Rating Model (LCR) *In: Proceedings for the 16th Annual Conference of the International Group for Lean Construction* Manchester, United Kingdom pp.241-250.

AlSehaimi A. & Koskela L. (2008) What Can be Learned from Studies on Delay in Construction? *In: Proceedings for the 16th Annual Conference of the International Group for Lean Construction* Manchester, United Kingdom pp. 95-106

Attri R., Dev N., Sharma R., (2013) Interpretive Structural Modelling (ISM) approach: An Overview. *Research Journal of Management Sciences* 2(2), 3-8.

Ballard G. & Howell G. A. (2003) Lean project management. *Building Research & Information* 31(1), 1–15

Bayhan H. G., Demirkesen S, Jayamanne E. (2018) Enablers and Barriers of Lean Implementation in Construction Projects. *Materials Science and Engineering 471* (2019) 022002 IOP Publishing. DOI: 10.1088/1757-899X/471/2/022002

Batchelor, C., et al., (1994) Patient satisfaction studies: methodology, management and consumer evaluation. *International Journal of Health Care Quality Assurance* 7(7), 22-30.

Bertelsen S. & Koskela L. (2004) Construction Beyond Lean: A New Understanding of Construction Management. *In: Proceedings 12th Annual Conference in the International Group for Lean Construction,* Elsinore, Denmark. pp. 1-11

Björnfot A. (2008) An Engineering Perspective on Lean Construction Theory *In: Proceedings for the 16th Annual Conference of the International Group for Lean Construction* Manchester, United Kingdom pp. 95-106

Blessie John (2018) Framework of agile management‟s sprint planning in construction projects – AFD method. *International Journal of Advance Research and Development* 3(5), 88-93.

Court P. F., Pasquire C., Gibb A., Bower D. (2005) "Lean" as an antidote to labour cost escalation on complex mechanical and electrical projects. *In: Proceedings 13th Annual Conference in the International Group for Lean Construction,* Sydney, Australia. pp. 1-1

Court P. F., Pasquire C., Gibb A. (2009) A lean and agile construction system as a set of countermeasures to improve health, safety and productivity in mechanical and electrical construction. *Lean Construction Journal* 61-76.

Divakar.K & Ashitha.E. V. R. (2016) Application of Agile Project Management to Reduce the Time Overrun in the Construction of Infrastructure Project. *International Research Journal of Engineering and Technology (IRJET)* 3(5), 3380-3384.

Dominik M., Rauch E., P. Dallasega (2015) Mobile Factory Network (MFN) – Network of Flexible and Agile Manufacturing Systems in the Construction Industry, Fraunhofer *Italia Research, Innovation Engineering Center* (IEC)

Fei Han (2013) Defining and Evaluating Agile Construction Management for Reducing Time Delays in Construction In: Han, Fei. "Defining and Evaluating Agile Construction Management for Reducing Time Delays in Construction." (2013). https://digitalrepository.Unm.Edu/Ce_Etds/74

Gan, X.; Chang, R.; Zuo, J.; Wen, T.; Zillante, G. Barriers to the transition towards off-site construction in China: An Interpretive structural modeling approach. J. Clean. Prod. 2018, 197, 8–18.

Ghazi J., Bo Xia,Fawzia S and Karim A., Olanipekun A. O., Coffey V.(2015) Framework for the implementation of lean construction strategies using theinterpretive structural modelling (ISM) technique. Engineering, Construction and Architectural Management Vol. 27 No. 1, 2020. 1-23 DOI 10.1108/0320180136

Ing. Radan Tomek, Ing. arch. Sergey Kalinichuk (2015) Agile PM and BIM: A hybrid scheduling approach for a technological construction project. *In: Creative Construction Conference 2015 (CCC2015)*

Jagannathan M., Chowdary K.R.N. & Malla V., (2019) Construction Contracts & Lean: Mapping Wastes to its Sources, *In: Proceedings Indian Lean Construction Conference.* B47-B55.

Jin, C. (2017). Agile in Construction Project. *Harrisburg University of Science & Technology*. Available from: http://digitalcommons.harrisburgu.edu/pmgt_dandt/26

Kasiramkumar T. & Indhu B. (August 2016) An Implementation Framework for Integrated Lean Construction System for Indian Scenario. *ARPN Journal of Engineering and Applied Sciences* 11(15), ISSN 1819-6608.

Koskela, L. (1992), "Application of the new production philosophy to the construction industry", CIFE Technical Report No. 72, Centre for Integrated Facility Engineering (CIFE), Stanford University

Koskela, L. (1997), "Lean production in construction", in Alarcon, L. (Ed.), Lean Construction, A.A. Balkema, Rotterdam, the Netherlands, pp. 1-9

Leksic I. (2018) Lean Model for Construction Project Effectiveness Measurement *ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering* 16 ISSN 1584 – 2665.

Masood Z. A. & Farooq S. (2017) The Benefits and Key Challenges of Agile Project Management under Recent Research Opportunities. *International Research Journal of Management Sciences.* 5 (1), 20-28.

Matt Stevens (June 2014) Increasing Adoption of Lean Construction by Contractors *In: Proceedings 22nd Annual Conference of the International Group for Lean Construction (IGLC)*, Oslo, Norway pp. 377-388

Meghwani S., Trivedi J., Devkar G., Joshi H. (2019) Value Stream Mapping- Changing the Perspective in Traditional Practice *In: Proceedings Indian Lean Construction Conference.* B199-B207.

Meredith S. & Francis D. (2000) Journey towards agility: the agile wheel explored *The TQM Magazine* 12(2).137-143, ISSN 0954-478.

Mostafa S., Chileshe N., Abdelhamid T. , (2016),"Lean and agile integration within offsite construction using discrete-event simulation: a systematic literature review", *Journal of Construction Innovation* , Vol. 16, Permanent link to this document: http://dx.doi.org/10.1108/CI-09-2014-0043:

Nowotarski P. & Pasławski J. (2015) Lean and Agile Management Synergy in Construction of High-Rise Office Building. *Archives of Civil Engineering* 62(4-2), 133-147

Owen R. L., Koskela, L. (2006) Agile Construction Project Management, *6th International Postgraduate Research Conference in the Built and Human Environment, 6/7 April 2006 Delft, Netherlands. Research Institute for the Built and Human Environment, University of Salford.*

Padalkar M., Gopinath S. & Kumar A., (2016) Using agile in construction projects: It‟s more than a methodology *Indian Institute of Management, Kozhikode.*

Paul A.J., Rahman S. K. (2018) Study on Agile Management in Construction Project Using Scrumban Methodology In*: International Research Journal of Engineering andTechnology (IRJET)*

P. Tzortzopoulos and Formoso C.T. (1999) Considerations on Application of Lean Construction Principles to Design Management. University of California, Berkeley, CA, USA, *Proceedings IGLC-7*

Pekuri A., Herrala M., Aapaoja A. & Haapasalo H. (2012) Applying Lean in Construction – Cornerstones for Implementation. *In: Proceedings 20th Annual Conference in the International Group for Lean Construction,* San Diego, California, USA pp. 15-26

Per Erik Eriksson (2015) Improving construction supply chain collaboration andperformance Supply Chain Management: An International Journal 15(5), 394 –403.

Reid J. S. (2019) Evaluating the Impact of Using Agile Methodologies in Heavy-Civil Construction. In: ProQuest LLC. 789 East Eisenhower Parkway.

Sarhan, S. and Fox A. (2013) Barriers to Implementing Lean Construction in the UK Construction Industry. *The Built & Human Environment Review*, 6, 1-17 Available at: www.iglc.net

Shen, L.; Song, X.; Wu, Y.; Liao, S.; Zhang, X.; Xiangnan, S. Interpretive Structural Modeling based factor analysis on the implementation of Emission Trading System in the Chinese building sector. J. Clean. Prod.2016, 127, 214–227.

Sohia A. J., Hertogha M., Bosch-Rekveldta M, Blom R (2016) Does lean & agile project management help coping with project complexity? In: *29th World Congress International Project Management Association (IPMA) 2015, IPMA WC 2015, 28-30 September – 1 October 2015, Westin Playa Bonita, Panama. Procedia - Social and Behavioral Sciences* 226, 252 – 259.

Søren Wandahl, (June 2014) Lean Construction with or without Lean – Challenges of Implementing Lean Construction. *In: Proceedings 22nd Annual Conference of the International Group for Lean Construction (IGLC),* Oslo, Norway pp. 97-108

Suetina T. A., Odinokov M. Y.& M. Sfina D. (2014) Benefits of Project Management at Lean Manufacturing Tools Implementation. *Asian Social Science.* 10(20), 62-66.

Tan Tan, Ke Chen, Fan Xue, Weisheng Lu (2019) Barriers to Building Information Modeling (BIM) implementation in China's prefabricated construction: An interpretive structural modeling (ISM) approach. *Journal of Cleaner Production* 219, 949-959. DOI: 10.1016/j.jclepro.2019.02.141

Thomas V. A. & Sudhakumar J. (2014) Factors Influencing Construction Labour Productivity: An Indian Case Study. *Journal of Construction in Developing Countries,* 19(1), 53–68.

Life Cycle Asset Management of Buildings Using Database Management System

Akansha KUNJAM [1] and K V JAYAKUMAR [2]
Graduate Student; email: akanshakunjam06@gmail.com[1]
Professor; email: kvj@nitw.ac.in[2]

ABSTRACT

With several different types, asset management of buildings has always been a complex problem. At the moment, no one methodology is available for such asset management in India. There is, hence, a need to develop a standard asset management methodology for different types of buildings. But the main problem with buildings is that every building is unique, based on its use and requirement of the users. Therefore, it requires different strategies to tackle the problems. So, a common platform is required to cover all types of building. The objective of this paper is to provide a method to optimally manage the assets during the operation period and develop a database that will help future decisions regarding maintenance and repair work. Many building asset management methodologies are being used in different countries. So, one of the methodologies has been chosen and developed it to suit the Indian scenario. The proposed method will give better outlook about the buildings in India.

KEYWORDS

Asset Management, Building, Database Management System, User Interface

1. INTRODUCTION

India is a developing country with population of around 137 crores (as on April 15, 2020 based on Worldometer elaboration of the United Nations data). This has increased the demand for construction of more new buildings and infrastructure. Increase in age, different exposure conditions, changing regulations and change in use of building are some of the reasons which make buildings inadequate for future use. So, for proper utilization of building, asset management plays a significant role. If asset management is used effectively it can help in better operational decision making, pre planning for future maintenance, estimation of cost involved and better response for uncertainties.

As per Alkasisbeh (2018) “Building asset management is a strategic and systematic process for effectively operating, maintaining, upgrading, and expanding physical assets throughout their life-cycle. It is a proactive process that consists of maintaining a systematic record of individual assets that includes acquisition costs, original and remaining useful life, physical condition, cost and history of maintenance”.

2.ASSET MANAGEMENT

2.1 Building Asset Management

For better understanding and easy to manage, the Ministry of Housing and Urban Affairs (MoHUA), Government of India, as a part of its “Modern Building By-Laws, 2016”, has categorized the buildings asset based on the usage as mentioned below:

i. Residential Buildings
ii. Educational Buildings
iii. Institutional Buildings
iv. Assembly Buildings
v. Business Buildings
vi. Mercantile Buildings
vii. Industrial Buildings
viii. Storage Buildings
ix. Wholesale Establishments
x. Mixed Land Use Buildings
xi. Hazardous Buildings

2.2 Building Asset Hierarchy System

Every building is different from each other in many ways based on its use, the components present in the building, etc. So, for making decisions, some common points based on the type of building is important. This will also help in decision making for planning or any repair work and help in decreasing the complexity of the structure.

Alkasisbeh (2018), proposed an eight-level asset hierarchy (Fig. 1). These levels are set such that it can cover different types of building. In this, different parts, systems, subsystems, floor and space function to identify the accurate location and assets are also considered. The hierarchy follows the sequence taking into consideration the operation, work, inspection and location. This hierarchy system will try to erase the differences between different building types such that this system can be used to any type of building.

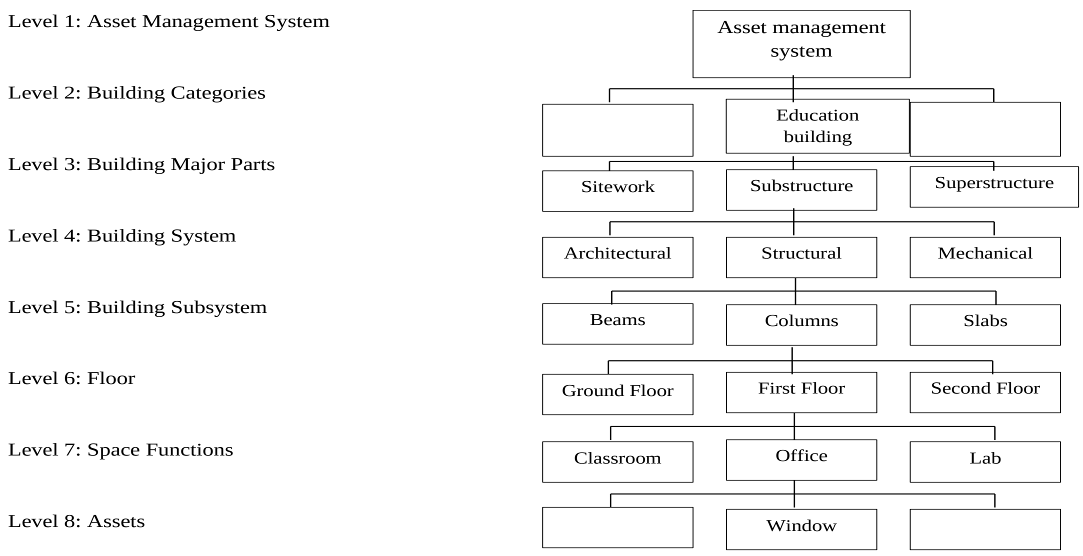


Figure 1: Asset Hierarchy (Alkasisbeh, 2018)

2.3 Database Management System

All the records in India are kept in form of hardcopies. As government is working towards digitalization all new works are being computerized. But for life cycle management of the building, it is important to have all the data from design, construction and operation & maintenance phase to be kept together to take any decision regarding building. The decision can be for any repair work, maintenance of the building, any change in use of the building.

All over the world, new developments are being made and among those, the perspective Data Base Management System (DBMS) provides a new hope to compile all the data at one place. It can be used to collect all the old data and provide a platform to feed new data and to regularly update the data. In the process of construction, for smooth flow of work, most important thing is right communication of information to the right person. All this data will be stored in database. This will be helpful for engineers and owners to keep the record of the maintenance done and help in decision making for future work.

2.4 Implementation of Data Base Management System

The construction industry is also using Database Management System (DBMS) for purpose of integration and to create interface by developing different software. This system can be designed based on the availability of data and necessity of the organization. Many software's are being used in many countries for the same purpose.

2.5 Net based Data Base Management System

Ozorhon et al (2014) found that web-based database systems are currently in use in most of the construction companies. However, only some of them are quite popular and widespread by means of their applicability

Three types of web-based applications were introduced by Zhu (2000) and they are;

i) Fee-Based Project Management Service
ii) Build-it yourself solutions
iii) Web-enabled software

2.6 Mechanism for Evaluation of Building

For evaluating the building, physical inspection is essential. This inspection should be done by any expert or related person and the data should be noted down. Buildings are consisting of different assets and for evaluating a building, it is important to evaluate all of its part. This should be noted down separately under each of the part. Some criteria are taken into consideration to effectively represent the present condition of the building. However, the expert will give the index values based on his experience and condition of the building.

2.6.1 Condition Index

The first step for analysis of building is to inspect the condition of the building. The total evaluation of the building is then carried out in terms of metrics which can give the quantitative measure about the condition of the building. This distribution of the metric is called as the condition index. (Amani et al,2013) The requirement of a good condition index method is that it should be:

i) It provides comprehensive condition description at each scale.
ii) Number of scales affects the survey results as a greater number of scales provides more accurate data.
iii) The scale should be extendable and this can provide more insight of the condition of the component.

2.6.2 Criticality Index

After the evaluation of the building the problem arises on the priority to be assigned to different assets. The critical one should be given more attention. Most critical asset can be pointed out by using Criticality Index (Hammad et al,2014).

2.6.3 Risk assessment of the building

As building regulations and laws keeps changing with the new developing technologies, it is important to check if the old buildings are following the same regulations for the safety of users. In the past, the construction works did not consider the hygiene, health and environmental related issues. Energy saving and proper use of resources have been ignored. The service life of the building is always higher than the service life of any other component of the building and this can result in use of outdated technologies for the solutions in the buildings. This also implies the old operation and safety standards of the building.

Some of the issues that should be checked for the safety of the building include, depreciation of load-bearing structures; constructing engineering and networks in old buildings; and incorporation of different new materials and construction products in an inappropriate manner (Druķis et al 2017)

3. RESEARCH METHODOLOGY

3.1 Data Required

The development of an asset management system requires to collect database from whole life-cycle of the building. This database includes information of all the available assets in the building. The whole database of life cycle is divided into three types. They are as discussed below:

3.1.1 Historical Data

The data from the design and construction phase is called as the historical data. This can be taken from the owner. If the building is new and is linked with BIM, then the data can be directly taken from there.

The table of historical data should include:

i. Historical data of building considers the building address, area of plot, installation year of building, category of building, type of facility, material of asset.

ii. Details of the assets in the building. These details should include the detail of the asset, installation year of asset, design life of the asset, and replacement cost of the asset.

3.1.2 Static Data

The data includes the information of the asset which will be static, means does not change with the time. This can be collected by physical inspection at the site by any expert. The table for static data should include:

i. Details of type of facility being inspected. This should show identity and description of the facility.
ii. Details of the experts or employees involved in the inspection. This should include the details of expert, name of the expert, position of the expert, experience of the expert, contact details of the expert.
iii. For inspection of the building, the type of method of inspection to be used. It should include the description of the inspection method.

3.1.3 Dynamic data

These are the data which change from time to time. This can be basically called as the output of the whole process. Dynamic data should include:

i. Condition assessment of building/asset. This table will have the Building details, Asset description, date of the inspection, expert details, inspection method used, weightage of the asset, condition rating of the asset, expert remarks.
ii. Criticality rating will have Building details, Asset description, date of the inspection, expert details, criticality rating, expert remarks
iii. Risk rating will have Building details, Asset description, date of the inspection, expert details, risk factor, consequence value of asset, expert remarks
iv. Maintenance requirement of the building. This table should include Building details, Asset description, date of the inspection, expert details, Maintenance required, estimated cost, experts remark if any.
v. Remaining service life of the building. This table should include Building details, Asset description, date of the inspection, expert details, Installation Year, predicted remaining service life, final year of service (present year+ predicted remaining service life), experts remarks if any.

3.2 Data Collection

All the data mentioned above should be collected for the building during inspection. The historical data and static data about the building can be collected from the records of the building and it will always be available for the future use. As for the dynamic data for present building assessment the data should be collected every time. For collection of dynamic data from the field, there is no research work addressing use of sensors or smart devices. This can be because the use of sensors and smart devices will require skilled person, it will be expensive and will require high maintenance. So, the method used for real time data collection is physical inspection by experts as this method will be affordable and more reliable. For new construction work using BIM to update the real time condition of the building, then the data can be directly retrieved from the BIM and feed into the DBMS.

3.3 Nomenclature of Assets

For the nomenclature, we need to process the data in our required format. Hierarchy used in this system is based on work breakdown structure. In this hierarchy system is divided into 8 levels. The sequencing is done on subdivisions. Every level defines the particulars that comes under it.

As the hierarchy is defined same can be used to provide a unique ID at every level to every component. This will make the identification of particular asset easy.

3.4 User Interface

The user interface is a platform which can be available to host and its user. The database server developed to provide data can be used through website. The platform will be provided with two type of user i.e., Admin user and Normal User. First is the admin user who is the host and has power to make any changes in the system. Whereas second type is the normal user which can input data and can generate results. The data physically collected needs to be saved in the database server. The user will be provided with three options in the platform i.e., Add or to make any changes or retrieve the data. So, as per requirement of the user can choose the options

So, the user interface will consist of two parts.

Part 1 will be comprised of the entry of historical, static and dynamic data into the system.

a. Historical data

b. Static data

c. Dynamic data

Part 2 will be the report generated about the building condition. The system can generate five reports.

a. Condition assessment report

b. Criticality rating report

c. Risk Assessment report

d. Remaining service life report

e. Maintenance report

4. SUMMARY

This research work focuses on the building asset. The identification of different assets, classification of assets, building asset management and building hierarchy system for nomenclature of different assets present in the building. This will help in uniquely identification of the particular assets. Then the whole building is evaluated using different parameters to project the correct condition of the building. As building is evaluated for life cycle all historical, static and dynamic data of the building are collected. For entering the data and comprising it for future use a net-based database management system is developed. The system developed will have two parts first for input and changes in data and second part will give results in tabular form for Condition Index, Criticality Index, Risk Assessment, Maintenance Report and Remaining Service Life of the building

5.CONCLUSION

In India, asset management is considered mostly in construction and design phase. But there is no such facility for the life cycle asset management. This research work helps to provide a life cycle asset management of the structures. This study mostly focuses on building during operational stage for assessment and provides an optimal solution for the problems in the building. The collection of data should be done by physical inspection as it is more reliable. As the approach is proactive and uses database management system, it provides common platform for users to add any new data and at the same time use of new data. The use of DBMS provides the sense of security to the organization as it can be accessed by the authorized people only. The method will lead to development of user interface which can be used as a website or an app. These features will make is easy to use for common people. However, the old buildings have most of their data in 2D drawings and in hardcopy. But, for new buildings which are using BIM from design and construction phase the historical data can be directly driven from there for use.

REFERENCES

Alkasisbeh, M. R. (2018). An Integrated Decision Support Framework for Life-Cycle Building Asset Management.

Amani, N., & Hosseinpour, E. (2013). An Overview of Component Condition Assessment Systems (CCAS). In ICSDEC 2012: Developing the Frontier of Sustainable Design, Engineering, and Construction (pp. 593-600).

Druķis, P., Gaile, L., & Pakrastiņš, L. (2017). Inspection of public buildings based on risk assessment. *Procedia Engineering*, *172*, 247-255.

Hammad, D. B., Shafiq, N., & Nuruddin, M. F. (2014). Criticality index of building systems using multi-criteria decision analysis technique. In *MATEC web of conferences* (Vol. 15, p. 01018). EDP Sciences.

Ozorhon, B., Karatas, C. G., & Demirkesen, S. (2014). A web-based database system for managing construction project knowledge. *Procedia-Social and Behavioral Sciences*, *119*, 377-386.

Types of buildings as categorized by government and how infrastructure development can shape India's future (2019). Retrieved from <https://economictimes.indiatimes.com/small-biz/productline/building-materials/types-of-buildings-as-categorised-by-government-and-how-infrastructure-development-can-shape-indias-future/articleshow/69925116.cms >

Zhu, J. (2000). Multi-factor performance measure model with an application to Fortune 500 companies. *European journal of operational research*, *123*(1), 105-124.

Section IV

CHALLENGES IN PROJECT MANAGEMENT

Editor's Note

This section specifically focusses on discussing the various challenges in project management. The explosion of information technology and advancements in telecommunications industry has led to the rise of geographically distributed work structure across the globe, which intensified furthermore after the global pandemic. In this increasing age of virtual teams, Lokhande identifies the major challenges faced by the project managers in managing the teams spread across different parts of the world. Based on the primary research, the paper also features various recommendations for the project management community to foster successful collaborations virtually.

Similarly, Jagannathan et al. discusses the financial factors that drive the construction firms to choose adversarial means of resolving disputes despite the availability of various other options. The study considers both firm specific and time specific factors in statistically quantifying its effect on the legal charges incurred by the firms. Meanwhile, Unnikrishnan summarizes the nature of oil and gas mega projects along with its associated complexities. This study also focuses on the use of digital technology tools and best management practices as one of the better ways to lead these mega projects into success while addressing the challenges in adopting the digital solutions in the current scenario, in oil and gas industry.

Likewise, Dutta et al. attempts to see One Nation One Market (ONOM) project introduced by Government of India, for the benefit of Indian farmers, from a telescopic view based on the implementation and success rate of other socially high impact Government projects. The study emphasises on various risks involved in the implementation of this nation-wide project, identifies gaps in the current project management and provides recommendations to ensure successful implementation of ONOM project. Similarly, Vijayashree and Trivedi reinforces the need to predict the changes in the process management to eliminate rework and design waste. The study attempts to validate the usage of Change Prediction Method (CPM) by applying it on a BIM based commercial building, thereby predicting the changes which can be used for crucial decision-making.

Overcoming Barriers to Creating Integrated Global Teams

Anand LOKHANDE
CMR University; lokhandeanand@yahoo.co.in

ABSTRACT

Global economics has made it imperative for corporations across the world to employ and engage workforce from different parts of the world. The dynamics of the balance sheet and bottom line dominate the strategic choices made by these organizations. Technological disruptions, changing politico-economic conditions, and ever-changing aspirations of the end user customer also determine the focus and direction of business strategy. Managing virtual teams is a challenging task for the project manager. This takes up most of the project manager's time and effort. The success of the project is dependent on the cordial and harmonious existence of team members even if not located in one place. In the current situation of pandemic, remote working and virtual teamwork is the only way to sustain and survive. The new ways of working are here to stay far ahead into the future. This paper examines the attributes of globally distributed teams and compares these to collocated teams. The paper identifies the reasons for discord between members of distributed teams and recommends measures to mitigate them. The paper suggests remedial measures to overcome the obstacles in managing globally distributed teams.

KEYWORDS

Project management, distributed team, remote working, virtual team

1. INTRODUCTION

The advent of the information technology industry gave rise to the concept of the geographically distributed team. The exponential growth in technology proved a big boon to this industry in enabling the deployment of the workforce who were not stationed locally but could be located anywhere else in the world. Innovations and inventions in the telecommunications industry, availability of large storage capabilities in computing devices, and increased computing power enhanced the remote working ability of the workforce. Competitive economic pressures also forced organizations to opt for offshoring their work and moving repetitive tasks to low cost geographies. In the initial period of globalization of economies, organizations worked hard to get a foothold in the third world countries. Their objective was to secure maximum profits for their shareholders back home and reduce labour overheads as much as possible. The work produced out of these locations was mainly repetitive and data centric. Medical transcriptions, financial accounting and invoice processing were the primary jobs which were pushed to offshore. In the second-generation wave of economic changes, multinational IT corporations rode successfully on the internet wave to create wealth for themselves. Employees were now spread across the globe and contributed to the low-end application support and development tasks and business process reengineering. Technological progress was rapidly evolving the industry in this second wave of change. A decade later in the early 2000s, the severe economic downturn and resulting cost pressures forced organizations to setup offshore development centres and application management services. Talent was now sourced locally from within these geographical locations and deployed to cater to multinational as well as local business. In the last decade, exponential rise in computing power, complex business environment has resulted in transforming the way organizations design their future strategies.

2. PROJECT MANAGEMENT IN THE VIRTUAL WORLD

Business continuity planning, disaster risk management and hostile competition have rendered organizations to constantly think on their feet. Strategic business management now entails a constant review of organizational systems and structures. Adapting to the newer ways of working while preserving the organizational value system is of paramount importance. People play an important role in the preservation of this value system. The concept of working in groups and teams is as old as humankind. People thrive well when working in teams. Collocation is an important attribute of successful high performing teams. This is however not feasible always and due to multiplicity of locations, teams could be dispersed across varied geographies. This decentralization of projects with the distributed location of team members doing different tasks at different points of time on the project with appropriate hand-offs has changed the face of project management in this sector completely. Traditional project management always relied on collocated teams working with the project manager to deliver the project goals and objectives. The hierarchy and command control mechanism were of prime importance in execution of the project. However, the advent of newer project management methodologies to organize, manage and deliver tasks equipped project managers and senior project leadership to venture into deploying resources from across locations. Performance dynamics of geographically distributed teams is distinctive and divergent from collocated teams. There are different bases for collocating teams – major reasons being functional skills, talent prowess, size of project, and more importantly availability of resources. Skills gap widens as technological advances take place. There is a need to continuously seek resources with the requisite skills to keep programs and projects functioning to execute business strategy. Multi country location of business provides the right visibility to fulfil resource requirements. The flip side to this resourcing advantage is the virtual visage of the team. Collaboration and coordination between the team members is not possible at the same level of a collocated team.

3. RESEARCH OBJECTIVE

The main objective of this study is to identify what are the various challenges being faced by project managers in managing virtual teams. Virtual teams as a concept is related to teams which are being managed in a virtual way, they are not located in the same place as the manager. One or more of the team members are in different places. The secondary objectives are to identify which management strategies are successful in effectively managing virtual teams, to compile list of techniques which are most popular, and to suggest commonly practiced methods to the project management community in general. The important question to be addressed in this research is 'what are the obstacles in the way of managing geographically distributed teams effectively?'

4. RESEARCH SCOPE

For the purpose of this research paper, the theoretical framework is designed to understand the history of organizational change which promoted geographically dispersed teams, the challenges in managing them and recommendations to overcome the barriers of collaboration, team building, harmonious work relationships and effective outcomes. The focus is on understanding the specific challenges faced by project managers in managing teams located in different geographical settings, under different cultural influences, working in different time zones and different skillsets. The scope of the paper is limited to the opinions, experiences, and knowledge of practicing project managers from around the information technology sector, energy, real estate, power equipment, healthcare, engineering and research and development.

5. RESEARCH METHODOLOGY

a) Data collection

The quantitative research method was selected to compile information from various practicing professionals in the field of project management. Questionnaire was prepared to seek information from each professional and was sent to them via electronic link of an online form. The questions were prepared based on the contemporary nature of work, the background experiences of the professionals available from their virtual profiles in professional network, and current scenarios in project management. The interview format of enquiry was also conducted on a few survey respondents to understand their opinions in a more specific and direct manner. In these interviews the respondents chose to share their experiences and reasons behind the responses emphasising on challenges regarding the specific research topics. The questionnaire was organized into three sections – general personal information, project related information and project management related information. The general personal information sought was about the industry sector, and years of experience. The project related information sought was about the location of the project, presence or absence of geographically distributed teams, and cultural aspects of the team members. In addition to that the survey had questions regarding the tools for communication used to collaborate and communicate with teams given the diverse cultural background and the level of collaboration achieved. The respondents were also asked about the role of interpersonal skills in the effective management of geographically distributed teams.

b) Data analysis

The survey responses have been categorized and included as part of this research study. The data has been transformed to enable inferences and is used to prove or disprove the arguments laid out by the experts. Data was categorized into relevant knowledge areas as per the Project Management Body of Knowledge (PMBOK) from the Project Management Institute (PMI). Statistical analysis was conducted on the data for presentation in this paper.

6. LITERATURE REVIEW

H.Franz (2002) investigated the impact of computer-mediated communication on teams which were in different places. The impact was checked for overload of information whether it was perceived or real for the teams. The author identified that communication related causes were central to many challenges faced by these teams who were geographically distributed. Goldthorpe, W.H. (2000) analysed the business risks arising from the distributed or mutable locations of teams. Use of internet and related technologies to manage business-to-business processes brought tremendous cost efficiencies to these companies. Freedman. N (2000) covered about the collective learning in Philips and how various action-oriented programs were developed for globally distributed project managers to manage the learning goals of their teams. Mannix EA et al (2002) researched on the topic of conflict in distributed teams. They reported how trust is a major component in relationship of individuals working at different locations but in the same team. The success of these teams depends on how they manage conflict. The authors also highlighted that since the teams are not constrained by physical location, use of new technologies and new kinds of interaction may benefit the team members and increase the diversity in their interactions. Smith JL et al (2005) examined several internet-based project management tools and ascertained how the collaborative design of these tools provides support the distributed project teams. The paper also discusses the evolution of these tools from simple knowledge management dimension to multi-functional collaborative design. Smith JL et al (2005) investigated the concept of reuse from a product-related knowledge management perspective to process-related knowledge management. The authors also discussed about the impact of design knowledge on the outcome of the key tasks they are performing, R, Akbar (2010) suggested how software development by centrally located in-house teams was replaced by geographically distributed offshore teams. This outsourcing also became a popular and profitable practice according to the authors. They identified the limitations associated with this trend and recommended measures to improve the process to overcome them. The authors suggested that the success of project management activities is dependent on reducing the risk factors and the capability of the project managers to manage the issues involved. Alutto JA (2007) investigated on fourteen factors of effectiveness of distributed teams and their performance. The results of the exploratory research suggested how future scholarly work can focus on interaction challenges and effects of distributed teams. Bergstorm S (2006) researched on the communication specialists' teams in Nokia and ascertained that the individual employees' motivation is important contributor in their participation in the geographically distributed network of members. Bishop A, et al (2010) investigated on software suite of programs which were used to analyse the email communications of set of offshore team to understand their response around cultural influences, critical topics, emotion and team collaboration. The knowledge of such details will help the managers to understand the situation better and get work done in globally distributed teams. Bououd, I et al (2012) conducted Delphi study on graduate management students on the topic of team collaboration in virtual world. They conducted SWOT analysis on team collaboration using electronic brainstorming techniques. Chinowsky P.S et al (2003) studied the opportunities and potential barriers to building successful virtual teams in the engineering, procurement, and construction industry. They identified that the social and cultural understanding, having common goals and objectives, and using appropriate technology can help in elevating the success of project teams which are geographically distributed. Denisova, V (2015) in her thesis identified the effective project management strategies and techniques for professionally managing virtual teams. She identified the challenges of working in globally distributed teams and how these impacts the virtual management of projects. Devasagayam HC et al (2014) highlighted how the Indian IT industry has benefitted due to the evolution and continuous improvisation of the concept of globally distributed teams. The competitive advantage of the Indian software industry is also attributed to the fact that technology has enabled teams to be located at several different places and yet be managed through virtual project management techniques. Downes R (2020) came up with interesting findings that when managers are separated from their staff, they are looking to create means to establish closer rapport with their staff. The author discusses a theoretical framework of how context and relationships exist in organizations which engage in distributed work. Filev A (2013) presented that remote collaboration is one of the key factors which is shaping the world of project management. The motivation and guidance provided to distributed teams can make them more successful than collocated teams. Hashia, A. et al (2007) investigated the practices of open source development teams and the challenges they face while working in distributed locations. The authors opined that distributed teams continue to experience problems due to communication issues, cultural differences and even managerial interventions or the lack of it. Demetrios, K et al (2014) discuss on the various collaborative tools available in the market for geographically distributed teams to use. They focus on the video conferencing tool and how this tool has facilitated communication, helped to build trust, prevent misunderstandings, reduce travel costs and even enhanced successful team interactions. Koednok, S (2008) discussed on the working process of distributed teams. The author also discusses the leadership approach for managing geographically distributed teams. The author identified key success factors for managing these teams like strategically selecting team members, developing a vision for managing each location, developing commitment and trust between team members, enabling empowered teams, facilitating organizational learning, evaluating team performance and reselecting team members. The author recommended that these steps help the leader to increase their efficiency and effectiveness. Lyon, T (2017) in his talk discusses about the challenges in managing geographically distributed teams. The author also shares best practices from his experience in managing globally distributed teams across Europe, Middle East, North and South America. The author lays down communication strategies along with career related growth options which can always keep the remotely managed individuals into the mainstream. Marks, D (2010) analysed the risks and objectives regarding moving to offshore development for a portion of software development. The author also reviewed the necessary corporate structure, roles, and processes. This was done to ensure efficient development with teams that were not collocated. 'Agile' methodologies were used for software development and this was considered significant improvement over the traditional water project management techniques. In addition, the author opined that the costs of such infrastructure will be less than the benefits derived. Offshore development centers are characterized by cloud infrastructure, and server hosting which is available for entire team.

7. FINDINGS

a. Results from conducted interviews

The main objective for this section is to make aware the reader of the group of project managers who manage their teams located across different geographical locations. The individuals are working for multinational corporations both of Indian as well as non-Indian origin. The industry sector is of wide variety ranging from energy, information technology sector, real estate, power equipment, construction, healthcare, engineering and research and development. The interviewees were keen to explain their challenges due to the current pandemic situation and were concerned about how to manage virtual teams on a long-term basis. The respondents also cited that management support was intermittent in creating a congenial atmosphere due to uncertainty over business goals and overall economic climate. The respondents have been managing globally distributed teams over multiple projects and have acquired experience in the onsite-offshore model prevalent in the IT services and consulting industry sector. The respondents opined that motivation levels are higher when the team members are provided with flexibility in working location. They have seen a higher output of deliverables from individuals who were granted flexibility of location as well as time slots. The same opinion was not voiced by those from the construction and real estate sector. The respondents pointed to trust and authentic behaviour as the primary hurdles in creating congenial atmosphere for those members who can work from remote locations. In addition to that not all activities can be done in a virtual manner and hence the nature of the industry is a critical factor in ascertaining the obstacles in successful management of geographically distributed teams.

b. Results from questionnaire and analysis

The questionnaire was divided into separate sections – personal information, project related information and project management related information.

Personal information – Gender diversity, industry, number of years of experience in project management

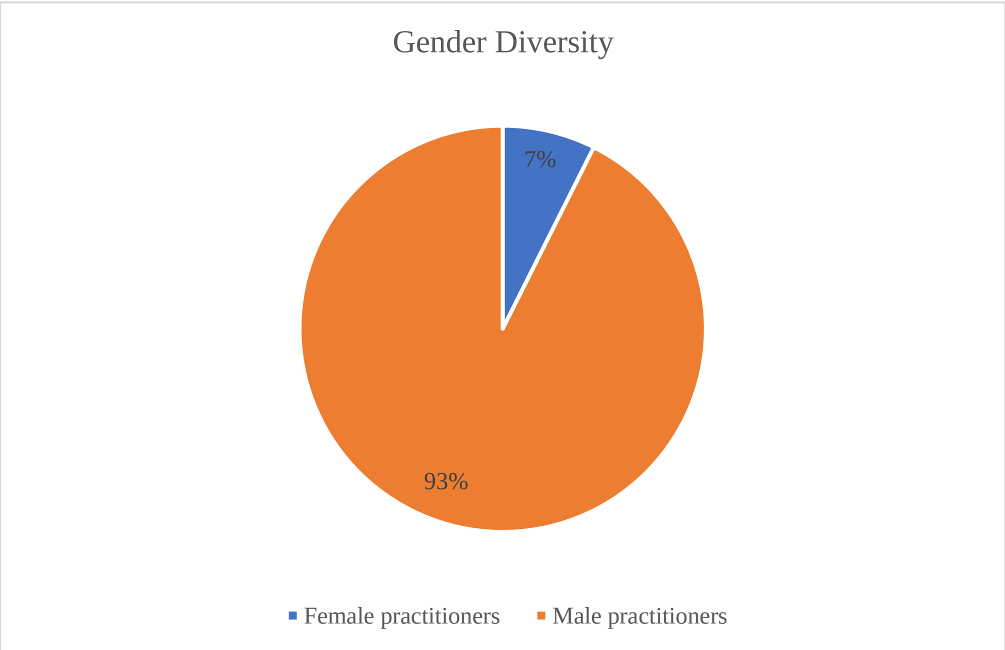


Chart 1

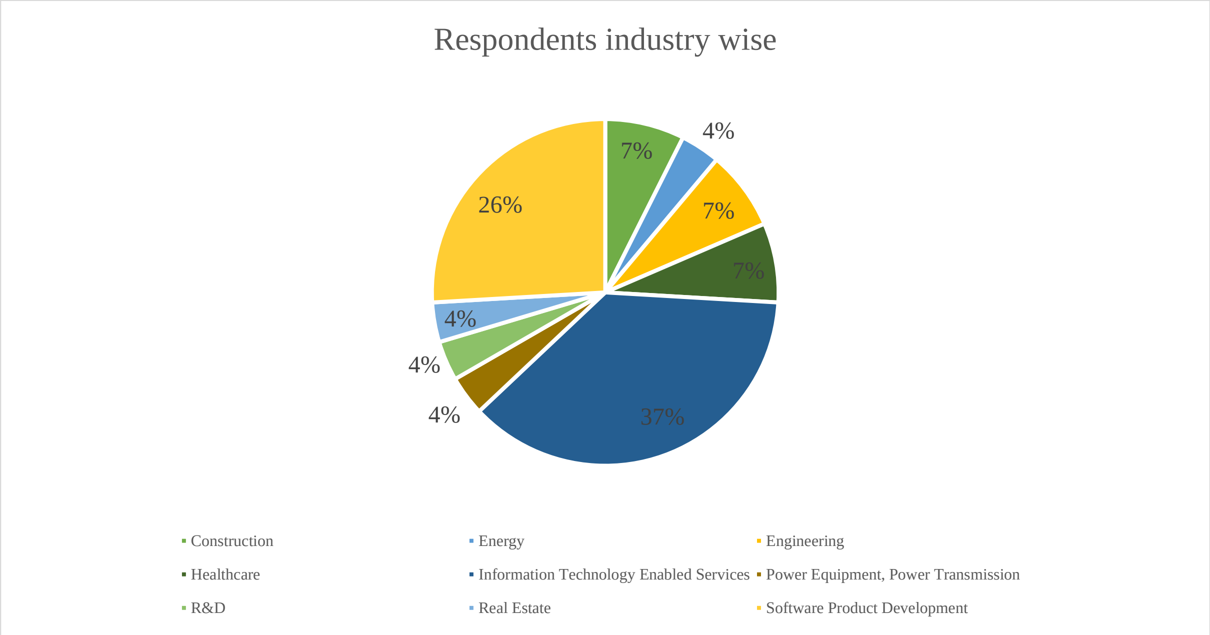


Chart 2

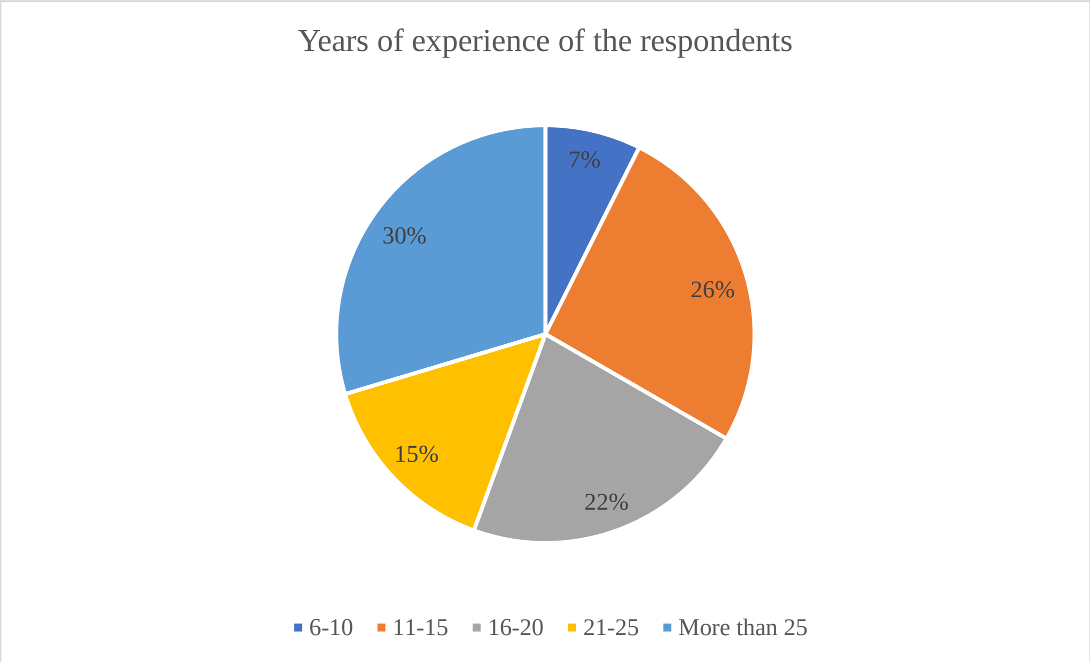


Chart 3

Project setup related information – Global projects, Local projects, Collocated teams, Virtual teams, Working time zones – whether multiple or single, Segregation of tasks as per geography/time zone, presence of multiple project managers or project leads, Gender diversity, industry, number of years of experience in project management. Chart 4 gives the break-up of the projects – global and local managed by the respondents. 89% projects were global projects with teams spread across multiple geographical locations. Only 11% projects were local projects.

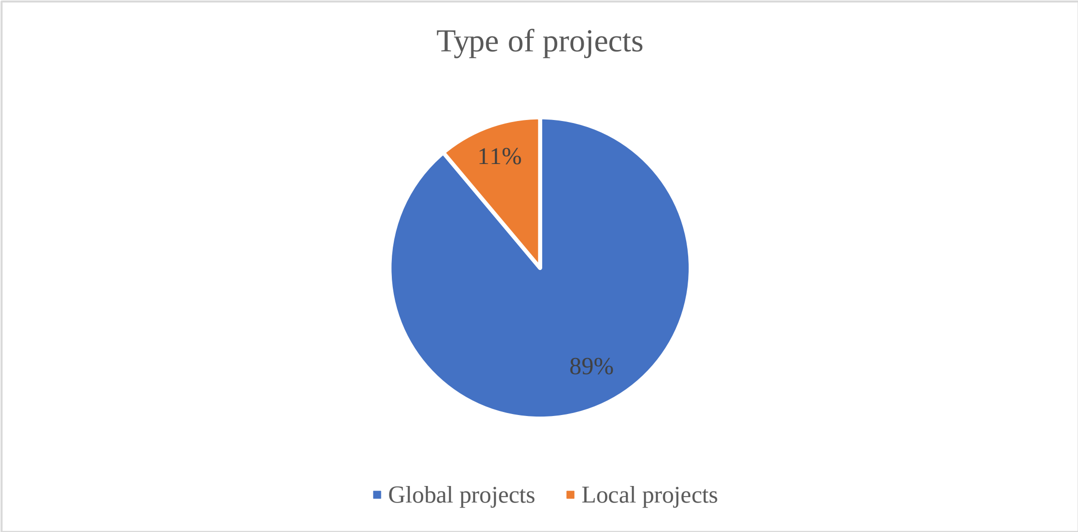


Chart 4

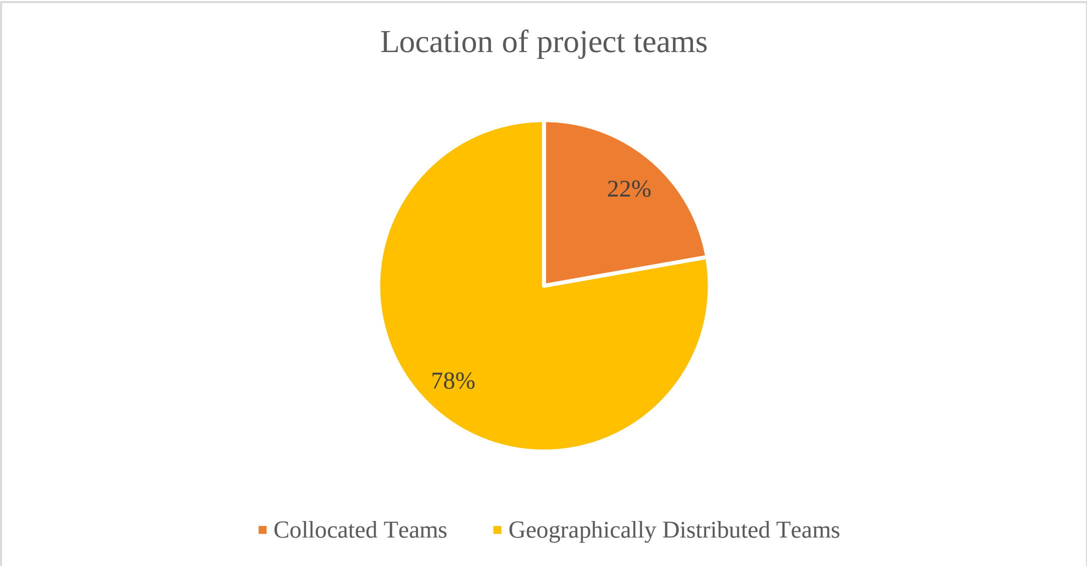


Chart 5

Chart 5 illustrates the location of project teams. Nearly 78% teams were geographically distributed. Chart 6 indicates one of the most important factors in success of geographically distributed teams – presence across time zones.

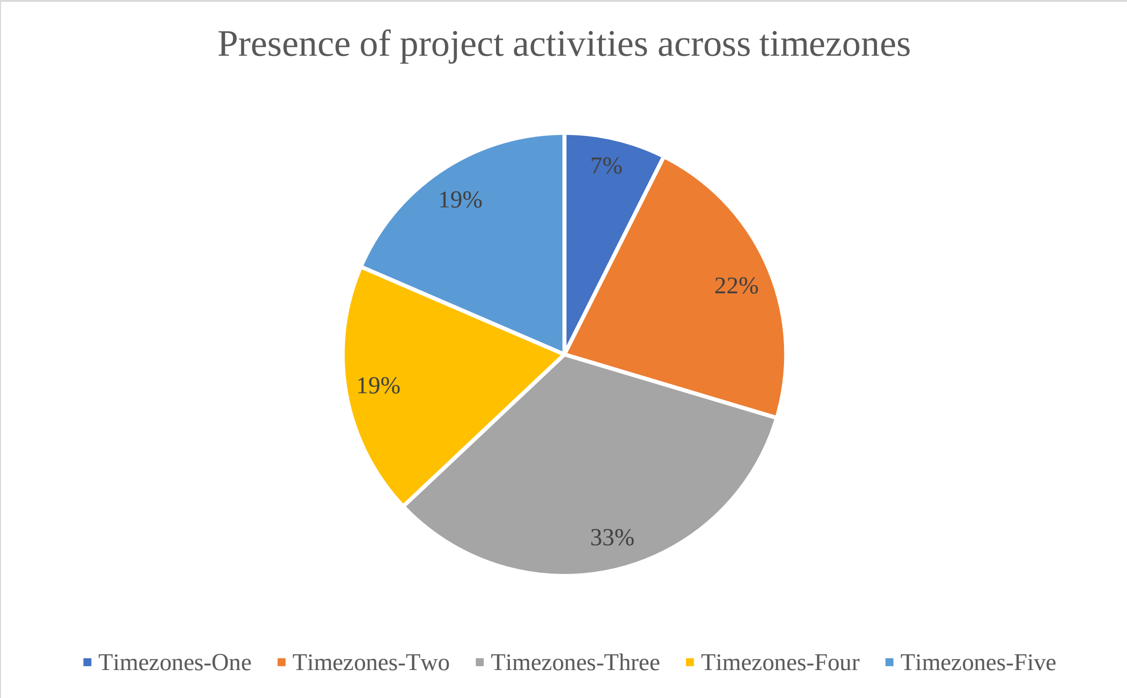


Chart 6

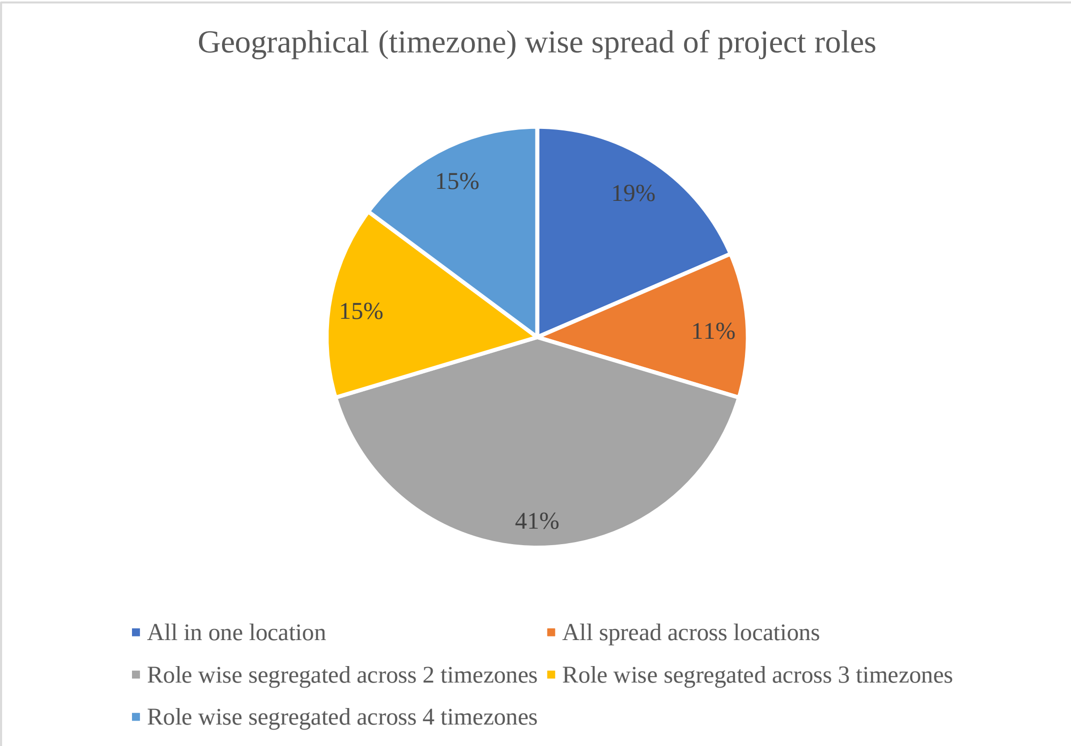


Chart 7

Chart 7 indulges further into the tactical operations of the projects. As discussed earlier, not all types of tasks are completed in one geography for a single project. Availability of skilled resources, technical applications, presence of experts, and project leadership determine how the work is spread across the locations. The roles in question were i)managerial ii)execution iii)development and iv)testing. 19% of the projects indicated that all the four activities were in one location. 15% projects indicated that the four activities were spread across different time zones. 11% projects indicated that there was no specific distribution, and any role could be done by any one from any time zone. Nearly 41% projects indicated only two time zones for all the four types of activities.

Chart 8 indicates the location of the project leadership if spanning across multiple locations. 41% respondents said that there was presence of multiple project management leadership staff at multiple locations.

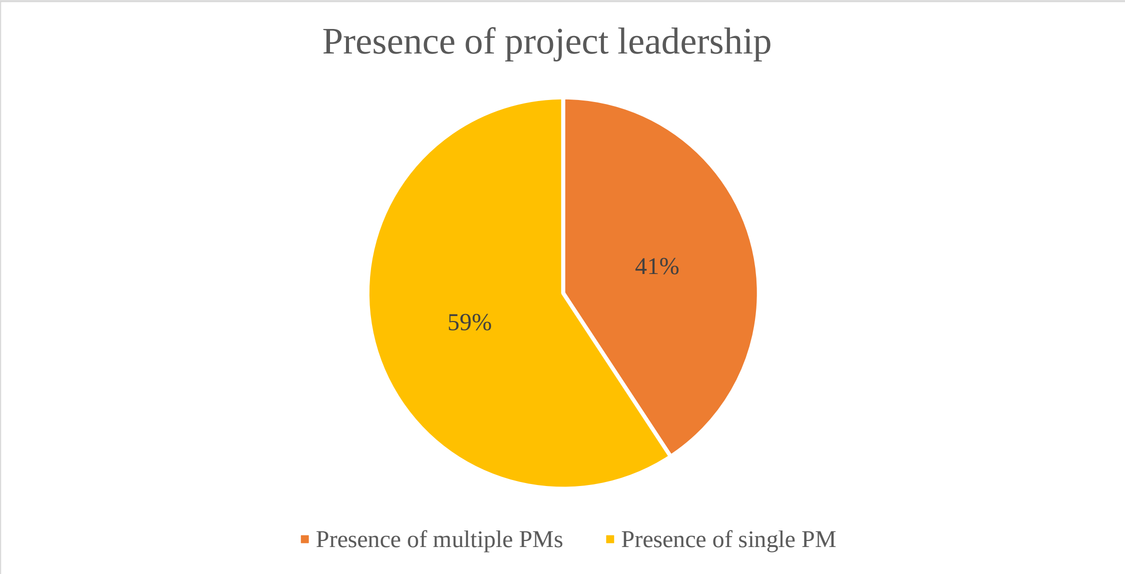


Chart 8

Language acquires a strong significance in the communication between team members from different geographical locations. Communication is key to the success of the project. (Chart 9)

Since language acquires an important place in the communication success of any project, culture and cultural awareness also go hand in hand. Introducing diverse cultural contexts to team members at the start of the project increases the chance of successful collaboration and improved team performance. Chart 10 illustrates that nearly 56% of the respondents did not organize any cultural awareness session at the beginning of the project. A mere 19% organized more than one or equal to one session to sensitize the team members on each other's cultural background. Approximately 26% of the project management practitioners organized at least one session to this effect.

Chart 9

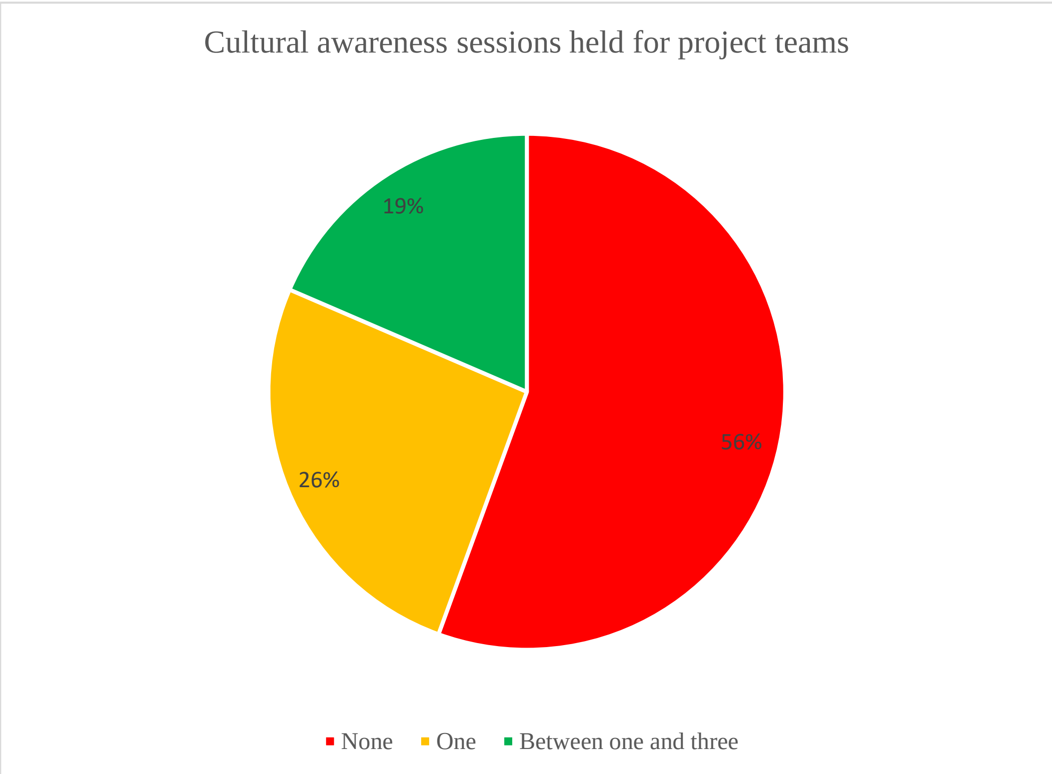


Chart 10

While cultural awareness acquires significance in multi-location teams and their performance on the projects, it was necessary to understand how the project managers managed to enable this awareness. On being asked (Chart 11) regarding the tools used for setting up these awareness sessions 19% indicated that they had organized webcasts. 37% relied on telephone conferencing tools and 44% relied on the video conferencing tools. The choice of media also determines the effectiveness of the sessions and overall impact of these sessions on the project related behaviours of the team.

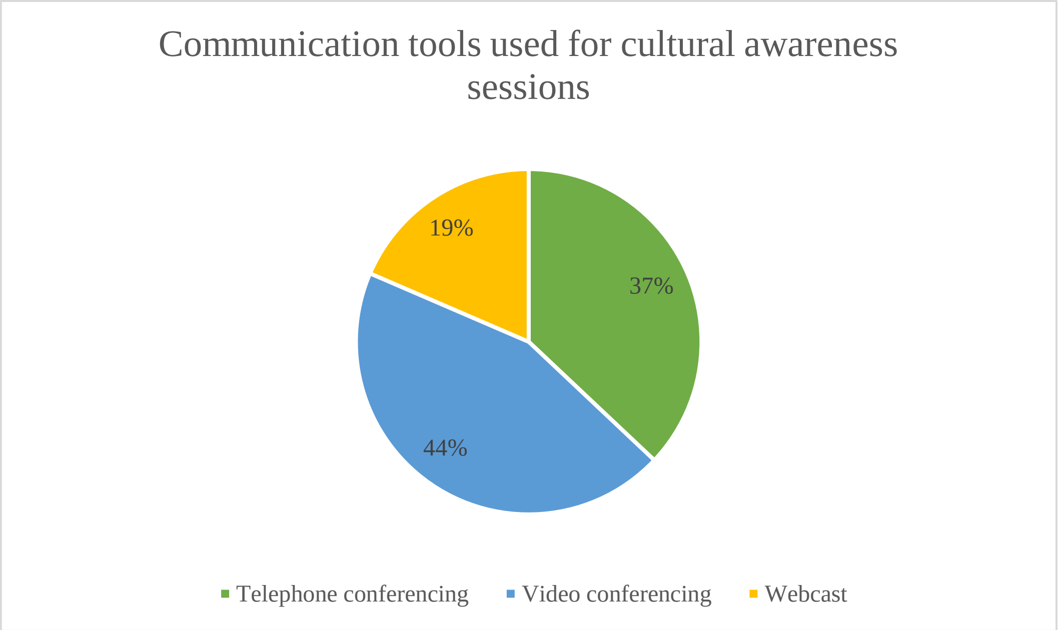


Chart 11

The project managers were also asked if senior stakeholders were present during the cultural awareness sessions. 60% responded that senior stakeholders were not present or not always present.

Project management related information – challenges faced by the project managers in working with cross geography teams, the mechanism of resolving issues between team members working from different geographical locations, effectiveness of the team structure which is geographically dispersed, ability of the project manager to manage such teams, level of collaboration between different team members, ability of the project manager to reduce conflicts between the team members located in different geographical locations, support received from the senior stakeholders in managing challenging situations between the teams or team members, and the relevance of interpersonal skills in overcoming barriers to creating integrated global teams.

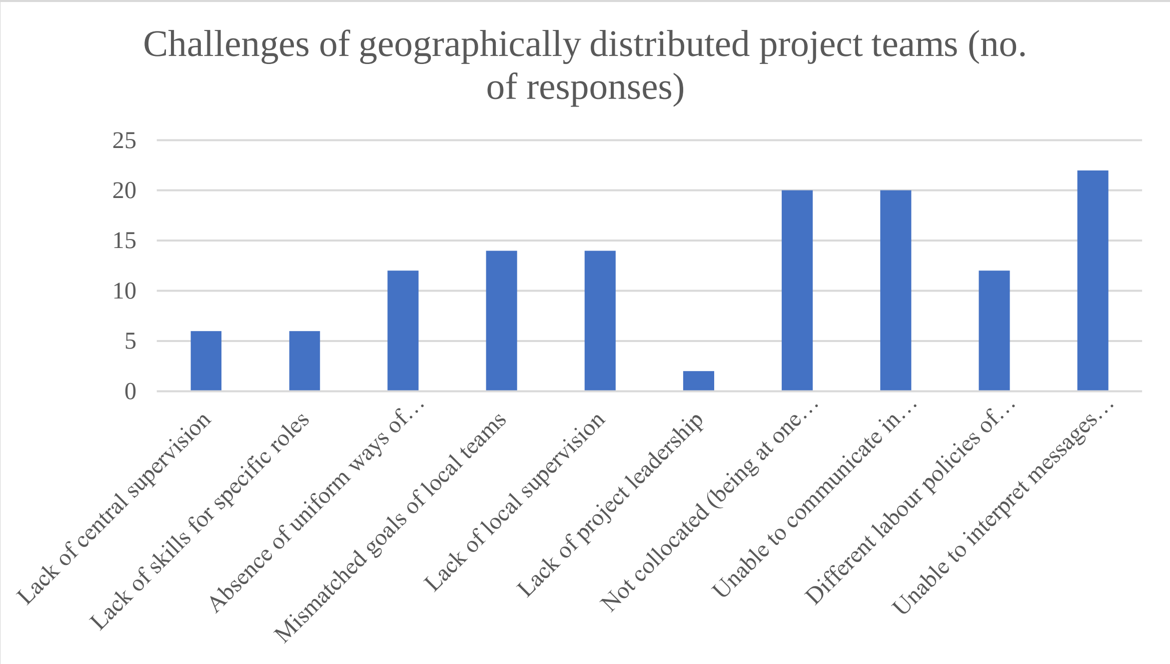


Chart 12

Table 1: Frequency distribution: Challenges of geographically distributed project teams

Statistic	Lack of central supervision	Lack of skills for specific roles	Absence of uniform ways of working	Mismatched goals of local teams	Lack of local supervision	Lack of project leadership	Not collocated (being at one location)	Unable to communicate in effective manner (in virtual environment)	Different labour policies of respective countries	Unable to interpret messages effectively received from others (in virtual environment)
Nbr. of observations	54	54	54	54	54	54	54	54	54	54
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1st Quartile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3rd Quartile	0.000	0.000	0.000	0.500	0.500	0.000	1.000	1.000	0.000	1.000
Mean	0.111	0.111	0.222	0.259	0.259	0.037	0.370	0.370	0.222	0.407
Variance (n-1)	0.103	0.103	0.179	0.199	0.199	0.037	0.242	0.242	0.179	0.251
Standard deviation (n-1)	0.320	0.320	0.424	0.447	0.447	0.192	0.492	0.492	0.424	0.501

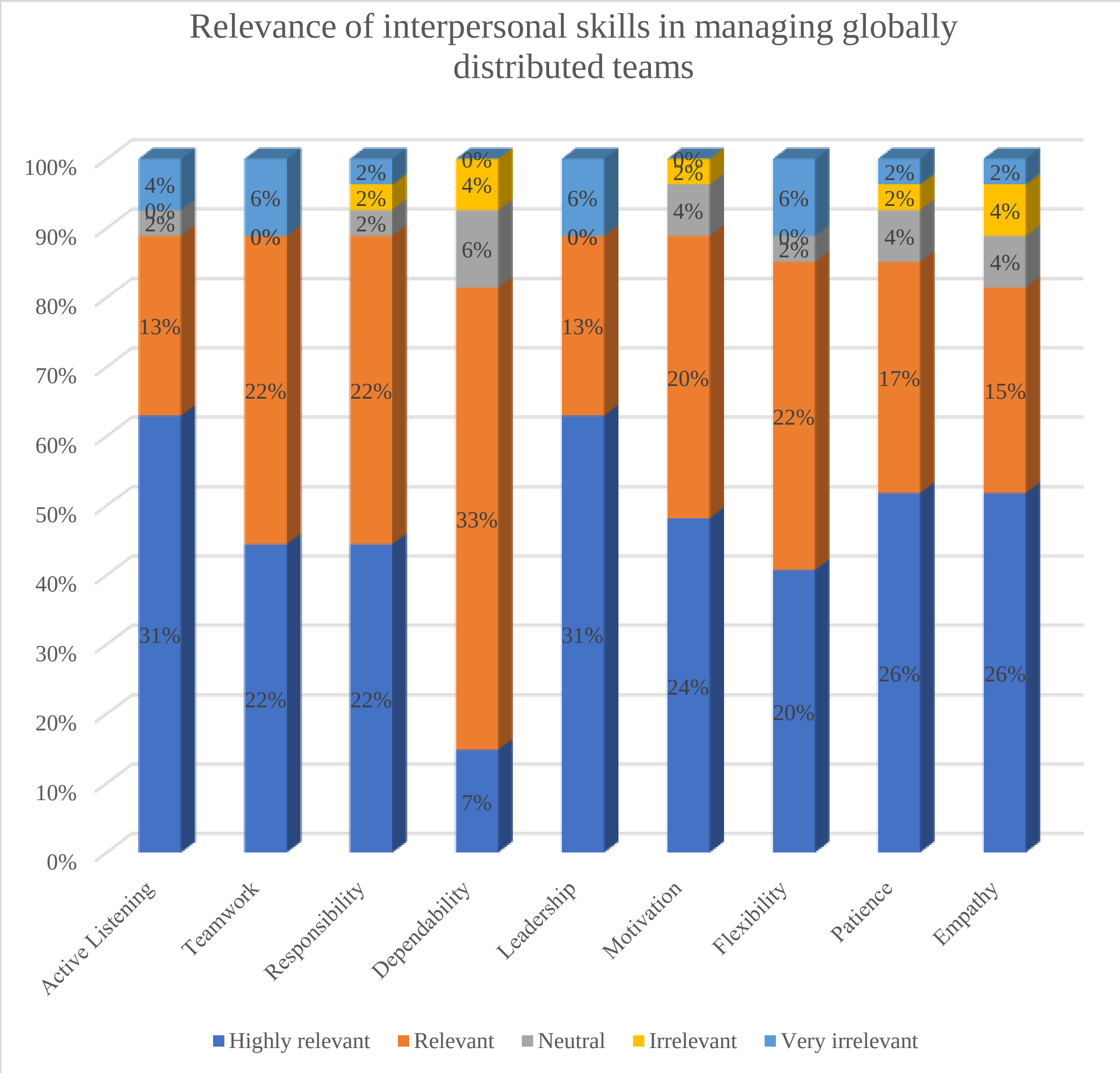


Chart 13

Reliability analysis – is used to study the properties of the scales of measurement and the constituted elements. In the question regarding elements of interpersonal skills that are necessary to manage geographically distributed project teams this reliability analysis can provide results to evaluate the internal consistency of the elements. This also helps to measure the ability of the items to measure the same phenomenon or the same dimensions of a scale. It also provides information on the relationships between the different elements composing the scale. It is used to check if questions (items) in a set of questions (questionnaire) are consistent with each other. In the questionnaire the following elements were included as part of the interpersonal skills – active listening, teamwork, responsibility, dependability, leadership, motivation, flexibility, patience, and empathy. The results of the test prove that indeed these elements are related closely for the success of managing geographically distributed teams.

Table 2: Summary statistics (Items):

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean
Active Listening	54	0	54	1.000	5.000	4.370
Teamwork	54	0	54	1.000	5.000	4.111
Responsibility	54	0	54	1.000	5.000	4.222
Dependability	54	0	54	2.000	5.000	3.889
Leadership	54	0	54	1.000	5.000	4.296
Motivation	54	0	54	2.000	5.000	4.333
Flexibility	54	0	54	1.000	5.000	4.037
Patience	54	0	54	1.000	5.000	4.259
Empathy	54	0	54	1.000	5.000	4.185

Table 3: Summary statistics (Scale):

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean
Scale	54	0	54	15.000	45.000	37.704

Correlation matrix :

Variables	Active Listening	Teamwork	Responsibility	Dependability	Leadership	Motivation
Active Listening	**1**	0.846	0.772	0.556	0.901	0.689
Teamwork	0.846	**1**	0.917	0.560	0.925	0.764
Responsibility	0.772	0.917	**1**	0.561	0.850	0.755
Dependability	0.556	0.560	0.561	**1**	0.683	0.588
Leadership	0.901	0.925	0.850	0.683	**1**	0.827
Motivation	0.689	0.764	0.755	0.588	0.827	**1**
Flexibility	0.863	0.899	0.832	0.716	0.936	0.828
Patience	0.756	0.778	0.712	0.640	0.860	0.751
Empathy	0.781	0.893	0.814	0.487	0.863	0.721

Covariance matrix :

Variables	Active Listening	Teamwork	Responsibility	Dependability	Leadership	Motivation
Active Listening	**1.218728**	1.128	0.822	0.457	1.247	0.591
Teamwork	1.128	**1.459119**	1.069	0.503	1.400	0.717
Responsibility	0.822	1.069	**0.930818**	0.403	1.027	0.566
Dependability	0.457	0.503	0.403	**0.553459**	0.637	0.340
Leadership	1.247	1.400	1.027	0.637	**1.570929**	0.805
Motivation	0.591	0.717	0.566	0.340	0.805	**0.603774**
Flexibility	1.156	1.317	0.973	0.646	1.423	0.780
Patience	0.846	0.952	0.696	0.482	1.092	0.591
Empathy	0.949	1.187	0.864	0.398	1.189	0.616

Analysis of variance: **Table 4**

Source	DF	Sum of squares	Mean squares	F	Pr > F
Between subjects	53	421.695	7.957	30.502	**<0.0001**
Within subjects	432	120.889	0.280		
Between measures	8	10.288	1.286	4.930	**<0.0001**
Residual	424	110.601	0.261		
Total	485	542.584	1.119		

Computed against model Y=Mean(Y)

Cronbach's alpha statistics :

Cronbach's alpha	Standardized Cronbach's Alpha
0.967	0.968

Guttman statistics:

Guttman L1	Guttman L2	Guttman L3	Guttman L4	Guttman L5	Guttman L6
0.860	0.973	0.967	0.986	0.949	0.981

Best partition:

Split-Half 1	Split-Half 2
Active Listening	Responsibility
Teamwork	Leadership
Dependability	Flexibility
Motivation	Empathy
Patience	

Cronbach alpha value is acceptable at 0.967 and exhibits the internal consistency of the question. The Guttman statistics from L1 to L6 further provide much more accuracy of the internal consistency of this test.

While analysing the impact of management skill of the project manager in mitigating conflicts between team members in different locations, the results are not so encouraging. The correlation value is 0.660 which can be attributed to lack of control in physical presence of the team members in differently spread locations.

Summary statistics (Quantitative data): Table 5

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Management skill	54	0	54	3.000	5.000	4.037	0.582
Level of collaboration	54	0	54	2.000	5.000	3.704	0.717

Correlation matrix (Pearson):

Variables	Management skill	Level of collaboration
Management skill	**1**	**0.660**
Level of collaboration	**0.660**	**1**

Values in bold are different from 0 with a significance level alpha=0.05

p-values (Pearson):

Variables	Management skill	Level of collaboration
Management skill	**0**	<**0.0001**
Level of collaboration	<**0.0001**	**0**

Coefficients of determination (Pearson):

Variables	Management skill	Level of collaboration
Management skill	**1**	0.436
Level of collaboration	0.436	**1**

Taking this analysis further to the other questions on the project manager's rating of a globally distributed team and their ability to achieve collaboration within the team, success in reducing friction between team members and a self-rating of their own management ability the results are average.

Table 6: Summary statistics (Quantitative data):

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Management skill	54	0	54	3.000	5.000	4.037	0.582
Rating of global team	54	0	54	2.000	5.000	3.778	0.839
Level of collaboration	54	0	54	2.000	5.000	3.704	0.717
Success in reducing friction	54	0	54	2.000	5.000	3.778	0.634

Correlation matrix (Pearson):

Variables	Management skill	Rating of global team	Level of collaboration	Success in reducing friction
Management skill	**1**	0.249	**0.660**	**0.534**
Rating of global team	0.249	**1**	**0.453**	0.118
Level of collaboration	**0.660**	**0.453**	**1**	**0.599**
Success in reducing friction	**0.534**	0.118	**0.599**	**1**

Values in bold are different from 0 with a significance level alpha=0.05

p-values (Pearson):

Variables	Management skill	Rating of global team	Level of collaboration	Success in reducing friction
Management skill	**0**	0.069	**<0.0001**	**<0.0001**
Rating of global team	0.069	**0**	**0.001**	0.395
Level of collaboration	**<0.0001**	**0.001**	**0**	**<0.0001**
Success in reducing friction	**<0.0001**	0.395	**<0.0001**	**0**

Coefficients of determination (Pearson):

Variables	Management skill	Rating of global team	Level of collaboration	Success in reducing friction
Management skill	**1**	0.062	0.436	0.285
Rating of global team	0.062	**1**	0.205	0.014
Level of collaboration	0.436	0.205	**1**	0.359
Success in reducing friction	0.285	0.014	0.359	**1**

8. CHALLENGES FACED BY PROJECT MANAGERS

Globally distributed teams offer multitude of challenges to project managers. Communication is one of the most important attributes of success. Being located at different places creates the first *stress on communication* between the team member and the manager. Resolving day to day tactical issues becomes a challenge due to *inconsistent priorities*. The innate need of individuals to *socialize with their colleagues*, to share informal conversations, 'water cooler conversations', and working together for common aspirational initiatives takes a back seat.

Team members are no longer looking towards collaborating on organization initiatives but *focus on their own deliverables*. *Trust takes a back seat* as the supervision in person reduces. The project managers are forced to rely on emails and other reports from the team members on the work status. Individual *coaching is also not feasible* for the project manager as they are now focusing on addressing multiple communication channels which are opened due to *lack of proximity*. Everyone spends more time of conference calls and *less time on catching up informally* for personal connects.

9. RECOMMENDATIONS

Based on the results of the analysis and the review of literature below are recommended steps for project managers and the project management office –

- i) Communication with the team should be priority for the project manager
- ii) Creating a ways-of-working charter for the team will help them to organize their work better
- iii) Having difficult conversations will help both project manager and team member to refocus on the stated goals and objectives
- iv) Setting up short term goals and adhering to timelines will help build confidence
- v) Frank, outright and authentic – adopting this communication style will help establish trust
- vi) Recognising the need for social connection and establishing informal connects and fun activities will contribute to healthy professional relationships between the members

10. CONCLUSION

Geographically distributed teams are the new reality and the new normal. The year 2020 also witnessed a paradigm shift in the way project teams work due to the pandemic. Maintaining social distance and working virtually was the only option available to all those who were able to do so with the technology means available at their disposal. Yet the barriers for managing such teams remain to be overcome. Technological growth offers solutions to improve computing speed and conducting complex calculations, yet it cannot replace the human need for social connect and contact. Project management professional must aspire to build stronger intra-team relationships. There is ample scope for research in this area given the new dynamics emerging in the current context.

REFERENCES

Akbar, R., & Hassan, M. F. (2010, June). Limitations and measures in outsourcing projects to geographically distributed offshore teams. In 2010 International Symposium on Information Technology (Vol. 3, pp. 1581-1585). IEEE.

Alutto, J. A. (2007). Issues in Distributed Team Performance'. Multi-Level Issues in Organizations and Time (Research in Multi-Level Issues, Volume 6). Emerald Group Publishing Limited, 59-64.

Bergström, S. (2006). Commitment in networks of practice.

Bhattacharya, R. (2012). Managing Large Programs-A Practitioner's View. CSI Communications, 19.

Bishop, A., Riopelle, K., Gluesing, J., Danowski, J., & Eaton, T. (2010). Managing global compliance through collaborative innovation networks. Procedia-Social and Behavioral Sciences, 2(4), 6466-6474.

Bououd, I., Boughzala, I., Wigert, B., & de Vreede, G. J. (2012). Team Collaboration in Virtual Worlds: Results from a Delphi Study. Volume II, 44.

Bourgault, M., & Nathalie Drouin, M. B. A. (2009, August). Understanding decision-making within distributed project teams. Project Management Institute.

Čale, B. A. (2013). Master thesis: Managing Virtual Teams.

Chinowsky, P. S., & Rojas, E. M. (2003). Virtual teams: Guide to successful implementation. Journal of management in engineering, 19(3), 98-106.

Clear, T., & MacDonell, S. G. (2010, August). Beyond" Temponomics'-the many dimensions of time in globally distributed project teams. In 2010 5th IEEE International Conference on Global Software Engineering (pp. 297-304). IEEE.

da Cunha Oliveira, T., & da Silva, M. M. (2011). Method for CMMI-DEV Implementation in Distributed Teams.

Denisova, V. (2015). Globally dispersed team management: research based on interviewing experts in virtual project management.

Deshpande, S. (2012). A coordination model for global software development teams.

Devasagayam, H. C., & Rao, M. (2014). The Human Aspects of Globally Distributed Work Teams in the Indian Information Technology Industry: Effect of Justice Perception on Team Performance. Global Journal of Management And Business Research.

Downes, R. (2020, January). The Proximity Paradox: How Distributed Work Affects Relationships and Control. In Proceedings of the 53rd Hawaii International Conference on System Sciences.

Ferreira, A. I. F., Pires, C., Canedo, M., Rego, P. A., Solutions, P. B. I., & Banco, B. B. M. Managing Geographically Distributed Software Projects: Success Factors and Lessons Learned.

Ferreira, P. G. S., de Lima, E. P., & Gouvea, S. (2013). Distributed teams performance measurement capabilities: a systematic literature review. In IIE Annual Conference. Proceedings (p. 827). Institute of Industrial and Systems Engineers (IISE).

Filev, A. (2013). Expansion of remote teams: What drives it forward, and how is it shaping the future of project management. PM world journal, 2, 3.

Franz, H. (1999, January). The impact of computer mediated communication on information overload in distributed teams. In Proceedings of the 32nd Annual Hawaii International Conference on Systems Sciences. 1999. HICSS-32. Abstracts and CD-ROM of Full Papers (pp. 15-pp). IEEE.

Freedman, N. J. (2000). Action Learning at Philips Electronics: from Training to Transformation. In Business Driven Action Learning (pp. 115-133). Palgrave Macmillan, London.

Gibbs, J. L. (2002). Loose coupling in global teams: Tracing the contours of cultural complexity (pp. 1-338). University of Southern California.

Gloor, P., Paasivaara, M., & Miller, C. (2015). Lessons from the Coinseminar. arXiv preprint arXiv:1502.05260.

Goldthorpe, W. H. (2000, January). The Mutable Distributed Team: A New Business Risk in the Information Age. In SPE Asia Pacific Oil and Gas Conference and Exhibition. Society of Petroleum Engineers.

Greig, P. (2018). Scaling Yourself for Managing Distributed Teams Delivering Reliable Services.

Hashia, A., Whelan, J., & Shewaramani, R. (2007). An Innovative Approach to Managing Distributed Teams. Technical Report, Seattle University, Department of Computer Science & Software Engineering, SU-CSSE-2007-2.

Hulshult, A. R. (2018). Agile narratives: faculty perceptions of using Agile concepts and practices in postsecondary courses to influence collaboration and transferable workforce skills (Doctoral dissertation, University of Wisconsin--Stout).

Hussain, N. (2018). Requirements Engineering for Globally Distributed Teams using Scaled Agile Framework.

Jain, S., & Fernandez, J. Dynamics of Multidimensional Controls in Dynamic Global Software Development: A Future Perspective.

Kalman, Y. M., & Leng, P. H. (2006). A HYBRID MODEL FOR MANAGING ACADEMIC STAFF IN AN INTERNATIONAL ONLINE ACADEMIC PROGRAMME. In IADIS International Conference e-Society 2006 (pp. 193-200).

Kalman, Y. M., & Leng, P. H. (2007). A distributed model for managing academic staff in an international online academic programme. Interactive Learning Environments, 15(1), 47-60.

Karis, D., Wildman, D., & Mané, A. (2016). Improving remote collaboration with video conferencing and video portals. Human–Computer Interaction, 31(1), 1-58.

Kauffmann, D., & Carmi, G. (2014). How team leaders can use ICT to improve trust among virtual teams to increase collaboration. International Journal of Engineering and Innovative Technology [IJEIT], 3(9), 204-221.

Koednok, S. (2008). Leadership Approach for Managing in Distributed Team. IFAC Proceedings Volumes, 41(2), 2974-2979.

Kovaleva, T. (2019, June). Assessment of Success Measures and Challenges of the Agile Project Management. In International Conference Cyber-Physical Systems and Control (pp. 716-725). Springer, Cham.

Levine, D. C. (2015). Workplace Change Management: An Overview.

Lyon, T. (2017). Don't Call Me Remote! Building and Managing Distributed Teams.

MacCormack, A. D., Forbath, T., Brooks, P., & Kalaher, P. (2007). Innovation through global collaboration: a new source of competitive advantage.

Mannix, E. A., Griffith, T., & Neale, M. A. (2002). The phenomenology of conflict in distributed work teams. Distributed work, 2002, 213-233.

Marks, D. (2010). Managing Distributed Teams Using Agile Methods: An Implementation Strategy for Regulated Healthcare Software.

Masood, Z., & Farooqi, S. (2017). Benefits and key challenges of agile project management under recent research opportunities. International Research Journal of Management Sciences, 5(1), 20-28.

Massie, R. A. (2020). A Qualitative Study Defining Behaviors for Effective User Stories in Distributed Scrum Teams Based in San Antonio, Texas (Doctoral dissertation, Colorado Technical University).

McCarthy, C. (2010). Global leadership: An analysis of three leadership competency models in multinational corporations (Doctoral dissertation, Dublin City University).

McComb, S., Kennedy, D., Perryman, R., Warner, N., & Letsky, M. (2010). Temporal patterns of mental model convergence: Implications for distributed teams interacting in electronic collaboration spaces. Human Factors, 52(2), 264-281.

Moore, E., & Spens, J. (2008, August). Scaling agile: Finding your agile tribe. In Agile 2008 Conference (pp. 121-124). IEEE.

Newell, S., David, G., & Chand, D. (2007, January). Exploring trust among globally distributed work teams. In 2007 40th Annual Hawaii International Conference on System Sciences (HICSS'07) (pp. 246c-246c). IEEE.

Niazi, M. (2015). Do systematic literature reviews outperform informal literature reviews in the software engineering domain? An initial case study. Arabian Journal for Science and Engineering, 40(3), 845-855.

Oshri, I., Kotlarsky, J., & Willcocks, L. P. (2009). Managing globally distributed teams. In The Handbook of Global Outsourcing and Offshoring (pp. 124-141). Palgrave Macmillan, London.

Persson, J., & Mathiassen, L. (2009). A process for managing risks in distributed teams. Ieee Software, 27(1), 20-29.

PMP, K. B. H. (2011). The Enterprise Business Analyst: Developing Creative Solutions to Complex Business Problems. Berrett-Koehler Publishers.

Poliandri, V., Mattarelli, E., Bertolotti, F., Tagliaventi, M. R., & Grandi, A. (2014). The Effect of Consistency Between Leadership and Technology on Knowledge Integration in GDTs. In Information Systems, Management, Organization and Control (pp. 263-271). Springer, Cham.

Pozin, M. A., Nawi, M. M., Mydin, A. O., Riazi, S. M., & Imran, A. (2019). An ability of WhatsApp usage in Industrialised Building System (IBS) construction project.

Rabinovich, P., Kurochkin, I., & Zavedensky, K. (2017). Distributed computing systems as project learning environment for" Generation NET. In CEUR Workshop Proceedings (pp. 85-93).

Ramachandran, M., & Chaugule, V. (2017). Software Project Management as a Service (SPMaaS): Perspectives and Benefits. In Software Project Management for Distributed Computing (pp. 87-115). Springer, Cham.

Sever, A. (2019). Modeling distributed agile software development utilizing cloud computing: A holistic framework. Current Journal of Applied Science and Technology, 1-12.

Shastri, Y., Hoda, R., & Amor, R. (2016, December). Does the "Project Manager" Still Exist in Agile Software Development Projects? In 2016 23rd Asia-Pacific Software Engineering Conference (APSEC) (pp. 57-64). IEEE.

Shuman, J., & Twombly, J. (2008). Innovation and Growth Through Collaborative Networks.

Smith, J. L., Bohner, S. A., & McCrickard, D. S. (2005, April). Toward introducing notification technology into distributed project teams. In 12th IEEE International Conference and Workshops on the Engineering of Computer-Based Systems (ECBS'05) (pp. 349-356). IEEE.

Smith, J. L., Bohner, S. A., & McCrickard, D. S. (2005, March). Project management for the 21st century: supporting collaborative design through risk analysis. In Proceedings of the 43rd annual Southeast regional conference-Volume 2 (pp. 300-305).

Stasser, G., & Augustinova, M. (2007). Social engineering in distributed decision-making teams: some implications for leadership at a distance. Leadership at a Distance: Research in Technologically-Supported Work, 151.

Stojanov, I. (2015). Scaling Agile using Scaled Agile Framework.

Svorstøl, S. O. (2017). Tailoring Agile Methods for Large Projects-A Case Study of a Large Agile Project (Master's thesis, NTNU).

Thilmany, J. (2011). Project+ lifecycle together. Mechanical Engineering, 133(02), 36-37.

Thissen, M. R., Myers, S. K., Sikes, R. N., Robinson, J. P., & Grouverman, V. (2011). Globalization of Software Development Teams. The Systemic Dimension of Globalization, 27.

Trendowicz, A., & Jeffery, R. (2014). Common Factors Influencing Software Project Effort. In Software Project Effort Estimation (pp. 47-80). Springer, Cham.

True, C. A. (2019). Distributed Team E-leadership: A Phenomenological Inquiry into Subordinate Perceptions of Career Development (Doctoral dissertation).

van Fenema, P. C., Oshri, I., & Kotlarsky, J. (2010). Management of Distributed Project Teams in Networks. In Networking and Telecommunications: Concepts, Methodologies, Tools, and Applications (pp. 1337-1345). IGI Global.

Wong, S. I., Giessner, S. R., Berntzen, M. N., & Warner-Søderholm, G. (2019, July). When Feeling Isolated Working in Distributed Teams: Its Antecedents and Consequences. In Academy of Management Proceedings (Vol. 2019, No. 1, p. 10201). Briarcliff Manor, NY 10510: Academy of Management.

Young, W. H., & Young, B. G. (2011). New Approaches Needed to Support the Distributed Environment. In Distributed Team Collaboration in Organizations: Emerging Tools and Practices (pp. 251-263). IGI Global.

Zhang, G. (2016). Making Sense of Conflict in Distributed Teams: A Design Science Approach.

Financial Drivers of Binding Dispute Resolution in Construction Firms: A Panel Data Investigation from India

Murali JAGANNATHAN[1], Harish Kumar SINGLA[2] and Venkata Santosh Kumar DELHI[3]
National Institute of Construction Management and Research; email: avemurali@gmail.com [1]
National Institute of Construction Management and Research; email: hsingla25@gmail.com[2]
Indian Institute of Technology Bombay; email: venkatad@iitb.ac.in[3]

ABSTRACT

Resolution of disputes through binding means such as arbitration or litigation is a practice that continues to be adopted by the firms involved in construction disputes. The choice to resolve disputes through binding means (which tend to get adversarial), notwithstanding the fact that there are multiple means to resolve complex disputes through amicable means, is a phenomenon that needs a deeper understanding of firm dynamics that lead to litigious behaviour. As a step in this direction, the authors in this paper attempt to explore the financial statements-linked factors influencing the 'legal charges' (LC) incurred by construction firms in understanding the rationale that drives them to switch to the binding mode of dispute resolution. The LC incurred by a construction firm indicates the expenditure towards fulfilling legal obligations undertaken as a result of business operations. On performing a panel data regression on a dataset sourced from the Centre for Monitoring Indian Economy - Prowess, India, containing LC expenditures of 198 Indian construction firms (dominated by private firms) from 2011 to 2018, it was observed that LC is positively impacted by the firm's receivables and payables whereas negatively affected by the firm's profit after tax (PAT) and more interestingly, LC is free from the effects of a firm's size. Although the 'legal fee', apparently, is a small figure (around one percent of the firm revenue), its magnitude and trend represent the rationale behind the choice made by the industry stakeholders and the findings indicate a significant influence of financial parameters on the legal vulnerability of a construction firm.

KEYWORDS:

Arbitration, Litigation, Finance, Construction, Dispute

INTRODUCTION

A recent newspaper article published in India noted that there are a total of 740 cases of arbitration arising from 426 Indian highway projects as on March 2018 with a total worth of

United States $ (USD) 14 billion (D. Dash, 2019). More worrisome statistics is that in some of the projects, the value of claims is more than 10 times the project cost envisaged originally. It is also observed that in many cases, the arbitration awards are challenged in the courts (CCEA, 2016; D. Dash, 2019). In yet another study in a general context, a positive relationship is observed between growing rates of literacy and per capita income and the number of cases filed in the court (NCMS, 2012) indicating that with increasing awareness and financial accessibility, there is a tendency to explore the judicial route to resolve disputes. At the firm level, it was observed from the database of Centre for Monitoring Indian Economy (CMIE) that the legal expenses of construction firms, both private and public, were steadily increasing over the years (Ministry of Finance, 2018). Taking stock of the scenario, it is evident that Indian construction sector is inching closer towards binding dispute resolution methods, at least, in the public construction segment. While the constitution of India guarantees access to the legal system to every citizen of the country, the judicial processes need to be evaluated from the context of construction projects. Keeping in view the procedural delays in the court processes (Iyer, Chaphalkar, & Joshi, 2008; Sinha & Jha, 2020; WorldBank, 2018) and relatively short spans of the execution phase of a project execution, the legal route may not yield workable solutions in a time-bound manner. The issue becomes even more serious if projects are stalled by the courts of law (Ministry of Finance, 2018) and parties tend to turn adversarial in the process. The Government of India has implemented enacted the Indian Arbitration and Conciliation Act, 1996 with a view to encourage parties to adopt binding arbitration procedures within a definite time-frame. While arbitration is regarded effective than litigation (Chaphalkar, Iyer, & Patil, 2015; Sinha & Jha, 2020), arbitration process continue to suffer from procedural delays (Moza & Paul, 2016) and the awards are susceptible to challenge in the higher courts of law (CCEA, 2016; D. Dash, 2019). Considering the adversarial environment and the delays that are characteristic of binding means of dispute resolution (Moza & Paul, 2016), there is an emphasis world over to adopt amicable dispute resolution methods like mediation and conciliation (Elziny et al. 2016; Lee et al. 2018; Xu and Cheung 2016). However, on contrary, there is still a tendency for the parties to knock at the doors of arbitrators and courts to obtain a binding judgment (Armstrong, 2008; Iyer et al., 2008; Jagannathan & Delhi, 2020; Kinhal, Gupta, & Chandrashekaran, 2018; Liu, Miao, & Liu, 2020; Sinha & Jha, 2020; Subramanyan, Sawant, & Bhatt, 2012). In the recent past, a considerable interest seems to have slowly picked up amongst researchers to study the reasons behind the litigious behaviour amongst parties to a construction contract. This research is further a step in the direction of finding out the underlying reasons that may drive a firm to resort to arbitration or litigation to resolve disputes despite the availability of amicable means of dispute resolution.

The decision to approach an arbitrator or a court is an approach that is driven by certain underlying factors. Jagannathan and Delhi (2020), through a review of literature, have noted that the disputes are influenced by ‘people factors’ (Jelodar, Yiu, & Wilkinson, 2016; Marathe, Hashem M. Mehany, Senior, & Strong, 2017) apart from factors linked to ‘contract’ (Chong & Zin, 2010; Doloi, 2011; Jagannathan & Delhi, 2019). However, there seems to be a gap because the existing construction management research focuses primarily on relationship and process angles from the perspective of dispute causation, leaving the influence of financial parameters (profit, firm size, receivables and payables) untouched. Motivated by the fact that almost all business decisions are centered on financial considerations (Friedman, 2007), and the decision to arbitrate or litigate being no exemption, the authors, in this paper, explore yet another angle, namely the financial statements-linked drivers that may prompt either (or both) party to resort to binding means. The framework adopted in the present study is shown in Figure 1.

To enable this study, it is first important to identify a parameter in a firm’s balance sheet or income statement that can aptly represent the firm’s decision to explore the arbitration or the legal route. As per the definition provided by the Centre for Monitoring Indian Economy (CMIE), the expenses incurred by a firm towards ‘fees paid to legal advisors, law firms, etc. for providing legal advice and related services (sic.)’ are reported as ‘legal charges’ in the income statement of the firms. Therefore, the expenses spent under this accounting head are an indication of proclivity of the firms towards binding methods of dispute resolution. However, the authors do not discount the probability of firms, in some cases, being dragged into legal disputes by the opposite party who is inclined to settle the dispute through binding means. Therefore, a firm’s decision to explore the arbitration or the legal route, termed as ‘litigation proneness’ may either be proactive or reactive. In either case, the expenses incurred in either filing or defending a case in arbitration or litigation, falls under the head ‘legal charges’, thereby making it a variable that can measure the litigation proneness of a given firm. A deeper understanding of the patterns of ‘legal charges’ in terms of evaluating its sensitivity towards certain key parameters of balance sheet and the income statement of firms may hold a key to understand the litigation proneness of firms.

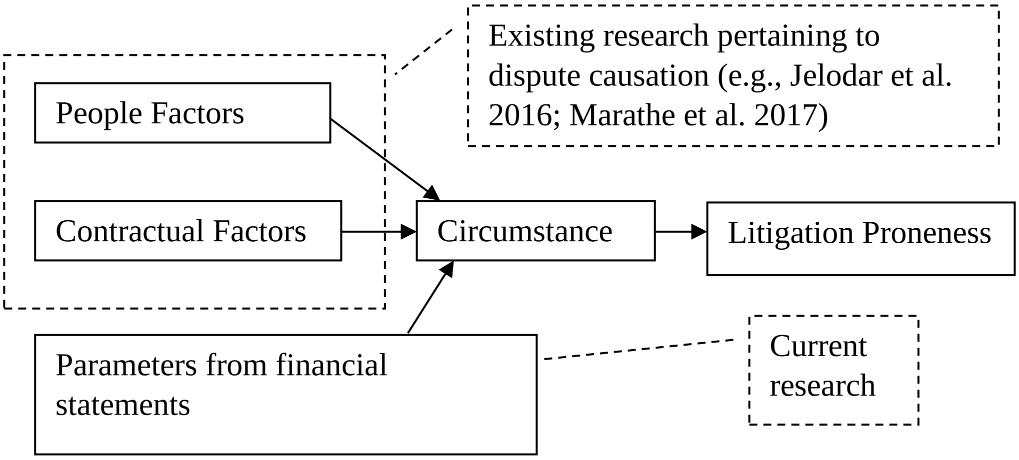


Figure 1: The framework

The hypotheses are framed and tested with the data from 198 firms in the domain of construction and infrastructure activities. The data is sourced from Prowess, a financial database maintained by Centre for Monitoring Indian Economy, India with a focus on Indian companies. The database is widely used by various government and private agencies for financial analysis and reports as well as by academicians and researchers for their scholarly work. Notably, the database is referred by the Ministry of Economic Affairs in its report on the Economic Survey of India 2017-18 as well (Ministry of Finance, 2018).

LITERATURE REVIEW

Studies on prediction of one parameter (like dividend payout, profitability, revenue, among others) using other parameters in either the balance sheet or the income statement is a practice widely followed amongst researchers across various domains (Kachlami & Yazfandar, 2016; Labhane & Mahakud, 2016; H. K. Singla, 2019; Zouaghi, Sanchez-Garcia, & Hirsch, 2017). Specific to construction industry, works by Singla and Samanta (2019) and Alaka et al. (2017) discuss on finding the determining of dividend payouts and insolvency prediction using financial parameters as dependent variables. With reference to litigation risk, studies are observed in the area linking insider trading and litigation risk (Han, Jagannathan, & Krishnamurthy, 2014), Initial Public Offer (IPO) and litigation risks (Lowry & Shu, 2002), litigation and corporate risk-taking (Liu et al., 2020), audit fee and quality and litigation (Venkataraman, Weber, & Willenborg, 2008) among others. With reference to construction context, the dynamics of legal intervention, adjudication and insolvency of construction firms, in the context of the United Kingdom (UK) construction industry, was discussed by Ndekugri and Russell (2005). However, exploration of legal charges as a function of balance sheet and income statement parameters with specific reference to construction sector is unexplored in the literature. One reason for the lack of focus in understanding the patterns behind the legal charges may be that the magnitude of legal charges constitutes a very small portion of the total expense and may not yield a significant material impact on the extent of profits. In fact, while analyzing the data of the 198 firms, it was found that based on the data from 2011-2018, the legal expenses as a percentage of revenue (or in other words, sales) of Indian construction and infrastructure firms hovers in the range of 0.8% to 1.15%. However, legal charges cannot be brushed aside based on its face value. As defined earlier, the expenses that legal charges represent belong to the charges paid to legal advisors and law firms, among others, that are rendering related services. The law firms or the legal consultants are employed by firms to evaluate the viability of resolving disputes through binding means like arbitration or litigation and higher the legal expenses, indicating greater push by the firms to evaluate dispute resolution through arbitrations and/or courts. In the event of adversarial behaviour by the parties involved in the dispute or in cases which may need legal precedence, consulting lawyers or legal experts are highly unlikely to recommend amicable means of settlement (Brooker, 1999). Consideration to adopt arbitration or litigation notwithstanding the availability of amicable resolution methods (like mediation or conciliation) indicates either lack of trust on the amicable non-binding means or failure to resolve the matters using amicable or non-binding means. A study by Government of India indicates the increasing trend of government agencies approaching courts to resolve disputes in spite of arbitration judgments in hand (CCEA, 2016; NCMS, 2012). Inclination towards dispute resolution through litigation is a practice that is not considered to be beneficial in maintaining working relationship amongst organizations, especially in construction (Jelodar et al., 2016). Therefore, LC is a small number, but representing a greater problem in the industry making it imperative to study its patterns and dependence on the other financial parameters.

IDENTIFICATION OF FACTORS INFLUENCING LC

Owing to the tight competitions in the market and bidder selection criteria which is usually based on 'lowest price' criteria, construction firms tend to submit tenders with margins that may be quite conservative (Fong & Choi, 2000; Hatush & Skitmore, 1997; Mahamid, Bruland, & Dmaidi, 2012; Rosenfeld, 2014). In addition, the project uncertainties that may strike during the execution of the projects adds further pressure on the firms to protect their existing margins

(D. W. M. Chan & Kumaraswamy, 1997; Diekmann & Girard, 1995; Okada, Simons, & Sattineni, 2017; Shen et al., 2017). Under such circumstances, firms resort to claims as one of the means to secure their profit margins (Ho & Liu, 2004; Ioannou & Awwad, 2010; Shrestha, 2014). In order to submit and sustain claims and ensure profitability, the firms may have to spend towards sailing through the dispute resolution ladder which ultimately culminates with arbitration and in the event of its failure, it will be litigation. The expenses incurred through the stages of arbitration and litigation is, as discussed before, represented by LC. From a study of Chinese firms, Liu et al. (2020) have observed that firms tend to improvise their risk-taking behaviour in future, based on the experiences they accumulate from litigation. Increased risk taking has a direct impact on firm's profit. Therefore, LC is hypothesized to be sensitive to the profits (represented by the term profit after tax or PAT) reported by the firms. At the same time, profits can also be enhanced by increased revenue which may result in increased receivables and payables. This happens because to boost revenue, credit conditions may be relaxed that gives rise to receivables and simultaneously to boost production, more raw materials are needed which can be procured at credit, ultimately giving rise to payables. It has also been observed that in many companies struggle to liquidate the claims stuck with the government agencies for years (D. K. Dash, 2019). An increase in the claims that are due for settlement indicates mounting pressure on either receivables or payables, depending on the viewpoints chosen (whether claimant or respondent). The firms' receivables and payables, thereby are considered in the current analysis.

Therefore, profits, revenue, receivables and payables are likely to have an impact on legal charges. In other words, the parameters chosen represent the different dimensions of the industry. Profits (in this study, the income statement parameter 'profit after tax' or PAT is used) represent the efficiency in conversion of expenses to revenues. Revenue (in other words sales) represents growth in business operations. The receivables and payables represent the firms' financial relationship with the clients and subcontractors respectively. In this study, rather than the usual practice of estimating project profitability and revenue, among others, financial parameters are used to estimate legal charges thereby exploring a completely new dimension.

In the next section, a description is given on the methodology adopted to test the hypothesis and results of the test is then presented. Subsequently, the results are interpreted in the discussions section and finally, conclusion is presented.

METHODOLOGY

Data of more than 2000 listed and unlisted construction firms for a period of 8 years (2011-2018) is collected using the Center for Monitoring Indian Economy (CMIE) data base. The period of eight years is chosen carefully so that different business cycles are covered and to ensure complete data availability. The firms for which the data for all years was not available in full were removed, and a final panel of 198 construction firms was created. Amongst the firms considered for analysis, 90 firms were client/developer firms and the rest were contractor/supplier firms from across a variety of sectors like real estate, infrastructure and energy. The study variables selected were legal charges, profit after tax (PAT), receivables of a firm, payables of a firm, and revenue, based on literature. At the same time, an additional variable i.e. 'Total assets' of a firm is also considered in the study to observe the impact of firm size on legal charges. A total asset is a measure of firm size used in construction specific earlier research (H. K. Singla, 2019; H. Singla & Samanta, 2019).

A regression model based on the study variables was developed. Panel data analysis is best suited for this type of study as it takes into account both the firm-specific (cross-section) factors and the time specific factors while determining the dependent variable. In other words, panel data consists of a group of cross-sectional units which are observed across the period considered (Hill, Griffiths, & Lim, 2007). In this case, 198 companies are spread over eight years. The panel regression equation is represented by the double subscript attached to each variable and a typical representation is shown in equation 1 (Amidu & Abor, 2006; H. Singla & Samanta, 2019).

$$Y_{i,t}=\alpha_i+\beta X_{i,t}+e_{i,t} \quad (1)$$

In the equation 1 above, 'i' denotes the cross-sectional dimension and 't' represents the time-series dimension. $Y_{i,t}$ is dependent variable, namely the legal charges (LC), α_i is constant over time and specific to an individual cross section firm 'I'. β is the coefficient of independent variable and X is the independent variable. e is an error or residual. The full model is represented by the equation 2.

$$LC_{i,t}= \beta_0+ \beta_1 PAT_{i,t}+ \beta_2 REC_{i,t}+ \beta_3 PAY_{i,t}+ \beta_4 SALES_{i,t}+ \beta_5 TA_{i,t}+ e_{i,t} \quad (2)$$

where LC is legal charges, PAT is profit after tax, REC is receivables, PAY is payables, SALES is net revenue and TA is total assets.

The panel so formed is strongly balanced and is analyzed using the statistical tool STATA IC/13. The panel data may suffer from the issues of multicollinearity, stationarity and heteroscedasticity. Multicollinearity describes the situation where two or more predictor variables in a statistical model are linearly related. On the preliminary analysis of variance inflation factor (VIF), it indicated that the data in present study suffers from the problem of multicollinearity. The variables that had VIF value above 10 have been dropped in order to resolve the problem as recommended by Hair et al. (2010). Hence SALES variable, representing revenue, was removed and finally the study retained four dependent variables as shown in Table 1.

Table 1: Multicollinearity (Source: Authors compilation)

Variables	VIF-First Round	VIF-Second Round
SALES	12.17	Dropped
REC	8.32	5.98
PAY	7.79	6.84
TA	3.3	1.73
PAT	1.07	1.04

Stationarity is a situation when the statistical properties of a process generating a time series do not change over time. Hence, the data was tested for stationarity using the Levin–Lin–Chu test. The results are presented in Table 2.

Table 2: Levin-Lin Chu Unit root test (Source: Authors compilation)

Variables	Statistic	p-value
LC	-27.1145	0.000**
REC	-32.8192	0.000**
PAY	-22.4296	0.000**
TA	-34.8517	0.000**
PAT	-25.8922	0.000**

**Significant at 1%

The null hypothesis of the unit root test is that 'Panels contain unit roots' and the alternative hypothesis is that 'Panels are stationary'. As observed in the table 2, the p value is less than 0.05, the null hypothesis is rejected, and the panels can be considered as stationary.

The panel data may also suffer from the problem of heteroscedasticity. Heteroscedasticity is a situation, where the residuals are not normally distributed. Breusch-Pagan/Cook-Weisberg test for heteroskedasticity was used to examine if our data suffers from this problem. The chi square value is 15746.32 (Prob > chi2 = 0.000), hence the null hypothesis of 'constant variance' is rejected, indicating that the data suffers from the problem of heteroscedasticity. To remove the effect of heteroscedasticity on the data, the robust estimation of fixed effect and random effect model was performed (H. Singla & Samanta, 2019; Yusof & Ismail, 2016). The choice of fixed effect and random effect model is based on observations from the existing research articles (Green & Tukey, 1960; Leeuw & Kreft, 1998; Nwakuya & Ijomah, 2017; H. Singla & Samanta, 2019). Finally, the model to be tested is shown in equation 3.

$$LC_{i,t} = \beta_0 + \beta_1 PAT_{i,t} + \beta_2 REC_{i,t} + \beta_3 PAY_{i,t} + \beta_4 TA_{i,t} + e_{i,t} \quad (3)$$

The following hypothesis are framed and tested based on the equation 3.

H1: Legal Charges incurred by a construction firm is inversely related to the profit after tax (PAT) of the firm.

H2: Legal Charges incurred by a construction firm is positively related to the extent of RECEIVABLES recorded in the firm's balance sheet.

H3: Legal Charges incurred by a construction firm is positively related to the extent of PAYABLES recorded in the firm's balance sheet.

H4: Legal Charges incurred by a construction firm is positively related to the extent of TOTAL ASSETS (Size) recorded in the firm's balance sheet.

RESULTS

The data is initially analyzed using descriptive statistics. The results are presented in Table 3.

Table 3: Descriptive Statistics (Figures in Millions of Indian Rupees) Source: Authors compilation

Note: All figures in Million Indian Rupees

Measure	Year	LC	PAT	TA	REC	PAY
Mean	2011	70.07	402.15	26330.14	2199.73	2081.89
SD		202.52	1701.81	84998.32	3955.96	4635.03
Skewness		6.31	1.97	7.08	2.91	4.46
Mean	2012	75.92	354.73	29682.92	2241.63	2319.44
SD		219.84	1388.75	96435.82	3990.75	5634.24
Skewness		6.12	2.56	7.28	2.99	5.88
Mean	2013	91.66	133.11	32990.90	2314.04	2595.19
SD		326.91	1681.42	102763.00	4108.57	5807.32
Skewness		8.39	-1.03	7.26	2.96	5.60
Mean	2014	121.76	-151.65	38046.12	2649.04	2949.16
SD		513.95	2911.34	112509.40	5904.58	7254.01
Skewness		8.35	-6.66	6.66	5.77	5.32
Mean	2015	109.02	-238.34	40164.96	3178.12	2976.32
SD		457.04	3405.08	109327.90	7743.38	7466.59
Skewness		9.56	-7.00	6.06	6.48	6.37
Mean	2016	128.23	-411.27	37970.67	3199.37	3135.82
SD		562.42	6903.61	90701.64	8612.10	8814.43
Skewness		10.04	-12.73	4.84	8.06	7.99
Mean	2017	141.69	-30.80	39223.04	3674.71	3836.04
SD		635.15	4425.31	91397.08	10947.69	12134.84
Skewness		10.63	2.97	4.64	9.17	9.79
Mean	2018	141.26	-183.05	42628.17	3667.45	4107.14
SD		624.63	4220.24	98517.50	10776.26	12474.09
Skewness		11.02	-4.45	4.53	9.39	9.13
Mean	TOTAL	109.95	-15.64	35879.62	2890.51	3000.13
SD		471.28	3756.07	98652.84	7534.17	8490.78
Skewness		11.55	-11.16	6.17	9.95	9.88

We can observe that legal changes are continually increasing over a period with exception to year 2015 with increased amount of variability. On the contrary, profit after tax is on the decline. Total assets, receivables and payables are increasing on a yearly basis. The results of panel regression are presented in Table 4.

Table 4 – Results of Panel Regression (Source: Authors compilation)

Variable	**Random-effects GLS regression**			**Fixed-effects GLS regression**		
LC-Dependent Variable	Coef.	Robust SE	P>z	Coef.	Robust SE	P>z
PAT	-0.008	0.002	0.001**	-0.008	0.003	0.002**
TA	0.001	0.001	0.509	0.000	0.001	0.732
REC	0.027	0.010	0.007**	0.027	0.010	0.007**
PAY	0.024	0.007	0.001**	0.026	0.007	0.000**
Constant	-60.222	24.514	0.014*	-58.306	33.829	0.086
R Square	0.743			0.737		
Wald chi square (4)	59.940					
Prob > chi square	0.000					
F (4, 197)				15.420		
Prob>F				0.000		

**Significant at 1%   *Significant at 5%

In the study, the random effects generalized least square (GLS) regression and the fixed effects GLS regression was performed. The results of panel regression show that PAT is negatively affecting the legal changes, whereas receivables and payables are positively affecting the legal charges. The results indicate that firms with higher profitability spend less amount of money on legal charges, whereas firms with lesser profitability spend more amounts on legal charges. Similarly, the firms with higher amount of current assets and current liabilities in terms of both receivables and payables are likely to spend more amount of money on legal charges. Hence, the hypothesis H1, H2 and H3 are accepted and H4 is rejected. The hypothesis, that PAT affects the legal charges inversely and receivables and payables affects the legal charges further strengthen the argument presented in the paper. At the same time, the study results show that legal charges are not influenced by the size of the firm. The intercept is negatively significant in the case of fixed effect model indicating that there are some firm level factors that are playing crucial role in determining the legal charges. The model, in both cases (random-effects GLS regression and fixed-effects GLS regression), have indicated a R^2 in the range of 73% to 75%, indicating that there is a good fit between the dependent and the independent variables. Both the models are good fit based on the model fit criteria i.e. Wald chi square and F.

DISCUSSION

The results have shown that the legal charges are negatively related to PAT. This means that the legal charges increase with the decrease in PAT and vice versa. One straightforward theoretical argument on the results could be that since legal charges form a part of 'expenses' it is bound to have a negative relationship with PAT. While this may be true to some extent, but there are reasons to believe that it may not completely explain the behaviour. Significantly, since, the legal charges are only 1.2% of the total expenses of 198 construction firms examined in this study, it is not a substantial amount that can cause a significant negative influence on PAT of the firm and thereby the phenomenon needed further probing.

In fact, in the event of submitted claims getting rejected by the respondent party (usually the employer), the claimant (usually the contractor) has two options, one, non-binding means like simple negotiation, mediation or conciliation and two, binding means such as arbitration and litigation. A third option – 'do-nothing' – does not exist here because the firms have to fall back on their claims to sustain financially. The observation made in this study rather indicates that when profits of the company tend to get lower, firms, driven by the need to secure the claim amounts, tend to move towards binding means to resolve disputes rather than negotiation or mediation (where a firm may have to give-up some claims for the sake of settling the matter on amicable means). However, that does not imply that if project profits are getting affected, all cases of claims would land up with the arbitrator or the courts, but it only means that the consultation of the firms with the legal consultants and lawyers increase to decide on the future course of rejected claims and secure their original profits (or even more!) that they intended to make from the project execution. In simpler words, when the project profits go down, firms tend to move towards binding means to resolve disputes rather than non-binding means, driven by the simple logic that is in agreement with the findings of the previous researchers that binding methods of dispute resolution, though time-consuming, provide better enforceability (Brooker & Lavers, 1997; E. H. Chan, Suen, & Chan, 2006) and hence better financial security in a stressful situation. The observation from this research is quite contrary to the observation in the context of Chinese firms (Liu et al., 2020) wherein (in case of Chinese firms) it was observed that litigious behaviour aides risk-taking attitude of firms, meaning, litigation drives profits in the context Chinese firms rather that profits driving litigious behaviour as found in context of Indian construction firms. During a discussion with an expert in the domain of construction contracts, we are informed that a well-known construction firm in India has now resorted to 'monetization of claims' wherein, the firm, reeling under a troubled financial condition, sold its claims that are stuck in various stages of arbitration and litigation, to another firm, which would take up those cases and further arbitrate or litigate the matter. In yet another case, it is observed that the concept of 'funding litigation claims' to help companies stuck in financial muddle due to unsettled claims, well-practiced in Australia, is slowly evolving in Indian markets (Gaur & Vyas, 2019).

Increasing receivables tend to impact the cashflows in a firm. Specifically, with reference to construction firms, a healthy cashflow is crucial to run the projects in a smooth manner. Therefore, when receivables tend to increase, firms may look for legal options to liquidate this asset thereby increasing the legal charges spent by the firm. This observation is in agreement with the increasing trends of financially stressed firms adopting binding means to liquidate their claims stuck in various stages of arbitration and litigation (D. Dash, 2019; D. K. Dash, 2019). Similarly, the relationship between legal charges and payables must be viewed from the same lens as that of the relationship between legal charges and receivables, with an exception that a firm with increasing amounts of payables (which are beyond the contractual payment date), are under increased risk of being challenged by the downstream firms affected by the non-payment of dues. In such cases too, the firm (whose payables are increasing) must consult legal experts to defend in the event of affected party chooses to explore legal options to secure their dues. The construction sector in India, similar to the observation across the globe (Jefferies, Brewer, & Gajendran, 2014), is highly fragmented with many small firms and few very large firms. Hence, total assets as a measure of size was introduced as a variable in the model. The result suggests that legal charges are free from the size effect.

The observation from the study does not indicate that the litigation proneness is completely explainable by the financial parameters (R square=75%), but rather indicates that the decision to arbitrate or litigate may be influenced by certain patterns observed in the financial statements of the firm. Off late, limited empirical evidence has been provided by Jagannathan and Delhi (2019) that a decision to litigate is influenced, partly, by contractual factors. On the other hand, (Armstrong, 2008; Jagannathan & Delhi, 2020; Jelodar et al., 2016) have argued that litigious behaviour is also influenced by people factors. The construction firms considered in this study are both contractor and client firms and the study finds that legal decisions in both client and contractor firms are a function of its financial performance. From the managerial application view point, this study can be helpful in making a futuristic evaluation of the litigation proneness of the bidder organizations through evaluation of their financial statements in the bidder's short-listing stage. A similar conclusion, however limited to evaluation of bidder's claim management system, was emphasized by (Vidogah & Ndekugri, 1998). In most of the prequalification questionnaires, questions are asked the bidders on their previous arbitration or litigation history rather than evaluating future litigation proneness of the organization. The observations from the research may serve useful to the owner organizations, especially to evaluate the bidder organizations in the prequalification or the technical evaluation stage, to make informed decisions on the potential of the bidder organizations to enter into binding means of dispute resolution like arbitration or litigation just by analyzing their financial statements (this input is often a part of the prequalification or technical evaluation submittals required to be submitted by the bidders). The same logic can be extended to contractor firms during their bid-no-bid analysis to evaluate the litigation proneness of their potential client organization based on their balance sheets and other account statements.

CONCLUSION

The construction industry is fully aware that arbitrations and litigation tend to be time-consuming process. Notwithstanding the availability of amicable means of settlement, dispute resolution through such binding means does not cease to exist as an option to resolve dispute amongst parties. Considering 198 construction firms from India, this study attempts to understand the influence of financial parameters on the legal expenses incurred by a firm. While Legal Charges is found to have an inverse relationship with the PAT of the firm, there seems to be a positive relationship between legal charges and receivables and payables of the firm. The study, by no means, is exhaustive and a vast scope is available to explore further in the context of similar financial data from construction industry in other countries. Comparative analysis of the construction sector litigation proneness with that of the sectors like manufacturing and information technology, among others, can be performed to develop more insights in this domain. Nevertheless, the study opens up a new discussion on the legal vulnerability of a construction organization from the accounting viewpoint.

REFERENCES

Alaka, H. A., Oyedele, L. O., Owolabi, H. A., Oyedele, A. A., & Akinade, O. O. (2017). Critical factors for insolvency prediction: towards a theoretical model for the construction industry. *International Journal of Construction Management*, *17*(1), 25–49.

Amidu, M., & Abor, J. (2006). Determinants of dividend payout ratios in Ghana. *Journal of*

Risk Finance, *7*(2), 136–145.

Armstrong, P. M. (2008). Why We Still Litigate. *Pepperdine Dispute Resolution Law Journal*, *8*(3), 379–384. Retrieved from https://digitalcommons.pepperdine.edu/drlj/vol8/iss3/3

Brooker, P. (1999). Survey of construction lawyers' attitudes and practice in the use of ADR in contractors's disputes. *Consruction Management and Economics*, *17*(6), 757–765.

Brooker, P., & Lavers, A. (1997). Perceptions of alternative dispute resolution as constraints upon its use in the UK construction industry. *Construction Management and Economics*, *15*(6), 519–526.

CCEA. (2016, August 31). Cabinet approves Initiatives to revive the Construction Sector Cabinet approves Initiatives to revive the Construction Sector. *Press Information Bureau, Government of India*, pp. 1–2. Retrieved from http://pib.nic.in/newsite/PrintRelease.aspx?relid=149388

Chan, D. W. M., & Kumaraswamy, M. M. (1997). A comparative study of causes of time overruns in Hong Kong construction projects. *International Journal of Project Management*, *15*(1), 55–63. https://doi.org/10.1016/S0263-7863(96)00039-7

Chan, E. H., Suen, H. C., & Chan, C. K. (2006). MAUT-Based Dispute Resolution Selection Model Prototype for International Construction Projects. *Journal of Construction Engineering and Management*, *132*(5), 444–451. https://doi.org/10.1061/(ASCE)0733-9364(2006)132:5(444)

Chaphalkar, N. B., Iyer, K. C., & Patil, S. K. (2015). Prediction of outcome of construction dispute claims using multilayer perceptron neural network model. *International Journal of Project Management*, *33*(8), 1827–1835. https://doi.org/10.1016/j.ijproman.2015.09.002

Chong, H. Y., & Zin, R. M. (2010). A case study into the language structure of construction standard form in Malaysia. *International Journal of Project Management*, *28*(6), 601–608. https://doi.org/10.1016/j.ijproman.2009.09.008

Dash, D. (2019, October 11). Arbitration Claims of Rs18k Cr by builders stump NHAI. *Bennett, Coleman & Co.Ltd.*

Dash, D. K. (2019, September 4). New rules to end disputes with infrastructure companies. *Bennett, Coleman & Co.Ltd.*

Diekmann, J. E., & Girard, M. J. (1995). Are Contract Disputes Predictable? *Journal of Construction Engineering and Management*, *121*(4), 355–363. https://doi.org/10.1061/(ASCE)0733-9364(1995)121:4(355)

Doloi, H. K. (2011). Understanding stakeholders' perspective of cost estimation in project management. *International Journal of Project Management*, *29*(5), 622–636. https://doi.org/10.1016/j.ijproman.2010.06.001

Elziny, A. A., Mohamadien, M. A., Ibrahim, H. M., & Abdel Fattah, M. K. (2016). An expert system to manage dispute resolutions in construction projects in Egypt. *Ain Shams Engineering Journal*, *7*(1), 57–71. https://doi.org/10.1016/j.asej.2015.05.002

Fong, P. S. W., & Choi, S. K. Y. (2000). Final contractor selection using the analytical hierarchy process. *Construction Management and Economics*, *18*(5), 547–557.

https://doi.org/10.1080/014461900407356

Friedman, M. (2007). The Social Responsibility of Business Is to Increase Its Profits. In W. C. Zimmerli, M. Holzinger, & K. Richter (Eds.), *Corporate Ethics and Governance* (pp. 173–178). Berlin, Hiedelberg.

Gaur, V., & Vyas, M. (2019). Punj Lloyd Wins Arbitration Award of INR 50 cr in ONGC Case. *Bennett, Coleman & Co.Ltd.*, p. 6.

Green, B. F., & Tukey, J. W. (1960). Complex Analysis of variance: general problems. *Psychometrika*, *25*, 127–152.

Hair, J., Black, W., Babin, B. Y. A., Aanderson, R., & Tatham, R. (2010). *Multivariate Data Analysis: A Global Perspective*. New Jersey, NJ: Pearson Prentice Hall.

Han, S., Jagannathan, M., & Krishnamurthy, S. (2014). *When does insider selling increase litigation risk?*

Hatush, Z., & Skitmore, M. (1997). Criteria for contractor selection. *Construction Management and Economics*, *15*(1), 19–38. https://doi.org/10.1080/014461997373088

Hill, R. C., Griffiths, W. E., & Lim, G. C. (2007). *Principles of Econometrics* (5th ed.). New Jersey: John Wiley & Sons, Inc.

Ho, S. P., & Liu, L. Y. (2004). Analytical Model for Analyzing Construction Claims and Opportunistic Bidding. *Journal of Construction Engineering and Management*, *130*(1), 94–104. https://doi.org/10.1061/(asce)0733-9364(2004)130:1(94)

Ioannou, P. G., & Awwad, R. E. (2010). Below-Average Bidding Method. *Journal of Construction Engineering and Management*, *136*(9), 936–946. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000202

Iyer, K. C., Chaphalkar, N. B., & Joshi, G. A. (2008). Understanding time delay disputes in construction contracts. *International Journal of Project Management*, *26*(2), 174–184. https://doi.org/10.1016/j.ijproman.2007.05.002

Jagannathan, M., & Delhi, V. S. K. (2019). Litigation Proneness of Dispute Resolution Clauses in Construction Contracts. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *11*(3), 1–8.

Jagannathan, M., & Delhi, V. S. K. (2020). Litigation in Construction Contracts: Literature Reveiw. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *12*(1), 1–9. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000342

Jefferies, M., Brewer, G. J., & Gajendran, T. (2014). Using a case study approach to identify critical success factors for alliance contracting. *Engineering, Construction and Architectural Management*, *21*(5), 465–480. https://doi.org/10.1108/ECAM-01-2012-0007

Jelodar, M. B., Yiu, T. W., & Wilkinson, S. (2016). Dispute Manifestation and Relationship Quality in Practice. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *8*(1), 1–10. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000171.

Kachlami, H., & Yazfandar, D. (2016). Determinants of SME growth: The influence of financing pattern. An empirical study based on Swedish Data. *Management Research Review*, *39*(9), 966–986.

Kinhal, D., Gupta, S., & Chandrashekaran, S. (2018). *Government Litigation: An Introduction*.

Labhane, N. B., & Mahakud, J. (2016). Determinants of dividend policy of indian companies: a panel data analysis. *Paradigm*, *201*(1), 36–55.

Lee, C. K., Yiu, T. W., & Cheung, S. O. (2018). Understanding Intention to Use Alternative Dispute Resolution in Construction Projects : Framework Based on Technology Acceptance Model. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *10*(1), 1–12. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000245.

Leeuw, J. D., & Kreft, I. G. G. (1998). *Introducing Multilevel Modelling*. SAGE Publications.

Liu, X., Miao, M., & Liu, R. (2020). Litigation and corporate risk taking: Evidence from Chinese listed firms. *International Review of Law & Economics*, *61*. https://doi.org/10.1016/j.irle.2019.105879

Lowry, M., & Shu, S. (2002). Litigation risk and IPO underpricing. *Journal of Financial Economics*, *65*, 309–335.

Mahamid, I., Bruland, A., & Dmaidi, N. (2012). Causes of delay in road construction projects. *Journal of Management in Engineering*, *28*(3), 300–310.

Marathe, A., Hashem M. Mehany, M. S., Senior, B., & Strong, K. (2017). Dispute Resolution and Contract Incentives: Perceptions of Project Stakeholders. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *9*(4), 1–10. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000243

Ministry of Finance. (2018). *Economic Survey of India*. New Delhi.

Moza, A., & Paul, V. K. (2016). Review of the Effectiveness of Arbitration. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *9*(1), 1–9. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000204.

NCMS. (2012). *Policy and Action Plan*. New Delhi.

Ndekugri, I., & Russell, V. (2005). Insolvency and resolution of construction contract disputes by adjudication in the UK construction industry. *Construction Management and Economics*, *23*(4), 399–408. https://doi.org/10.1080/0144619042000326747

Nwakuya, M. T., & Ijomah, M. A. (2017). Fixed effect versus random effects modelling in a panel data analysis; a consideration of economic and political indicators in six African countries. *International Journal of Statistics and Applications*, *7*(6), 275–279.

Okada, R. C., Simons, A. E., & Sattineni, A. (2017). Owner-requested Changes in the Design and Construction of Government Healthcare Facilities. *Procedia Engineering*, *196*(June), 592–606. https://doi.org/10.1016/j.proeng.2017.08.047

Rosenfeld, Y. (2014). Root-Cause Analysis of Construction-Cost Overruns. *Journal of Construction Engineering and Management*, *140*(1), 04013039-1–10. https://doi.org/10.1061/(ASCE)CO

Shen, W., Tang, W., Yu, W., Duffield, C. F., Hui, F. K. P., Wei, Y., & Fang, J. (2017). Causes of contractors' claims in international engineering-procurement-construction projects. *Journal of Civil Engineering and Management*, *23*(6), 727–739. https://doi.org/10.3846/13923730.2017.1281839

Shrestha, S. K. (2014). Average Bid Method – An Alternative to Low Bid Method in Public Sector Construction Procurement in Nepal Low Bid Method. *Journal of the Institute of Engineering*, *10*(1), 125–129. https://doi.org/10.3126/jie.v10i1.10888

Singla, H. K. (2019). A comparative analysis of long-term performance of construction and non-construction IPOs in India. *Engineering, Construction and Architectural Management*, *26*(10), 2447–2473. https://doi.org/10.1108/ECAM-01-2019-0009

Singla, H., & Samanta, P. (2019). Determinants of Dividend Payout of Construction Companies: A Panel Data Analysis. *Journal of Financial Management of Property and Construction*, *24*(1), 19–38.

Sinha, A. K., & Jha, K. N. (2020). Dispute Resolution and Litigation in PPP Road Projects: Evidence from Select Cases. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *12*(1), 1–11. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000336

Subramanyan, H., Sawant, P. H., & Bhatt, V. (2012). Construction Project Risk Assessment: Development of Model Based on Investigation of Opinion of Construction Project Experts from India. *Journal of Construction Engineering and Management*, *138*(3), 409–421.

Venkataraman, R., Weber, J. P., & Willenborg, M. (2008). Litigation Risk, Audit Quality, and Audit Fees: Evidence from Initial Public Offerings. *The Accounting Review*, *83*(5), 1315–1345.

Vidogah, W., & Ndekugri, I. (1998). Improving the management of claims on construction contracts: Consultant's perspective. *Construction Management and Economics*, Vol. 16, pp. 363–372. https://doi.org/10.1080/014461998372385

WorldBank. (2018). Ease of Doing Business in India. Retrieved October 1, 2018, from The World Bank Group website: http://www.doingbusiness.org/en/data/exploreeconomies/india#

Xu, Q., & Cheung, S. O. (2016). Influence of Confucianism and Taoism on Construction Dispute Handling Behaviors in China. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *8*(1), 1–11. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000166

Yusof, Y., & Ismail, S. (2016). Determinants of dividend policy of public listed companies in Malaysia. *Review of International Business and Strategy*, *26*(1), 88–99.

Zouaghi, F., Sanchez-Garcia, M., & Hirsch, S. (2017). What drives firm profitability? *Spanish Journal of Agricultural Research*, *15*(3), 1–15.

The Challenge of Megaprojects in Oil & Gas industry: A Report from the Field

G. UNNIKRISHNAN
Kuwait Oil Company, Kuwait

email: ukrishnan77@yahoo.com

ABSTRACT

World's appetite for oil continues unabated. The corona virus has slowed down the demand, but it could be temporary. But the fact is, we cannot decouple from the oil yet.

Delivering oil from well to the market has always been a challenge for the industry. The production of oil, its treatment and transport essentially constitute the upstream oil and gas industry. Many of the oil and gas projects Capex come in the mega range (greater than 1 billion dollars). But several of them were built without paying much attention to the project performance and efficiency. Research shows that, 65% of the megaprojects around the world can be termed as failures in terms of cost and schedule overruns. To make such projects perform up to expectations is also difficult. A recent assessment of 20 such projects revealed that only 7 of them were completed on budget.

This paper will present latest data of megaprojects in the Middle East to highlight that megaprojects are here to stay. Then, it will advance an argument that, given the above, it is possible to improve project deliveries only by using the promising digital technological tools and management practices. Existing practices are not going to yield anything better!

However, industry's adoption of newer technologies lacks momentum. Hurdles include the technology averse aging workforce, uninformed leadership and untrained workforce.

The paper will discuss practical problems facing in the industry in adopting 3D modelling, digital data management systems, Building Information Systems, modularization, Digital twins, etc. Internet of Things await usage to its full potential.

What is needed is a vision of the project of the future. The leadership of the industry need to rethink their policies and rewrite the rulebooks. That together with digital technologies alone can deliver better projects, ensuring continuous flow of oil from wellhead to markets.

KEYWORDS:

Megaprojects, Low oil price, Digital technologies

INTRODUCTION

The corona virus may have temporarily slowed down the demand for oil, but world's appetite for oil is not yet over. The fact is that the world cannot decouple itself from oil yet. Alternate forms of energy offer considerable promise, but these will take time.

Delivering oil from wellhead to the markets has always been a challenge for the industry. From the oil fields of Pennsylvania in 1859, the hot deserts of Middle East, deep sea and icy arctic, oil continues to flow to the world market on a daily basis uninterruptedly.

The efforts behind producing oil are diverse and considerable. Projects have to be designed and built in difficult sites at huge expense. Entire industries and businesses have sprung up and thousands of people are employed in the hydrocarbon wellhead to market eco-system. The projects for oil production are built by the owner companies themselves, or by outsourcing to engineering companies. Oil and gas projects are capital intensive, and many of the projects come in the mega range (greater than 1 billion US dollars) in capital expenditure terms. It seems surprising, but several of them were built without paying much attention to the project performance and efficiency, but it was during the time of higher oil price.

In the era of low oil price, companies have started paying more attention to the capital expenditure and efficiency. Research on the subject shows that 65% of the mega projects around the world can be termed as failures by cost and schedule overruns. Are megaprojects mega follies?

Oil and gas projects are no different and several of them come in the mega range. A recent assessment of 20 oil and gas projects by a consultant revealed that only 7 of them were completed on budget. All the same, to make such projects perform up to expectations is also difficult.

This paper presents an argument that while megaprojects have become a necessity to certain extend in the Middle East (ME), its huge scope, cost and complexity offers tremendous challenges in design and execution. Adopting digital technologies will go a long way in improving such mega project's delivery. However, implementing the new digital technologies also faces several hurdles. The paper provides data to substantiate each of above points and identifies the most applicable digital technologies and the key challenges faced by the industry in implementing the same.

This paper is in four sections. First section will present data of mega projects in the Middle East region to highlight the fact that mega projects are here to stay at least for some more time. The second section will summarize the nature of oil and gas mega projects, its inherent complexities, the project delivery methodologies used and how it affects the project performance. The third section will advance an argument that, given the above, it is possible to improve project deliveries only by using the promising digital technology tools and management practices. Existing practices are not going to yield anything better!

In the fourth section, the paper will discuss the practical problems facing in the industry in adopting even the more common digital technologies such as 3D modelling, Building Information Modelling, digital document & data management systems, Digital twins, Drone technology etc. Internet of Things and Artificial Intelligence await usage to its full potential.

In conclusion, the paper will suggest a vision of the projects of the future. It is the responsibility of the industry leadership to rethink their policies and rewrite the rulebooks.

SECTION 1: OIL AND GAS PROJECTS IN THE MIDDLE EAST (ME)

Let us first look at the world oil production and the share of Middle East. Undoubtedly, the ME still is a major contributor even though there is increasing production from non-OPEC countries. About 30 % of world crude production comes from OPEC countries Please see Figure 1.

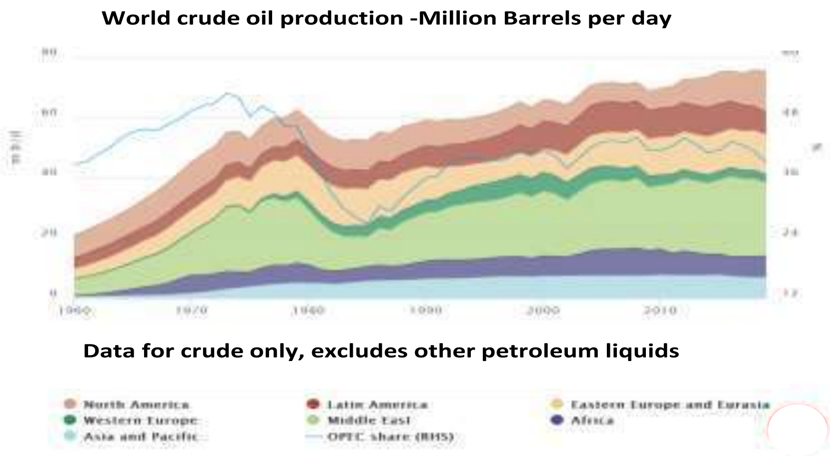


Figure 1 World crude oil production (Source: OPEC)

What about future? The indications are that the OPEC countries are planning for continued investments in oil and gas. See Figure 2.

The steep drop in supply (in millions of barrels per day) during 2019-20 can be seen from Figure 2. Several mega projects have been deferred or put on hold due to the Covid 19 impact. But it can be revived once the world economy picks up.

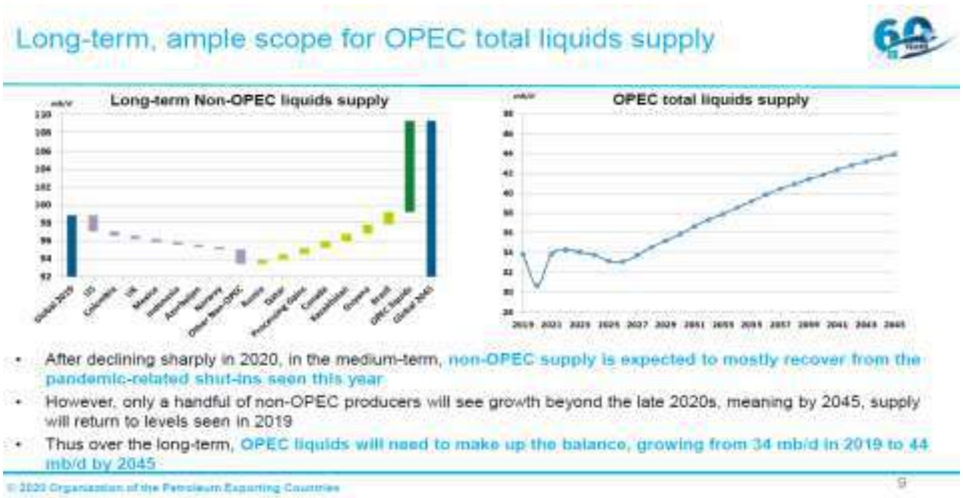


Figure 2 OPEC upstream investment plans (Source OPEC)

Typical oil and gas projects take 5 to 8 years from concept to commissioning, that too from finalizing the reservoir viability. Therefore, long term planning is necessary, which sometimes is difficult given the current situation. Given below is a summary of the mega projects currently going on in various stages in the ME.

Megaprojects in the ME

1. Upper Zakum -Production Capacity Enhancement. Location: United Arab Emirates Cost: USD 21.8 billion, Operator: Zakum Development Company (ZADCO)
2. Yanbu-Crude Oil to Chemicals complex. Location: Saudi Arabia,Cost: USD 20 billion, Operator: Saudi Aramco & Saudi Basic Industries,(The project is under reassessment.)
3. Ruwais Refinery Complex. Location: United Arab Emirates, Cost: USD 20 billion Operator: Abu Dhabi National Oil Company (ADNOC)
4. Zubair Oil Field-Rehabilitation & Redevelopment. Location: Iraq,Cost: USD 18 billion, Operator: Consortium (ENI, Oxy, KOGAS & Missan Oil Company)
5. Basra Gas Gathering Project. Location: Iraq, Cost: USD 17.2 billion, Operator: Basrah Gas Company
6. Al Zour Refinery. Location: Kuwait,Cost: USD 16 billion,Operator KIPIC

7. Abu Dhabi North West Development, Location UAE, Cost USD 15 billion
   Operator: Abu Dhabi National Oil Company (ADNOC)
8. Rumalia Oil Field, Location: Iraq, Cost: USD 15 billion, Operator: Govt. of Iraq
9. Marjan Oil Field Expansion. Location: Saudi Arabia, Cost: USD 15 billion, Operator: Saudi Aramco.
10. Ras Laffab -Qatar-Northern Field Expansion. Location: Saudi Arabia, Cost: USD 18 billion, Operator: Qatar Petroleum.

Why ME is still investing in megaprojects?

A simple answer to the question is that they need it! However, the underlying reasons are several.

Firstly, oil is the main revenue of the governments in ME countries. To meet the rising expectations of the people, huge amount of money have to be spent in infrastructure development and it has to come from the oil business. Saudi Arabia's 'Vision 2030' (Neom City), Kuwait's 'New Kuwait 2035' (Silk City) and Abu Dhabi's 'Economic Vision 2030's are examples. Please see Figure 3 for the world population trends showing the increasing rate of population growth in Middle East and Africa. Secondly, rather than ship crude oil to other parts of the world, to be processed for value added downstream petrochemical products, many ME countries have set up petrochemical facilities or, are constructing them, which are huge projects by itself. Kuwait's Equate and Saudi Aramco & Dow Chemical joint venture Sadara project are examples.

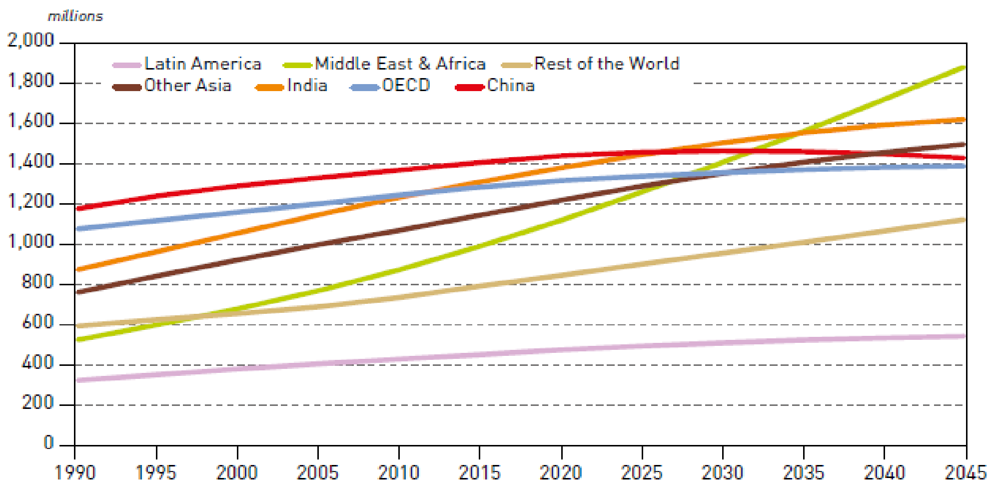


Figure 3 World population trends (Source, UN, OPEC)

Further, to maintain the oil and gas facilities and sustain the current production levels itself, sizable investments are needed.

SECTION 2: STRUCTURE OF MEGA PROJECTS & DELIVERY MODELS

In oil and gas megaprojects, the key players generally are the owner companies, the Front End Engineering Design (FEED) companies and the Engineering Procurement and Construction (EPC) contractors. Please see Figure 4 below for a schematic showing the key players and the inter-relationships. There are certain other types of contracts where the entities role and responsibilities are different. Here the FEED and EPC model is taken up to illustrate the key issues and to avoid digressing from the main topic. In other types of contracts also, the information flow will remain more or less the same.

Let us quickly review how the Front End Engineering Design is developed and passed on to the Engineering Procurement Construction (EPC) contractor.

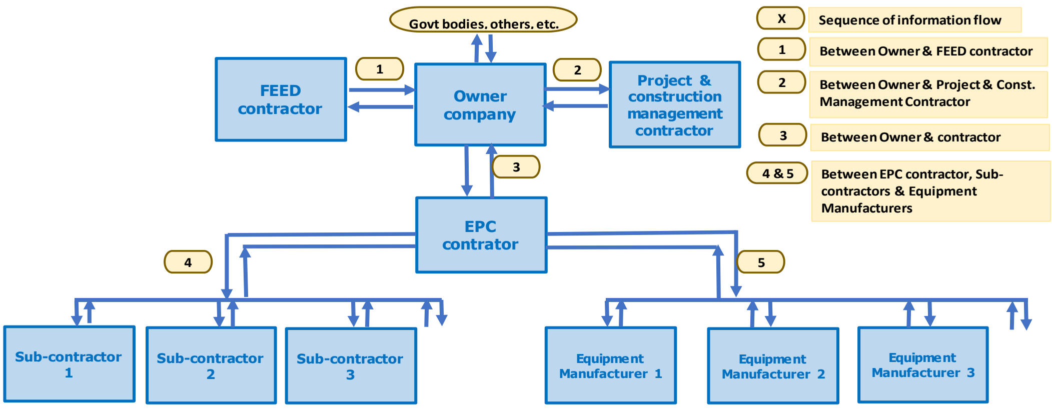


Figure 4 Information flow between the key players in EPC contracts

As can be imagined, the volume of engineering and project documentation for megaprojects are huge, in the order of tens of thousands. During the development of FEED, approvals to critical documents are required from the owner company and for a megaproject this itself runs to thousands. Megaproject technical documentation is interlinked and the full set of documentation consisting of outputs from all relevant engineering discipline namely, process, mechanical, civil, electrical, instrumentation etc. have to be woven together like a giant jigsaw puzzle to obtain a full picture. If one of them has a missing element, grey area or inconsistency, the entire picture is affected. Please see Figure 4, which captures the tight interlinks between all the disciplines and its connection to the cost estimates in a simplistic manner. Actual connections are much more.

The cost estimates are based on the Material Take Off (MTO), for equipment, bulk materials and work packages from each discipline as can be seen from the Figure 5. (For clarity, only deliverables from Process and Electrical disciplines are shown in the diagram).

The responsibilities of the FEED contractor are over when the FEED is completed, and documentation handed over to the owner company. The owner company later enters into a separate contract with an EPC contractor/s. Usually, the contracts terms and conditions stipulate that the EPC contractor endorses the FEED and then start detailed engineering and construction.

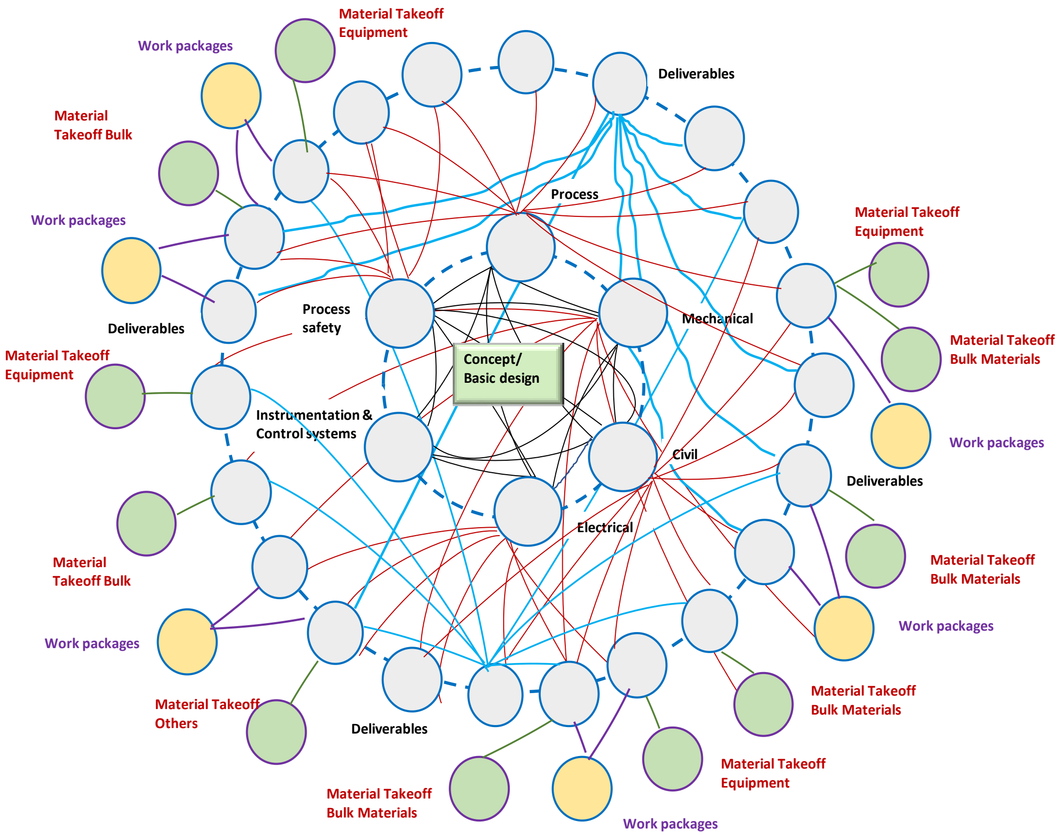


Figure 5 Links between various disciplines & deliverables-illustrative

The EPC contractor do not get the benefit of the work that is already done by the FEED contractor simply because contractually all responsibilities are transferred to the EPC contractor when the contract is signed. They are required to do their work independently. For example, the original native files of the process simulation models, the 3D model, Plot plan layout, etc. are not usually handed over to the EPC contractor due to the inherent legal–contractual nature of the terms and conditions. The EPC contractor is forced to develop and verify all the above again from scratch, taking up time and resources, often ending up doing it in a different digital platform and making the earlier models useless!

Further, owner company's specialist departments and their Project Management Consultant (PMC) take their own time for review and approval of the huge number of documents from the EPC contractor. Orders of critical long delivery equipment are often delayed due the delay in client approvals. In effect, the document review cycles are a time consuming and innately an inefficient activity affecting the project schedules.

SECTION 3: PROMISING DIGITAL TECHNOLOGIES

Sections 1 established that the megaprojects are here to stay in the ME. Section 2 highlighted that the huge amount of interconnected information that is needed to flow among the entities (stakeholders) in a cyclic fashion. Management of thousands of interconnected deliverables involving hundreds of engineering specialists with traditional paper hard copy, pencil & paper is inherently inefficient and error prone. The chances are that it will create errors, mismatches and gaps in design that will crash during construction causing quick fixes, expensive rework and project delays.

This section summarizes the more common promising technologies.

3.1 3D Modelling

3D Modelling is the dream come true for the mechanical layout specialist. The technology is constantly advancing, requiring intensive training to understand and use it.

Latest innovations in software offers unified platform that ensures secure and collaborative working mechanism for each individual discipline. It has features to prevent inconsistencies and mismatches. With the help of Artificial Intelligence, the model can automatically check for optimization and out of normal design values. Walk through cameras give a full experience of seeing the plant, equipment, and piping in full reality even before it is built.

The striking level of detail, up to the nut and bolt, that the 3 D models can go, is a significant improvement for the EPC companies. Their Material Take Off (MTO) will be more accurate resulting in a better cost estimates.

The next step is to incorporate the functional data into the 3D model, which is a combination of simulation and physical model, towards the Digital Twin.

For pipeline projects, use of Geographical Information Systems (GIS) with latest satellite data can make a big difference for pipeline route, future expansion, potential interferences, etc.

3.2 Building **I**nformation **M**odelling (BIM)

BIM combines the 3D physical and functional data in to one intelligent model. This enables the full building or infrastructure to be experienced before it is built. Some of main advantages of BIM include more accurate design and estimates, faster and efficient work, increase in productivity and quality of construction, reduction in rework, useful even after construction to detect faults, maintenance requirements, etc.

3.3 Digital **T**win (DT)

Digital twin is essentially a virtual model of a process. It combines the physical dimensional model with the dynamic functions of the object. The physical dimensions of refinery can easily be captured by 3 D model but combining it with the processes going on inside is still under development. It can be made real time by having the hundreds of inputs from the instrumentation (smart sensors) and control system connected to model. Once it is done, this becomes a Digital Twin of the refinery. It offers unprecedented visualization capabilities of the plant and its workings virtually along with continuous optimization potential. Figure 6 shows a schematic of the connectivity between the physical model and the virtual DT.

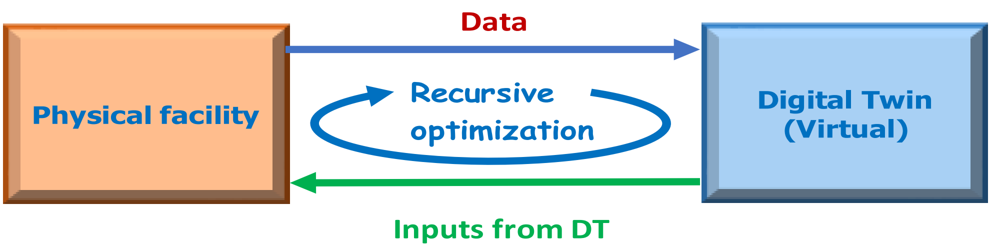


Figure 6 Connectivity between physical facility & DT & recursive optimization

All of the above digital technologies are definitely beneficial considering the wide variety of uses, most important of them being:

- Correct and optimized design, reduced risk and accurate cost data for capital projects thereby increasing its chances of success.

- Digital documentation that is searchable and updatable easily
- Once it is built, analysis of the operating data (eventually 'big data') enables better informed decisions and running of various 'What -if' scenarios, asset integrity management, improved efficiency during operations and maintenance.
- Virtual learning, knowledge sharing is easier, and it improves learning and training.

3.4 Remotely **O**perated **A**erial **V**ehicle (ROAV) or **D**rone **T**echnology

Some of the areas where drones are already in use are inspection of unmanned oil platforms, monitoring of pipeline routes, inspection of oil tankers and assisting in emergency operations during oil spills, flare stack inspections, gas emissions monitoring, inspection of storage tanks, mapping and monitoring of remote and difficult terrains.

SECTION 4: CHALLENGES FACED BY THE OIL AND GAS COMPANIES

This section highlights the main challenges that face the oil and gas companies in implementing digital technologies. They are primarily from author's experience as well as from literature:

- Plain unawareness of the latest digital technologies by senior executives

  Lack of knowledge about the digital technologies and its positive impacts, prevents long term planning about digital technologies.
- Mismatch and misconceptions about digital transformations: Oil & industries senior executives in most of the IOCs and NOCs are insiders, groomed and readied for senior positions over a long period of time. The ideas and concepts of the potential for digital technologies have to come from outside. Added to that, the aging work force, especially in the middle management level, has not much idea about the new digital technologies and prefer to keep the things as they are.
- Skill shortage and looming retirement of almost 50% of the work force in 5 to 7 years' time: The aging workforce with no commensurate intake of skilled workers in all disciplines have created a real skills gap in the sector. Because of Opex reduction exercises in recent years, the recruitments have hit all time low. There is shortage of skills and competencies in digital technologies that needs to be tackled urgently.
- Existing oil and facilities have old technology and legacy systems preventing interfacing with newer systems. Digitizing is not easy.

- Owner companies' in-house knowledge gaps: The boom & bust cycle in oil price have resulted oil companies losing their core in –house experience and knowhow of design, engineering and project management. Most of it have been outsourced. The outsourced experts do not have the time to study the existing successful design an often end up reinventing the wheel often the wrong way!

  After all NASA's revival and success is due to the development of successful design of space shuttle that could be reused again. They designed the shuttle only once!
- Impact of Covid -19: The unprecedented Covid-19 has dampened the momentum of digital transformation.

CONCLUDING REMARKS

In short, the oil and gas industry in the Middle East is in 'compression mode'.

There are continuous societal and other needs that calls for investments in infrastructure and developmental activities. These ambitious programs need huge fiscal outlay, and the revenue comes mainly from oil business. They cannot be cut back drastically.

On the other hand, there is the low oil price environment. It is not only the low price, but the instability of the price that upsets all the plans. The above situation demands astute planning, optimization and allocation of funds together with improving efficiency of the capital being employed for the mega projects.

In the above scenario it is unwise to continue trusting and applying the same old project management methods. The usual slogan of reducing Capex and Opex may yield certain immediate benefits thereby creating a false sense of comfort, but in the long run some of it could be counterproductive. What is required a new vision about oil and gas projects.

A Vision for Projects of the Future

i. ***D**igital **P**roject:* The journey to digital project needs momentum to achieve the goals five years hence. Oil and gas companies must graduate from pilot projects on digital transformation to full-fledged applications. Skills must be acquired either by retraining or by hiring.

Digital project means working on a single digital platform that contain a suite of applications, from concept to commissioning. This will enable the different functional specialists to collaborate and work on the same set of data, calculations and assumptions during concept and FEED definition stages. Data updates/mismatches are automatically alerted. When the owner company is hiring a FEED contractor, then the data and model from earlier project stages developed by the owner company can be shared with them as well. Chances of omissions or errors are much less.

As mentioned earlier, one of the important milestones in oil and gas project is the EPC contract award, whereby all the responsibilities are transferred to the contractor. In digital project, the process simulation model, 3 D model and other data are transferred to the EPC contractor's digital environment, after award of the contract. Adequate contractual provisions and protocols have to be developed to implement the above.

The 3 D model would eventually develop into the digital twin (DT) of the plant that would be handed over to the owner at the end of the project. The DT will continue to be of good use to the owner company during the entire lifecycle of the plant.

ii. ***R**espect for **d**ata and **U**tilising the **P**ower of **D**ata **A**nalytics:* There is an urgent need for the unstructured and disorganized data that is currently stored in manual forms, Word, Excel and other personal files to be 'datafied'. This is required before it is lost. Big data techniques can slice and dice the unutilized data and come up with surprising relationships and results. Big data is not confined to analysing numbers only, it can analyse text files, such as Minutes of Meeting, recommendations, reports, etc.

iii. *Construction **P**roductivity:* One thing that consultants agree on construction is that there is not much improvement in its productivity over the years. Use of 3 D Models enables visualization of the entire facility to the nut and bolt detail. This can be used for rigorous planning of work at site.

Another area is modularization. Minimization of work at site and modularisation at the shop level can deliver better efficiency and skids that can be installed easily at site. Supply chain management is one of the key factors for project success. Big data together with 3 D Model & BIM can accurately predict the bulk materials required for construction.

iv. ***S**tandardisation:* Traditionally oil and gas companies have inclined to use more of custom-made equipment. However, standardised design and equipment can improve quality, cost and delivery. International Oil and Gas Producers (IOGP) initiatives in this regard, particularly the Joint Industry Project (JIP 33) is a step in the right direction. IOGP notes that 'Standardization is key lever that we can pull as an industry to structurally reduce large capital project lifecycle costs."

Another important point is the need for certain freedom for EPC contractor while finalizing the vendor packages. Instead of sticking rigidly to owner company specifications, which could be obsolete, or custom made, the EPC contractor must be given freedom to optimize the vendor packages based on the market conditions. What is important is the performance of the equipment and overall objectives of the project.

v. **I**mproved **B**uilding **M**aterials: Cost effective lightweight construction material is revolutionizing the industry. On the advanced end, there is the promise Nanotechnology that may one day, bring solar energy to buildings in a more efficient manner than the current solar panels. Sustainability is another question that needs to be addressed.

vi. ***R****eskilling the* ***C****onstruction* ***W****orkforce:* Though huge amount of data is available on every aspect of construction at national and international level, there is little effort to study it in detail and make anything out of it. Worker performance is a field of study its own and Construction Labour Productivity (CLP) needs to be studied to design and deliver effective training programs. In Asia and ME, the investments on reskilling would pose a challenge because of the limited exposure of the construction workers to digital education. International Labour Organization Future of Work Commission in its 2019 report stated that 'Today's skills will not match the jobs of tomorrow, and newly acquired skills may quickly become obsolete.' ILP recommend in unequivocal terms that governments, employers and workers invest in training to improve all around productivity.

All the above taken together, show that the oil and gas industry in ME is facing major challenges. To meet these challenges, fundamental changes are required in the mind-sets of industry leaders and the way organizations and projects are structured and working. World still need oil and economies of several countries depend on it. Therefore, the leaders of business and industry need to realize the situation and rewrite the rulebooks on projects, its management and delivery.

REFERENCES

2020 Digital Operations study for energy Oil and gas (2020). www.strategyand.pwc.com. Retrieved October 26, 2020, from https://www. strategyand.pwc.com/insights/2020-digital-operations-study –for-energy

A regional overview of project finance on the Middle East (2020). www.lexology.com. Retrieved October 26, 2020, from https://www.lexology.com/gtdt/intelligence/project-finance/middle-east-a-regional-overview

Barbosa, F., Woetzel, J., Mischke, J., Ribeirinho, M.J., Sridhar, M., Parsons, M., Bertram, N., & Brown, S. (2017). Reinventing Construction: A Route to Higher Productivity. https://www.mckinsey.com/search?q=REINVENTING%20CONSTRUCTION

Blanco, J., Mullin, A., Pandya, K., & Sridhar, M. The new age of engineering and construction technology. https://www.mckinsey.com/business-functions/operations/our-insights/the-new-age-of-engineering-and-construction-technology

Baron, H. (2016). Why Our Way To Develop Projects Fails To Minimize Capex—Part 1. Retrieved October 26, 2020, from https://pubs.spe.org/en/ogf/ogf-article-detail/?art=2480

Barrel-price-and-covid-19-impact-on-oil-gas-and-petrochemicals (2020). 2b1stconsulting.com. Retrieved Oct 26, 2020, from https://2b1stconsulting.com/barrel-price-and-covid-19-impact-on-oil-gas-and-petrochemicals/

EPC Contracting Issues in the Oil and Gas Industry (2015). files.klgates.com. Retrieved October 26,2020, from https://files.klgates.com/files/upload/epc_contracting_issues_in_the_oil_and_gas_industry.pdf

EPC Contracts in the oil and gas sector (2016). https://www.pwc.com.au. Retrieved October 26, 2020, from

https://www.pwc.com.au/legal/assets/investing-in-infrastructure/iif-5-epc-contracts-oil-gas-feb16-3.pdf

International Labour Organization, (2019). Work For a Bright Future, Retrieved October 26, 2020, from https://www.ilo.org/wcmsp5/groups/public/---dgreports/---cabinet/documents/publication/wcms_662410.pdf

Joint Industry Initiative. (n.d.). http://www. iogp.com. Retrieved October 26, 2020, from https:// www.iogp.org/initiatives/jip33

Kocakaya, M. N., Namlı, E., & Işıkdağ, Ü. (2019). Building Information Management (BIM), A New Approach to Project Management. Journal of Sustainable Construction Materials and Technologies, 4(1), 323–332. https://doi.org/10.29187/jscmt.2019.36

Kuwaiti megaproject faces investment challenges at home and abroad (2019). Castlereagh.net. Retrieved Oct 26, 2020, from https://castlereagh.net/kuwaiti-megaproject-faces-investment-challenges-at home-and abroad

McGowan, A. C., & Reddy, S. B. (2020). What would it take to reskill entire Industries, Harvard Business Review, Retrieved October 26, 2020, https://hbr.org/2020/07/what-would-it-take-to-reskill-entire-industries

Mega Projects; Avoiding Contractual Disputes (2016). www.oilandgasiq.com. Retrieved October 26, 2020, from https://www.oilandgasiq.com/oil-and-gas-production-and-operations/articles/mega-proejct

Mohammadpoor, M., & Torabi, F. (2018). Big Data analytics in oil and gas industry: An emerging trend. Petroleum. https://doi.org/10.1016/j.petlm.2018.11.001 http://www.keaipublishing.com/en/journals/petroleum

Organization of Petroleum Exporting Countries. (2020). 2020 World Oil Outlook 2045. Retrieved October 26, 2020, from https://woo.opec.org/

Srivastava, S., & Takeidinne, O. (2012). Feed Endorsement-A Challenge to EPC Contractors Engineering Team, Abu Dhabi International Petroleum Exhibition & Conference, Abu Dhabi, UAE, 11-14 November 2012. Society of Petroleum Engineers. https://doi.org/10.2118/158941-MS

Wanasinghe, T. R., Wroblewski, L., Petersen, B. K., Gosine, R. G., James, L. A., De Silva, O., Mann, G. K. I., & Warrian, P. J. (2020). Digital Twin for the Oil and Gas Industry: Overview, Research Trends, Opportunities, and Challenges. IEEE Access, 8, 104175–104197. https://doi.org/10.1109/access.2020.2998723

Which Oil Producers are Breaking Even? (2017). http://graphics.wsj.com/oil-producers-break-even-prices

One Nation One Market Project- Identifying challenges and way forward

Bade Mihir UMESH, Aveek DUTTA, Rupesh Kumar PATI
IIM Kozhikode; email: mihirb23@iimklive.com
IIM Kozhikode; email: aveekd23@iimklive.com
IIM Kozhikode; email: rupesh_pati@iimk.ac.in

ABSTRACT

The "one nation one market" project using eNAM (Electronic National Agriculture Market) platform intends to provide a more reasonable price for a quality produce, remove information asymmetry between buyers and farmers. The social project of such magnitude generally impacts many stakeholders (may or may not have conflicting objectives). Hence, the present study would attempt to explore the response to the following research questions from stakeholder theory perspective: (a) What are the attributes of various socially high impact project of GoI (like Aadhaar, NREGA) and map it to a common project management framework for necessary comparison/learning (b) Did these projects meet the desired milestones as per plan and how various challenges affected its scope? (c) What were the various approaches used by respective teams to handle various risk or uncertainty across these social projects? (d) Who are the stakeholders of these social projects and how were they managed? Can these learnings help us to manage some of the identified risk as well as stakeholders in the "One Nation One Market" project?

KEYWORDS:

eNAM project, Farmers, Risk Management, Diamond Framework

INTRODUCTION

The largest source of livelihood in India is agriculture. 70% of India's rural households depend primarily on agriculture and 82% of the farmers are small and marginal. The farming sector has been aggrieved by recurring droughts, floods, shrinking land holdings, increasing chemical/fertilizer costs, falling prices of crop produce (even though final price for end customer is very high), and lack of execution of minimum support price mechanism. To improve the condition of the farming community, the Government of India had come up with an ambitious social project of "One nation One market (ONOM)" in 2016.

ONOM PROJECT PROCESS:

The Farmers' Produce Trade and Commerce (Promotion and Facilitation) Bill, 2020 allows intra-state and inter-state trade of farmers' produce beyond the physical premises of APMC markets. Thus, it increases the buyers' availability for farmers' produce by allowing farmers to trade freely throughout the nation. Competition among buyers will result in better prices for farmers. Most farmers lack access to government procurement facilities or APMCs and small rural markets could emerge as key players in the ONOM framework if provided with proper infrastructure. APMCs were unsuccessful in alleviating the information asymmetry between buyers and farmers and it was often observed that middlemen distorted the prices. A step towards the ONOM was the pan India electronic trading platform e-NAM. One of the major challenges in e-NAM has been to ensure homogeneity across states and dealing with the number of APMC mandis to be electronically interconnected. Ground level realities suggest low interstate trade and low participation of farmers and private sector in e-NAM. For ONOM to be popular, critical success factors to on-board farmers include better logistics, farm-friendly infrastructure, access to modern capital, price assurances, sharing of market risk and incentive for diversification towards more paying quality produce. **Figure 1** explains the proposed process.

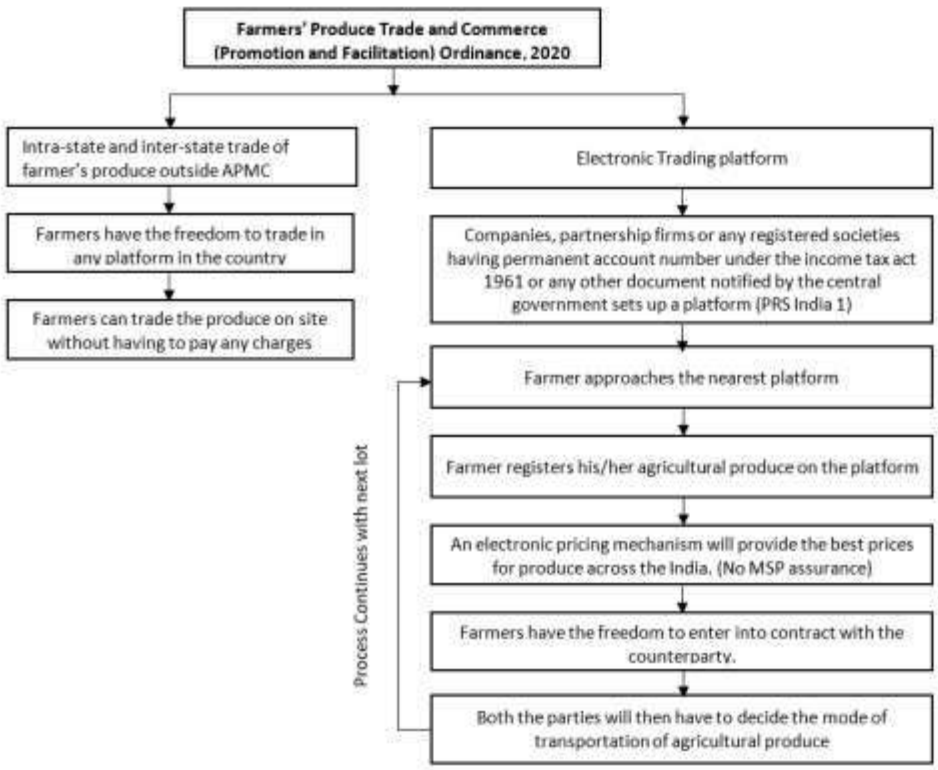


Figure 1. ONOM process flowchart

SOCIALLY HIGH-IMPACT GOVERNMENT PROJECTS WE INTEND TO COMPARE:

NREGA: The primary objective of the NREGA project was the enhancement of livelihood security in the rural areas by guaranteeing 100 days of wage employment in a financial year to every registered household. This clearly identifies rural population as the primary beneficiary and the rural wage labourers as the key stakeholders.

Aadhar: The objective of the project was to develop a common identity document for each individual which could be used for all government transactions/ benefit schemes.

RISK ANALYSIS AND DISCUSSION ON ONOM PROJECT

Based on the documents available we attempt to develop the Time-cost- scope matrix and is presented in Figure 2.

- **Scope**: (Constrain): Ambitious project with a strategic vision of doubling farmers' income by 2022. It intends to create a common national market accessible to every farmer and buyer.
- **Time** (Enhance): Although this has a time-critical objective, the robustness of the project needs to be established by several iterations and optimizations which may require an extended timeframe.
- **Cost** (Accept): The project is in its incipient stages and will go through several iterative cycles; hence any additional estimate of cost has to be accepted.

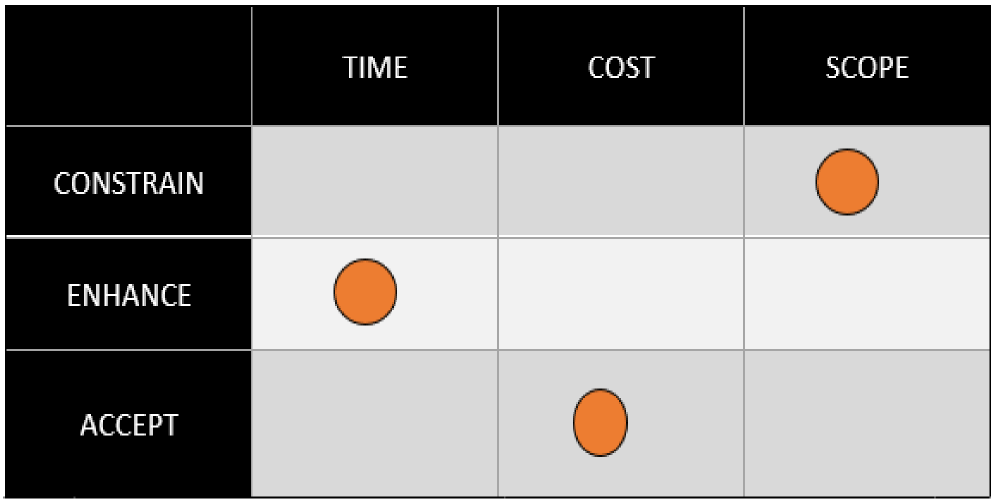


Figure 2. Time-Cost-Scope matrix

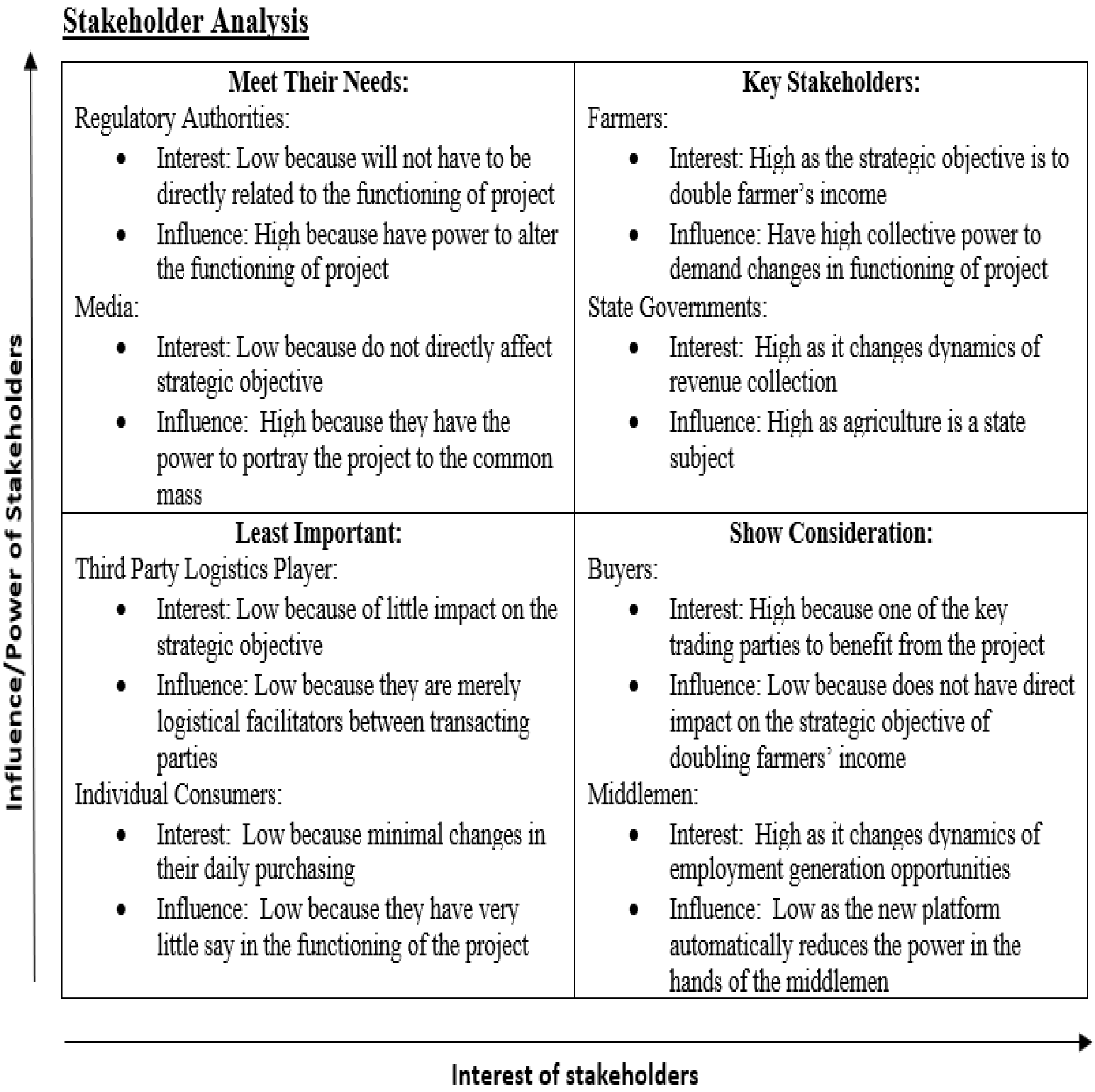


Figure 3. Stakeholder analysis

Stakeholder management:

The critical stakeholders for the success of the project are thus farmers and state governments as shown in Fig 3. The benefits of the new model need to be communicated effectively to farmers. Discussions with state governments need to continue and any objection needs to be fully scrutinised. The project can take lessons from ITC's e-Choupal initiative where they successfully incorporated an electronic information system by incentivising the middlemen (in mandis) to set up computer centres in villages and organise discussions. A widespread campaign could interest more private participation in the project. The government should ultimately focus on those affected mostly by the transition into the new model, especially the farmers and middlemen.

Methodology

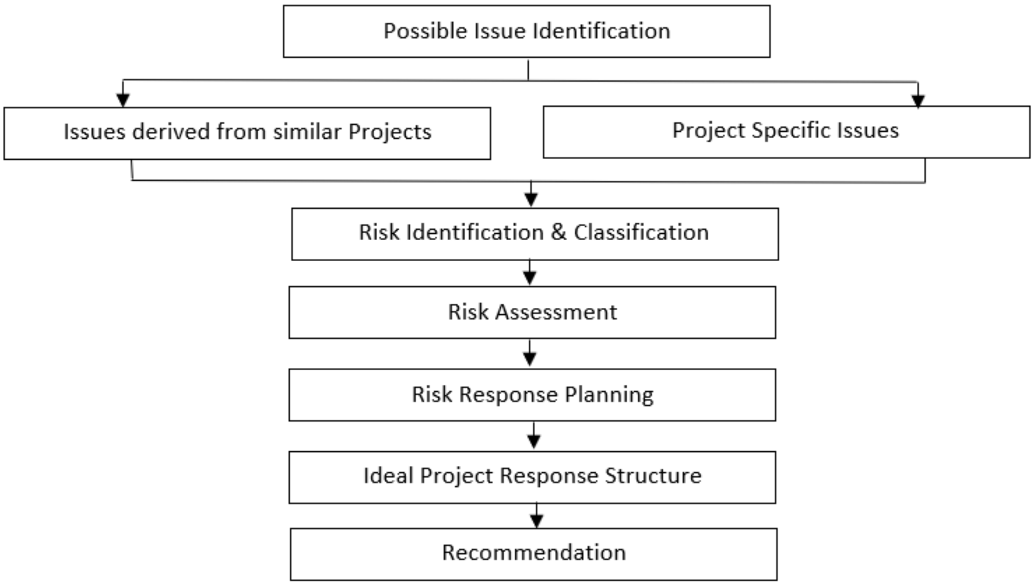


Figure 4. Methodology

Risk Identification

Based on the literature review of the new bill and e-Nam, four major categories of risks have been identified. (Hillson, D., 2014)

- **Event Risk**: Event risks are the types of risks typically addressed in the project management. The project hinges on the ability of farmers to adapt to the new method and hence the same assumption has been identified as an event risk. Also, traders and state governments may oppose the changes.
- **Variability Risk**: Variability risk is associated with the variance of the actual outcome from the planned outcome. The project may not be able to increase the farmer's income to the expected level or may even surpass it. Similarly, buyers' benefits and willingness can also vary. Also, data localisation and information security have variability risk associated.
- **Ambiguity Risk**: These are the risks associated with the areas of project where the imperfect knowledge affects the ability to take the correct decisions. Setting up a robust nationwide price discovery platform is a new task for ministry, similarly solving the logistics network problems and designing the contracts are not the areas of expertise of ministry.
- **Emergent Risk**: Technically called Ontological Uncertainties and more commonly known as "Black Swan". These risks are difficult to identify and the best way to tackle the same is to make the project resilient.

Table 1. Issue identification

	Aadhar	**NREGA**	**ONOM**
Scale	Nationwide	Nationwide	Nationwide
Key Stakeholder	Citizens, Central and state government	Any Indian citizen above 18 years of age and residing in rural areas	Farmers, State governments
Project Sponsor	Central Government	Central Government	Central Government
Technology	High-tech	Low-Tech	High-Tech
Issues faced:			**Possible issues:**
Social	Initial apprehension regarding data security and privacy	Apprehension regarding delayed and missing payment of salaries	Apprehension regarding performance of the overhauled system
Implementation gaps	Unstable biometrics, Accessibility to residents of remote areas	Corruption, unavailability of job cards, exclusion from banking system	Accessibility, corruption, scalability
Technical	Fingerprint and risk spoofing, inability of handling large volume of transactions	Faulty MIS data captured, fake job cards leading to misidentification	Data localisation and privacy
Political	Grilling by opposition parties on the scope of the project	Questions on corruption and the benefits of the project	Possible resistance from opposition parties
Use case issues	No significant issue found	Economic value added was lesser than expected	Benefits received from removing trade barriers may not be as expected

- (Aadhar issues: Pati, Rupesh & Kumar, Vipin & Jain, Nishtha, 2015)
- (NREGA issues: Shah, Deepak & Mohanty, Sovna., 2010)

Table 2: Risk Classification

Risk Type	Sr No	Risk	Impact	Likelihood	Risk Rating
Event Risk	R1	Trader unions opposing the new bill by stating that it concentrates power in the hands of few corporates **(Project specific)**	2	5	10
Event Risk	R2	Farmers unable to adapt to the online change or not using the	4	3	12

		platforms to their fullest potential **(Implementation gap: accessibility)**			
Event Risk	R3	State governments which can be of different political parties may not be ready to accept the changes suddenly **(Political issue)**	3	4	12
Variability Risk	R4	The benefits received from eliminating trade barriers may not be as high as perceived earlier **(Use Case Issues)**	3	3	9
Variability Risk	R5	Unwillingness or seasonal patterns observed from the buying party **(Project Specific)**	2	3	6
Variability Risk	R6	Data localisation and privacy issues **(Technical Issues)**	5	3	15
Ambiguity Risk	R7	Possibility of changes in UPI transaction regulations **(Project Specific)**	1	4	4
Ambiguity Risk	R8	Problems in setting up a robust nationwide infrastructure and adding another platform to it **(Implementation Issue)**	5	3	15
Ambiguity Risk	R9	Exploitation of weaker parties which are mostly farmers through legislative loopholes (No MSP, contract Farming) **(Project Specific)**	4	4	16
Ambiguity Risk	R10	Logistical issues in transporting smaller batch sizes of produce across long distances **(Project Specific)**	4	4	16
Emergent Risk	R11	Any possibility of the law itself becoming an obstacle to the objective it aims to achieve. (As the APMC law itself has become barrier in ONOM) **(Use Case Issues)**	5	1	5

Table 3: Risk Assessment

Sr No	Root Cause	Action	Contingency Plan	Risk Owner
R1	Asymmetric Bargaining Power	Mitigate	Clauses to make the system more balanced	Government
R2	Digital illiteracy of farmers	Sharing	Collaborating with different stakeholders including prospective buyers to educate the farmers	Regional Bureaucrats
R3	Political rivalry and/or discontentment	Retaining	Involve state governments in early stages of project	Ruling Party
R4	Implementation and data collection inefficiencies in silos	Mitigate	Periodic monitoring and embedding feedbacks in to the system	Regional surveyors and software experts
R5	Profit booking and forward buying	Accept	Build a diversified network of buyers	Government
R6	Poor information security	Accept	Stringent audit and inspection of data management practices	Software Partners
R7	Changing financial regulations	Transfer	Internalizing changes in the payment regulations in to the system	Software Partners
R8	Uncertainty associated with the initial stages of development project	Mitigate	Benchmarking against similar projects worldwide and drawing lessons	Project Development Team (To be appointed by ministry)
R9	Legislative loopholes	Mitigate	Changes in the clauses according to learnings in the pilot run, Constant Vigilance	Government
R10	Supply chain issues in transporting smaller volumes	Transfer	Encouraging big logistic firms to participate in the process	Buyers

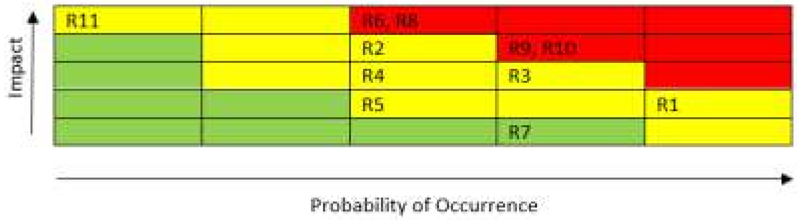


Figure 5: Heat map of risks

DIAMOND FRAMEWORK

Shenhar and Dvir (2007) proposed the 'Diamond Framework'. It proposes to map the project into four dimensions, that is 'Novelty, Technology, Complexity and Pace', thus creating a diamond structure. Detailed explanation is in Table 4. Figure 6 maps diamond for the ONOM project.

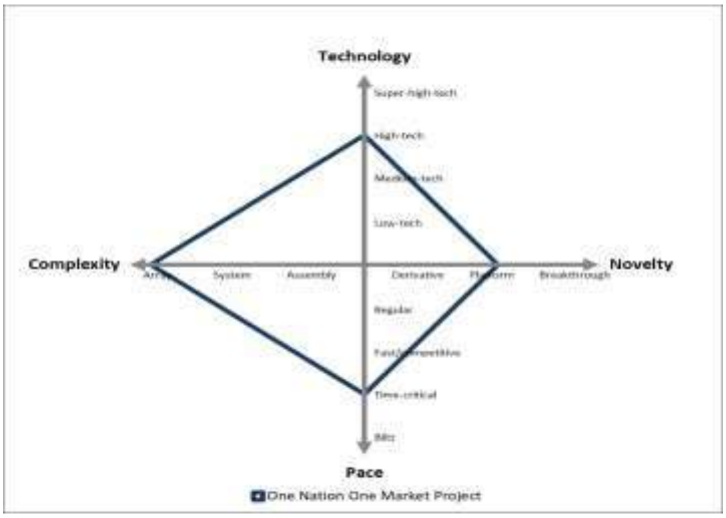


Fig 6. NTCP framework

Dimension	Level	Description
Novelty	Derivative	Extending or improving existing products or services
	Platform	Developing and producing new generation of existing product lines or new types of services to existing or new markets and customers
	Breakthrough	Introducing a new product or concept, or new idea, or new use of a product that customers have never seen
Technology	Low-Tech	Uses only existing, well established, and mature technologies
	Medium-Tech	Mostly existing technologies; limited new technologies or a new feature
	High-Tech	Uses many new, recently developed, existing technologies
	Super-Tech	Key project technologies do not exist at the time of project initiation
Complexity	Assembly	Material, component, subsystem, assembly
	System	System, platform of systems
	Array	Array, system of systems
Pace	Regular	Time not critical to organisational success
	Fast/Competitive	Project completion on time is important for company's competitive advantage and/or organisation's leadership position
	Time Critical	Meeting time goal is critical to project success; and delay means project failure
	Blitz	Crisis project; utmost urgency; project should be completed as soon as possible

Table 4: NTCP framework Scale

Novelty: As of now, GOI has the nationwide database such as Aadhar, PAN, Ration Card data etc which can be integrated into a dynamic platform for ONOM. The idea for ONOM is an extension of the existing state market yards and APMCs.

Technology: The project aims to build a technological platform that intends to reduce the information asymmetry between the transacting parties through an adaptive price discovery mechanism.

Complexity: For the project to succeed, multiple iterations of refined regulations are required. It also intends to change the existing legacy system wherein already a lot of stakeholders are involved.

Pace: The project aligns with the strategic vision of the govt to double farmers' income by 2022.

RECOMMENDATION:

Based on the entire study, certain gaps in the current project management and handling approach have been found. The gaps along with the recommendations are presented in the table 5.

Table 5: Gaps and recommendations

Gaps	**Recommendation**
Media Management	Designating responsible people to become spokesperson to address all the concerns and clarify the project objective to the public
Clarity of plan	Defining SMART objectives at every step of the project and communicating the same through improved media management
Stakeholder Involvement	Creating regional platforms and processes to involve farmers, prospective buying partners, State governments and agents to understand their concerns and incorporate the same in design

The project requires coordination between multiple key stakeholders. It is not advised to implement the project directly on a nationwide scale. It will magnify the amplitude of losses in case of failures and will also take longer time to materialize and show results. Also, the project is time critical for the government and hence it is important to show results as early as possible. Thus, it is advised to implement the project on a smaller scale, understand challenges, make the changes, show the results and get everyone on the board. A model for smaller scale implementation is proposed below.

- Decide 5 locations which will be connected as One Market
- Involve relevant stakeholders in designing the pilot (Trade Union Leaders, Farmers, State Bureaucrats, APMC representatives Supermarkets/Wholesale Buyers, Transporters)
- Run the pilot for one complete season of harvest
- Assess the implementation of above risk management framework and record the observations
- Make the suitable corrections with inputs from all the stakeholders
- Implement the agreed upon plan across the nation

CONCLUSION

One Nation One Market is an ambitious development project undertaken by GOI. The objective of the project is to create a nationally connected trading platform which can be accessed by farmers from anywhere thus removing the erstwhile constraints of selling in only the specified APMC. The project is of high strategic importance as it contributes to the grand vision of doubling farmers' income by 2020. The project involves 2 key stakeholders: State governments and farmers.

The key risks identified with the project are exploitation of weaker parties, logistical issues and challenge of setting robust nationwide infrastructure. It is recommended that the government should try implementing the project on a smaller scale by involving all stakeholders. Nationwide implementation should include the learnings from the above. The findings of the study can be used to have a significant impact on the project management approach to be used by GOI. The frameworks can also be used to manage the projects involving multiple stakeholder development projects. The major limitation of the study is dependence on the secondary research method. Further the data used in the risk assessment matrix is the primary assessment of the risks based on the discussion within authors, survey, and extensive literature review and as the project progresses the risks must be assessed and quantified again.

REFERENCES

Hillson, D. (2014). *How to manage the risks you didn't know you were taking*. Paper presented at PMI® Global Congress 2014—North America, Phoenix, AZ. Newtown Square, PA: Project Management Institute.

Pati, Rupesh & Kumar, Vipin & Jain, Nishtha. (2015). "*Analysis of Aadhaar: A Project Management Perspective". IIM Kozhikode Society & Management Review*. 4. 124-135. 10.1177/2277975215610687.

Shah, Deepak & Mohanty, Sovna. (2010). "*Implementation of NREGA during Eleventh Plan in Maharashtra: Experiences, Challenges and Ways Forward". Indian Journal of Agricultural Economics.* Vol. 65. 540-551.

The Farmers' Produce Trade and Commerce (Promotion and Facilitation) Bill, 2020 (2020) https://www.prsindia.org/billtrack/farmers-produce-trade-and-commerce-promotion-and-facilitation-bill-2020

Farm ordinances: One nation, one market (2020): Financial Express https://www.financialexpress.com/opinion/farm-ordinances-one-nation-one-market/2089462/

'One Nation, One Market' Is Vital: Niti Aayog's Dr Ramesh Chand On Reforms In Agricultural Trading, Outlook (2020) https://www.outlookindia.com/website/story/india-news-interview-one-nation-one-market-is-vital-niti-aayogs-dr-ramesh-chand-on-reforms-in-agricultural-trading/354200

Supermarket procurement and farmgate prices in India-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

Appendix I. Likelihood Scale

Likelihood	Rating	Criteria	Probability
Almost Certain	5	Expected to happen. Will certainly happen this fiscal year or within the next 3 years.	80% to 100% or once a year or more frequently
Likely	4	Expected to happen. It would be highly surprising if it did not happen.	61% to 79% or once every 3 years
Possible	3	Just as likely to happen as not. We don't expect it to happen but there's a chance.	40% to 60% or once every 5 years
Unlikely	2	Not anticipated. We won't worry about it happening.	11% to 39% or once every 15 years
Almost certain not to happen	1	It would be surprising if this happened. There would have to be a combination of unlikely events for it to happen.	0 to 10% or once every 25 years

Appendix II. Detection Difficulty Scale

Detection Difficulty	**Rating**	**Criteria/Examples**
Very difficult	5	Can't be detected till completion of the project
Difficult	4	Can't be detected immediately and can be known only in the next stage
Moderate	3	May or may not be seen at the time of occurrence; Requires due diligence to detect it
Not difficult	2	Can be detected at the time of occurrence
Easy	1	Can be easily seen without any effort

Construction Project Risk Management using Change Propagation Method

Vijayashree T M[1] and Jyoti TRIVEDI[2]

CEPT University, Ahmedabad; email: architectvijayashree@gmail.com [1]
CEPT University, Ahmedabad; email: jyoti@cept.ac.in [2]

ABSTRACT

The design development and planning phase has a major impact on the project, and the level of uncertainty is high with complex iterations between different disciplines involved. There is high risk involved due to this complex and iterative nature leading to numerous changes that must be managed effectively. There is a need to predict the changes in the process to avoid rework and design waste. These changes have cost and time impacts, and there is a requirement for these changes to be forecasted in the planning process to develop necessary control measures. The general risk management techniques involve direct risk assessment, which does not consider the propagation of a change within the system. The Change prediction and propagation method is a combination of DSM and Risk management technique. This study aims to validate the usage of Change Prediction Method (CPM), in a BIM applied design project of a commercial building, to predict the changes and the way it propagates and validate with the actual changes occurred in the decision-making process. The stakeholders of the selected project breakdown the design development process into tasks and score the dependencies between them. These scores are then used to generate heat maps with a simulation tool that predicts the changes, their spread, and their impact within the system. These results are then validated with changes that were recorded during the design development process by the stakeholders. This method is proposed to aid decision-making, by integrating the people and the processes of the system with technology and tools.

KEYWRODS

Risk Management, Information Management, Change propagation, Decision making

INTRODUCTION

Design phase of the project consists of iterative process, and there is a need of effective model and framework to manage them. It constitutes of products (tools, technology), people and processes and there is complex inter relationship among these domains to be managed, to take appropriate decisions. Parameter based information management tools like Design structure matrix (DSM) and their extensions like Multiple domain matrices (MDM) are predominantly used in the manufacturing sectors to predict changes in the systems and take measures to avoid time and cost overturn. (Wynn et al., 2014) The design of the system is decomposed into its components and the dependencies between them are captured and quantified. The basic challenge in application of these parametric models are the large data that is required to build the structural model and the need of user-friendly tool to model and simulate the data. (Browning, 2015)(Akintola, Senthilkumar, & Root, 2015) . These methods have proven to be good planning and visualization tool, but their implementation is limited. (Prasad, Jacob, Engineering, & Athanasius, 2018)

As complex design process is highly iterative in nature, changes in the tasks spread and have both direct as well as indirect effects on the subsequent tasks and use of conventional risk assessment are proven to be ineffective in making decisions. (Ariyo, Eckert, & Clarkson, 2007) There is a need for assessment of these iterations, in terms of risk prediction of what major changes may occur leading to rework or redesign, and what risk impact they may have on the other tasks in the system and formulate project plans that incorporate such assessments to support decision making in handling the changes. Application of BIM in construction projects has seen numerous benefits, however there are challenges associated with the information management. (Bataw, Kirkham, & Lou, 2016) (B, 2019) This type of parameter-based risk assessment will be a base for stakeholders to take process-oriented decisions to address the changes in the project.

LITERATURE REVIEW

Change prediction is a tool developed to run the simulations for change propagation, developed by Cambridge Engineering design center. CPM simulation quantifies and visually represents the change propagation and impact. (Eger, Eckert, & Clarkson, 2007) Reworks are generated because of iterations and changes, and conventional systems like PERT and CPM being one way progressive in nature are unable to track these iterations. The DSM helps in dealing with these iterations by taking decisions based on the task's dependencies by both top down and bottom-up decision making, adding value to the process. (Pultar, 2006) The most challenging aspect of BIM implementation is the need to change the existing work flows in organizations. DSM and MDM have been theoretically suggested as a method to organize and decompose the complex dependency between the delivery process, tools, and teams, also for assessment of the implementation. (Akintola, Senthilkumar, & Root, 2015) The use of BIM represents the inter relationship between process, people and technology. (Jacob, 2018) Though the use of BIM, has been advantageous in solving the complex management of information between different disciplines (Of & Engineering, 2017) PDCA (Plan Do Check Act) cycle along with DSM to form "Multiple Domain matrixes" is used to identify root causes of design wastes in the process of BIM execution. This matrix method identified the root causes of clashes in the BIM flow process and emphasizes on the idea of flexible checks to be performed in the BIM implementation process to avoid design wastes. (Hickethier et al., 2011) A framework for linking the DSM and design process is conducted in the study by (Prasad, Jacob, Engineering, & Athanasius, 2018). A DDSM model was created using the drawings (deliverables) and their relationship to each other and the information flow were mapped using this process. (Prasad et al., 2018) Organizing and creating dependencies between the "ad havoc" information and the organization done by (Jacob, 2018) (Of & Engineering, 2017) explores the problem of changes in a complex design process and addresses the aspects of design inter-relationships. (Wynn, Caldwell, & Clarkson, 2014) , with the help of visual technology, and Revit data predicts the changes in the design process.

The nature and extent of change propagation in design process that involves complex dependencies between the tasks is currently neither clearly understood nor predictable in traditional project risk management practices. However, it can cause large delays or unexpected spending in projects. Predicting the changes, must incorporate the direct and the indirect effects, changes and their likelihood and impact which will give the stakeholders the idea of where to concentrate more and make informed decisions.

METHODOLOGY

The methodology is based on the application of the change Propagation method as applied in the case study of GKN West helicopter model of rotorcraft design by (Wynn et al., 2014) The change propagation depends upon two processes – i) the change flow from one component to another component and ii) the combination of changes from these components within the product. The case study approach facilitates exploration of complex issues at a micro level. (Tight, Symonds, & Symonds, 2016) A commercial project located in Ahmedabad; India is considered as a case study with approximately 20,000 sq.m of built-up area under design development with application of BIM. The building has a basement for car parking, ground floor and 6 upper floors. The relationship between the tasks involved in design development of the project are established and the CPM method is applied and validated to predict the risks involved due to the impact caused by the changes taking place. Detailed methodology applied on the case study is explained here,

Step 01: Detailed breakdown of the tasks involved in the design development of the selected project is done with the help of the weekly schedules and discussions with the consultants of the project. The milestones set for the completion of the design is mentioned in Table 1.

Step 02: Creation of DSM to establish direct relationships or dependencies between the tasks is done by conducting meetings and discussions with the Architect, Structural designer, and the MEPF consultant of the project at the site office of the project. The x-axis or each column of the matrix contain the change initiators and the rows, or the y-axis contain the affected tasks of Table 1 in the Annexure. The relationships are quantified by scoring the likelihood(l) and impact(i) of each change initiator against the respective affected tasks in the range 0 to 1, with 0 representing no impact of occurrence, and 1 representing the highest impact and likelihood. The average probability is that the change in one activity will lead to change in another.

Step 03: This data is loaded in the Cambridge Advanced Modeler (CAM) software. The 'Combined risk' of an activity is calculated via the Change Propagation Method (CPM) simulation. The CPM Simulation generates a heat map, with the combined values of Combined Likelihood (L), Combined Impact (I) and the combined Risk (R) of the change initiator tasks. Figure 1 shows the combined risk dependencies of the system. For instance, in Figure 1, the task 'k' – Integrated LOD 200, seems to be the most influential sub-systems with respect to change, while the task 'l'- Cost estimation LOD 200 is the most susceptible to change. This becomes a "map" to analyze the change propagation in the process that can initiate a change and can be used for analysis and assessment of the process.

Table 1: Breakdown of tasks involved in developing the design of the selected project

Legend	Milestone Activities	Legend	Milestone Activities
a	Client Brief	**i**	MEPF LOD 100
b	BIM execution plan	**j**	MEPF LOD 200
c	Architecture LOD 100	**k**	Integrated LOD 200 Arch + Structure+ MEPF
d	Structure LOD 100	**l**	Cost estimation LOD 200 - 02
e	Architecture LOD 200	**m**	Architecture LOD 300
f	Structure LOD 200	**n**	Structural LOD 300

g	Integrated LOD 200 Model 01	**o**	Integrated LOD 300 BIM Model
h	Cost estimation LOD 200 - 01	**p**	Final Cost estimation by contractor

ANALYSIS AND VALIDATION

The changes made in the design iteration processes are validated with the generated combined risk maps. For example, for the task (b)- BEP formulation as change initiator, the highest likelihood of change happens with the development of structural LOD300 model according to the simulation based on the discussions can be seen in Figure 2. The Table 2 shows the records of changes were made during the design process to be validated with the CPM analysis. As calculated in the product matrix – combined risk, there were change iterations to and from between the BIM execution plan and the tasks during the execution process. The combined risk prediction matches with the actual change impact that has taken place during the design change process. (highlighted in bold in the Table-3)

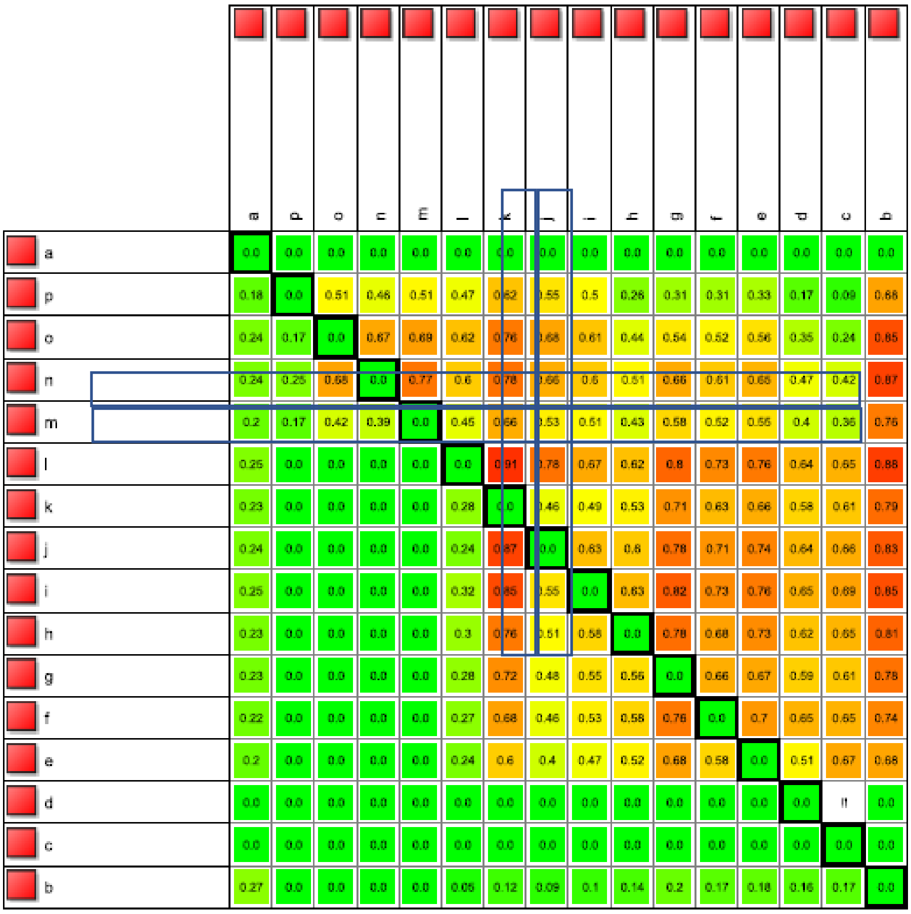


Figure 1. The CPM simulation result - combined risk map

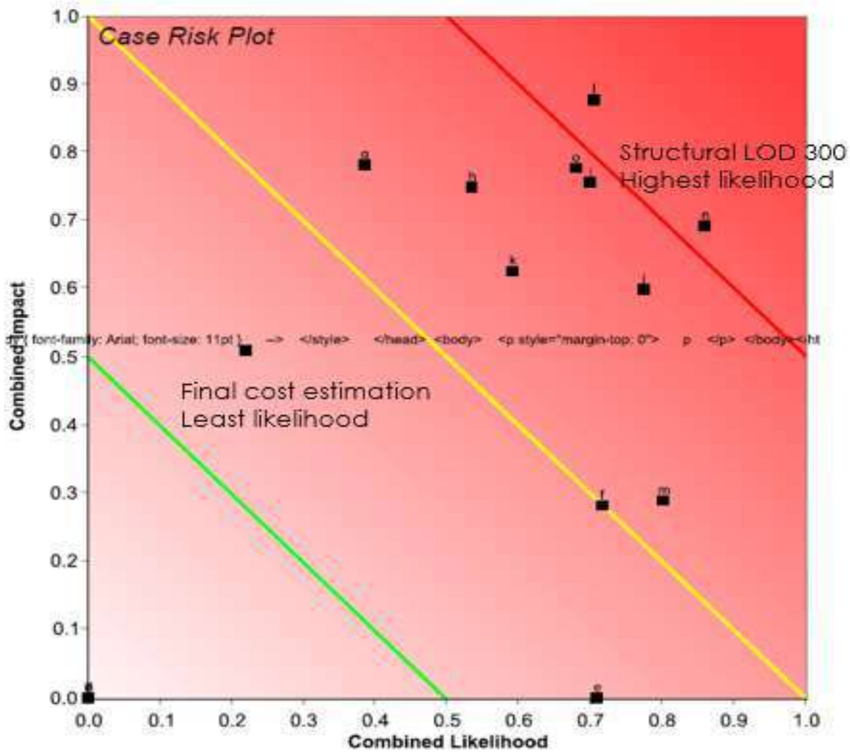


Figure 2. Example of Risk map for the change initiator task b- BEP formulation

Table 2. Changes recorded during the BIM management process

Change initiator Task	**Affected changed task**	**Impact**
Requirement changes According to HVAC (MEPF 100)	Integrated model change - Architecture LOD 200 changes – Wall locations Structure LOD 200	Change in beam sizes, column positions changed the integrated model and structural model
Integrated LOD 200 Model + BIM execution plan	Architecture and Structure LOD 200 changes	Time taken to correct the model to remove repeated elements
Cost estimation	LOD 200 A+ S changes	Cost optimization Change in design
Architecture LOD 300	Structure LOD 300	Change in beam sizes, column positions
MEPF LOD 200	Structure LOD 300 Architecture LOD 300	Change in beam sizes, column positions

Table 3. Analysis and validation of the changes, their impact, and the results of simulation

Change initiator Task	**Affected changed task (observed)**	**Direct affecting changes predicted**	**Direct Risk value Predicted**	**Combined affecting changes predicted**	**Combined risk value predicted**
Requirement changes According to HVAC (MEPF 100) *(i)*	Integrated model was completed, then it was required to redesign the architecture and structure models of LOD 200.	MPEF Lod 200	0.45	l. Cost estimation LOD 200 - 02	0.67
				j. MEPF Design LOD 200	0.63
				o. Integrated A300 + S300+ MEPF 200	**0.61**
				h. Cost estimation 200	0.58
				g. BIM Integrated LOD 200 Arch + Structure	0.55
				f. Structural LOD 200	**0.53**
		Integrated Lod 200	0.36	**m. Architecture LOD 300**	**0.51**
				n. Structural LOD 300	**0.50**
				p. Final Cost estimation by contractor	0.50
				k. Integrated LOD 200 Arch + Structure+ MEPF	0.49
				e. Architecture LOD 200	**0.47**

CONCLUSION

A simulation tool called the Cambridge Advanced modeler is used to run the Change propagation method (CPM) to obtain the predicted spread, and impact of the changes in the system, to analyze using the 'combined' Risk (combination of direct and indirect risks) – with the help of the likelihood and impact scores. Designers and Engineers involved in the design development are asked to score the direct likelihood and impact in the DSM matrix. The difficulty observed in this method was the quantifying of the change likelihood and impact, as no single domain engineer or the consultant knew about the overall process Changes and their impacts are recorded during the actual BIM design process of the commercial complex project and then compared with the CPM simulation results for validation.

With new BIM workflows and processes, there are ambiguities which can cause large delays or unexpected spending in design projects. Predicting the changes- their occurrence and impact will help in prioritizing corrective measures to be taken in case of delays and change management. This simulation can be used as an assessment to predict what activities will be affected when a new change takes place in the system.

Overall, the assessment requires the people of the system to come together, discuss and breakdown the processes, understand the system and predict the potential risks that might occur. This exercise aids the Top down and bottom-up approach in planning the tasks. However, the model requires numeric inputs, scoring the relationships between the tasks involved, from the consultants of the project, based on their experience of working in similar projects.

REFERENCES

Akintola, Y., Senthilkumar, V., & Root, D. S. (2015). *Identification of Process , Team and Tool Dependencies in Building Information Modelling (BIM) Implementation using Multi-Domain Mapping (MDM) – A Theoretical Framework*. 65–74.

Ariyo, O. O., Eckert, C. M., & Clarkson, P. J. (2007). Prioritising engineering change propagation risk estimates. *Proceedings of ICED 2007, the 16th International Conference on Engineering Design*, *DS 42*(August), 1–12

Bataw, A., Kirkham, R., & Lou, E. (2016). *The Issues and Considerations Associated with BIM Integration*. *00005*, 1–8.

B, D. A. C. (2019). BIM implementation in India. *BIM Implementation in India*.

Browning, T. R. (2015). *Design Structure Matrix Extensions and Innovations : A Survey and New Opportunities*. (December). https://doi.org/10.1109/TEM.2015.2491283

Eger, T., Eckert, C. M., & Clarkson, P. J. (2007). *ENGINEERING CHANGE ANALYSIS DURING ONGOING PRODUCT DEVELOPMENT*. (August), 1–9.

Hickethier, G., Tommelein, I. D., Hofmann, M., Lostuvali, B., & Gehbauer, F. (2011). MDM as a tool to improve BIM development processes. *Invest on Visualization - Proceedings of the 13th International DSM Conference*, 349–362.

Jacob, J. (2018). *A framework for ad hoc information management for the building design process*.

Jacob, J., & Varghese, K. (2012). Analysing process-oriented BIM Execution Plan using MDM. *Gain Competitive Advantage by Managing Complexity - Proceedings of the 14th International Dependency and Structure Modelling Conference, DSM 2012*, (August 2016), 329–341.

Of, J., & Engineering, C. (2017). *A METHOD TO PREDICT CHANGE PROPAGATION WITHIN BUILDING*. *23*(6), 836–846.

Prasad, A., Jacob, J., Engineering, C., & Athanasius, M. (2018). *A Framework for Incorporating Dependency Structure Matrix in Building Design Process*.

Pultar, M. (2006). *Modelling detailed information flows in building design with the parameter-based design structure matrix*. *27*, 99–122. https://doi.org/10.1016/j.destud.2005.07.004

Tight, M., Symonds, P., & Symonds, P. M. (2016). The Case Study as a Research Method. *Case Studies*, 15–15.

Ustinovičius, L., Puzinas, A., Starynina, J., Vaišnoras, M., Černiavskaja, O., & Kontrimovičius, R. (2018). *Challenges of BIM technology application in project planning*. *10*(2).

Wynn, D. C., Caldwell, N. H. M., & Clarkson, P. J. (2014). Predicting change propagation in complex design workflows. Journal of Mechanical Design, Transactions of the ASME, 136(8), 1–1

Annexure Table 1. Direct likelihood (l) and impact(i) scored by the consultants

			Change initiating Tasks															
Affected Tasks			a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
	l	a																
	i																	
		b	0.3						0.1				0.5					
			0.9						0.2				0.2					
		c																
		d			0.5													
					0.6													
		e		0.7	0.7	0.2		0.2	0.7	0.5			0.7					
				0.5	0.8	0.5		0.3	0.5	0.6			0.4					
		f		0.7		0.6	0.8		0.5	0.2			0.6					
				0.5		0.8	0.9		0.5	0.6			0.4					
		g					0.5	0.6		0.1								
							0.8	0.9		0.2								
		h					0.5	0.7	0.5									
							0.8	0.7	0.7									
		i				0.2	0.6	0.6	0.4	0.5		0.2						

						0.6	0.6	0.6	0.9	0.7		0.5						
		j		0.7							0.5		0.5	0.6				
				0.5							0.9		0.6	0.4				
		k									0.6	0.6						
											0.6	0.7						
		l										0.8	0.7					
												0.8	0.8					
		m		0.6										0.5		0.2	0.7	0.1
				0.5										0.5		0.5	0.5	0.7
		n		0.6										0.5	0.8		0.6	0.1
				0.5										0.5	0.9		0.5	0.7
		o													0.5	0.8		0.2
															0.7	0.8		0.2
		p													0.2	0.2	0.5	
															0.5	0.8	0.7	

Section V

PROJECT COST AND RISK MANAGEMENT

Editor's Note

Managing the cost and risks have been an important concern in the project management domain for decades. This section presents five studies in this domain that discusses various innovative methodologies that could be used for managing cost and risks in projects. For instance, Singla et al. investigates the causes of lack of precise estimation of indirect costs in construction projects and attempts to initiate the standards for indirect costs preparation from an Indian context. Through primary research methods, the paper discusses on the significance of close estimation of indirect costs in construction industry and root causes for the concerning degree of lack of effort in estimating the same.

Meanwhile, Sharma et al. developed a correlation model using LINDO and regression analysis, to understand the time-cost trade-off assessment for various projects. Similarly, Goswami used BIM to prioritize the various risks involved in construction projects. It considers that while the autonomous technological and legal risks of BIM are critical, their relative importance is outweighed by other common project risks. Likewise, Reddy and Nagakumar used a combination of Monte Carlo simulation and the robust Taguchi method to assess a road project's optimum risk reduction strategy. The findings of this paper will assist project managers in deciding on the method for choosing optimal methods for risk mitigation.

Meanwhile, the study by Tiwari and Suresha analysed project risk management and top management commitment to examine the effect of each of these on the success of the project. A contingency perspective was adopted to analyse the impact of project flexibility and project innovativeness, and the outcomes of this research have theoretical and managerial implications for IT project management.

Factors influencing the efforts to estimate project indirect cost accurately in construction projects: An exploratory study from Indian perspective

Harish Kumar SINGLA[1], Srividya Raju, SRIDHARAN[2] and Murali JAGANNATHAN[3]
National Institute of Construction Management and Research; email: hsingla25@gmail.com[1]
National Institute of Construction Management and Research; email: casrividhyaraju@gmail.com[2]
National Institute of Construction Management and Research; email: avemurali@gmail.com[3]

ABSTRACT

Previous studies have highlighted that indirect costs form a critical part of the total project cost. However, despite this knowledge, the precise estimation of indirect cost is often neglected in construction projects. This study is undertaken to empirically examine the reasons for the lack of effort in estimation of indirect cost. A survey of 53 projects managers along with two in-depth interviews are conducted. It is found that indirect costs constitute up to 15% of the project costs and may vary depending on the project. However, the study reports that time spent on accurate estimation is not rewarding enough. Further, indirect costs are the first victims of any attempt to reduce the bid cost with a goal to increase the competitiveness of bid to be submitted. In fact, in most projects, the indirect cost is inversely calculated as the residual of the Target bid price and (Direct costs + Profits). Therefore, no effort is made accurately estimate indirect costs. The paper concludes highlighting the need to develop construction-specific standards for overhead estimation that will serve as a reference when parties resort to overhead trimming, enabling them to take informed and calculated risks of shortfalls in indirect cost provisions and prevent surprises during execution. This research, which is carried out from an Indian perspective, can provide the necessary impetus to initiate preparation of indirect cost standards exclusively for construction projects.

KEYWORDS

Indirect cost; Overheads; Projects; Estimation; Accuracy; Efforts; India.

INTRODUCTION

The expectancy theory of motivation explains motivation as a cognitive process, where people believe that there exists a relationship between the effort they put forth at work, the performance they achieve from that effort, and the rewards they receive from their effort and performance. Though explained in an individual's context, it says that, people will be motivated if they believe that strong effort will lead to good performance and good performance will lead to desired rewards (Vroom, 1964). Extending this to project management perspective, we can hypothesize that efforts in cost estimation leads to accurate cost estimation, leading to better cost control, ultimately resulting in superior project profitability.

Cost estimation is a critical activity in any construction project. The robustness of estimation decides the certainty of project margins. Cost estimates are prepared by both client and contractor organizations before the start of the project. However, the purpose of estimation in both cases are different. While, the goal of estimation for client organizations is to secure budget sanctions and to publish the value in the notice inviting tenders (NIT), contractor organizations prepare estimates for tendering purposes (bid amount) and for internal cost calculations that will help them to arrive at project profitability. In any case, the cost estimates broadly consist of direct costs, indirect costs and profit margins. The scope of current research is limited to estimation of indirect costs by contractor organizations. The sum total of these organizational/project indirect costs are also known as overheads (Carr, 1989)). These overheads may be fixed, variable and semi-variable depending upon the level of activity. Limiting to the scope, a discussion on indirect cost is presented in the subsequent section.

Estimation of Indirect Costs – General Guidelines

The basic principle of code of estimating practice (Chartered Institute of Building – CIOB 1997) suggests that indirect cost items are mostly made up of time-related costs, for instance, rental charges, salaries, and fixed costs such as installation and dismantling costs, among others. If the requirements of each cost centers can be properly identified, estimation can be undertaken in the same way as the estimation of the unit rates for measured works. According to the Cost Accounting Standard (CAS 3), "all those material, employee and indirect expenses which are not directly identifiable to a cost object are overheads. However, these must be loaded to the cost object in an economically feasible way." Absorption costing technique allows for loading of overheads to each product/project or service following a relevant criterion, but does not prescribe a single criterion for specific cost types. Some commonly used allocation criteria are direct labor hours, direct labor rate, machine hours or square feet area occupied. There are other techniques like Activity Based Costing (ABC) which propose a scientific way to allocate indirect costs based on most suitable cost drivers. However, these methods are most suitable to the manufacturing industry where the product cycle is more or less fixed and activities are repetitive in nature. The discussion of indirect costs in the construction industry will be significantly differ due to the unique nature of the industry which is project based rather than product based.

Significance of Indirect Costs

The indirect costs in project include support services like salary of project team, indirect fuel consumption, insurance etc. The sum total of all indirect costs is also known as overheads. These project overheads can be divided into two levels. At level one, are those project overheads that are economically traceable to a project but that would not have occurred had the project not been performed. The second level overheads consist of the costs of running the construction business that are not economically traceable to its projects (Carr, 1989). These overheads along with profit margin constitute 20-30% of project cost (Janani, Rangarajan, & Yazhini, 2015; Patil & Bhangale, 2014). This percentage can be of significant value in large projects (Padroth, Davis, & Morrissey, 2017). Therefore, uncontrolled overheads can pose a serious challenge to the project profitability. (Tah, Thorpe, & McCaffer, 1994) suggested that efforts in improving tender prices should be directed towards improving the methods of determining indirect costs as indirect cost can be a determining factor for the success of a contractor's bid in the tendering process (Chan & Pasquire, 2004). Though, the exact traceability of overheads is very difficult (Assaf, Bubshait, Atiyah, & Al-Shahri, 2001), adequate efforts to appropriately estimate the overheads, record them as separate line items or to load them to item rates can lead to better monitoring and control over cost structure; thus, can result in greater profitability (Enshassi, Rashid Abdul Aziz, & Karriri, 2008).

Inaccurate estimations of indirect costs reduce the control over the project cost and profit margins (Assaf et al., 2001; ElSawy, Hosny, & Razek, 2011; Kim & Ballard, 2002). The absence of the system of regular appraisal of cost estimation and overhead loading methods may, in the long run, lead to bankruptcy in case of underestimation (Akintoye & Fitzgerald, 2000; Chan & Pasquire, 2004). (Plebankiewicz & Leśniak, 2013) suggested that improper calculation of mark-ups, that is, indirect cost with profit margin can have significant effect on the financial situation of the company. Despite, the importance of indirect costs and clear CIOB code of estimating practice and CAS 3, contractors normally do not accurately estimate the project overhead cost. Only 10% of those questioned in Poland, determined overhead costs in detail (Plebankiewicz & Leśniak, 2013).

Significant, yet neglected

In construction projects, (Aibinu & Pasco, 2008) discovered that pre-tender building cost estimates were mostly inaccurate. This inaccuracy was much more with respect to estimation of indirect cost. The lack of effort on estimation of indirect cost resulted in this inaccuracy of estimates. The inaccurate estimation leads to poor control over the cost, in turn leading to reduced profitability. Notwithstanding the impact on profitability, many studies have quoted that precise estimation of indirect cost is often neglected by construction stakeholders, especially contractors (Assaf et al., 2001; ElSawy et al., 2011) and in unfavorable economic conditions, the immediate clamp down is always on overheads (Osadchy & Akhmetshin, 2015). While it is accepted that the indirect costs form a significant part of project cost estimation, their estimation receives muted attention in comparison with the direct cost estimation, resulting in approximate, rather than, accurate estimation.

The problems with 'accurate estimation'

The indirect costs are widely discussed in literature and mainly divided into four research trends (Siskina, Juodis, & Apanaviciene, 2009). These four trends are the analysis of situation and statistical research on the understanding of the overhead costs concept, analysis of construction delays vs. overhead costs, analysis of the construction company's overhead costs distribution, and allocation and analysis of fixed expenses recovering (Leśniak & Juszczyk, 2018). It is believed that for large construction projects, 70-80% of the project cost is, generally, direct in nature (Enshassi et al., 2008). This cost is mostly consumed in activities like material, labor and equipment. (Tah et al., 1994) suggested that estimation of direct cost is relatively easy because of the knowledge of input sources. Further, variety of highly sophisticated estimation software and techniques are available that can result in reasonable accuracy of estimation of direct project cost. However, as discussed earlier, such efforts are not directed towards estimation of indirect costs. Some of the reasons (through literature review) are identified in the subsequent sections.

Several scholars investigated the practices of estimating the indirect costs involved in tendering for construction work and suggested that the methods used for estimating overheads are highly subjective and are based on past experience. In a survey of UK contractors by (Tah et al., 1994), estimation of indirect costs was found to be highly subjective and a heavy reliance on management decisions was observed. In the study of large contractors in Hong Kong by (Chan & Pasquire, 2004), 57% of the respondents estimated their project indirect cost items subjectively with the help of senior estimators. Another survey by (Assaf et al., 2001) revealed that around 29% of large Saudi Arabian contractors estimated project indirect costs as a percentage of the direct costs. Similar results were obtained from a study of top general contractors in the United States of America (the U.S.A) and Canada (Hegazy & Moselhi, 1995). A survey of cost estimating practices amongst construction contractors in the United Kingdom (UK) showed that methods used to estimate overheads are inaccurate and unstructured based on the contractor's own experiences or based on the requirements that are sometimes dictated by the software system they use. These models are together called "experience-based" models. In all these estimations tasks, the involvement of site management in cost estimation is minimal as the estimation is done primarily by commercial managers in charge of the tendering process, a team that will not be involved in execution of works at site (H. Doloi, Sawhney, Iyer, & Rentala, 2012). Even though project overheads cost estimation has been a widely discussed topic (Juszczyk & Leśniak, 2019), accurate estimations of indirect costs seem to be a comparatively less discussed topic owing to the perception about indirect costs by the concerned parties. However, while analyzing the overheads management process in Saudi Arabia, (Assaf et al., 2001) noted that a majority of survey respondents agreed that overheads will be of greater importance in the future. Additionally, owing to the cut-throat competition in the tendering process witnessed in the recent times (leading to conservative bid submission), research in the indirect cost estimation domain seems to be picking up. (Leśniak & Juszczyk, 2018) developed an early-stage construction site overhead cost prediction algorithm using artificial neural networks (ANN) considering the accurate but time-consuming or fast but inaccurate methods of overhead calculation available in the construction market. While the extent research has listed down the reasons for the limited discussion on detailed and accurate indirect cost estimation, this paper attempts to empirically examine it with data from India.

The definition of indirect costs as per CAS 3 is worth recalling at this juncture because it recognizes that, first these overheads must be estimated properly and secondly, these must be ultimately 'economically' loaded to direct project costs. The word 'economically' is inserted in the definition to suggest that while overheads have to be allocated or absorbed by the cost items in a true and fair way, the allocation should be done on the basis which does not involve undue wastage of time and effort in estimation and calculation. One of the reasons for not putting enough efforts into this exercise is that it may not be economically feasible for project managers to go for detailed estimation (H. K. Doloi, 2011). Also, unlike manufacturing companies, where the cost estimation of a unit is easy because the process is repetitive nature, the product cycle is small and the cycle produces clear work-in-progress and finish goods inventory; the construction projects are non-repetitive, non-standardized (Back, Maxwell, & Isidore, 2000; Kern & Formoso, 2006; Scevik & Vitkova, 2017) and time-intensive. Therefore, the nature of construction projects makes it unviable to put efforts into estimation of overheads.

Studies by (Assaf et al., 2001) and (Chan & Pasquire, 2004) suggested that overhead estimation was intentionally compromised by project managers. To cope up with very thin margins in bidding, costs, particularly overheads, were more often conservatively estimated (Assaf et al., 2001). In a study, (Chan & Pasquire, 2004) found that in Hong Kong construction projects, estimate of the indirect costs was done in detail, but the accuracy of estimation was dubious. The under-estimation of project indirect cost in general is more common due to the current competitive environment, as the overestimation may generate an uncompetitive bid, whereas the under-estimation gives rise to a higher chance of success in the bid (Ioannou & Awwad, 2010; S. K. Shrestha, 2014). Therefore, to under estimate the cost, the project managers intentionally compromise with indirect costs (Assaf et al., 2001). The compromise with indirect cost is easier because of the non-standardization of the requirements of indirect cost. On the contrary, it is difficult to underestimate the direct costs, because of the standardization of material, labor and equipment in tender document. Any reduction in direct costs will be easily visible in the bid document.

Apart from economic feasibility, nature of construction projects and competitive bidding scenario, there can be number of other reasons, as to why projects do not pay adequate attention to the estimation of overheads or search for criteria to load these overheads to direct project cost. One such factor is the project delivery model.

The project delivery model sets the base for the selection of the type of contract and this results in allocation of risk among parties to the contract. Hence, there might be direct connect between the choice of project delivery model and the efforts that goes into overhead estimation, recording or search for loading criteria. Theoretically, in a design-build (DB) project delivery with a lump sum payment, the tight monitoring and control of overheads can lead to significant cost savings and increased profit margin. Whereas, for a Design-bid-build (DBB) project delivery model, for item rate contracts, the risk of quantities is borne by the client. The contractor gets paid by a pre-determined rate, inclusive of the direct and indirect cost, with a provision to compensate the contractor in the event of increase in the original quantities (payment is done on the basis of actual measurement). However, such provisions are not available in fixed sum or lump sum contracts (followed for DB projects) thereby warranting greater control on overhead costs which is fixed irrespective of quantity estimation errors, if any, during bid submission. Researchers (Bennett, Pothecary, & Robinson, 1996; Carpenter & Bausman, 2016; Hale, Shrestha, Gibson, & Migliaccio, 2009; Konchar & Sanvido, 1998; Minchin, Li, Issa, & Vargas, 2013; Rosner, Thal, & West, 2009; P. P. Shrestha & Fernane, 2017; P. P. Shrestha, O'Connor, & Gibson, 2012) compared the cost of DB and DBB models and concluded that the DB project delivery method show better cost benefits. However, no examination of the superior cost performance of DB, in context of the efforts of estimation of indirect cost is witnessed in the literature. Can it be the case, that since DB transfers most of the risk to contractor and therefore it leads to more efforts in estimation and accurate estimation leads to cost benefits? A clear answer is not available in the literature.

One study (Lowe & Skitmore, 2001) investigated the relationship between the accuracy of 'early-stage' forecasts and experience of estimator, learning styles of estimator, and approaches to learning. They found no significant relation between accuracy in estimation and the experience of estimator.

Notwithstanding the references found in the literature in the area of subject research, limited empirical research is generated to understand, why accurate estimation of overhead cost is not given importance in construction projects. Therefore, the present study, is an attempt to understand the practices of construction project managers in India, with respect to the level of efforts made in estimation of indirect cost, elements driving these efforts, and the criteria followed to allocate (loading) indirect costs to direct cost items. The study is conducted in the context of India. A model of the research framework is presented in figure 1.

Therefore, authors hypothesize the following.

Ha1: Indirect costs are significant part of the project cost.

Ha2: Estimation of indirect costs are often neglected.

Ha3: There is a lack of effort in estimation of indirect costs because of the low perceived cost benefits.

Ha4: A lack of effort in estimation of indirect costs is driven by competitive bidding process.

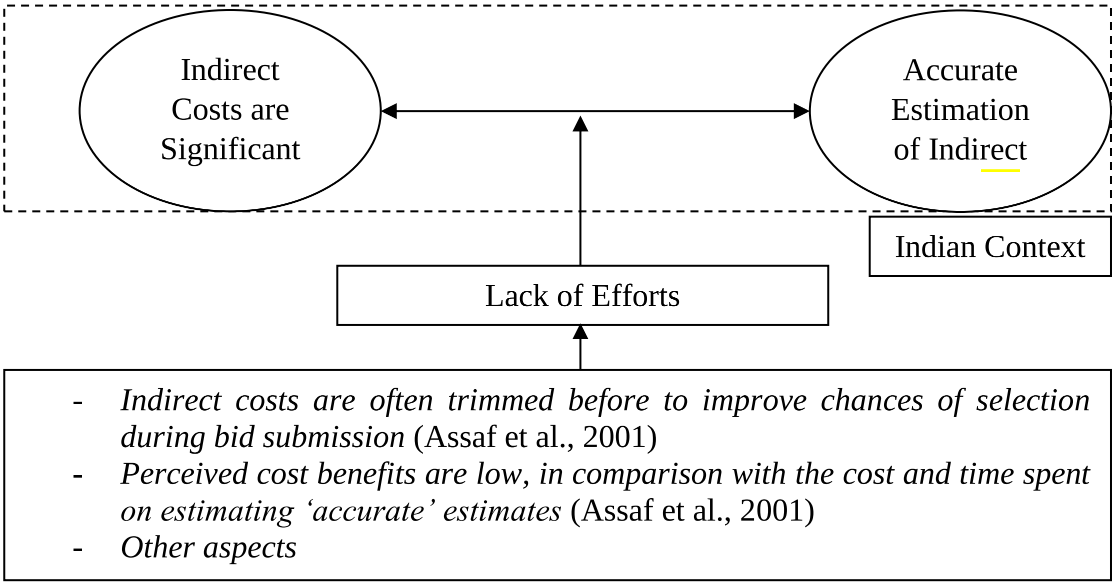


Figure 1. Research Framework

RESEARCH METHODOLOGY

A list of approximately 500 construction and real estate projects, with project size above 5000 Million INR ($66.67 Million or above) was available in the website of Center of monitoring Indian economy, CAPEX. The in-charges of these projects were contacted through electronic mail (e-mail). A comprehensive questionnaire was provided to them, which included questions on type of project delivery model, nature of project and experience, among others.

These respondents were asked to rate the following questions on a five-point scale, where 1 means strongly disagree, 2 means disagree, 3 means neutral, 4 means agree and 5 means strongly agree. The questions were

1. Indirect costs are significant part of the project cost.
2. Estimation of indirect costs are often neglected.
3. A lack of effort in estimation of indirect costs is driven by the low perceived cost benefits.
4. The lack of effort in estimation of indirect costs is driven by competitive bidding process.

Apart from answering the questions on the five-point scale, the respondents were requested to explain the reason for each choice. In addition to these questions, the respondents were asked the following questions,

• How are these indirect costs loaded to direct project cost?

• What type of efforts that are made to accurately estimate overheads, or search for relevant loading criteria for project overheads? If any.

The response rate to the survey was very low as only 53 responses were received, giving a response rate of approximately 11%. A brief profile of the respondents is placed here in Table 1. All the respondents are working on projects in India; however, their name, project site/work location was not collected during the survey to maintain anonymity of responses. To strengthen the findings, authors conduct two in depth interviews. The interviews are presented in form data analysis. The interviewees are having an experience of more than 25 years in handling complex construction projects. They have experience in management and execution of domestic as well as international projects.

Table 1. Table I. Profile of respondents

Location of Work	**Number of respondents**	**%**
Head office	11	20.75%
Project Site	38	71.70%
Regional Office	4	7.55%
Country-India	53	100%
Department	**Number of respondents**	**%**
Planning	14	26.42%
Project Control	15	28.30%
Cost Control	19	35.85%
Others	5	9.43%
Experience	**Number of respondents**	**%**
0 to 5 Years	20	37.74%
5 to 10 Years	18	33.96%
More Than 10 Years	5	9.43%

DATA ANALYSIS

Table 2 presents the data analysis of seven five-point scale questions using one sample t test. In a one sample t test, the mean is hypothesized as 3 (neutral) and two tail t test results are presented.

Table 2. One sample t test

Question	Mean	Std. Deviation	Std. Error Mean	Mean Difference	Sig. (2-tailed)
Indirect costs are significant part of the project cost.	4.057	1.045	0.144	1.057	0.000**
Estimation of indirect costs are often neglected.	3.774	1.031	0.142	0.774	0.000**
The lack of effort in estimation of indirect costs is driven by lack of perceived cost benefits.	3.547	1.102	0.151	0.547	0.001**
The lack of effort in estimation of indirect costs is driven by competitive bidding process.	4.000	1.019	0.140	1.000	0.000**

Source: Authors compilation using SPSS 21 **Significant at 1%

The results in Table 2 indicate that all the hypotheses are accepted ($p \leq \alpha$ at 0.01). The indirect costs are significant part of the project cost. Most respondents agreed that indirect costs constitute 12-15% of their project cost and form a significant part. However, the precise estimation of overheads requires huge efforts and such efforts are not invested in indirect cost estimation. It is because, mostly respondents believe that the efforts in terms of time and cost involved in the estimation is high and the perceived benefits are small. When asked about the difficulties in estimation, the most common view is that construction projects do not have a standardized structure. Therefore, unlike manufacturing companies, the precise estimation or allocation of overheads, though possible is often ignored. In fact, few respondents suggested that, a proper set of guidelines or a comprehensive framework on estimation and allocation of overheads, specially designed for construction projects may help. However, due to the lack of any standardized process for allocation of overheads in construction projects, they primarily follow thumb rules or use experience-based estimates. Further, they find, the estimation of indirect costs as a futile exercise, because, in the end, overheads are often compromised in the process of making the bid competitive. To make a bid competitive, contractors underestimate the cost, (mainly indirect cost) and also indulge in front and back loading strategies which will disrupt the accuracy of estimation again. This is precisely the reason, that whenever, there is an uncertainty, the immediate clampdown is on indirect cost. The respondents also shared the view that most overheads are time linked but they are rarely allocated to direct cost using a standard criterion. Often, they are loaded to the direct cost as a fixed percentage of cost or revenue.

The repeated adjectives associated with indirect cost are 'difficult to monitor', 'creates complexity/ hard to tackle/ causes confusion', 'allocation based on past experience', 'depends on company policy' 'arrive at approximate figure/not estimated accurately'.

Interviews

The analysis of two interviews did gave additional insights, which are presented below.

The first interviewee is currently working on a metro project. The project delivery model is engineering, procurement and construction (EPC), involving construction of elevated corridor and underground tunnel. The second interviewee is currently working on a design-build project in one of India's largest construction companies and has a work experience of more than 30 years in this field.

What constitutes Overheads in a construction project

All respondents to the survey as well as both the interviewees agree on the basic nature of costs that cannot be considered as overheads – Costs which are directly attributable to the project (material, labor and equipment). However interestingly there exists a difference in the perception of what costs constitute overheads. The first interviewee defined overhead costs as those costs which are incurred when there is no productive work/ action at site.

"Generators used to run machines is a direct cost. But the same generator used for site office is overhead. For example, when the tunnel work is going on, irrespective of whether the work is in process or not at site, the temperature and ventilation should be maintained in the surrounding areas. For this we sometimes need to keep the generator running to produce electricity for the same. The cost incurred on running the generator in such cases where no work is being carried out on site for the period is very difficult to explain to the commercial team when allocating them to cost heads. So, we simply treat them as indirect costs"

Hence as per him, costs which are difficult to trace to a particular activity because of non-progress of work are better treated as indirect costs. The second interviewee perceives overheads as those costs that are fixed in nature and do not vary according to size of the project or level of activity in the project.

"For each project there is a minimum requirement of support staff and other supporting arrangements, irrespective of the size of the project. These costs are defined as overheads and they are fixed in nature. For example, cost of Bank guarantees such as performance guarantees are indirect costs that are no way connected to labor, material or equipment and would not change according to level of activity completed in the project."

Therefore, in his opinion, all fixed costs only that are not material, labor or equipment related costs would be overheads. In other words, if the same cannot be said for variable costs that are not material, labor or equipment.

Overhead estimation in projects

While respondents to our survey and interview agree that overheads are estimated as a percentage of a base while tendering and bidding, there is very less agreement on the base used for determining this percentage. Since the tending and bidding are a business head decision and they take the final call on the extent of overheads allowed in a project, the percentage figure is a commercial decision rather than a decision based on accurate forecasts. Therefore, it's a backward-looking process, where a cut off is decided in advance, that our overheads should not exceed a certain X% of the project cost. Generally, this % is given as a target by the business head and the team is expected to operate within that fixed percentage.

When questioned about the ability to standardize the percentage of overheads, the first interviewee felt that it was possible to achieve a certain level of standardization by project classification but beyond that standardization was not feasible.

"In our organization, standardization as a fixed % is possible based on project classification as highway project, metro project, tunnel project etc. As long as overheads are below that level, it does not alarm the managers. Hence, indirect cost estimation is the last thing that estimators are concerned about at the time of bidding."

The second interviewee draws a direct relation between duration of the project and percentage of overheads, insisting on experience-based estimation rather than standardized estimation.

"For monitoring and control purpose, the overheads are always restricted to a fixed percentage of the project cost. It's better to control these costs by setting a fixed %, rather than estimate them. So, in a way, it's a backward-looking process. Project overheads are never estimated in advance. Therefore, when a project goes for mass level mobilization, and if there is a delay, the overheads will shoot up. We never make a standard for overheads. Estimation and allocation are always based on experience. As a rule of thumb, overheads and profits cannot exceed 20% of bid."

Efforts vis a vis rewards in overhead estimation

Most respondents identify with the extent of difficulty involved in accurate estimation of overheads at the time of tending and bidding. While accuracy in estimation is not impossible, they agree that it is too time taking and rewards from such accurate estimation are not commensurate with the efforts. In the words of the first interviewee,

"There are no such projects where the indirect costs are accurately estimated. I feel the estimators may even lack the requisite skills and training for accurate measurement. Cost-wise, it may not be a big issue but the effort that goes into it is significant. I won't say it is impossible but it is very cumbersome. Allocation of overheads to direct cost is also very challenging task, until the task is very specific. i.e., if people and machines are used for multi-tasking or multiple works, linking these to direct cost items becomes challenging. Given such complications, the task of allocation becomes a mathematical exercise and the worrisome part is despite the effort, allocation will suffer from certain assumptions that may be questioned for the validity and accuracy."

An additional angle which emerged from the second interview was that the construction industry associated with working on unit rates. Therefore, adding overhead costs to these unit rates may distort the entire calculation, questioning the established unit rates. Hence, for bidding purpose, overheads are not loaded through precise calculations based on actual indirect costs because any such attempt may lead to unnecessary deviations from the established rates leading to unfavorable bid submission.

"It is possible to load these overheads to direct cost items like concrete, shuttering, block work, among others… but if we do that, we will be questioned for deviating from industry standards and market rates on the direct costs. We may then end up losing the bid. Further, adding them to unit rate reduces the control we would otherwise have on these over overheads. For monitoring and control purpose, the overheads are always restricted to a fixed percentage of the project cost. It is better to control them this way. I feel it is not worth the effort to find loading criteria or to allocate overheads to units. It's a waste of time and does not serve any purpose. At the time of bidding, overheads are not a differentiator."

Project delivery model and overheads

Theoretically speaking, the project delivery model has to influence the method and effort involved in estimation of overheads. Not much light was thrown on this however by our interviewees. They however did agree that the role of project delivery model in estimation efforts and accuracy was significant.

"With EPC kind of projects, earlier the project gets completed, lesser is the expenditure towards indirect costs although I may not really want to deliberate on this issue."

DISCUSSION

All the survey respondents are in agreement with the fact that indirect costs are significant. This observation from the survey is in line with the observations of the researchers in this domain (Assaf et al., 2001). Further, it is also agreed by respondents and the interviewees that indirect costs constitute up to 15% of the project costs and may vary depending on the project. The range, if not exactly, is also in agreement with the observation ranges of earlier researchers (Assaf et al., 2001; Janani et al., 2015). The researchers are also in agreement on the fact that indirect cost estimation is often a neglected exercise. The reasons for lack of interest are because of the lack of perceived benefits in spite of the efforts and secondly the pressures of competitive bidding. This needs further elaboration.

To begin with, it appears that the definition of indirect costs is company-specific. This observation came to the fore from the in-depth interviews with two experts from two leading construction organizations in India. While the first interviewee records all the ‘costs that are incurred when unproductive work’ as indirect costs, the second interviewee records the items that cannot be apportioned to direct costs (owing to the difficulty of mapping it) as indirect costs, where the latter definition which is in line with the definition by researchers (Assaf et al., 2001; Scevik & Vitkova, 2017; Siskina et al., 2009). The definition, as explained by the first interviewee, where the overhead costs are linked to the work productivity, is something that is not, in our opinion, a popular definition among researchers. If overheads are recorded based on productivity, minimum acceptable levels of productivity need to be defined, below which the expended costs would be recorded as indirect costs. While researchers agree that there are various definitions of these costs (Enshassi et al., 2008; Plebankiewicz & Leśniak, 2013), the definition that links productivity with indirect costs warrants deeper research.

The respondents are of the view that the time spent on accurate estimation is not rewarding and this can be attributed to the bidding practices, which is again in agreement with the observations of researchers (Assaf et al., 2001; H. Doloi et al., 2012; Plebankiewicz & Leśniak, 2013). Indirect or overhead costs (Enshassi et al., 2008) are the first victims of any attempt to reduce the bid cost with a goal to increase the competitiveness of bid to be submitted. The reason for this, in our opinion, is linked to the manner in which overhead costs are perceived. Instead of estimating from the first principles, indirect costs are calculated in the industry as = Target bid price – (Direct costs + Profits), which puts the words of (Assaf et al., 2001) in the form of an equation. In other words, instead of estimating the target bid price from indirect costs, indirect costs are estimated after fixing the target bid cost. The drawback of this treatment is that, though mathematically it does not make any difference in calculation, overhead costs are taken for granted and what is remaining after ‘accurate’ direct costs and ‘secure’ profits, is considered to be indirect costs rather than the treating profits as residual after deduction costs from revenue. Therefore, the focus is on profit protection at the risk of indirect expenses. This goes perfectly well with the basic premise of the economic theories of firm, that considers profit maximization as the goal of organizations (Neumann & Morgenstern, 1944) and not indirect cost protection. However, the next question arises, why indirect costs are sacrificed and not direct costs? The answer to this is simple. Direct costs are backed up by detailed estimation and industry standards and any compromise made gives a glaring reflection on the inadequacies in the estimation, whereas there are no such standards for indirect costs, making it the victim of profit-maximizing goals of organizations. When the Central Public Works Department (CPWD)’s (India’s state-owned owned apex construction management organization) standard schedule of rates are referred, while direct costs are estimated in detail, indirect costs are bundled as a single line item (together with profits) without any break-up. In simple words, there is no logic for an increase or decrease in overheads and hence no questions asked when they are adjusted to make the bid attractive and improve winning chances. Indirect cost estimates are subjective and something that can be adjusted without much reasoning. Along with this treatment of indirect costs, the lack of a consistent definition across the industry, further strengthens the reasons for estimators to neglect its accuracy during estimate preparation. Estimators are aware that indirect costs are up for sacrifice when it comes to management call to reduce the bid amount and there is no need to spend much time estimating it accurately especially, that too when its calculation is challenging and prone to inaccuracies in estimates (Chan & Pasquire, 2004). This excuse can be prevented when there are standards for the analysis of overhead costs, similar to the rate analysis in case of direct costs.

Another observation that emerges from the study is that the project delivery model affects the estimation accuracies of indirect costs, however, it is not clear from the interviews or the survey as to what extent the degree of estimation accuracy is affected by the project delivery models and thereby leaving us where we are in this regard. We are unable to comment on this further through this research and this area seems to be a promising for future research.

While we understand that profits are the focus of organizations, there is no reason to neglect overhead estimation accuracies. Accurate estimation helps in better control of project margins – thereby serving the profit-maximizing goals of organizations. To bring in seriousness, standards need to be developed to compare estimated overhead costs with such standards, especially when overheads can have an impact on the project profits. A conscious effort by industry experts, academicians and researchers can bring some discipline in overhead estimation rather than leaving the critical domain only to thumb rules or experiential assumptions.

Limitations and future scope

While the intention was to empirically find the reasons for lack of focus on accurate estimates of indirect costs, the study also concludes with identification of areas that may require focused and deeper research specially to accurately define overheads and understand the effects of project delivery models on overhead cost estimation. Future research attempts may include head office overheads in the analysis and also explore the views of other stakeholders like cost consultants and employer organizations. Lastly, the research is based on data from Indian construction contractors. A cross-country analysis may end up in giving further insights.

CONCLUSIONS

The main objective of the research was to empirically examine the reasons for the lack of efforts expended by parties to accurately estimate the indirect costs. From the review of the literature, it is clear that though indirect costs are considered important and many times as a game-changer, efforts are not made to accurately estimate it. While many researchers state some reasons for the apparent lack of focus on indirect costs, empirical analysis is required to validate them. To get into the roots of the causes for lack of efforts, a survey is conducted, followed by two in-depth interviews of industry experts as summarized in Table 3.

It is evident from the study, like previous observations, that while overheads are viewed inferior to direct costs (and hence prone to adjustment when it comes to fine-tuning the bid amount to make it competitive), the behaviour seems to stem from the notion that accurate overhead estimation is, if not impossible, a difficult process that does not yield economic benefits for the efforts expended. However, on the other hand, there is an agreement that overheads are a significant part in the cost estimations prepared by stakeholders. The contradictory opinions only say that there is a need for a ready reference that can quickly help estimators to arrive at accurate overhead costs. Accuracy is always achieved by comparing with accepted standards and in the domain of indirect cost estimates such standards are exactly what is needed. The presence of an acceptable standard for indirect costs, similar to direct cost standards, will help meeting the call of researchers across the globe, that is, to consider accurate overhead estimation, rather than just thumb rules. The efforts towards this task must be initiated by contractors as they bear the first and the maximum impact of overhead estimation inaccuracies. We hope that this research can provide the necessary impetus to initiate preparation of indirect cost standards exclusively for construction projects.

DATA AVAILABILITY STATEMENT

Data generated or analyzed during the study are available from the corresponding author by request.

Table 3: Root cause analysis – Lack of effort in estimation of indirect cost (construction industry)

Root Cause	Justification	Evidence from literature	Evidence from current research (Indian perspective)
Backward estimation	Indirect costs are subjective and can be adjusted without much reasoning in the form of "Target bid price – (Direct costs + Profits)"	(Assaf et al., 2001; Chan & Pasquire, 2004; Hegazy & Moselhi, 1995)	Competitive bidding process drives backward estimation of indirect costs.
Lack of industry standards	Non repetitive nature of activities in construction, a project based industry as against repetitive activities in manufacturing product based industry, lead to inability to establish standards.	(Assaf et al., 2001; Back et al., 2000; ElSawy et al., 2011; Kern & Formoso, 2006; Osadchy & Akhmetshin, 2015; Scevik & Vitkova, 2017)	Experience based models are used widely in industry for indirect cost estimation, although they are a significant part of costs.
No mandate for breakup	Directive for loading of indirect costs mentions that it should be done in an economically feasible way. There are no further directives on need to provide complete cost break down of this component.	(Aibinu & Pasco, 2008; Chan & Pasquire, 2004; Plebankiewicz & Leśniak, 2013)	Rule of thumb encouraged as no international standard mandates detailed indirect cost break up.
Economically non-viable	Expected benefit from detailed estimation of indirect costs does not exceed expected cost and effort of estimation.	(H. K. Doloi, 2011; Enshassi et al., 2008; Tah et al., 1994; Vroom, 1964)	Lack of effort to estimate indirect costs accurately is driven by lack of perceived cost-benefits.

ACKNOWLEDGMENTS

The authors express sincere thanks to all the respondents and the interviewees for sharing their valuable time and providing significant insights.

REFERENCES

Aibinu, A. A., & Pasco, T. (2008). The accuracy of pre-tender building cost estimates in Australia. *Construction Management and Economics*, *26*(12), 1257–1269. https://doi.org/10.1080/01446190802527514

Akintoye, A., & Fitzgerald, E. (2000). A survey of current cost estimating practices in the UK. *Construction Management and Economics*, *18*(2).

Assaf, S. A., Bubshait, A. A., Atiyah, S., & Al-Shahri, M. (2001). The management of construction company overhead costs. *International Journal of Project Management*, *19*(5), 295–303. https://doi.org/10.1016/S0263-7863(00)00011-9

Back, W. E., Maxwell, D. A., & Isidore, L. J. (2000). Activity-Based Costing as a Tool for Process Improvement Evaluations. *Journal of Management in Engineering*, *16*(2), 48–58.

Bennett, J., Pothecary, E., & Robinson, G. (1996). *Designing and building a world-class industry*. Reading, United Kingdom: University of Reading.

Carpenter, N., & Bausman, D. C. (2016). Project Delivery Method Performance for Public School Construction: Design-Bid-Build versus CM at Risk. *Journal of Construction Engineering and Management*, *142*(10). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001155

Carr, R. I. (1989). Cost-Estimating Pronciples. *Journal of Construction Enginering and Management*, *115*(4), 545–551.

Chan, C. T. W., & Pasquire, C. (2004). An Analysis for the Degree of Accuracy in Construction Project Indirect Costs. *The Journal of Cost Analysis & Management*, *6*(1), 46–66. https://doi.org/10.1080/15411656.2004.10462247

Doloi, H. K. (2011). Understanding stakeholders' perspective of cost estimation in project management. *International Journal of Project Management*, *29*(5), 622–636. https://doi.org/10.1016/j.ijproman.2010.06.001

Doloi, H., Sawhney, A., Iyer, K. C., & Rentala, S. (2012). Analysing factors affecting delays in Indian construction projects. *International Journal of Project Management*, *30*(4), 479–489. https://doi.org/10.1016/j.ijproman.2011.10.004

ElSawy, I., Hosny, H., & Razek, M. A. (2011). A Neural Network Model for Construction Projects Site Overhead Cost Estimating in Egypt. *International Journal of Computer Science Issues*, *8*(3), 273–283. Retrieved from http://arxiv.org/abs/1106.1570

Enshassi, A., Rashid Abdul Aziz, A., & Karriri, A. (2008). Investigating the overhead costs in construction projects in Palestine. *Journal of Financial Management of Property and Construction*, *13*(1), 35–47. https://doi.org/10.1108/13664380810882066

Hale, D. R., Shrestha, P. P., Gibson, G. E., & Migliaccio, G. C. (2009). Empirical comparison of design/build and design/bid/build project delivery methods. *Journal of Construction Engineering and Management*, *135*(7), 579–587. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000017

Hegazy, T., & Moselhi, O. (1995). Elements of cost estimation: a survey in Canada and the United States. *Cost Engineering*, *37*(5), 27–33.

Ioannou, P. G., & Awwad, R. E. (2010). Below-Average Bidding Method. *Journal of Construction Engineering and Management*, *136*(9), 936–946. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000202

Janani, R., Rangarajan, P. T., & Yazhini, S. (2015). A Systematic Study on Site Overhead Costs in Construction Industry. *International Journal of Research in Engineering and Technology*, *4*(10), 149–151.

Juszczyk, M., & Leśniak, A. (2019). Modelling construction site cost index based on neural network ensembles. *Symmetry*, *11*(3). https://doi.org/10.3390/sym11030411

Kern, A. P., & Formoso, C. T. (2006). A model for integrating cost management and production planning and control in construction. *Journal of Financial Management of Property and Construction*, *11*(2), 75–90. https://doi.org/10.1108/13664380680001081

Kim, Y., & Ballard, G. (2002). Case Study - overhead costs analysis. *Proceedings IGLC-10*, 1–13.

Konchar, M., & Sanvido, V. (1998). Comparison of U.S. project delivery systems. *Journal of Construction Engineering and Management*, *124*(6), 435–444. https://doi.org/10.1061/(ASCE)0733-9364(1998)124:6(435)

Leśniak, A., & Juszczyk, M. (2018). Prediction of site overhead costs with the use of artificial neural network based model. *Archives of Civil and Mechanical Engineering*, *18*(3), 973–982. https://doi.org/10.1016/j.acme.2018.01.014

Lowe, D. J., & Skitmore, M. R. (2001). Human Effects in Construction Contract Price Forecasting Experience and Experiential Learning Styles. *Journal of Construction Engineering and Management*, *127*(6), 485–493. https://doi.org/10.1016/j.profnurs.2009.04.006

Minchin, R. E., Li, X., Issa, R. R., & Vargas, G. G. (2013). Comparison of cost and time performance of design-build and design-bid-build delivery systems in Florida. *Journal of Construction Engineering and Management*, *139*(10), 1–5. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000746

Neumann, J. von, & Morgenstern, O. (1944). *Theory of Games and Economic Behavior* (Princeton). Princeton University Press.

Osadchy, E. A., & Akhmetshin, E. M. (2015). Accounting and control of indirect costs of organization as a condition of optimizing its financial and economic activities. *International Business Management*, *9*(7), 1705–1709. https://doi.org/10.3923/ibm.2015.1705.1709

Padroth, C., Davis, P. R., & Morrissey, M. (2017). Contract Information Asymmetry: Legal Disconnect within the Project Team. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *9*(3), 1–10. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000231.

Patil, S. S., & Bhangale, P. P. (2014). Overhead Cost in Construction Industry. *International Journal of Industrial Engineering & Technology*, *4*(2), 1–6.

Plebankiewicz, E., & Leśniak, A. (2013). Overhead costs and profit calculation by Polish contractors. *Technological and Economic Development of Economy*, *19*(1), 141–161. https://doi.org/10.3846/20294913.2012.763008

Rosner, J. W., Thal, A. E., & West, C. J. (2009). Analysis of the design-build delivery method in air force construction projects. *Journal of Construction Engineering and Management*, *135*(8), 710–717. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000029

Scevik, V., & Vitkova, E. (2017). Optimization of Overhead Costs of a Construction Contract. *26th International Scientific Conference on Economic and Social Development – "Building Resilient Society,"* 515–523. Zagreb, Croatia.

Shrestha, P. P., & Fernane, J. D. (2017). Performance of design-build and design-bid-build projects for public universities. *Journal of Construction Engineering and Management*, *143*(3), 1–10. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001241

Shrestha, P. P., O'Connor, J. T., & Gibson, G. E. (2012). Performance comparison of large design-build and design-bid-build highway projects. *Journal of Construction Engineering and Management*, *138*(1), 1–13. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000390

Shrestha, S. K. (2014). Average Bid Method – An Alternative to Low Bid Method in Public Sector Construction Procurement in Nepal Low Bid Method. *Journal of the Institute of Engineering*, *10*(1), 125–129. https://doi.org/10.3126/jie.v10i1.10888

Siskina, A., Juodis, A., & Apanaviciene, R. (2009). Evaluation of the competitiveness of construction company overhead costs. *Journal of Civil Engineering and Management*, *15*(2), 215–224. https://doi.org/10.3846/1392-3730.2009.15.215-224

Tah, J. H. ., Thorpe, A., & McCaffer, R. (1994). A survey of indirect cost estimating in practice. *Construction Management and Economics*, *12*(1).

Vroom, V. H. (1964). Work and motivation. In *Wiley*. New York.

Correlation between Project completion time and cost in a project crashing analysis for a Research Project

Shivam SHARMA[1*], Nishit BEDI[2], Vijay Kumar SUKHWANI[3]
Department of Mechanical Engg., Ujjain Engineering College Ujjain, India 456010;
shivamsharma1107@yahoo.com [1]
bedin732@gmail.com [2]
v1sukhwani@gmail.com [3]

ABSTRACT

The present paper focuses to crash the duration of a research project. The research project titled "Development of heat transfer correlation in micro channels" was sponsored by TEQIP – III. Assessment of time-cost tradeoff for various project activities was conducted. Linear Programming model was prepared in LINDO for the same purpose. The crashing was performed on the completion time of the project in the interval of 5 days. A maximum of nearly 20% reduction in project completion time was observed with 9% increase in the cost of the project. The correlation model was developed between the examined total cost and the completion time of the project. Regression analysis performed for these two variables indicated positive results of the study conducted for the project activities.

KEYWORDS

Time-Cost Trade Off, Critical Path, Project Crashing, Coefficient of Correlation.

INTRODUCTION

In Today's competitive environment, every organization focuses to complete the project within scheduled time at minimum cost. However, examination for least time for the same project will prove to be even beneficial. Crashing, fast tracking and substitution are the three most commonly used techniques for compression of the project [*Ballesteros-Perez*, 2019]. The assessment can be performed to variety of projects in industrial, construction, scientific or academic fields. On the other hand, compression for a project, with a number of activities, in a manual manner becomes very tedious. The use of programming models for such purpose is thus preferable. The two available and closely related techniques are Critical Path Method (CPM) and Linear Programming [*Lawrence*, 1998]. Crashing of the project activities is performed either during the planning phase or in execution phase.

In 1961, Fulkerson is the first who suggested a crashing concept for compression of the project by using Linear Programming approach and determined the cost slope of the activities using time-cost tradeoff for each activity of the project [*Fulkerson*, 1961]. During the same time Kelley employed Critical Path method along with a Linear programming approach for compression of the project duration [*Kelley*, 1961]. Ragsdale recommended that still the most reliable approach to analyze time-cost tradeoff is an LP Solver technique [*Ragsdale*, 2003]. LPP algorithm is a very promising technique in accessing time-cost tradeoff for project activities because it is simple in nature, requires less computational time to solve with the least expense as compared to other algorithms like heuristic algorithm [*Liu*, 1995].

On the basis of above discussed studies and available past information, in the current study time-cost tradeoff for the research project was conducted using LP method. To formulate LPP, first of all, the data related to project activities such as *Normal Time* and *Crash Time* were collected from *Dr. Nishit Bedi*, the principal investigator of the project. Then, Activity on Arrow (AOA) network diagram of the project was constructed on the basis of their precedence relationship. Here, AOA diagram is constructed instead of activity on node (AON) because it provides ability to show duration of activities along with their starting and ending time in a similar manner to Gantt Chart. Further, less number of arcs/arrow are required in AOA to show precedence relationship between activities of the project. In LPP model, decision variables and objective function (i.e. minimum crashing cost for a particular deadline) with considering several constraints of the project were defined on the basis of collected data and computed cost slope for the activities of the project. Finally, results were obtained by organizing the objective function, equations and constraints in LINDO for the specified deadline of the project. Then, correlation model was developed between Project completion time and cost for project by specifying the deadline in interval of 5 days to observe the significance of crashing.

The Time-cost tradeoff is different for each activity of the project as the cost and time associated with each activity of the project is different under both normal and crashing condition. It follows linear distribution as well as non-linear distribution for some activities and can be drawn in a manner as described by Taylor [*Taylor*, 2006]. A general equation for these distribution can be written as $y = mx + c$. Here, y is the cost required for completion of activity in x duration and m,c are arbitary constant which represent cost slope (m) of the activity and cost (c) required under normal conditions. For non-linear distribution (i.e. curved in nature) a secant line can be drawn to obtained the cost slope of the activities. Slope of the activity can be defined as the slope of the line which is joining from Normal Time and Crash Time; on the basis of which equation (1) was obtained [*Vrat*, 1986]. Cost slope signifies the cost required for increasing or decreasing an activity's duration by one day. The slope of this line can be calculated by knowing the coordinates of the normal and crash points. Mathematically, Slope of the activity or Cost Slope can be written as:

$$Cost\ Slope\ (m) = \frac{Crashing\ Cost - Normal\ Cost}{Normal\ Time - Crashing\ Time} \quad (1)$$

Maximum crash time for an activity is defined as the difference between of Normal Time and Crashing Time of that activity [*Vrat*, 1986].

Mathematically, $$Max.\ Crash\ Time = Normal\ Time - Crashed\ Time \quad (2)$$

In the present study, reduction in duration for various activities of an academic research project was observed. Consequently the modified cost for the project was noticed.

PROBLEM FORMULATION FOR CONSIDERED RESEARCH PROJECT

The data of the considered research project was taken from Principal Investigator of the research project. The Research project consists of 17 activities, each activity has two sets of data for time and cost under one in normal condition and another one in crashing condition, the Total cost for completion of the project under Normal Condition is Rs. 505300 and the maximum budget available for the project is Rs. 581200 i.e. the maximum completion cost for the project (for maximum crashing).

The data for the first activity of the research project, i.e. *Literature Reading* designated here by activity A has Normal Cost, Normal Time, Crash Cost and Crash Time of Rs. 1800, 130 days, Rs. 4200, and 115 days respectively was obtained from the principal investigator of the research project. In the same manner data for all the 17 activities of the considered research project was collected. Using these data the Gantt Chart of Project activities was drawn as shown in Figure 1 which helps in drawing project network diagram and formulating the LPP model as stated by Perera S. [*Perera*, 1980].

The limitation of the Gantt chart is that it does not show the precedence relationship between the activities of the project. Therefore, to visualize the project activities in a better manner AOA network diagram of the project (see Figure 2) was constructed.

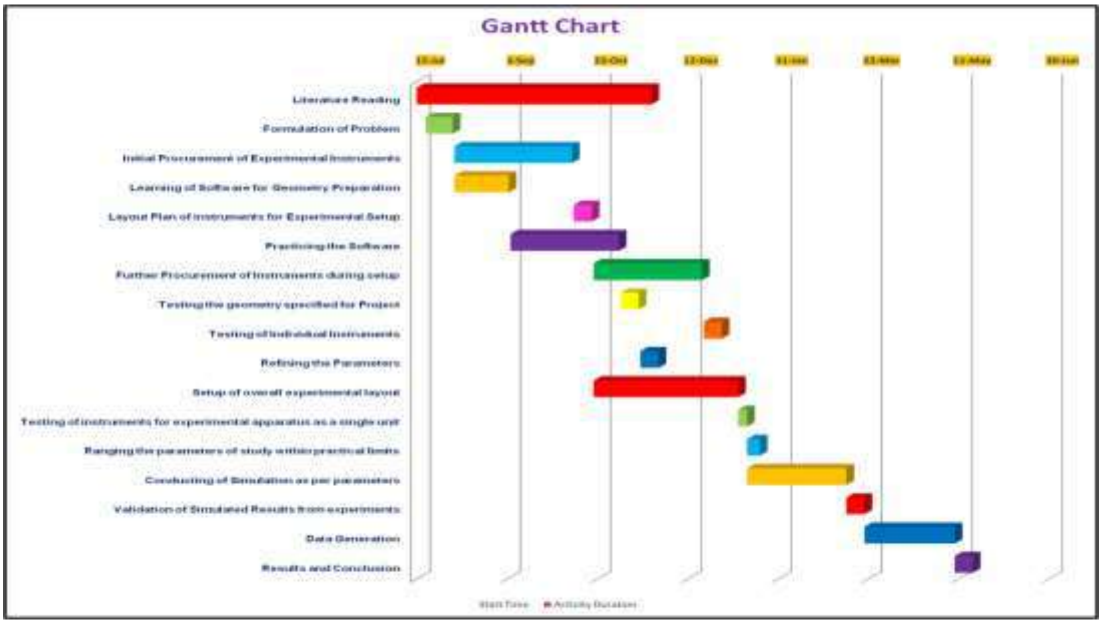


Figure 1. Gantt Chart of the Project

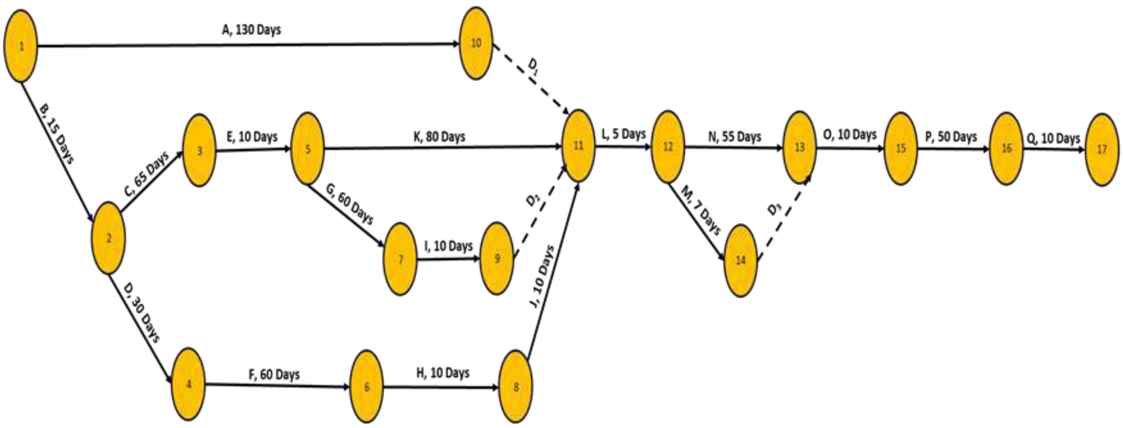


Figure 2. AOA Network Diagram of the Project

The Critical Path of the Project is B-C-E-K-L-N-O-P-Q. The observed duration of the Project or Length of Critical Path is 300 days.

PROJECT CRASHING USING LINEAR PROGRAMMING TECHNIQUE

The objective of the LPP model for project crashing was to crash the project at least cost for any specified project completion time [*Li*, 2012]. The designation used to describe decision variables of the LP model in a manner that if an activity starts at node 1 and ends at node 2 then it can be designated as activity 1 ⟶ 2. Therefore, duration of any activity i ⟶ j was designated by t_{ij}. Now, Let us consider x and y be the decision variables of the LP model.

where, x_i = earliest start time of an event i and x_j = earliest start time of an event j

Therfore, x_1= earliest start time when event 1 will occur…... x_{17}= time when event 17 will occur.

y_r = No. of days an activity (r) will be crashed where, r representing an activity from node i ⟶j. Therefore, y_A = No. of days activity A will be crashed. y_B = No. of days activity B will be crashed. In the same way y_C, y_D, y_E, y_F,……y_Q are the number of days activity C,D,E,F,.….Q will be crashed respectively.

Objective Function:

Here, the objective of LP formulation for project crashing was to obtain minimum crash cost for crashing the project to a specified deadline. The crash cost per day (or cost slope) is calculated by using equation (1). The objective function is the summation of the product of activity's cost slope and their allowable number of days for which an activity will be crashed (y_r).

The generalized objective function for this project crashing can be written as:

$$\text{Minimize Crash Cost } Z = \sum_{r=A}^{Q} CS_r y_r \qquad (3)$$

where, CS_r is the cost slope for any activity r.

By substituting the cost slope in equation (3) then the objective function becomes:

Minimize Crash Cost Z = $160y_A + 100y_B + 1500y_C + 833.33y_D + 1500y_E + 250y_F + 1000y_G + 66.67y_H + 125y_I + 500y_J + 666.67y_K + 500y_L + 150y_M + 700y_N + 666.67y_O + 461.54y_P + 0y_Q$

The above objective function is subjected to the following constraints of the project.

Start Time Constraint: These sets of constraints show the precedence relationship of the activities of the project as the starting time of an activity will be dependent on the completion of any other activity. For any project network diagram one of the necessary condition is that the activity time t_{ij} must be less than the difference between the earliest start time of node j and earliest start time of node i (i.e. $t_{ij} \leq x_j - x_i$). Further, the crash time variable y_{ij} must be added in these constraints as activity duration is affected due to crashing. So, it becomes $t_{ij} \leq x_j - x_i + y_r$.

Crash Time Constraint: These sets of constraints describe the maximum crash time up to which an activity can be crashed. The maximum crash time for any activity r (C_r) was determined by equation (2). The above constraints can be written in a generalized form as $y_r \leq C_r$.

Project Completion Constraint: This constraint describes the project completion time (or deadline) or the desired time of the last event of the project network.

$$x_{Last} \leq \text{Project Completion Time} \qquad (4)$$

Non-Negativity Constraint: These constraints describe that all decision variables must be positive i.e. $x_i \geq 0$, $x_j \geq 0$ and $y_r \geq 0$.

The above model is solved in LINDO to find out the minimum crashing cost for a specific deadline by changing (reducing) the Project completion time in the interval of 5 days each time using equation (4) whereas other constraints remain same.

RESULTS OBTAINED BY SOLVING LPP

The formulated Linear Programming model was solved by LINGO 18.0 to determine the minimum crashing cost corresponds to each project completion time. As earlier observed the maximum project completion time or critical path of the project was 300 days. Results for some of the project completion time with observed values of decision variable are shown in Table 1.

On applying crashing in interval of 5 days, then for initial crashing of 5 days, i.e. for project completion time of 295 days the optimum cost obtained for crashing was Rs.500. Similar calculations were performed up to a maximum extent for which crashing was possible. The minimum completion time obtained by maximum crashing of project was 241 days for which optimum crashing cost of Rs. 45500.08 was observed. Table 2 shows the cost incurred due to crashing for any specified deadline and also the total cost to complete the project by that deadline. Similarly, total cost is computed for each deadline in the interval gap of 5 days.

Table 2 also indicates the percentage increase in cost and percentage reduction in time for each project completion time obtained by crashing. Here it was seen that for initial crashing of 5 days, 1.67% reduction in time occurs with a 0.1% increase in cost and for maximum crashing of the project, i.e. crashing for 59 days, 19.67% reduction in time observed with a 9% increase in total cost of the project.

Table 1. Solution of the LPP for a Specified Project Completion Time

Objective	Project Completion Time			
	300	**295**	**275**	**241 (Min.)**
Min. Crashing Cost Z	**0**	**500**	**11000.04**	**45500.08**
Variable	Final Value			
y_A	0	0	0	0
y_B	0	5	5	5
y_C	0	0	0	10
y_D	0	0	0	0
y_E	0	0	0	2
y_F	0	0	0	0
y_G	0	0	0	1
y_H	0	0	0	0
y_I	0	0	0	4
y_J	0	0	0	0
y_K	0	0	3	15
y_L	0	0	1	1
y_M	0	0	0	0
y_N	0	0	0	10
y_O	0	0	3	3
y_P	0	0	13	13
y_Q	0	0	0	0
x_1	0	0	0	0
x_2	15	10	10	10
x_3	80	75	75	65
x_4	45	40	40	40
x_5	90	85	85	73
x_6	105	100	100	100
x_7	160	155	152	132
x_8	115	110	110	110
x_9	170	165	162	138
x_{10}	170	165	162	138
x_{11}	170	165	162	138
x_{12}	175	170	166	142
x_{13}	182	177	173	163
x_{14}	230	225	221	187
x_{15}	240	235	228	194
x_{16}	290	285	265	231
x_{17}	300	295	275	241

Table 2. Total Cost of the Project, % change in Time & Cost due to crashing

No. of days Project is Crashed	Project Completion Time (in days)	Direct Cost	Cost incurred due to Crashing	Total Cost	Percentage Reduction in Time	Percentage increase in Cost
5	295	505300	500	505800	1.67	0.10
10	290	505300	2807.7	508107.7	3.33	0.56
15	285	505300	5115.4	510415.4	5.00	1.01
20	280	505300	7666.69	512966.69	6.67	1.52
25	275	505300	11000.04	516300.04	8.33	2.18
30	270	505300	14333.39	519633.39	10.00	2.84
35	265	505300	17766.73	523066.73	11.67	3.52
40	260	505300	21266.73	526566.73	13.33	4.21
45	255	505300	25041.74	530341.74	15.00	4.96
50	250	505300	31833.41	537133.41	16.67	6.30
55	245	505300	39333.41	544633.41	18.33	7.78
59 (Max.)	241	505300	45500.08	550800.08	19.67	9.00

Correlation concept was used here to develop and describe the relationship between project completion time and total cost required to achieve that completion time. It helps in analyzing how much effective if the project is crashed to complete earlier than its maximum completion time [*Baak*, 2020]. To calculate correlation coefficient between these two variables Let us consider the project completion time (or Specified deadline) be the independent variable and the total project cost to achieve that completion time be the dependent variable from Table 2. Then, the Pearson's correlation coefficient (R) for this model [*Asuero*, 2006] was calculated.

Further significance test was done to understand that whether the correlation between these two variable is really exist or it may occur by chance [*Thompson*, 1993 & *Levin* 1993]. So, here t- test was performed for the same purpose.

The value of correlation coefficient (R) was observed to be -0.9781. It shows that project completion time and total cost have negative correlation of 0.9781. By using t test it is observed that $P < 0.01$ on significance level of 0.05 and even it is less than on significance level of 0.01, therefore the correlation coefficient between these two variables may be regarded as highly significant.

CONCLUSION:

The study presents a practical approach to time - cost analysis conducted for a research project. An algorithm based on Linear Programming technique for crashing in order to obtain minimum time - cost for the research project was prepared. The effect on total cost of the project by specifying the estimated duration to various alternative values was investigated. A significant percentage of reduction in time with nominal increase in cost was noticed for each crashing. Consequently the completion time of the project and its total cost was observed to be extremely correlated with correlation coefficient of -0.9781. A maximum of nearly 20% reduction in project completion time was observed with 9% increase in the cost of the project.

However, crashing of the project using linear programming model did not reduce the duration of non-critical activities. This may be attributed to the crashing of such activities did not result in any change in the completion time of the project. In turn, manual crashing is recommended for such non critical activities. The study conducted for the sponsored research project can also be conducted in a similar manner on scientific or construction industry. The conduct of such studies will not only produce much more reliable results but will also help in completion of the projects on time in an effective manner.

REFERENCES:

Asuero, A.G., Sayago, A., & González, A.G. (2006). "The correlation coefficient: An overview." *Critical reviews in analytical chemistry*, 36(1), 41-59.

Baak, M., Koopman, R., Snoek, H., & Klous, S. (2020). "A new correlation coefficient between categorical, ordinal and interval variables with pearson characteristics." *Computational statistics & data analysis*, 152 (107043).

Ballesteros-Pérez, P., Elamrousy, K. M., & González-Cruz, M. C. (2019)." Non-linear time-cost trade-off models of activity crashing: Application to construction scheduling and project compression with fast-tracking." *Automation in construction*, 97, 229–240.

Fulkerson, D.R. (1961). "A network flow computation for project cost curves." *Management science*, 7(2), 167-178.

Kelley, J.E. (1961). “Critical-path planning and scheduling: mathematical basis.” *Operations research*, 9(3), 296-320.

Lawrence, J.A., & Pasternack, B. (1998). *Applied management science: A computer-integrated approach for decision making.* 2nd Edition John Wiley & Sons, New York, pp: 370-433.

Levin, J. R. (1993). “Statistical significance testing from three perspectives.” *The journal of experimental education*, 61(4), 378-382.

Li, K., Shao, B., & Zelbst, P. (2012). “Project crashing using excel solver: A simple AON network approach.” *International journal of management & information systems*, 16(2), 177-182.

Liu, L., Burns, S.A., & Feng, C.W. (1995). “Construction time-cost trade-off analysis using LP/IP hybrid method.” *Journal of construction engineering and management*, 121(4), 446-454.

Perera, S. (1980). “Linear programming solution to network compression.” *Journal of the construction division*, 106(3), 315–326.

Ragsdale, C. (2003). “A new approach to implementing project networks in spreadsheets.” *INFORMS transactions on education*, 3(3), 76-85.

Taylor, B.W. (2006). *Introduction to management science*. 10th Edition Prentice Hall, pp: 357-363.

Thompson, B. (1993). “The use of statistical significance tests in research: bootstrap and other alternatives.” *The journal of experimental education*, 61(4), 361- 377.

Vrat, P., & Kriengkrairut, C. (1986). “A goal programming model for project crashing with piecewise linear time-cost trade-off.” *Engineering costs and production economics*, 10(2), 161–172.

Critical Risk Factors in a BIM Project & their Significance in the Indian Real Estate/Infrastructure Sector

Pallab GOSWAMI
Tsinghua University, L&T Construction,
email: PALLAB-GOSWAMI@lntecc.com

ABSTRACT

The construction industry is fragmented and globally known for lost productivity, reworks, etc. Furthermore, among all sectors, the agriculture and construction sectors are found to be at the bottom of the pyramid in the adoption of new technologies. Currently, India is an emerging economy, and there are significant opportunities for growth in the real estate and infrastructure sectors; however, the growth momentum in the construction industry is sluggish. Most of the projects in the Indian construction sector face severe issues in terms of scheduling delays and budget overruns. Building information modeling (BIM) is a solution that can address the coordination-related issues that are the root cause of such overruns and provide a new competitive edge for organizations. Previous studies have examined the benefits of adopting BIM and what BIM tools can bring to an India specific construction industry. While BIM brings many benefits, it also brings a unique set of risks to projects.

Using a mixed research method, this study summarizes all the project risks that can affect the success of a project when BIM is adopted. The research question is addressed using a mix of exploratory and explanatory methods to determine the critical risk factors in BIM-enabled projects in India. The study prioritizes all the risk factors to focus on the key risks and provides examples of BIM-related issues faced in practice. The study solves two issues critical to promoting the use of BIM. Firstly, the study is meant for medium size enterprises that are not adopting BIM largely lack awareness of this approach. Secondly, it is also meant for large organizations that are implementing BIM only in certain phases of a project instead of using BIM from the concept development to completion during the whole project lifecycle.

KEYWORD

Critical Risk Factors, BEP, LOD, Risk Management

1 INTRODUCTION

1.1 Construction Outlook in India

The construction sector is one of the most significant contributors to the Indian economy, accounting for 7-8% of GDP in a financial year. The industry lost its growth during the global financial meltdown in the 2008-2009 fiscal year. Since then, growth has been sluggish and trying to recover since 2013. Because of substantial time and cost overruns in most projects, financial institutions have been cautious about lending to construction enterprises.

1.2 Research Objective

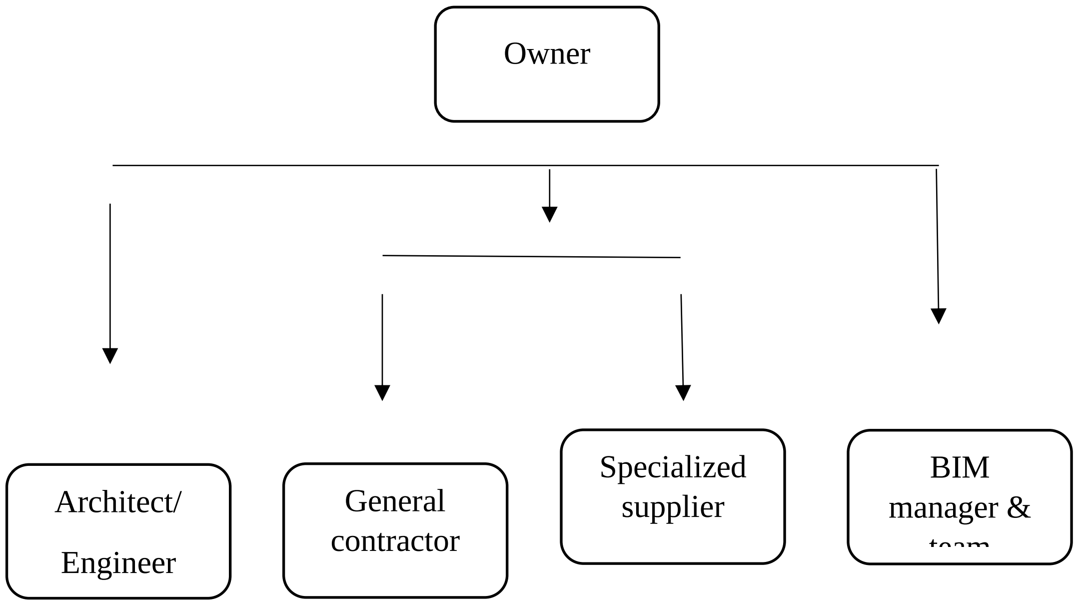


Figure 1.3: Traditional EPC approach practiced in BIM paradigm

Figure 1.3 explains the traditional model of project model delivery in a BIM-enabled environment in which even after implementing BIM, the BIM management team is just another entity in the project that maintains its roles and responsibilities and reports to the owner, just as other departments do.

While the aim of BIM implementation is somewhat lost in a situation, as stated in Fig.1.3, BIM is more than just a tool; it is a method of collaboration between different stakeholders that is used to address many issues. Hence, in Fig.1.4, the BIM/information managers take the principal role after the owner to manage the stakeholders and ascertain the smooth flow of data and communication between all the involved parties.

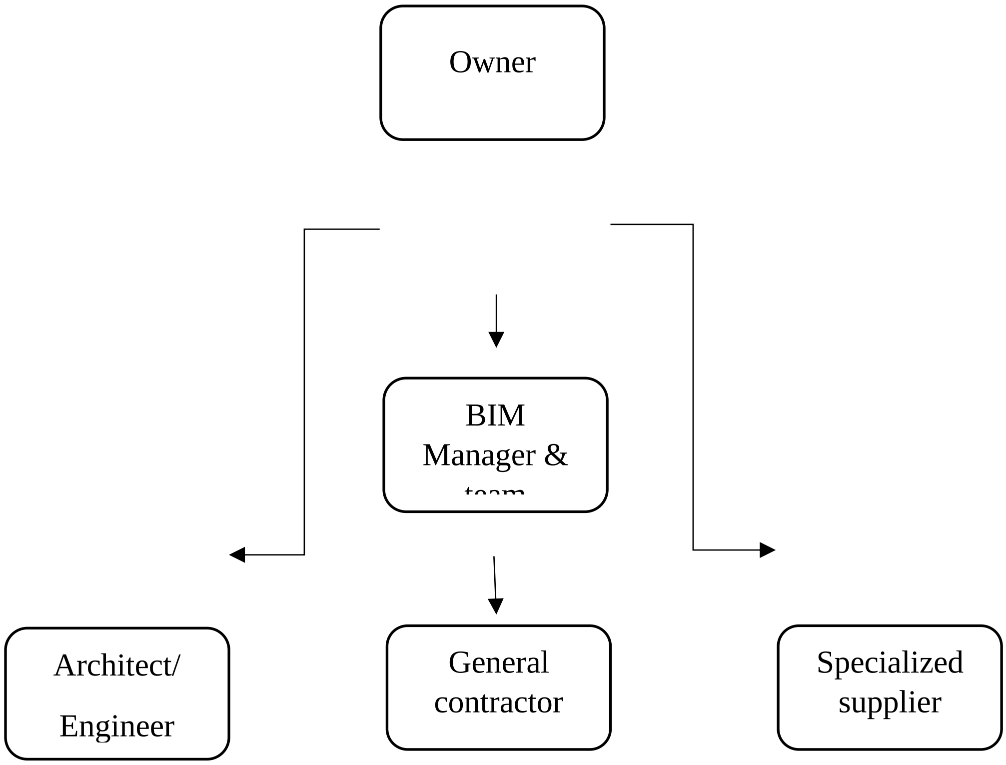


Figure 1.4: EPC approach practiced in ideal BIM collaborative paradigm

While BIM can bring many benefits, it also creates some new risks.

A new interpretation of risk analysis needs to be done to create a benchmark for the BIM team.

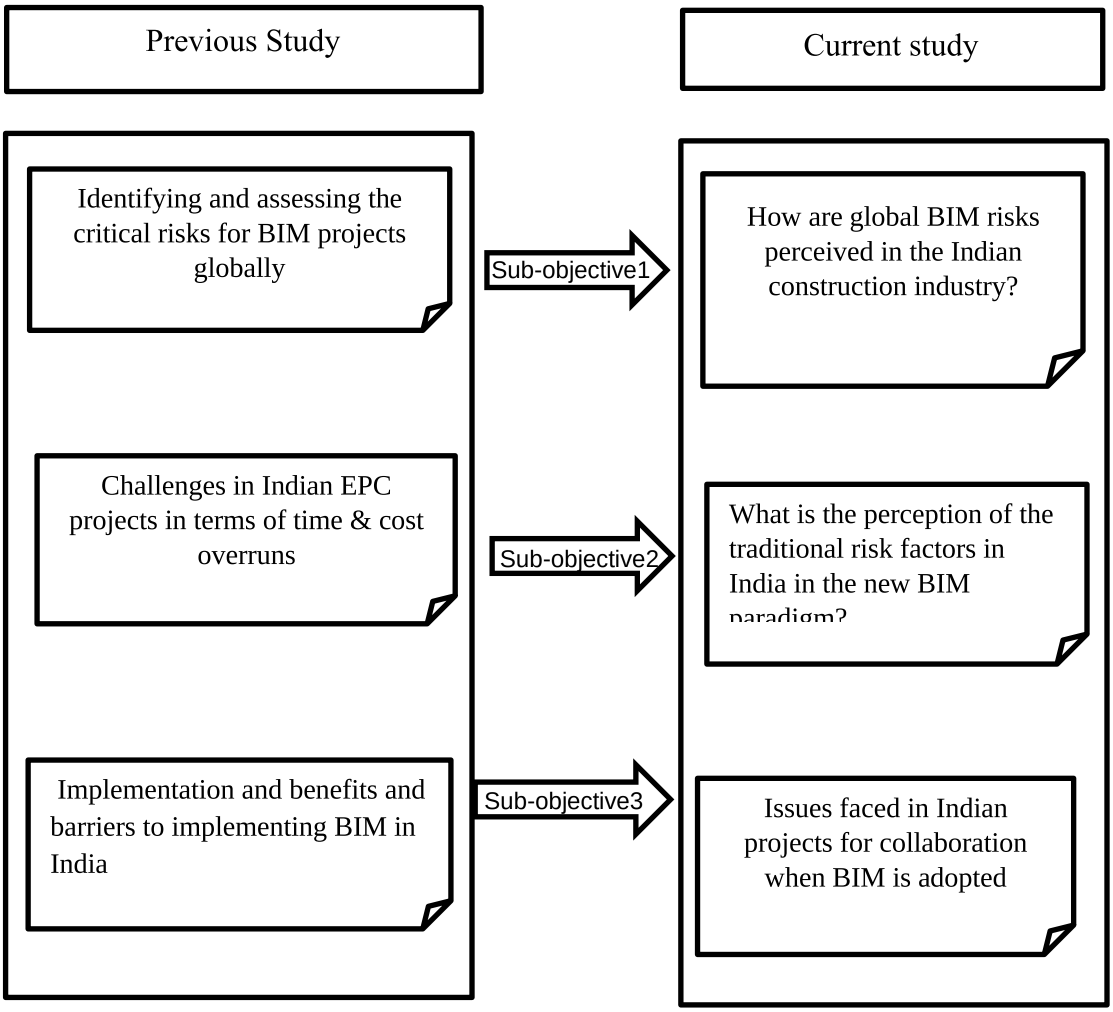
1.5 Problem Statement

A summary of previous studies is categorized into three parts: globally perceived risks in BIM projects, challenges faced in regular construction projects in India, (refer to Fig. 1.5).

"What are the critical risk factors in a BIM project & their significance in the Indian real estate/infrastructure sector?"

LITERATURE REVIEW

The literature gives details of risk assessments for BIM projects. In terms of categories, the risks are divided in two parts. The first one assesses the trade-off between BIM standalone risks in a project and the hazards that can be avoided by using BIM in a project. The second one is the risk that is traditionally the reason for time and cost overruns in a project.



2.1 BIM Legal Risks

2.1.1 Lack of Standard Guidelines & Framework

Based on the literature, other than early BIM adopters, the lack of a framework and guidelines is a global issue in most markets. (Chien Wu, Huang,2014).

2.1.2 Legal Acceptance & Validity of BIM & 3D

The FIDIC recommends that any notices and instructions must be written and signed to lodge any claim. It also suggests the stakeholders communicate approvals, and requests, etc. should also be printed and signed.

Though information is shared electronically, during the digital transfer, only the hardcopy is denoted as controlling information. Hence, the current practice indeed seems dysfunctional and inefficient (Leon L Foster).

2.1.3 Privity of Contract

The common legal principle of 'privity of contract' states that unless one entity is a party to a contract, the contract cannot impose its obligations (Wikipedia).

The design firms mostly quote that electronic data are an inferior representation and only a "hard copy" that they can sign and authorize should prevail in a common data environment like BIM. Although the designer's justification no longer makes sense, any disclaimers need to be ineffective in a CDE (common data environment).

2.1.4 Insurance-related Unclear Liability

Insurance is meant to cover a definite liability. While working on BIM, the clear delineation of the responsibilities is becoming much more fluid because of its collaborative nature; hence, without a clear representation of responsibility, insurers are hesitant to cover the liabilities (Leon L Foster).

2.2 BIM Technical risks

2.2.1 Standard of Care

In the previous section 2.1.3, we discussed why the party who is creating the model must be responsible for the model, but investing the right amount of care into a BIM model when there is collaboration among multiple stakeholders is an issue (Pandey, Burger, 2016).

2.2.2 Interoperability

Though currently there is an IFC (industry foundation class) to bring true compatibility among different software programs, many users demonstrate that still there is subsequent data loss while using a modified version of the software. (Ussing, Svidt, 2010)

2.2.3 IP Rights issue

When working on a single file in a common data environment, the creator has sole legal copyright over the drawing, Legally, the proprietary information needs to be protected, and so every project should create some unique contractual arrangement to avoid inhibitions towards working in a common data environment (Thompson, Miner, 2006).

2.2.4 Acceptance of BIM in the Organization

While acceptance of BIM-based enterprise environmental factors is not much of an issue in developed markets, in emerging BIM markets, significant challenges emanate from the acceptance of BIM in an organization by its senior management (Jin, Hancock,2017).

2.3 Traditional Project Issues in India

Risks can be broadly categorized into regulatory, company management, financial, EHS, technical & legal risks. While the legal & technical risks in a new BIM paradigm were already discussed, here the remaining ones are considered.

2.3.1 Regulatory Risk-Delay in Land Acquisition

2.3.2 Regulatory Risk-Delay in Environmental Clearances

2.3.3 Company Management Risk

2.3.4 Financial Risk

2.3.5 **Other Risks:** *EHS & Force majeure risks etc*

Table 2.1: Compiled list of risks in BIM-enabled projects

Risk Name	1	2	3	4	5	6	7	8	9	10
Delay in land acquisition	**									
Delay in environmental clearance		**								
Local administrative corruption			**							
Acceptance of BIM by stakeholders							**			
Delay in procurement		**								
Labor disputes and strikes			**							
Resource mismanagement risk				**						

Availability of long-term financing		**				
S/C's poor performance		**				
Aggressive bidding	**					
Costly software and hardware updates			**			
Automatic rule checking				**		
Interoperability issues			**			
IP rights issues, data theft					**	
Lack of standard BIM guidelines			**			
The legal status of BIM-2D over 3D drawing						**
Privity of Contract						**
Standard of care			**			
Insurance-related unclear liability			**			
Force majeure			**			
Cultural differences			**			
Environmental, Health & Safety hazard		**				

1= EY-EPC world ’14; 2= KPMG-PMI; 3= Wang, Tang ’16; 4= Shankar '13; 5= Feng Wu, Hung ’14;

6= Jin, Craig ’14; 7= RICS-Amity '14; 8= Zou, Kivi ’16; 9= Salman Azhar ’11; and 10= Chong, Fan ’17

METHODOLOGY

As explained at the beginning of the literature review, initially, a preliminary literature review was done, and then the research gaps were found. The problem statement is prepared based on the observations on the research gaps. Research can be done using qualitative or quantitative data. In this study, the method adopted is a **mixed method research.** The research method is a mix of qualitative and quantitative methods. Though the respective data collection processes happen one after the after, the procedures are not related to each other.

3.1 Data Collection Planning

The risk dynamics are prepared by combining traditional project risks in India with global BIM-related risks. Now, the lack of planning and coordination and design change related issues are a few significant reasons for the delay in construction projects in India, but BIM can eventually solve the risks associated with coordination and design change related issues The primary data collection is planned in two stages: one is thru questionnaires, and the other one is thru semi-structured interviews.

3.1.1 Data Collection with Questionnaires

115 professionals with diverse backgrounds in BIM were approached to complete prepared online questionnaires.

The survey is divided into two parts. The first part is about demographics, and the second part is about the risk-probability matrix. As PMBOK suggests, the impact–probability pattern should ascertain both risk and opportunities.

Table 3.2: Customized impact–probability matrix

Probability \ Impact	1(Very low-5%)	2(Low-10%)	3(Moderate-20%)	4(High-40%)	5(Very high-80%)
5(Very likely-90%)	1	10	15	20	25
4(Likely-70%)	1	8	12	16	20
3(Moderate-50%)	1	6	9	12	15
2(Unlikely-30%)	1	4	6	8	10
1(Rare-10%)	1	2	3	4	5

It is noted that the 22 risk factors are a part of six significant high-level risks, and they are 1. Regulatory Risk, 2. Financial Risk, 3. Company Management Risk, 4. Legal risk, 5. Technical Risk, and 6. EHS risk

3.1.2 Multicriteria Decision-making with the Analytical Hierarchy Procedure

The AHP method helps to set the priorities among multiple criteria using a pairwise comparison that provides a comparative judgment of hierarchical elements. Furthermore, to ensure that the responses are consistent enough, a consistency index is also calculated.

3.1.3 Data Collection with Interviews

The nature of the data collection is semi-structured, non-standardized interviews. the interview principle followed was a nominal group technique with private discussions for each of the professionals.

PRIMARY DATA ANALYSIS

After the collection of data, at first, a reliability test is conducted using SPSS. Then, for the second part of the survey, at first, the probability is calculated for each risk impact by taking the **mean value** of all the data. The magnitude of risk is calculated as

Risk= Impact X Probability.

After calculating the risk for each factor, all the 22 risks are ranked together based on their risk scores. After recognizing the critical risk factors, based on PMBOK principles, the significances of the risk factors were analyzed with a one sample T-test using SPSS with a 95% confidence interval.

For the high-level risk, the high-level risks are ranked using the AHP method. Further, a consistency ratio is also calculated to check if the results are within the permissible limits.

After the risk factors are analyzed, interviews are conducted with seven industry professionals to understand the practical implications of the risks, the issues facing collaboration, etc.

The data analysis is categorized into three parts: first is the profile of the respondents, then is the detailed analysis and finally are the summarized findings.

4.1 Reliability Testing

The recommended minimum value for Cronbach's α is 0.7. For this study, Alpha is calculated using SPSS and found to be 0.703, which is above the limit. Hence, it can be concluded that there is high consistency and the data are indeed reliable.

4.2 Risk Ranking & Hypothesis testing

Based on the PMBOK guidelines, as in Table 3.2, a risk parameter greater than or equal to '10' (5x2) will be considered high risk. Now, after taking the mean value for each of risk, all the impact probabilities of the 22 risk factors are ranked in the matrix.

Table 4.1: Risk ranking for evaluation

Risk Rank	Name of risk	Risk score (Impact Probability) X
1	Delay in environmental clearances	11.63
2	Delay in land acquisition	11.33
3	Lack of legal framework and standard BIM guidelines to follow for different stakeholders	9.99
4	Legal status of BIM & electronic data (Acceptance of 3D over conventional 2D)	9.8
5	Aggressive bidding makes the project non-viable	9.42
6	Regarding 'privity of contract'	9.37
7	Physical resource utilization & mismanagement	8.68
8	Delay in procurement of materials/equipment	9.23
9	Subcontractor's poor performance & failure	8.68
10	Adoption of BIM based on enterprise environmental factors	8.66

In Table 4.1, based on the ranking, the top ten risks are kept together. It is to be noted that only the top three risks are qualified to be high risk since the risk units are higher than '10'. These three are a delay in land acquisition, a delay in environmental clearance, & the lack of a legal framework & guidelines. While the first two are high-level regulatory risks, the latter is a legal risk.

4.4 High-level Risk Ranking with AHP

Regarding the six high-level risks, to apply AHP, first, the mean scores are calculated thru the survey. The AHP matrix suggests the matrix is filled with following norms:

1. If the Regulatory risk is ranked over legal risk as a 4, the legal risk vs regulatory uncertainty will be ¼ or 0.25; and

2. In the matrix, the same hazards will be rated 1 in the column, such as technical risk vs technical risk.

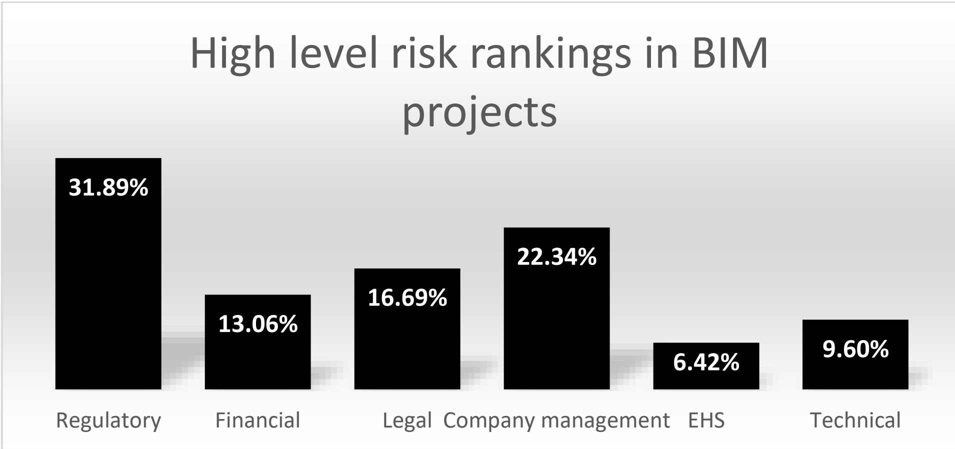


Fig.4.4: High-level risk prioritization with AHP

It can be observed that regulatory risk is the most critical one among all others. The result is synonymous with the findings of the impact–probability matrix. Regulatory risk is followed by company management risk & then legal risk.

Now, the reliability of the AHP test needs to be assessed by calculating the Consistency ratio (CR).

Now, based on the formula here, CR =0.119/1.25 = 0.09 <0.1, signifying that the results are consistent, and hence the results can be trusted.

4.5 Hypothesis Testing & Further Analysis

H_0= The three critical high risks as evaluated have significantly similar impacts on the low impact risk (‘2’ numerical value).

It is observed that the significance is p= 0.00<0.05 for the three cases. Therefore, we reject the null hypothesis that the impacts of the risks are not significantly similar with those of the low impact risk.

Then, a second null hypothesis is considered.

H_0= The three critical high risks have significantly similar impacts as the medium impact risk (‘3’ numerical value).

Therefore, a one sample T-test is conducted in SPSS with a 95% confidence interval to either support or reject the null hypothesis.

One Sample Test

Table 4.2: One Sample T-test with a 95% CI with a test value of 2

	Test Value = 2					
			Sig. (2-tailed)	Mean	95% Confidence Interval of the Difference	
	t	df		Difference	Lower	Upper
delay in Land acquisition	8.113	27	.000	1.82143	1.3608	2.2821
delay in Environmental clearance	8.333	27	.000	1.78571	1.3460	2.2254
Lack of legal framework & Standard guidelines	6.000	27	.000	1.14286	.7520	1.5337

For the first two risk factors, the two regulatory risks 'Delay in land acquisition' and 'Delay in environmental clearance' are significant since p=0.001<0.05. The other risk factor, i.e., the lack of a legal framework and standard guidelines, is not significant since p=0.46>0.05, Hence in the first two cases, the null hypothesis can be rejected and it can be said that the impacts of the two regulatory risks are more significant than those of medium impact risk. For the third case, the null hypothesis cannot be rejected. The lack of standard guidelines has a medium impact on project risk.

Table 4.3: One Sample T-test with a 95% CI with a test value of 3

One Sample T-test

	Test Value = 3					
				Mean	95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Differenc e	Lower	Upper
Delay in Land acquisition	3.659	27	.001	.82143	.3608	1.2821
Delay in Environmental clearance	3.667	27	.001	.78571	.3460	1.2254
Lack of legal framework & Standard guidelines	.750	27	.460	.14286	-.2480	.5337

4.6 Inputs by the interviewers for risk factors specific to India:

1. As found out with critical risk, having no standard guideline in India is one of the essential risks. Many Indian organizations arbitrarily following either British codes PAS 1192-2 or Consensus Doc301 by AIA, but problems arise because of different work cultures and the ways in which construction is being managed in India compared with other markets.
2. Multiple issues are noticed while working in a cloud-based collaboration platform like in the BIM-360 suite (BIM-360 plan, BIM-360 Doc, etc.). The following are some of the problems.
    - When the team is large, e.g. multiple contractors/ consultants are engaged, BIM 360 can be quite useful. Now, based on the typical laid our contract conditions, all the parties must use the latest software.
    - The BIM360 suite can also manage RFIs (Reports for inspection), conduct EHS management, and keep track of one's daily progress with the help of its cloud computing technology, but all uploads and downloads need loads of GBs for the data transfer. If one is located at a greenfield site, then a robust IT infrastructure is rarely available at such a site.
    - Because many of the site staffs/supervisors in India are on temporary contracts, when these people have been issued a device such as an IPad, there is a need to inspect them to ensure that they are using them properly.

4.7 Discussion

Earlier, in traditional practices without BIM, the most design effort was put into construction documents before the bidding stage. In the case of the AEC industry, once the structure is built, it is difficult to modify its fabric in terms of a design change. The effort needs to be maximized before the construction document preparation stage to reduce the cost impact of design changes and not afterward

CONCLUSION

In the study, various risks in BIM-enabled projects in India are explored. There are still many risks related to BIM-enabled projects that are 'unknown unknowns' and only as of the level of maturity in an organization increases will the unknown risks unravel. It is also found that BIM is an essential aspect for a project but not the sole point of focus in a project. A project will still encounter some of the traditional issues with or without BIM in a project, such as company management & finance related issues. While some risks are dealt with in new ways when BIM & other associated technologies such as GIS are implemented, BIM brings many new technical risks that need to be tackled by professionals, but the weights of such issues are not as significant as the other risks in the project. If only BIM standalone risks are considered, then legal risks now outweigh the importance of technical risks in the project.

As referred to in Fig. 1.11 regarding the research gap, the focus of the study was to explore the different risks and their priorities in the Indian context. The review summarizes all the technical and legal risks of global BIM implementation, studies the perceptions of these risks in the Indian context and prioritizes them with the traditional risks for cost and time overruns in a project. Because the implementation is fragmented and not structured, the study provides a new direction towards using different BIM tools and things that can be considered in the construction site context before implementation and it also provides some of the BIM practices that can be adopted in the organization.

If BIM is to be popular in the construction industry in India, there needs to be a demand for it. There cannot be a demand unless the stakeholders are aware of the different aspects of BIM and are confident of BIM while using it. The study will provide a roadmap for an organization that is new to BIM adoption with ways to manage risk and where to focus on preparing a strategy to create a risk response accordingly.

REFERENCES

Adam Alwash; Peter E. D. Love, P. D., Sc.D.; and Oluwole Olatunji, PhD (2017). Impact and Remedy of Legal Uncertainties in Building Information Modelling.

Adhikari, V. K. a. M. (2016). Exploring The Adoption of Building Information Modelling in India And Need For Further Implementation.

AZHAR, S. (2011). <Building Information Modeling (BIM) Trends, Benefits, Risks and Challenges for the AEC Industry.pdf>.

BSI. (2013). <BSI_PAS_1192_2_.pdf>. In.

Burger, A. P. F. S. a. J. (2016). Legal and Contractual Challenges of Building Information Modeling—Designers' Perspectives.

Chien, K.-F., Wu, Z.-H., & Huang, S.-C. (2014). Identifying and assessing Critical risk factors for BIM projects: Empirical study. Automation in Construction

Chong, H.-Y., Fan, S.-L., Sutrisna, M., Hsieh, S.-H., & Tsai, C.-M. (2017). Preliminary Contractual Framework for BIM-Enabled Projects. Journal of Construction Engineering and Management, 143(7).

Council-UK, C. i. C (2013). The-bim-protocol. In.

Ernst & Young, E. W. (2014). EY-making-India-brick-by-brick. Retrieved from Foster, L. L. Legal Issues and Risks Associated with Building Information Modeling Technology.

GAO, A. N. a. Z. (2014). BIM Implementation Practice at India AEC Firms.

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in The AEC industry. Automation in Construction, 19(8), 988-999.

Jin, R., Hancock, C., Tang, L., Chen, C., Wanatowski, D., & Yang, L. (2017). Empirical Study of BIM Implementation–Based Perceptions among Chinese Practitioners. Journal of Management in Engineering, 33(5).

KMPG-PMI. Study on the project schedule and cost overruns

Kumar*, J. V., & Mukherjee, a. M. (2009). Scope of building information modelling.

Luthra, A. (2010). Implementation of Building Information Modeling in Architectural Firms in India.

Migilinskas, D., Popov, V., Juocevicius, V., & Ustinovichius, L. (2013). The Benefits, Obstacles, and Problems of Practical Bim Implementation. Procedia Engineering.

Shankar, K. R. (2014). RISK ASSESSMENT AND CONTRACT MANAGEMENT FOR EPC PROJECTS.

T. Park, T. K., Y. Lee and K. Seo. (2014). Project Cost Estimation of National Road in Preliminary Feasibility Stage Using BIM/GIS Platform.

Thompson, M. (2006). <Building information modeling-BIM- Contractual risks are changing with technology.pdf>.

University, R.-A. (2014). RICS-SBE-Research_State-of-BIM-Adoption

Wang, T., Tang, W., Du, L., Duffield, C. F., & Wei, Y. (2016). Relationships among Risk Management, Partnering, and Contractor Capability in International EPC Project Delivery. Journal of Management in Engineering, 32(6).

Weisheng LU, A. F., Yi PENG, Cong LIANG, and Steve ROWLINSON. (2015). Demystifying construction project time-effort distribution curves: a BIM and non-BIM comparison.

Zou, Y., Kiviniemi, A., & Jones, S. W. (2017). A review of risk management through BIM and BIM-related technologies. Safety of Science.

Garbuzova-Schlifter, M., & Madlener, R. (2016). AHP-based risk analysis of energy, performance contracting projects in Russia. Energy Policy, 97, 559-581.

SUNSOFT. BIM-Level of detail.

NBS. BIM Levels explained

India, M. o. E. F.-G. o. (2010). Environmental Impact Assessment Guidance Manual for BUILDING, CONSTRUCTION, TOWNSHIPS, and AREA DEVELOPMENT PROJECTS.

Sacks, C. E. P. T. R., & Listo, K. BIM handbook.

Mulcahy, R. (2013). <rita-pmpexamprep8thedition>.

Alexander, M. (2012). Decision-Making using the Analytic Hierarchy Process (AHP) and SAS/IML.

Applications of Taguchi Design and Monte Carlo Simulations for Effective Risk Mitigation in Road Projects

Harish L REDDY[1] and Nagakumar M S[2]
Assistant Professor, National Institute of Construction Management and Research, Pune; email: hreddy@nicmar.ac.in[1]
Professor, R V College of Engineering, Bengaluru; email: nagakumar@rvce.edu.in[2]

ABSTRACT

Project Time, Cost and Quality are the three important project performance characteristics closely monitored for any project. It is the most important duty for any project manager to deliver the project on or before the deadline. Meeting the project deadline is often fraught with one or more risk factors or delay factors impeding the achievement of this goal. The project managers can mitigate these risk factors but might have to incur expenditure on the mitigation measures. This presents a decision problem to optimal choose the level of mitigation needed for a particular risk such that there is an overall net benefit to the project. In this paper, a combination of Monte Carlo simulation and Taguchi's robust design philosophy are combined and applied on a road project schedule to determine the optimal risk mitigation strategy for the project. The outcomes of this paper will help project managers in the decision-making process for the selection of optimal mitigation strategies.

KEYWORDS

Taguchi Design, Monte Carlo Simulation, Risk Mitigation, Road Projects

INTRODUCTION

The project duration is undoubtedly one of the most important deliverables for a project. It is also worthwhile to mention here that most of the contract documents mention 'Time is the Essence of the Contract'. The duration for a project is mostly found using the critical path method making use of deterministic time estimates or probabilistic time estimates. Also, there could be several risks or delays that will occur during project execution stages hampering the achievement of project duration. Accurate identification of the risk factors, estimating their impacts on the project duration, and implementing strategies to mitigate their adverse effects is the risk management activity in a project.

In this study, a sample road project is taken as a case study to apply the techniques of Monte Carlo simulation and Taguchi robust design to arrive at optimal risk mitigation strategies for the project. Monte Carlo simulation provides quantification of the impact of risk factors on the project while Taguchi design computes optimal risk mitigation strategies for the project. The combined application of the two methods will help project managers to arrive at a list of critical risk factors for a project as well as the best strategy for their mitigation.

LITERATURE REVIEW

A review of peer-reviewed journals and publications have revealed numerous studies being done to predict project duration by using the Monte Carlo simulation process. Monte Carlo simulation relies on repeated random sampling and statistical analysis to compute the results. In this process, a statistical distribution is identified for the risk factors which are the input variables. These risk factors are linked to the individual activities of a project schedule. Then, random samples are drawn from these distributions, which will represent the value of the input variables. For each set of input parameters, we will obtain a set of output parameters. Few researchers have applied these techniques for estimating project time contingencies or constructing models for time predictions (Barraza, Alarcon, Nguyen). Also, these models have been developed and used for a variety of projects such as high-rise buildings, transportation projects, university projects to mention a few. [1], [2], [3], [4], [5], [6]. In some projects, sensitivity analysis was performed to assess the criticality of the risk factors thereby enabling ranking of the risk factors [6], [7].

Design of Experiments (DoE) is a methodology for the systematic application of the statistical process to experimentation. DoE involves designing a sequence of tests to purposefully vary the input parameters (factors) to examine the reasons for variation in the output response. The Taguchi method provides a special set of orthogonal arrays (OA) to conduct experiments which reduce the number of experimental runs. Taguchi method distinguishes between control variables and noise variables designated as inner and outer arrays. The combination of the two approaches results in a crossed array which gives information about the relation between the variables. The quality loss function defined as the signal to noise ratio measures the performance characteristics of the design. Taguchi method aids in the determination of optimal settings of input parameters and minimizes the variations of noise factors [8]. While numerous studies are showing the application of Taguchi design philosophy in product design, there are only a handful of research papers on the application of this method in construction management.

METHODOLOGY

The following steps are followed in this paper

Project schedule generation: A state highway project in the state of Karnataka was selected as a sample case study. The project details and project schedule was obtained from the design consultant of the project. The project duration was determined using Microsoft Project software.

Risk register generation: A careful study of site conditions and project documents was made to identify the risks of the project. The probability of occurrence and impact of these risks were assessed in association with the design consultant. This lead to the formation of a risk register of the project with a list of risks and their impacts on the project.

Monte Carlo Simulation: The project schedule and risks were integrated using Risky Project software. The risks were assigned to individual activities as per their nature of impact while some risks were assigned to all activities. The software was used for the Monte Carlo simulation. In Monte Carlo simulation, the project schedule is iterated multiple times with the activity durations chosen at random from the probability distributions. The schedule is recalculated over and over again, each time using a randomly selected set of values for activity durations.

Taguchi Optimisation: Taguchi optimization is done in two steps namely system design and parameter design. System design is already achieved by developing a project schedule and performing a Monte Carlo simulation. In parameter design, the following steps are done: selecting the proper Orthogonal Array (OA) according to the number of controllable factors (parameters); running experiments based on the OA; analyzing data; identifying the optimum condition, and conducting confirmation run with the optimal levels of all the parameters. An L9 orthogonal array was chosen for the study. A total of five critical risk factors were identified with three levels of mitigation strategies i.e., full mitigation (100%), partial mitigation (50%0 and no mitigation (0%). Monte Carlo simulations were then run again incorporating the mitigation strategies as per the OA combination. The experimental results were tabulated and tested for the performance characteristics – “Larger the Better” as shown in the equation below.

This is chosen such that the net benefits resulting from delay reduction against the expense of mitigation measures is maximum. A final list of optimal risk mitigation strategies was then found for the project.

$$SN_L = -10 \log \frac{1}{n} \sum_{i=1}^{n} 1/_{y^2}$$

Where,

SN_L *= Signal to Noise ratio for Larger is Better*

n = Number of Experiments

y = Average of values of experiments

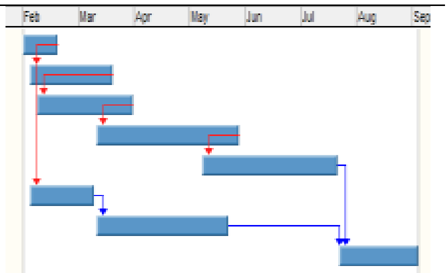
ANALYSIS AND FINDINGS

Project Schedule Generation: The project involves the construction of rigid pavement for a 12.5km stretch in Shiradi Ghat, in the state of Karnataka, India. The location of the road stretch is shown in **Figure 1**.

Figure 1. Location of the Road Project

The schedule of the project is made according to the scope of work. The schedule is kept to the minimum to make the calculations and interpretations easier. The schedule of the project is shown in **Table 1**.

Table 1. Project Schedule

ID No.	Task Name	Duration	Start	Finish	Predecessor	Bar Chart
1	Earthwork	14 Days	02/01/18	02/20/18	--	
2	GSB	34 Days	02/05/18	03/22/18	1FS-12 Days	
3	DLC	37 Days	02/09/18	04/02/18	2FS-30 Days	
4	PQC Left	57 Days	03/13/18	05/30/18	3FS-15 Days	
5	PQC Right	53 Days	05/10/18	07/23/18	4FS-15 Days	
6	Culverts	26 Days	02/05/18	03/12/18	1FS-12 Days	
7	Bridges	53 Days	03/13/18	05/24/18	6FS	
8	Guard Rails	32 Days	07/24/18	09/05/18	5FS,7FS	

Risk register generation: After reviewing the site conditions, project documents, and discussion with experts, five risks have been anticipated for the project. The list of risks along with their probability of occurrence, impact on activities is shown in **Table 2**. A separate questionnaire survey was carried out among several experts in the road construction industry to assess the probability and impact of risks on project activities. The findings are under review and hence not included in this paper.

Risk simulation: The project schedule and the risks were incorporated together in Risky Project software and Monte Carlo simulations were run until the standard deviation and mean of the schedule duration converged. The results of the simulation with risk impacts are shown in **Table 3.** The location of the project site does not pose severe risks to the project. After discussion with the client and design team, only moderate risks were incorporated into the model. With the identification of new risks along the project execution stage, a modification to the model and findings can be made. There is no foolproof process to identify all the risks in the initial stages of planning and hence, the results of the simulation are to be taken as initial guidelines for risk mitigation strategy and needs to be complemented if new risks emerge.

It can be seen from Table 3 that shortage or depletion of resources and source relocation is the biggest risk for the project accounting for a 17% delay in duration. This is followed by design errors (11%) and accessibility problems (10%). Uneven risk share and unforeseen site conditions are found to have little impact on project duration in this case. It is also seen from Table 3 that the net impact of all the risks on the project will be an increase in project duration from 155 to 218 days accounting for a 41% increase in the timeline.

Table 2. Risk Register for the Project

Risk No.	Delay Factor	Activities	Probability	Impact on Time	Type
1	Shortage or Depletion of resources/ Source relocation	All activities	High (60-90%)	Moderate (10-20%)	Global Risk
2	Accessibility problems	All activities	Moderate (30-60%)	Moderate (10-20%)	Global Risk
3	Design errors	PQC works, Bridge works	High (60-90%)	Moderate (10-20%)	Local Risk
4	Uneven risk share	All activities	Low (0-30%)	Moderate (10-20%)	Global Risk
5	Unforeseen site conditions	Earthworks	Moderate (30-60%)	Moderate (10-20%)	Local Risk

Table 3. Risk Impacts on Project Duration

Description	Planned Duration	Simulated Duration in Days					
		All Risks included	Risk 1 only	Risk 2 only	Risk 3 only	Risk 4 only	Risk 5 only
Earthwork	14 days	17	15.46	15	14	14	15
GSB	34 days	41	38.18	36	34	34.33	34
DLC	37 days	48.88	40	39.74	41	38.14	37
PQC(LHS)	57 days	74.63	64	60.14	64	57	57
PQC (RHS)	53 days	69.42	58.61	57	58.99	54	53
Culverts	26 days	31	28.18	28.38	26	26.33	26
Bridges	53 days	70	60	55	59	53	53
Guard wall	32 days	38	35.85	33.17	32	32.58	32
Project Duration (days)	**155**	**218**	**181**	**170**	**172**	**160**	**156**
Delay in %	**--**	**41%**	**17%**	**10%**	**11%**	**3%**	**1%**

Taguchi method of optimization: To perform Taguchi robust design, a list of mitigation measures were decided for the factors. To generalize the mitigation measures, these were divided into three categories namely full, partial, and no mitigation. The resulting impacts on the project with mitigation is shown in **Table 4.**

As there are five risk factors and three levels of mitigation measures chosen for the analysis, an L9 orthogonal array with 18 experimental runs is chosen. **Table 5** shows the combination of risk factors with mitigation measures adopted for Monte Carlo simulation.

Simulations are run for every combination shown in Table 5. The results of experimental runs are shown in **Table 6.**

Table 4. Selection of Mitigation Measures

No.	Factor	Levels of Impact on Project Schedule		
		No mitigation	Partial mitigation	Full mitigation
1	Design Errors	10-20%	5-10%	0%
2	Shortage of Resources	10-20%	5-10%	0%
3	Accessibility Problems	10-20%	5-10%	0%
4	Unforeseen site conditions	10-20%	5-10%	0%
5	Risk Sharing	10-20%	5-10%	0%

Table 5. L9 Orthogonal Array for Experimental Runs

Run	Design Errors	Shortage of Resources	Accessibility Problems	Unforeseen site conditions	Risk Sharing
1	No	No	No	No	No
2	No	Partial	Partial	Partial	Partial
3	No	Full	Full	Full	Full
4	Partial	No	No	Partial	Partial
5	Partial	Partial	Partial	Full	Full
6	Partial	Full	Full	No	No
7	Full	No	Partial	No	Full
8	Full	Partial	Full	Partial	No
9	Full	Full	No	Full	Partial
10	No	No	Full	Full	Partial
11	No	Partial	No	No	Full
12	No	Full	Partial	Partial	No
13	Partial	No	Partial	Full	No
14	Partial	Partial	Full	No	Partial
15	Partial	Full	No	Partial	Full
16	Full	No	Full	Partial	Full
17	Full	Partial	No	Full	No
18	Full	Full	Partial	No	Partial

Table 6. Results of Taguchi Experimentation

Expt.	Risk 1			Risk 2			Risk 3			Risk 4			Risk 4		
	No	Partial	Full	No	Partial	Full	No	Partial	Full	No	Partial	Full	No	Partial	Full
Signal to Noise	119.825	118.353	122.143	118.013	117.818	127.491	120.277	118.013	128.259	122.357	119.201	99.269	121.801	120.963	119.499
Max. (S/N)	**122.143**			**127.491**			**128.259**			**122.357**			**121.801**		

The final optimal list of risk mitigation strategies are hence found as shown in **Table 7.**

Table 7. Optimal Risk Mitigation Strategy

No.	Risk Factor	Mitigation Measure
1	Design Errors	Full Mitigation
2	Shortage of Resources	Full Mitigation
3	Accessibility Problems	Full Mitigation
4	Unforeseen site conditions	No Mitigation
5	Risk Sharing	No Mitigation

i) DISCUSSION AND CONCLUSIONS

The study finds that investigating the impacts of risks on the project schedule is a requirement for any project. There can be numerous risks anticipated or encountered during the project, but only a few of them will have a significant impact on the project. Proper identification of risks and their impact assessment is a crucial step to be followed in the risk management process. While it is necessary to counter the adverse effects of all the risks, it may not be completely economical to invest in mitigation measures if the net benefits are on the negative side. Taguchi optimization was able to bring out the correct level of mitigation needed for different risks. The final result showed that all risks need not be fully mitigated but only the risks which have a higher potential of impacting the project should be mitigated. The expenditure incurred for mitigating these risks can be justified with the benefits of avoiding project delays.

ii) LIMITATIONS OF THE STUDY

The study relied on many variables such as the probability of occurrence of risks, their impacts on project duration, level of mitigation for risks and benefits of mitigation measures. These variables are quite subjective and tend to vary. In such cases where the actual value of these variables are found to be different from assumed values, then the results will not hold good. Due to the nature of projects and the uncertainty involved in them, it may difficult to complete objectify the value of variables and as such will be a limitation to the method shown in this paper.

REFERENCES

Aderbag, M.A.; Elmabrouk, S.K.; Sherif, M.A. "Risk analysis related to costing and scheduling of construction projects." In Proceedings of *the International Conference on Industrial Engineering and Operations Management*, IEOM Society International, Bandung, Indonesia, 6–8 March 2018

Alarcón, L.F.; Ashley, D.B.; de Hanily, A.S.; Molenaar, K.R.; Ungo, R. "Risk Planning and Management for the Panama Canal Expansion Program." *J. Constr. Eng. Manag*. 2011, 137, 762–771.

Chang, C.-Y.; Ko, J.-W. "New Approach to Estimating the Standard Deviations of Lognormal Cost Variables in the Monte Carlo Analysis of Construction Risks." *J. Constr. Eng. Manag*. 2017, 143

Choudhry, R.M.; Aslam, M.A.; Arain, F.M. "Cost and schedule risk analysis of bridge construction in Pakistan: Establishing risk guidelines." *J. Constr. Eng. Manag*. 2014, 140

D. Hulett, Practical Schedule Risk Analysis, Farnham, Surrey, United Kingdom, 2009.

Moret, Y.; Einstein, H.H. "Construction Cost and Duration Uncertainty Model: Application to High-Speed Rail Line Project." *J. Constr. Eng. Manag*. 2016, 142.

Nguyen, L.D.; Phan, D.H.; Tang, L.C.M. "Simulating construction duration for multistory buildings with controlling activities." *J. Constr. Eng. Manag*. 2013, 139, 951–959.

PMI. *PMBOK Guide*, 6th ed.; Project Management Institute: Newtown Square, PA, USA, 2017.

Rees,M. "Business Risk and Simulation Modelling in Practice Using Excel, VBA and @RISK"; *JohnWiley & Sons Ltd*.: Hoboken, NJ, USA, 2015.

Sivarao, S., Anand, T. and Ammar, A. (2010), "DOE based statistical approaches in modeling of laser processing-review and suggestion", *International Journal of Engineering & Technology*, Vol. 10 No.04, pp.1-8

Vanhoucke, M. "On the dynamic use of project performance and schedule risk information during project tracking." *Omega 2011*, 39, 416–426.

Linking Project Risk Management and Top Management Commitment with Project Success: Mediating Role of Project Innovativeness and Project Flexibility in Financial Services

Pankaj TIWARI[1] and Suresha B[2]
PMP, PhD Research Scholar, School of Business and Management, Christ (Deemed to be University), Bengaluru; email: pankaj.tiwari@res.christuniversity.in [1]
Associate Professor, School of Business and Management, Christ (Deemed to be University), Bengaluru; email: suresh.b@christuniversity.in [2]

ABSTRACT

Established organizations are always engaged in technological project execution to manage and keep up with the threat of technological disruption. The primary objective of this study is to examine the influence of project risk management and top management commitment on project success through the mediating effects of project innovativeness and project flexibility in the financial services sector. This study is cross-sectional in nature and uses project -level data collected through a questionnaire survey from a sample of over 400 project managers in financial services organizations operating in Bengaluru, India. A regression analysis is performed to determine whether project risk management and top management commitment are associated with project innovativeness, project flexibility and project success. It also examines the mediating effects of project innovativeness and project flexibility. Study findings suggest that project risk management and top management commitment positively influence project success. Mediation effects of project innovativeness and project flexibility are also observed between project risk management, top management commitment and project success. The contingency theory supports that there is no single right way of doing things but context is required to decide the best way of doing things. This study addresses the fact and weakness of the contingency perspective as lesser empirical studies are available to date. Project managers should focus on risk management by ensuring to have effective decision-making. When establishing disruptive and radical innovation, project managers should prioritize identified key obstacles over traditional obstacles while designing an effective innovation process and careful resource allocation. Senior managers should remain committed and have periodic reviews of the project controls. Simultaneously, senior managers should have adequate expertise and knowledge to bring transformational changes in the organizations. Therefore, top management should oversee and review the strategic orientation of technology projects to reap business benefits.

KEYWORDS: Top management commitment, Project risk management, Project innovativeness, Project flexibility, Project success

INTRODUCTION

Established organizations are constantly engaged in technological project execution to manage and keep up with the threat of technological disruption (Clayton, 1997). Despite technology advancements and project management know-how, project failures still abound. With digitalization and globalization as the key drivers of change; established organizations have to adapt and face challenges that come with the change (Parida et al., 2015). Several organizations have been embracing the need of technology led digital transformation. For example, since the 1990s, financial services organizations have digitized business processes to create new products and services, resulted in the availability of more financial products and services through online and offline channels. However, with the stiff competition that continuously sees improved financial products and services; financial organizations need to keep innovating and improving their offerings to stay ahead. Mainly, since the financial crisis occurred in 2008, it has been challenging to remain competitive in this dynamic environment with new competitors and greater market volatility (Berry et al., 2010). For decades financial services organizations have focused on incremental improvements of their products and service offerings and a few organizations were able to create innovative projects to offer new products and services to customers in new markets. Under the present market dynamics, established financial services organizations experience challenges with emerging technologies to explore new business propositions (Tushman et al, 1996). Such technology intensive projects depend on the technology skills and expertise of the involved to be successful and beneficial for the business (Morkunas et al.,2019).

Earlier studies found several critical success factors needed for the overall project success, for example, project type, customer satisfaction and top management commitment (Muller and Jugdev, 2012). Whereas, Baccarini (1999) argued that project success is the combination of product and project management success. A project's unfavorable state reflected by project risks (Zhang, 2007). Even a simple task or event may result in unexpected glitches in an uncertain environment. Also, it may change the project activity regardless of important factors considered by the project leader. Project risk management needs to carry throughout the project implementation. Also, anticipated project outcomes are risk management measures based on decision milestones that prevent adversity so that project resources are utilized efficiently. Still, projects face budget overruns, delay in schedule, and compromised project quality (Meyer et al., 2017). Previous research studies have observed that project risk planning and management should be the key focus of project management for improving project performance (Teller et al., 2014; Alias et al., 2014). The research work by Ahmed (2012) confirmed that incorporating project planning and risk management while applying management practices positively influences overall organizational efficiency and business benefits.

Researchers have recommended various risk mitigation strategies to reduce the delays occurring in business (Gunduz et al., 2013; Haseeb et al., 2011). The effectiveness of such recommended risk mitigation strategies in lowering the effect of delays on IT projects has not been empirically investigated. Projects with higher complexity, greater relational instability, lower technological uncertainty, and moderate innovativeness, need to have detailed project risk planning. They also need a more formalized process to communicate with stakeholders and tight project controls, to manage the projects (Salomo et al., 2007). But these conventional project management methods suppress innovativeness and restrict managers from dealing with contingencies and any changes (McNally et al., 2010). Therefore, systemic thinking along with operational project flexibility contributes to project innovativeness and managerial activities. More emphasis should be given on the project performance outcomes for project innovativeness (i.e. cost, schedule, and scope) instead of goals- based outcomes. Further research is warranted to determine the applicability of innovativeness in different dynamic environments to devise a successful project management practice leading to project success (Kapasali, 2011).

Gradually, financial institutions are challenged to offer services based on customers' preferences that are evolving due to technology advancements and changes, such as payments processing systems, financial risk, and asset management systems. Given the dynamic market conditions, the financial companies (especially IT business units) face increased pressure to sustain and improve their efficiency and promptness towards market changes while having control over cost. However, the challenge in Financial Services is to remain flexible with processes, stakeholder negotiations, and responsiveness over rigid planning and risk management, and to focus on technology projects to improve the likelihood of project success (Montoya, 2016). Importantly, project flexibility is related to the preventative risk mitigation strategies that offer means to achieve project success especially in a dynamic environment. Earlier studies (Curtis et al., 2019; Zailani et al., 2016) have proposed the need for more empirical research on project flexibility in project-based organizations. Thus, this research paper will study the influence of project risk management and top management commitment on project success in Financial Services.

Though project characteristics affect the project outcome, till date a few empirical studies (Kapasali, 2011; Fu et al., 2013; Zailani et al., 2016) have examined the extent to which the top management commitment and risk management activities are contingent upon a project's degree of innovativeness and flexibility. To address the scarcity in project management research, this research paper will focus on project innovativeness and project flexibility to examine its consequences by posing general research questions:

1. How do top management commitment and project risk management influence project success?

2. How does project innovativeness and project flexibility affect the relationship between top management commitment, project risk management and project success?

This study contributes to the literature on top management commitment, project risk management and project management by providing empirical evidence and suggests that (1) top management commitment, project risk management are positively related to the project success in financial services; (2) project innovativeness and project flexibility plays a significant role in achieving project success and are very important for projects that operate in a dynamic environment. Therefore, contingency theory is adapted to have more relevance.

LITERATURE REVIEW

Top Management Commitment

As noted earlier, many studies have been conducted on the factors that impact organizational performance and project success within an organization (Hermano et al., 2016; Terlizzi et al., 2016; Khattak et al., 2020). Consistently, top management commitment shows up as a critical success factor in these studies. The term top management represents the senior management level (e.g. Executive managers) in an organization. The term top management commitment is used to capture the different ways in which involvement, engagement, influence, oversight, leadership, and support of senior management occurs in a project management environment. Top management commitment is important because resources are controlled within an organization by the top management. Having top management commitment during project scope changes, budget overruns, delays in project schedules, and similar crises helps to obtain required resources and approvals. Specifically, for IT projects, budget allocation and extra funding for process engineering and additional training can be easily managed if they have top management commitment. Without top management commitment there will be no one to persuade the senior managers who run functional silos within the company to temporarily subordinate the interests of their functional areas to those of the project when difficulties arise. Top management needs to sell the rationale for the project with visible enthusiasm and by championing the project's activities in order to enhance the business outcomes.

Project Risk Management

Project risk refers to an uncertain event or a situation that poses a threat to successful project completion and has a positive or negative effect on the overall project goals (PMI, 2013). Several studies support the view of including both threat and opportunity when project risk management process is considered (Ward et al., 2003). Project risk management helps organizations to reduce the impact of uncertain events while aiming to have more opportunities (Petit, 2012). The project risk management process concentrates on determining and assessing risk factors that adversely affect project performance and reduce them. (Peiyu et al., 2011). The information collected during project risk management helps in decision making while several tools and techniques are developed to support project risk activities. Earlier researchers have stated that project-based organizations should have effective governance structures for risk mitigation (Atkin et al., 2008). Also, efficient risk management is imperative for an effective governance structure (Zwikael et al., 2015). Theoretically, project risks may appear unpredictably anytime during the project lifecycle, deter governance strategies, and impact project performance (Raz et al., 2002). Several studies have found a positive relationship between project risk management and project success especially in new product development projects (Mu et al., 2009; Salomo et al., 2007). Whereas, other studies (Bannerman, 2008; Raz et al., 2002) have shown that project risk management underperforms the project success. Project risk management is used to deliver messages to project stakeholders with the aim of influencing their perception, behavior and awareness of the environment. Teller et al. (2014) highlighted the need for empirical research on project risk management to enhance knowledge and learning.

Project Success

The project success or failure is subjective to the stakeholder consideration (Muller et al., 2012). To have a common understanding, it is imperative to define the success criteria in the initial stages of the project to determine the project success or failure (PMI, 2013). Various authors define project management based on an operational and conceptual context (Wu et al., 2017; Carvalho et al., 2017; Pinto et al., 1991). Pinto and Pinto (1991) defines project success as a combination of customer satisfaction, schedule, cost, and quality. Whereas, Carvalho et al. (2017) define project success by having three aspects, firstly, the influence of a project on the employees, clients and overall business, client and staff, secondly, the efficiency of a project, and lastly, prep for the future. Interestingly, Wu et al. (2017) described project success as the byproduct of quality, schedule, cost, environmental controls, participants and users' satisfaction, health & safety, and related commercial values. As projects comprise various actors, multiple goals exist and this makes it difficult to measure project performance. It is difficult to choose one overarching goal representing all actors. Moreover, as projects generally have prolonged time duration, due to the different preferences the goals may change over time (Klijn et al., 2016). Therefore, observed project performance is considered as a proxy for outcomes. Project performance is a multi-dimensional construct relating to cost, time, scope and quality dimensions (Chipulu et al., 2014; Winch, 2014). Shenhar et al. (2001) recommended a distinction among two project types, first are the operationally managed projects focus on meeting the project performance (i.e. cost, time and goals), and second are the strategically managed projects which focus on business outcomes and creating value in the marketplace. Organizations spend a lot of time and attention on improving business outcomes in the long term. Therefore, the business success dimension includes the creation of business value by the projects.

The success factors for information technology organizations relate to the capability in developing and delivering a product or project that fulfills customer needs and offer greater value leading to business success. Thus, a business benefit is as unique as the organization and relates to the business outcomes. Business success incorporates the extent to which corporate strategy is realized by group of projects (i.e. portfolios), and has the ability to react to the dynamic environment by seizing the opportunities for long terms results (Teller et al., 2014; Gregor et al., 2006).

HYPOTHESES DEVELOPMENT AND CONCEPTUAL FRAMEWORK

The hypotheses and the resulting model are developed based on existing research. The basic idea is built based on general contingency theory concept, which suggests that project control activities are critical for project success, and this is translated to the realm of project management (Aljawder et al., 2013). Project risk management influences project performance and business success (Zwikael et al., 2014). The organization gets benefited by using project risk management by having greater project performance and business success through creating business value. Therefore, project success is measured by project performance considering short term goal and business success considering long term goal in achieving the expected outcomes (Muller & Jugdev, 2012). Top management can organize and synergize people's activities to achieve the common goal of the organization and a crucial component for project success. Top management commitment directly enhances firm performance. It is suggested to consider for instance performance of leadership, quality of project management process. Satisfying the expectations of project stakeholders addresses long-term benefits and shows how new opportunities are generated and how well the projects support the organization to develop its infrastructure for the future. Hence, the proposed hypotheses are as follows:

H1: *Project risk management has a significant effect on project success.*

H2: *Top management commitment has a significant effect on project success.*

In the turbulent and rapidly changing environment, organizations have two strategic tools for gaining competitive advantage; innovation and continuous process improvement. According to Nowak (1997), innovation is interlinked with process improvement and should be treated same. Some of the aspects such as organizational culture can be managed by senior leaders. To achieve innovativeness and offer innovative culture, top management should be committed, initiate the creative process, support creative ideas and continuously focus on technological advancements by managing project risks, to achieve project success. Hence, the following hypotheses are presented:

H3: Project risk management is significantly associated with project innovativeness.

H4: Top management commitment is significantly associated with project innovativeness.

Project flexibility provides the ability to change with respect to cost, effort, performance or time. It portrays the project's capacity to undergo project scope changes. Project flexibility compensates for those changes with lesser influence on project schedule, quality and cost by applying suitable measures to manage the project. It is considered imperative to make sure the project remains on track irrespective of the success factors that will help to achieve the iron triangle. Project flexibility aligns the organization's short-term as well as long-term success goals, offers appropriate intuition of project success (Shahu et al., 2013). Therefore, projects to be successful need flexibility in their predetermined structures; financial and technical capabilities so as to lessen project risks and result in business success. Thus, project flexibility can influence project success (Zailani et al., 2016). Project risk management and top management commitment are critical for project flexibility. Hence, the following hypotheses are proposed:

H5: *Project risk management is significantly associated with project flexibility.*

H6: *Top management commitment is significantly associated with project flexibility*.

H7: *Project flexibility has a significant effect on project success.*

The outcomes of empirical studies advocate that project characteristics, for example, project complexity and project uncertainty moderate project management– performance associations (Salomo et al., 2003; Shenhar et al., 2002; Lewis et al., 2002). Uncertainty and complexity of new technological projects is strongly related to project innovativeness. Though earlier research provides a variety of definitions of innovativeness (Garcia et al., 2002; Green et al., 1995), the amount of change related with a new project is commonly a good predictor of innovativeness. It is usually defined distinctly considering technological, organizational and market based dimensions. Furthermore, recent research also suggests that it relates to the amount of internal and external resources necessary to build a new project or product (Danneels et al., 2001). With more innovativeness, technological discontinuities increase and call for more organizational, market-based and environmental changes. Whereas a radical innovation applies an entirely new technological principle and creates a new market by reshaping the organizational value. Therefore, an increase in innovativeness in projects brings more uncertainties (Fu et al., 2013). On the other hand, innovation in projects or products drives increased business benefits and makes it vital for organizations to innovate.

Contingency theory suggests that to increase performance, structural factors should align with contextual factors in organizations and applied to the projects (Teller et al., 2014). The contingency theory perspective predicts the conditions under which the effects of project risk management and top management commitment will be stronger or opposite. As the degree of uncertainty varies, it calls for various approaches for project risk management and more commitment from senior managers. Project flexibility and innovativeness are also explained thoroughly through contingency theory since innovative projects are comparatively less familiar with their standard course of actions (including resource allocation) and the required processes (Hanisch et al., 2012). Hence, the hypotheses proposed are -

H8: Project innovativeness has a significant effect on project success.

H9: There is a mediation effect of project flexibility between project risk management and project success.

H10: There is a mediation effect of project flexibility between top management commitment and project success.

H11: There is a mediation effect of project innovativeness between project risk management and project success.

H12: There is a mediation effect of project innovativeness between top management commitment and project success.

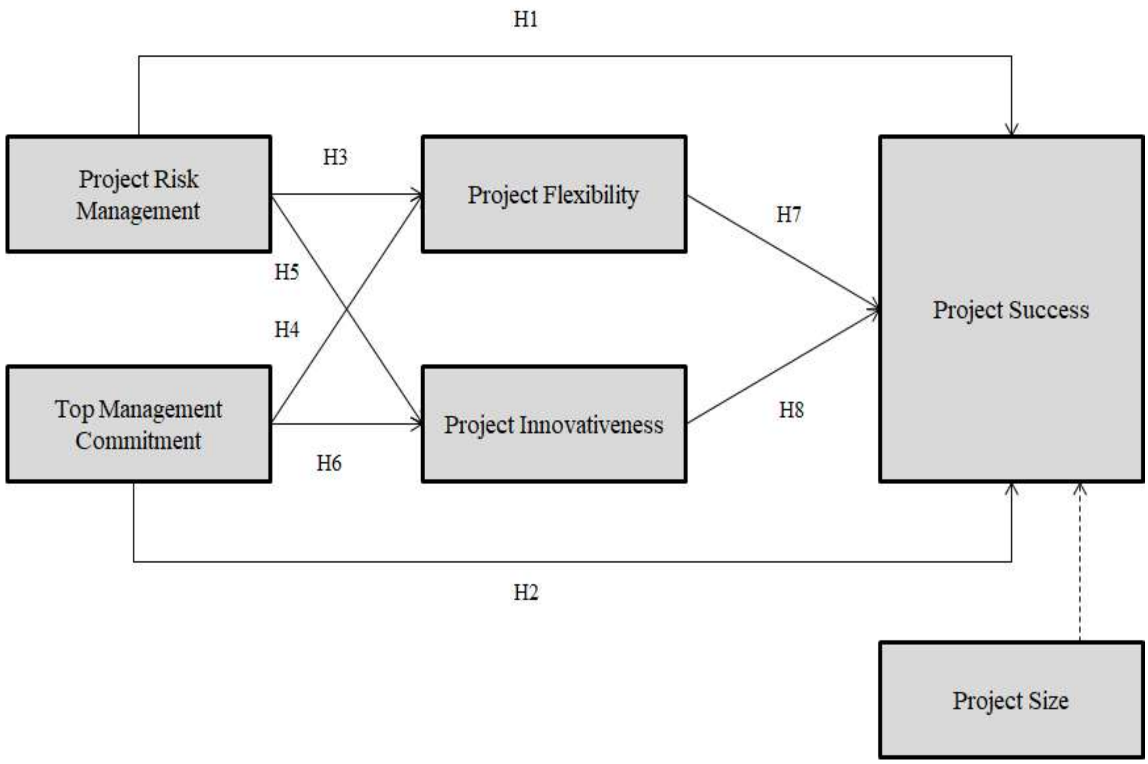


Figure 1. Conceptual Framework

The conceptual framework is based on the project management empirical studies and related theoretical foundations (see Figure 1).

RESEARCH METHODOLOGY

Data Collection

To test the hypotheses, a sample of 166 datasets is considered. The scope of data analysis of this study is the IT projects. To investigate the effects of project risk management and project flexibility, the IT projects chosen for the study were executed and implemented between 2014 and 2020, and have been in the market for over one year. In total, approximately 450 project managers from the Financial Services industry were contacted through email. A web-based survey questionnaire was sent out to various managers during December 2019 to May 2020. All questionnaires were carefully cross-checked for data accuracy with respect to the sample respondents and the target organizations (Hair et al., 2010). The response rate for this survey was 27.6%. There were no significant differences (alpha 5%) between early and late responses (Armstong et al., 1977). To reduce the risk of bias due to common-method variance (Podsakoff et al., 2003), a dual-informant design was adopted, which included project managers at different management levels.

Sample characteristics

About 20% of the respondents mentioned the project duration as around one year, about 43% mentioned the duration to be more than one year but less than three years, and 37% indicated project duration of more than three years.

Measures

The study variables were based on multi-item scales derived from literature on project management, project risk management, project innovativeness, project flexibility and related fields. To suit the study context, the wordings of certain scales were adapted. Five industry experts in the sample organizations were contacted to assess each item on a seven-point Likert scale, ranging from 1 ("strongly disagree") to 7 ("strongly agree"), and the variables were constructed by averaging the respective items (Hair et al, 2010). To have the check for meaning accuracy, a double-blind back-translation process was followed. A pilot test with practitioners was steered for the validation of all measures in the context of the Financial Services industry. The validity of the item scales was verified by a principal components factor analysis (PCFA), followed by a confirmatory factor analysis (CFA). The PCFA was used to test whether all items load on a single factor. Cronbach's alpha denotes the scale reliability, and acceptable values are greater than 0.7. A CFA was used to verify the measurement model (Guide et al., 2015). The measurement model is considered satisfactory as the comparative fit index (CFI) and goodness of fit index (GFI) exceeds 0.90, root mean square error of approximation (RMSEA) is below 0.07 and the standardized root mean square residual (SRMR) is below 0.08.

Project success is measured based on the dimensions of project performance (α = 0.843) (four items) and business success (α = 0.836) (three items) developed by Cooper et al.(2001), Shenhar et al. (2001), Müller et al. (2008); Jonas et al. (2013) ;Teller et al. (2014). *Project risk management* is assessed using four items (α = 0.880) are based on and Willauer (2003) and Ilincuta (1997). *Top management commitment* was measured using a 6-item scale developed by [36]. *Project Innovativeness* is measured based on the technological dimension with three items (α = 0.771) suggested by Salomo et al. (2007). *Project flexibility* is captured using three items (α = 0.705) are conceptually based on work by Zailani et al.(2016). Control variable i.e. *Project Size* is one of the important determinants of project success. Project size is captured by natural logarithm of the average of project budget allocated, project effort in person hours and project duration in months (Afful, 2019).

Descriptive Statistics

The descriptive statistics and correlations of all variables (see Table 1).

Table 1. Descriptive Statistics

	Variables	0	1	2	3	4	5
	Mean	4.924	3.843	4.774	5.04	4.911	5.129
	Std. Dev.	1.903	1.493	1.224	1.017	1.094	1.026
0	Project Success	1					
1	Project Size	-.330**	1				
2	Project Risk Management	.431**	.176*	1			
3	Top Management Commitment	.520**	-.167*	.515**	1		
4	Project Flexibility	.583**	-.037	.558**	.545**	1	
5	Project Innovativeness	.659**	-.013	.560**	.497**	.519**	1
	**. Correlation is significant at the 0.01 level (2-tailed).						
	*. Correlation is significant at the 0.05 level (2-tailed).						

RESEARCH OUTCOMES

The hierarchical ordinary least square (OLS) regression analysis is used to determine the effects of project risk management and top management commitment on project success (Hair et al., 2010). Model 1 and Model 2 (see Table 2) shows the direct effects of project risk management, top management commitment and control variable (i.e. project size) on project flexibility and project innovativeness. Model 3 tests the direct effects of project risk management and top management commitment on project success. Model 4 to Model 6 tests the mediation effects of project flexibility and project innovativeness. The maximum VIF (Variance Inflation Factor) within the models was 2.558, well below the rule-of-thumb cut-off of 10, indicating that no serious concerns should be raised about multi-collinearity (Hair et al., 2010).

Model 1 reveals that project risk management (b= 0.290 , p< 0.01) and project top management commitment (b= 0.218 , p< 0.05) has significant positive impact on project innovativeness. Model 2 reveals that project risk management (b= 0.292 , p< 0.01) and project top management commitment (b= 0.296 , p< 0.01) has significant positive impact on project flexibility. Control variable project size shows no significant effects in Model 1 and Model 2. Model 3 reveals that project size (b= - 0.216, p<0.01) project risk management (b=0.255, p<0.01) and top management commitment (b=0.253, p<0.01) has a significant impact on project success. Hence, H1, H2, H3, H4, H5 and H6 are supported.

Table 2. Regression Outcomes for Mediation Effects

	Project Innovativeness	Project Flexibility	Project Success			
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Control Variable						
Project Size	-.025	-.032	(-) 0.216**	(-) 0.204**	(-) 0.202	(-) 0.194**
Independent Variables						
Project Risk Management	0.290**	0.292**	0.255**	0.146*	.092	.031
Top Management Commitment	0.218*	0.296**	0.253**	0.143*	0.131*	.065
Mediating Variables						
Project Flexibility				0.372**		0.272**
Project Innovativeness					0.558**	0.496**
R-Square	0.375	0.404	0.411	0.494	0.574	0.616
Adjusted R-Square	0.364	0.393	0.400	0.481	0.564	0.604
R-Square change	0.375	0.404	0.411	0.494	0.574	0.616
F change	32.418	36.581	37.667	39.235	54.266	51.407
Sig. F change	.000	.000	.000	.000	.000	.000

Note: Unstandardized regression coefficients are reported, N=166
** Significant at the 5% level.
*** Significant at the 1% level.

Model 4 shows that project size (b=0.204, p<0.01), project risk management (b=0.146, p<0.05), top management commitment (b=0.143, p<0.05) and project flexibility (b=0.372, p<0.01) has significant effects on project success. Model 5 shows that the top management commitment ($b=0.131$, $p<0.05$) and project innovativeness ($b=0.558$, $p<0.01$) has significant effects on project success. Model 6 shows that the project size ($b=-0.194$, $p< 0.01$), project flexibility ($b=0.272$, $p<0.01$) and project innovativeness ($b=0.496$, $p<0.01$) has significant effects on project success. The direct association of project risk management and top management commitment with project success, is considerably lessened (and insignificant) after introducing project flexibility and project innovativeness which signifies for mediation. Hence, H7, H8, H9, H10, H11 and H12 are accepted.

DISCUSSION AND CONCLUSION

The objectives of this study were to link project risk management and top management commitment with project success, and to investigate the impact of both of these on project success. A contingency perspective was adopted to examine the effects of project flexibility and project innovativeness. The results of this study have theoretical and managerial implications for managing IT projects.

The major finding is that project risk management and different risk mitigation strategies (i.e. project flexibility) are highly relevant for project success. This study therefore answers the call to further examine the link between single project management and business success (Martinsuo & Lehtonen, 2007). Martinsuo and Lehtonen (2007) showed that single project management affects the overall business success. The outcome of the present study provides the evidence that project risk management is linked to project success. Project risk management process is necessary for high project performance and achieving business success. Furthermore, it is found that project risk mitigation strategies (i.e. project flexibility) are integrated into the project management process and important for increased project success. These findings support the claim that project risk management and project flexibility impact the project success as a whole (Olsson, 2008).

The positive influence of Top management commitment on project success has been supported by the present study. More precisely, greater commitment of top management has a positive influence on strategic benefits and transformation benefits (Gregor et al., 2006). The study outcomes show that the positive impact of top management that has been identified at the organization level can also be found at the project team level. The strong influence of top management commitment helps in achieving project success and business benefits, and is in line with the earlier upper echelon behavior that focuses on the effect of top management support like advice seeking, behavioral integration, entrepreneurial drive, and risk taking on business benefits. The study results support this positive effect at the project level by applying a project level approach. The relationship between project risk management, top management behaviors and project outcomes is not exclusively direct. The study results show that project risk management and top management commitment positively influences project flexibility and innovativeness, which in turn has a positive effect on project success. The study outcomes on the mediating effects of project innovativeness and project flexibility on project success suggest that the resource and coordination issues among project stakeholders (i.e. internal and external) can be improved by maintaining transparency, sharing knowledge on the project related processes and practices, enhancing the knowledge across project teams, informing project stakeholders about the customer's future requirements, regular project reviews helps project stakeholders to collaborate and monitor the project progress, communicating with project stakeholders on the future strategic needs, more information exchange among stakeholders and continued effort to search for new ways to integrate the project processes (Zailani et al., 2016). Results indicate a full mediation.

CONCLUSION

The contingency theory supports that there is no single right way of doing things but context is required to decide the best way of doing things. As projects are unique in nature, every project requires a diverse contingent approach to work upon because of most of the project variables changes to some extent. The study outcomes are consistent with the earlier research, which states the greater benefits of risk management for high risk projects and top management commitment leads to project success and business benefits. This research enhances the contributions that have been offered with respect to the influence of project risk management, top management commitment, project innovativeness and project flexibility on project success. Overall, this study addresses the fact and weakness of contingency perspective as lesser empirical studies are available to date.

MANAGRIAL IMPLICATIONS

The project activities are generally driven by stakeholder involvement from the project initiation until the project completion. This makes it important for project managers to include the expectations of key stakeholders during initial planning stage. Project managers should build a supportive team culture with "can do" attitude, demonstrate ability to deliver based on project goals, more collaboration with other teams, and enhance continuous learning and knowledge sharing. Similarly, senior managers should focus on risk management by ensuring effective decision-making. When implementing disruptive and radical innovation, managers should prioritize key obstacles that have been identified over traditional obstacles while designing an effective innovation process, and on careful resource allocation. In the current market scenarios, project managers should do more than just achieving schedule and budget goals, which is not enough. To achieve project success and the intended business goals, project managers should instead be focusing on the delivery of business value and support the organization to achieve success. With project management driving business benefits, project team members can be enabled to offer benefits to their business, such as competitive advantages with new technology, new products, or services. A project manager should outline key steps to deliver benefits to stakeholders, by understanding the project vision, having open communication with project teams, empowering them to achieve project goals, fostering an environment that helps project teams to deliver value, and measuring how the value will be delivered throughout the project, leading to business success. Hence, it is imperative to have continued professional development for project managers through continual learning. This helps them build communication and leadership skills in the workplace. Project managers should continuously focus on project performance and team members' knowledge and skills enhancement to achieve higher innovativeness. Also, project managers should be trained in tactics that offer flexibility, such as contingency planning, dynamic resource allocation, late locking of project requirements (e.g. in stage gate model), etc.

Many managers acknowledge the importance of technological advancement; the study outcomes show the average involvement of senior managers in decision making, long term strategies and adoption of new technologies. Senior managers should promote an innovation-driven leadership style (for example, transformational leadership) to make use of organization's capabilities effectively, and entrepreneurial- oriented culture to foster the business benefits. Furthermore, senior managers should spend more time in periodic reviews of project controls, and put in more effort in promoting innovation project activities within the organization and building dynamic capabilities at project and portfolio levels. Project or portfolio managers should seek new opportunities, learn more from market changes and improve capabilities to transform project innovativeness into better long term benefits. Therefore, managers at every level should also focus on resource development in line with strategic goals and allocate tangible and intangible assets to the entire development process. Finally, when an organization wants to enter into emerging markets, projects' innovativeness may contribute more to business success as this helps managers to achieve transformational benefits such as new skills or knowledge gain, new business strategies, organizational processes, etc.

LIMITATIONS AND FUTURE RESEARCH RECOMMENDATIONS

This study has some limitations that can be addressed by future studies. First, the study uses a cross sectional data from Financial Services organizations. Therefore, future studies can be conducted considering projects from different industries, and sectors. Second, the study uses the managers' perspective on project flexibility and project innovativeness in achieving project success. Future studies can examine the same at organizational level flexibility and innovativeness to compare any differences in research outcomes. Third, although this study examines the mediating role of project flexibility and project innovativeness between project risk management, top management commitment and project success, managers' decision making consists of many contingency factors. Future studies can examine other potential variables influencing the entire process.

REFERENCES

Afful, E., & Matey, H. A. (2019). "IT Project Success: Practical Frameworks based on key Project Control Variables." *arXiv preprint arXiv:1910.06215.*

Ahmad, M. S. (2012). "Impact of organizational culture on performance management practices in Pakistan." *Business Intelligence Journal*, 5(1), 50-55.

Alias, Z., Zawawi, E. M. A., Yusof, K., & Aris, N. M. (2014). "Determining critical success factors of project management practice: A conceptual framework." *Procedia-Social and Behavioral Sciences*, 153, 61-69.

Aljawder, M., & Davis, J. G. (2013). "*A Contingent Model of Project Organization and Management."*

Armstrong, J. S., & Overton, T. S. (1977). "Estimating nonresponse bias in mail surveys." *Journal of marketing research,* 14(3), 396-402.

Atkin, B., & Skitmore, M. (2008). "Stakeholder management in construction." *Construction Management and Economics,* 26(6), 549-552.

Baccarini, D. (1999). "The logical framework method for defining project success." *Project management journal,* 30(4), 25-32.

Bannerman, P. L. (2008). "Risk and risk management in software projects: A reassessment." *Journal of Systems and Software*, 81(12), 2118–2133.

Berry, L.L., Bolton, R.N., Bridges, C.H., Meyer,J., Parasuraman, A. and Seiders, K. (2010). "Opportunities for innovation in the delivery of interactive retail services." *Journal of Interactive Marketing*, 24(2), 155-167.

Clayton Christensen M. (1997). "*The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail."* Boston: Harvard Business School Press.

Carvalho, M. M., & Rabechini Jr, R. (2017). "Can project sustainability management impact project success? An empirical study applying a contingent approach." *International Journal of Project Management*, 35(6), 1120-1132.

Chipulu, M., Ojiako, U., Gardiner, P., Williams, T., Mota, C., Maguire, S., ... & Marshall, A. (2014). "Exploring the impact of cultural values on project performance." *International Journal of Operations & Production Management*.

Cooper, R. G. (1999). "The invisible success factors in product innovation." *Journal of Product Innovation Management*, 16(2), 115–133.

Curtis, E., & Sweeney, B. (2019). "Flexibility and control in managing collaborative and in-house NPD." *Journal of Accounting & Organizational Change*.

Danneels, E., & Kleinschmidt, E. J. (2001). "Product dimensions and their relation with project selection and performance." *Journal of Product Innovation Management*, 18(6), 357-373.

Fu, F. Q., & Elliott, M. T. (2013). "The moderating effect of perceived product innovativeness and product knowledge on new product adoption: An integrated model." *Journal of Marketing Theory and Practice*, 21(3), 257-272.

Garcia, R. and Calantone, R. (2002). "A Critical Look at Technological Innovation Typology and Innovativeness Terminology: A Literature Review." *Journal of Product Innovation Management*, 19, 110– 32.

Guide Jr, V. D. R., & Ketokivi, M. (2015). "Notes from the Editors: Redefining some methodological criteria for the journal." *Journal of Operations Management*, 37(1), v-viii.

Green, S.G., Gavin, M.B., and Aiman-Smith, L. (1995). "Assessing a Multidimensional Measure of Radical Technological Innovation." *IEEE Transactions on Engineering Management*, 42, 203–14.

Gregor, S., Martin, M., Fernandez, W., Stern, S., & Vitale, M. (2006). "The Transformational Dimension in the Realization of Business Value from Information Technology." *The Journal of Strategic Information Systems*, 15(3), 249-270.

Gunduz, M., Nielsen, Y. and Ozdemir, M. (2013). "Quantification of delay factors using the relative importance index method for construction projects in Turkey." *Journal of Management in Engineering*, 29(2),133-139.

Hair, J. , Black, W. , Babin, B. , Anderson, R. , & Tatham, R. (2010). "*Multivariate data analysis*." Pearson Prentice Hall.

Hanisch, B., & Wald, A. (2012). "A bibliometric view on the use of contingency theory in project management research." *Project Management Journal*, 43(3), 4-23.

Hermano, V. and Martín-Cruz, N. (2016). "The role of top management involvement in firms performing projects: a dynamic capabilities approach." *Journal of Business Research* , 69(9), 3447–3458.

Ilincuta, A. (1997). "*Risk, project management and project success for software industry*."

Jonas, D., Kock, A., & Gemünden, H. G. (2013). "Predicting project portfolio success by measuring management quality: A longitudinal study." *IEEE Transactions on Engineering Management*, 60(2), 215– 226.

Kapsali, M. (2011). "Systems thinking in innovation project management: A match that works." *International journal of project management*, 29(4), 396-407.

Khattak, M.S. and Shah, S. Z. A. (2020). "Top Management Capabilities and Firm Efficiency: Relationship via Resources Acquisition." *Business & Economic Review*, 12(1), 87-118.

Klijn, E. H., & Koppenjan, J. (2016). "The impact of contract characteristics on the performance of public– private partnerships (PPPs)." *Public Money & Management*, 36(6), 455-462.

Lewis, M.W., Welsh, M.A., Dehler, G.E., and Green, S.G. (2002). "Product Development Tensions: Exploring Contrasting Styles of Project Management." *Academy of Management Journal*, 45,546–64.

Martinsuo, M., & Lehtonen, P. (2007). "Role of single-project management in achieving portfolio management efficiency." *International Journal of Project Management*, 25(1), 56–65.

McNally, R. C., Cavusgil, E., & Calantone, R. J. (2010). "Product innovativeness dimensions and their relationships with product advantage, product financial performance, and project protocol." *Journal of Product Innovation Management*, 27(7), 991-1006.

Meyer, W. G., Engelbrecht, H., & Steyn, H. (2017). "Escalation of commitment: evaluating project termination behaviour of masters of engineering management students." *Journal of Contemporary Managemen*t, 14(1), 893-919.

Montoya, M. (2016). "Agile Adoption by the financial Services Industry." Retrieved from cPrime: https://www.cprime.com/2012/09/agile-adoptionfinancial-services-industry/

Morkunas, V.J., Paschen, J. and Boon, E. (2019). "How blockchain technologies impact your business model." *Business Horizons*, 62(3), 295-306.

Mu, J., Peng, G., & MacLachlan, D. L. (2009). "Effect of risk management strategy on NPD performance." *Technovation*, 29(3), 170–180.

Müller, R., & Jugdev, K. (2012). "Critical success factors in projects: Pinto, Slevin, and Prescott-the elucidation of project success." *International Journal of Managing Projects in Business*, 5(4), 757-775.

Nowak, A. (1997). "Strategic relationship between quality management and product innovation." *The Mid-Atlantic Journal of Business*, 33(2), 119.

Olsson, N.O.E. (2008). "External and internal flexibility–aligning projects with the business strategy and executing projects efficiently." *International Journal of Project Organisation and Management*, 1(1), 47- 64.

Parida, V., Sjödin, D.R. ,Lenka, S. and Wincent, J. (2015). "Developing global service innovation capabilities: How global manufacturers address the challenges of market heterogeneity." *Research-Technology Management*, 58(5), 35-44.

Petit, Y. (2012). "Project portfolios in dynamic environments: Organizing for uncertainty." *International Journal of Project Management*, 30(5), 539–553.

Peiyu, L. I. U., & Dong, L. I. U. (2011). "The new risk assessment model for information system in cloud computing environment." *Procedia Engineering*, 15, 3200-3204.

Pinto, M. B., & Pinto, J. K. (1991). "*Determinants of cross-functional cooperation in the project implementation process*." Newtown Square, PA: Project Management Institute.

PMI Standards Committee (2013). "*A Guide to the Project Management Body of Knowledge*." Fifth ed. Project Management Institute, Newtown Square, PA.

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). "Common method biases in behavioral research: a critical review of the literature and recommended remedies." *Journal of applied psychology*, 88(5), 879-903.

Raz, T., Shenhar, A. J., & Dvir, D. (2002). "Risk management, project success, and technological uncertainty." *R&D Management*, 32(2), 101-109.

Salomo, S., Steinhoff, F., & Trommsdorff, V. (2003). "Customer orientation in innovation projects and new product development success-the moderating effect of product innovativeness." *International Journal of Technology Management*, 26(5-6), 442-463.

Salomo, S., Weise, J., & Gemünden, H. G. (2007). "NPD planning activities and innovation performance: the mediating role of process management and the moderating effect of product innovativeness." Journal of product innovation management, 24(4), 285-302.

Shahu, R., Pundir, A.K. and Ganapathy, L. (2013). "An empirical study on flexibility: a critical success factor of construction projects." Global Journal of Flexible Systems Management, 13(3), 123-128.

Shenhar, A. J., Dvir, D., Levy, O., & Maltz, A. C. (2001). "Project success: a multidimensional strategic concept." Long range planning, 34(6), 699-725.

Shenhar, A.J., Dvir, D., Lechier, T., Poli, M. (2002). "*One size does not fit all — true for projects, true for frameworks*." Proceedings of PMI Research Conference 14–17 July. Project Management Institute, Seattle, U.S.A, 99–106

Teller, J., Unger, B. N., Kock, A., & Gemünden, H. G. (2012). "Formalization of project portfolio management: The moderating role of project portfolio complexity." *International Journal of Project Management*, 30(5), 596–607

Teller, J., Kock, A., & Gemünden, H. G. (2014). “Risk management in project portfolios is more than managing project risks: A contingency perspective on risk management.” *Project Management Journal,* 45(4), 67-80

Terlizzi, M.A., de Souza Meirelles, F. and de Moraes, H. R. O. C. (2016). “Barriers to the use of an IT Project Management Methodology in a large financial institution.” *International journal of project management,* 34(3), 467-479.

Tushman, M.L. and O'Reilly, C.A. (1996). “Ambidextrous organizations: Managing evolutionary and revolutionary change.” *California management review,* 38(4), 8-29.

Ward, S., & Chapman, C. (2003). “Transforming project risk management into project uncertainty management.” *International Journal of Project Management,* 21(2), 97–105.

Willauer, B. (2003). “*Consensus as key success factor in strategy-making*.” 1st ed. Dt. Univ.-Verlag, Wiesbaden, Vallendar.

Winch, G. M. (2014). “Three domains of project organising.” *International journal of project management,* 32(5), 721-731.

Wu, G., Liu, C., Zhao, X., & Zuo, J. (2017). “Investigating the relationship between communication conflict interaction and project success among construction project teams.” *International Journal of Project Management,* 35(8), 1466-1482.

Zailani, S., Md Ariffin, H.A., Iranmanesh, M., Moeinzadeh, S. and Iranmanesh, M. (2016). “ The moderating effect of project risk mitigation strategies on the relationship between delay factors and construction project performance.” *Journal of Science and Technology Policy Management,* 7(3), 346-368.

Zhang, H. (2007). “A redefinition of the project risk process: Using vulnerability to open up the eventconsequence link.” *International journal of project management,* 25(7), 694-701.

Zwikael, O., Pathak, R. D., Singh, G., & Ahmed, S. (2014). “The moderating effect of risk on the relationship between planning and success.” *International Journal of Project Management,* 32(3), 435- 441.

Zwikael, O., & Smyrk, J. (2015). “Project governance: Balancing control and trust in dealing with risk.” International Journal of Project Management, 33(4), 852-862.

Authors Index

A V S S Surya SRINIVAS *158*
Achintya GHATAK *98*
Adarsh GARG *98*
Akshita PATEL *194*
Akansha KUNJAM *225*
Anand LOKHANDE *236*
Ankita ANAND *194*
Amarnath CB *183*
Ashwin MAHALINGAM *50*
Aveek DUTTA *295*
Bade Mihir UMESH *295*
Bhargav DAVE *122*
Dhiraj R.K SHARMA *194*
Dhruv PATEL *143*
G Srikantha SHARMA *79*
G. UNNIKRISHNAN *280*
Ganesh DEVKAR *30*
Georgie JACOB *122*
Harish Kumar SINGLA *262, 320*
Harish L REDDY *367*
Ivor TSANG *20, 30*
J.S. SUDARSAN *143*
Jai KEDIA *50*
Johan NINAN *30*
Jyoti TRIVEDI *111, 308*
K.C. IYER *67*
K V JAYAKUMAR *225*
Kirti RUIKAR *176*
Lauri VUORINEN *30*
Mohit KUMAR *194*
Murali JAGANNATHAN *262, **320***
Nagakumar M S *374*
Nandan KUMAR *111*
Nikhil BUGALIA *50*
Nishit BEDI *341*
Pankaj TIWARI *377*
Pallab GOSWAMI *351*
Purva GUPTA *67*

Rahul DESHPANDE *3*
Ravindranadh K.CHOWDARY *207*
Rohan JAIN *143*
Rupesh Kumar PATI *295*
Samuel MACAULAY *20*
Sandeep MATHUR *20*, *30*
Saniya Faiyaz PATHARWAT *207*
Sayali SANDBHOR *176*
Shalaka HIRE *176*
Shankar SANKARAN *20,30*
Shivam SHARMA *341*
Shobha RAMALINGAM *194*
Srividya Raju, SRIDHARAN *320*
Suresha B *377*
Suparna KAPOOR *79*
Tapash GANGULI *3*
Tushar JADHAV *3*
Vaibhav KUMAR *194*
Venkata Santosh Kumar DELHI *262*
Vijay Kumar SUKHWANI *341*
Vijaya DIXIT *158*
Vijayashree T M *308*
Vijayeta MALLA *207*
Vurukuti TARANI *50*
Yongjian KE *30*

Editors

Dr. Albert Thomas

Dr. Albert Thomas is an assistant professor at the department of civil engineering at IIT Bombay. Dr. Thomas obtained his PhD from the University of Michigan, Ann Arbor, and M-Tech in construction technology and management from IIT Madras. Dr. Thomas possess a unique mix of teaching, research and industry experience in various domains such as business strategic planning, management information systems, construction project scheduling, simulation analytics, and project management consulting. Dr. Thomas is the recipient of Build India Scholarship for the M-Tech program at IIT Madras, top performance awards from L&T, young faculty award from IIT Bombay, and best paper awards from various conferences.

Dr. Venkata S Delhi

Venkata Santosh Kumar Delhi is an Assistant Professor at Civil Engineering Department at IIT Bombay. He has obtained his PhD in Construction Management from Department of Civil Engineering, IIT Madras. He is also an alumni of IIT Madras having graduated with a Bachelor's of Technology in Civil Engineering as topper of the batch. He was also a Fulbright Nehru Doctoral and Professional Research Fellow at Global Projects Center, Stanford University, USA in 2012.

His research interests include Information Management on Large Engineering Projects. Particularly, he works on BIM, AI/ML applications to Construction Planning, Construction Contract Management, AR/VR/MR applications to Construction Safety and Planning. He is also actively involved in a number of projects that aim at providing policy and strategy guidance to various governmental agencies and private companies.

Dr. Karuna Jain

Prof. Karuna Jain is a Professor of Technology & Operations Management at Shailesh J Mehta School of Management (SJMSOM), Indian Institute of Technology Bombay. She has served as Director, National Institute of Industrial Engineering (2013-2019), Dean, SJMSOM IIT Bombay (2007-2012) and MHRD IPR Chair at IIT Bombay (2011 -2014). She has published extensively in journals of repute like DSJ, EJOR, NRQ, IJPE, IEEE- TEM, and TFSC to name a few. She has presented her research in national (ORSI SOM, PMIRAC, ISDSI, POMS India) and international conferences (POMS, DSI, IAMOT, PMI).

In recognition of her inspired leadership of sustained excellence and valuable contributions to the field of project management, PMI India has conferred upon her the 'Distinguished Fellow' award in 2019. International Association of Management of Technology (IAMOT) Board has conferred upon her the 'Distinguished Service Achievement Award in 2019 for exemplary service in the area of MOT. She has published extensively in journals of repute like DSJ, EJOR, IEEE- TEM, IJPM, IJPE, NRQ and TFSC to name a few. She has presented her research in many national (ORSI SOM, PMIRAC, ISDSI, POMS India) and international conferences (DSI, IAMOT, PICMET, PMI, POMS).

Project Management Institute

PMI presents
Project Management
Research & Academic Virtual Conference
3 - 6 MARCH, 2021

ENHANCING PROJECT PERFORMANCE: APPLICATION OF AI AND DECISION SCIENCE