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Exploring Project Complexity Factors: Case Study of Track-Doubling Line Railway Projects in India

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Large projects are crucial as they play an important role, particularly in the economic development of a nation. Globalization and technological advancements enhance the complexity of such projects, which, if not managed properly, lead to poor performance. Although complexity is an important characteristic of large projects, the project-specific complexity factors call for a different approach for each project. Though railway projects are important contributors to economic growth, very few studies focus on the complexity involved in Indian railway projects. Hence, this study fills this knowledge gap by exploring and identifying project complexity factors that can impact project performance in railway projects. The research is based on a qualitative approach. Data were collected through open-ended interviews with project managers involved in the two select cases of brown field doubling line projects, each having unique characteristics. Further, the complexity factors were confirmed by conducting three rounds of Delphi method. The analysis revealed that the project performance is impacted by seven key complexities: organizational, technological, environmental, cultural, infrastructural, communication, and stakeholder management. The study offers findings that are valuable to both future research scholars and practitioners. The identified complexity factors will help project managers plan the projects effectively, leading to smooth execution. Though the findings of this research are based on track-doubling railway projects, they may also apply to other projects of similar characteristics.

Keywords: Delphi, NTCP, Project complexity, Project management, Railway projects

Introduction

The railway system is an efficient mode of transport for long and short distances to transport people and goods in many countries in the world. Further, the continued increase in demand for freight and passenger rail services will require more railway projects to be executed. Almost 1500 mega railway projects worth at least $ 2.1 trillion were planned globally in 2022.[(1)] Indian Railway system stands in the fourth position globally and is the most significant in Asia with a track length of 75,000 km.[2] It operates 22,593 trains every day and a total of 1260 billion passengers use its services annually, with a record of total freight-1233.85 million ton in the year 2023. India has a vast railway network which includes different types of rail systems such as freight and passenger trains, metro, monorail, and upcoming bullet trains. The government agencies seek to increase the speed and frequency of passenger trains operating on certain freight lines, further adding to the demand for new railway capacity and optimizing the utilization of the total track system. Consequently, many single-track routes will require additional tracks to accommodate traffic demand. Single track has a considerably lower capacity than double track as they often lead to bottlenecks that constrain overall line capacity. On double-track mainlines, since one track can essentially be dedicated to a particular direction of traffic, so capacity is improved.[3] As per the Press Information Bureau (2024), railway projects with new lines, gauge conversion, and multi tracking (doubling/tripling) have expanded from 21,413 km to 31,180 km in the last 10 years. The railway projects and their expansions undergo major challenges and complexities such as unforeseen ground conditions (geological and hydrogeological conditions), changes in scope due to uncertainty and unpredictability during construction or design, poor material management and logistics, difficulties in land acquisition and public opposition, and political influence and instability, especially in developing countries[4] like India.

Project complexity (PC) has been described as the property of a project that challenges managers in

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understanding, foreseeing, and controlling a project's overall behavior even when relevant information about the project system is provided.[5,6]

Railway projects are inherently complex and uncertain as many stakeholders are involved. Different project management practices are needed for various projects due to location-specific conditions and constraints. The literature indicates a negative relationship between PC and project success.[7] Therefore, identification of PC factors in the early stages of the project is required for smooth execution of the project resulting in effectively meeting the project objectives.[8] Thus, this research aims at exploring the PC factors based on project characteristics in the Indian Railway context.

Literature Review

Definition of PC and its Factors

Project Complexity (PC) emerged from complexity theory, which was introduced from a management perspective in the late 90s. Baccarini[9] defined PC for the first time theoretically as technological and organizational factors and proposed PC to be characterized by numerous interrelated components and operationalized in terms of differentiation and interdependency. According to Williams[10], PC was defined in terms of structural complexity (differentiation and interdependency) and uncertainty (goals). Sinha *et al.*[11] proposed a PC framework for measuring complexity in engineering projects for the entire life cycle in the form of a complexity index. According to Geraldi and Adlbrecht[12], PC was classified into fact (structure), faith (uncertain situations), and interactions (interface). The research outcome affirmed that the initial phase of the project had the highest intensity of complexity. Maylor *et al.*[13] proposed five dimensions MODeST (Mission, Organization, Delivery, Stakeholders, and Team) that made the project complex. Each dimension had dynamic and interactive complexity.

Bosch-Rekveldt *et al.*[14] proposed a technological, organizational and environmental (TOE) framework for measuring complexity in large engineering projects. Vidal *et al.*[6] developed a PC measurement model using Delphi and the Analytic Hierarchy Process (AHP) and validated them in the entertainment industry. Seventeen PC factors were proposed, out of which the number of stakeholders ranked the highest. He *et al.*[15] proposed a measurement model with six complexities, namely technological, organizational, goal, cultural, information and environmental, using an Analytic Network Process (ANP) and found that organizational complexity ranked the highest in the construction project. Lu *et al.*[16] proposed a model for measuring PC in terms of task and organizational complexity for the construction project.

Qureshi *et al.*[17] emphasized organizational complexity as prime importance and observed that project variety and interdependencies are highly important. Nguyen *et al.*[18] developed a PC measurement model comprising sociopolitical, environmental, organizational, infrastructural, technological, and scope complexities using the Fuzzy AHP and highlighted sociopolitical as the most important. He *et al.*[19] in his study of projects in China revealed cultural complexity as the most important. Bakhshi *et al.*[20] explored PC through three views: the complexity theory view, the system of systems view, and the project management institute view. They defined PC in terms of elements that constantly change and evolve with an effect on the project objectives. Chapman[21] formulated a framework to examine PC factors and characteristics of railway megaprojects in the UK and found six PC factors, namely finance, context, management, site, task, and delivery. Rad *et al.*[22] proposed a measurement model for energy megaprojects using Delphi and AHP. The external complexity factors comprising government policies and environmental concerns were crucial for project success. Kim *et al.*[23] discussed a framework for international development using the Decision-Making Trial and Evaluation Laboratory (DEMATEL). Site compensation and clearance was found to be dominant among the twelve complexity factors. Sing *et al.*[24] discussed an approach for classifying PC into work content, building structure, site conditions, and scope at the preconstruction stage for the contractors and project managers. Vaz-Serra *et al.*[25] proposed a Project Early-Stage Complexity Assessment Tool (PESCAT) for the architecture, engineering and construction industry. AlKheder *et al.*[26] developed a PC measurement model using the analytic hierarchy process and Fuzzy Analytic Hierarchy Process (FAHP) for megaprojects in Kuwait. It was found that technological complexity was important followed by goal and cultural complexity. The various complexities are briefed in Table 1.

Relationship between PC and Project Success

Also, the researchers have studied the relationship between PC and project success. Nguyen *et al.*[31], in

Table 1 — Definitions of the PC factors

Project Complexity factor	Definition
Cultural complexity (CC) [18,27]	Difficulties arising from cultural differences, different backgrounds, political systems, and international languages
Environmental complexity (EC) [18]	Complexity arising due to sustainable environment, weather conditions and regulatory norms
Organizational complexity (OC) [28]	Difficulty in project due to numerous factors in the organization
Technological complexity (TE) [9]	Complexity with respect to new technology and innovation employed
Infrastructural complexity (IC) [18]	Difficulties arising due to land acquisitions, poor site accessibility, and contractor qualifications
Communication complexity (CM) [19]	Difficulty in sharing complete information between several stakeholders
Stakeholder management complexity (SM) [29,30]	Difficulty in managing various stakeholders who have varied interests

their study of transportation projects in Vietnam found a negative correlation between PC and schedule performance with resource allocation as the moderating variable.

Luo *et al.* [32] found that technological complexity positively affected project success of construction projects in China with respect to time, cost, quality, and customer satisfaction, whereas goal complexity was found to have a negative effect. Odusanya *et al.*[33] performed a case study on IT projects in Australia and highlighted complexity contributing factors as technical uncertainties, uncertainties in goals and deliverables having a negative impact on the project performance. Further, the study of Zhang *et al.*[34] revealed that knowledge hiding acts as a mediator of the relationship between PC and project performance of new product development projects in the high-tech industry. In addition, Zheng *et al.*[35] performed a systematic review of PC from three perspectives: project management perspective, complex system perspective, and complex adaptive system perspective. An integrated framework of PC was proposed, comprising antecedents, mediators, moderators, and outcomes.

PC Management Strategies

Researchers while exploring PC and its factors also highlighted a few management strategies to deal with PC. Odusanya *et al.*[33] highlighted key project management approaches such as the use of an adaptive management approach and good communication as key to managing complexity. Kermanshachi *et al.*[36] proposed management strategies to address PC to improve performance using qualitative techniques. The complexity arising from the stakeholder management could be managed by developing a stakeholder management plan. Toni *et al.*[37] indicated that various organizational learning sub-processes can help nurture the project teams for dealing with PC. Princes *et al.*[38] highlighted that to overcome the PC, the organization must devise strategies to enhance the readiness of the employees to perform.

The majority of studies on PC are concentrated in developed nations. Very limited studies have explored complexities in transportation specific to railway projects. Hence the paper is aimed to identify PC factors that can impact project performance in Indian railway projects.

Methodology

An exploratory qualitative research design using a case study approach is adopted. Case studies are ideal for investigating how or why phenomena occur and offer richer and deeper insights of a process.[39] The track-doubling projects are considered in the study as a unit of analysis as they are critical to improving the efficiency of the transportation of goods and passengers. The average budget allocation for track-doubling projects has increased from 26026 crore (3.14 billion) per year during the period 2014–2019 to 35000 crore (4.22 billion) per year for the period 2020–2025.[(40)] The two such cases of Indian Railways were selected.

Case 1: Project "X" is a brown field project aiming to expand the line capacity to provide smooth and speedy movement of trains through additional express, and goods trains between two Indian states Maharashtra and Madhya Pradesh. The project "X" was initiated in the year 2015–2016 and the time-target to complete the project was 2020–2021. However, the project is delayed by 4 years and is currently ongoing in the year 2024. Besides facilitating travel, the line would provide additional transport capacity for industries in and around the two states. The initial proposed cost of the project was 2449.91 crores (0.298 billion). The stakeholders of this project are various railway departments, railway board officials, local administrative officials, road transportation authorities, landowners, and local governing bodies of that region. Project is challenging

Table 2 — Profile of Experts

Case	Expert	Position	Experience in years
Case 1 (Project "X")	Expert 1	Chief project manager	21
	Expert 2	Deputy chief engineer	17
Case 2 (Project "Y")	Expert 3	Chief project manager	21
	Expert 4	Deputy chief engineer	16

as it includes tunnels and a track through an inhospitable terrain consisting of forests and mountains. The project was unique as it was the first time the Engineering, Procurement and Construction (EPC) approach was considered and the contract was awarded to a private company for designing, procurement and execution of the project.

Case 2. Project "Y" is a brown field project aiming to increase the line capacity utilization located in the northeastern part of Maharashtra. This doubling project was initiated in the year 2015–16. The line capacity utilization of the section is saturated, and the running of additional Mail/Express and Goods traffic over the section caused detention to the trains thereby increasing the travel time. The stakeholders of these projects are various railway departments, railway board officials, local officials, road transportation authorities, landowners, and local administrative representatives. The region is likely to experience an economic and transportation boost upon project completion. The initial cost of the project is 1272.19 crores (0.15 billion), but experiencing a cost overrun with the anticipated cost to reach 1384.72(0.68 billion). The project is currently delayed and is still ongoing (September 2024). This project is unique as a new private land was to be acquired which posed additional challenges.

Data Collection

To meet the research objectives, data was collected in two phases: Phase 1, open-ended interviews, and Phase 2, Delphi. In Phase 1, two experts from each case were approached, as shown in Table 2, to conduct the interviews to understand the project details and their characteristics. Interviews were conducted online and physically based on the availability of the experts. The interview discussion was broadly focused on three aspects: a) basic details of the project, b) NTCP aspects (novelty, technology, complexity, and pace), and c) complexity factors involved in the project.

Further, in Phase 2, to understand and to have consensus on various PC factors across track-doubling projects, Delphi method of expert opinion elicitation was adopted (Fig. 1).[41]

Table 3 — Profile of Experts (Delphi)

Particular	Classification	Number of experts
Type of organization	Indian railway	17
	Total	17
Gender	Male	17
	Female	—
	Total	17
Educational qualification	Graduation	6
	Post-graduation	9
	PhD	2
	Total	17
Years of experience	7–13 years	2
	14–20 years	3
	Above 20 years	12
	Total	17

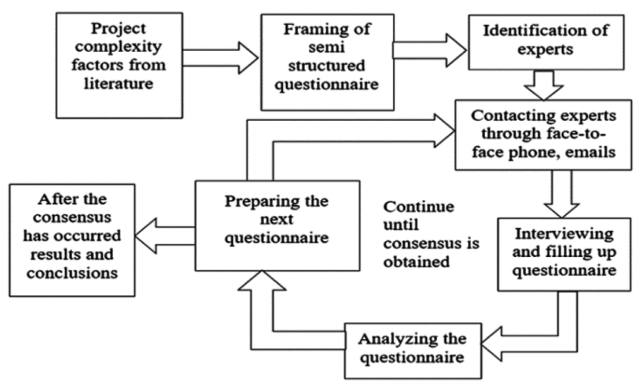

Fig. 1 — The Delphi procedure process

Identifying and selecting a panel of experts was crucial in the Delphi process. Gunduz *et al.*[42] suggested that experts with 17, and Kermanshachi *et al.*[8] suggested an expert size of 15 could give good results.

In this study, a panel of 20 experts were approached; however, 17 experts (Table 3) working on the select projects were available to offer their inputs throughout the rounds of Delphi. The experts were interviewed in person and through telephonic conversations with prior appointments with a semi-structured questionnaire. Each participant was asked to assess each factor using a rating scale.

Analysis and Findings

Phase 1: Content Analysis and NTCP Framework

The interview transcripts gained from interviewing the experts (Phase 1) of the two doubling projects were analyzed using content analysis and the NTCP framework (Table 4). Content analysis is a systematic coding and categorizing approach used to analyze text to find out trends and patterns of the words and phrases used.[43]

The NTCP framework was developed by Shenhar *et al.*[44] and since then has been used by various researchers to analyze different projects such as the railway underground[46]; space[47]; IT[48–50]; and dam.[51] Size (cost), number of elements (tasks, stakeholders), and their interrelatedness (Indian Railways, government agencies, private firms, and external financing institutions) depict the level of complexity in railway projects. The larger the size, the greater the number of elements, and the interdependency, the more the complexity. In railway projects, the pace is driven by political forces, technology, geological (unforeseen ground conditions), and climatic constraints (rainfall). Highly skilled project managers are needed where a higher level of technology is involved.[50] Novelty is the key aspect of innovation involved in developing SMART Coaches and Signaling Systems).

The select doubling projects undertaken in the study are redesign of a track similar to the existing track. Hence the concept is not new. However, building new tracks incorporates improved material, signal, and control systems, and hence “X” and “Y” projects are classified as *platform.*

The projects in both cases fit into the *medium-tech* position on the technology scale. The railway projects lack massive investments, and they focus on affordability for the general population. The track has been modernized by using a Pre-stressed Concrete Sleeper with higher tensile strength, and Steel Channel Sleepers on girder bridges are used while carrying out primary track renewals. The technology for work inspection has been significantly upgraded, particularly with systems that use 3D drone technology.

The “X” project presents *system* level complexity. The project involves multiple contracts and interdependent stakeholders who need coordination between them. The projects involve a few major bridges. The “Y” project is classified as an *array.* It covers densely populated areas and involves a large number of major bridges (weather conditions), making it more complex.

The “X” project is categorized as *regular.* This project followed well-established engineering practices and standards, adhering to a regular timeline. The doubling project aims to improve the frequency of trains and reduce delays. However, “Y” project was considered as time critical as the utilization factor for the existing track was more than 160 percent and this could benefit in reducing in traffic congestion.

The NTCP diamond framework of both projects is presented in Fig. 2. The diagram clearly presents that project “Y” is riskier and more complex as compared to project “X”.

It is clearly visible that project “X”, despite being time-critical, is still delayed. Hence it is important to understand the complexities associated with the projects. From the NTCP framework perspective, project “Y”is riskier than project “X” due to its greater complexity and faster pace. High complexity increases the chances of miscommunication, delays, and coordination challenges, making the project riskier. When strict deadlines are imposed, as outlined, the pressures of meeting timelines often lead to unintended delays.

Table 4 — NTCP Framework Scale[44,45]

Dimension	Level	Description
Novelty	Derivative	Extending or improving existing products or services
	Platform	Developing and producing new generations of existing product lines or new types of services
	Breakthrough	Introducing a new concept or product, a new idea, or a new use of a product that customers have never seen before
Technology	Low-tech	Uses only existing, well established and mature technologies
	Medium-tech	Mostly existing technologies; limited new technology or a new feature
	High-tech	Uses many new, recently developed, existing technologies
	Super high-tech	Key project technologies do not exist at the time of project initiation
Complexity	Assembly	Material, components, subsystem, assembly
	System	System, Platform of systems
	Array	Array, system of systems
Pace	Regular	Time not critical to organizational success
	Fast/ Competitive	Project complexity on time is important for company’s competitive advantage and or the organizations leadership position
	Time-critical	Meeting time goal is critical for project success and delay means project failure
	Blitz	Crisis projects, utmost urgency; project should be completed as soon as possible

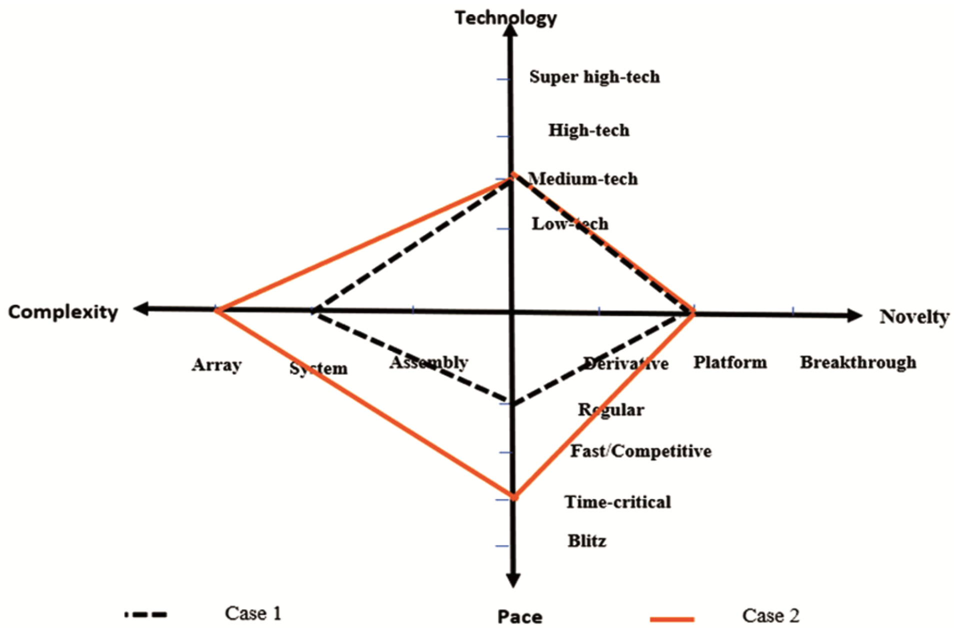

Fig. 2 — NTCP framework for the select railway doubling projects

Railway projects involve numerous external and internal stakeholders, such as railway departments, railway board officials, local administrative officials, road transportation authorities, landowners, and local governing bodies of that region, each having specific interests, power, and different cultural backgrounds. One of the experts working on the project “X” said,

“The complexity stemmed out of managing various stakeholders who had varied interests. The socio-economic situations and political pressures made the projects highly complex. The vague and strict clauses of the contract created complexity”

The greatest challenge in the project “Y” was infrastructural complexity. One of the project managers opined,

“The greatest challenge in this project was acquiring land. The socio-economic situations and political pressures made the projects highly complex”

Insights from Phase 1 interviews revealed seven complexities (environmental, technological, organizational, communication, cultural, stakeholder management, infrastructural) arising in doubling projects impacting the project performance (cost and time).

Phase 2: Delphi Analysis and Findings

The factors identified from the literature and Phases 1 of the interviews were used to design the semi-structured questionnaire (Table 5). Three rounds of the Delphi technique were conducted.

The sequence of each round is as stated below.

Round 1: Validate the factors identified from the literature in the Indian context using the Likert scale. Also, additional factors and subfactors (from the literature review) were considered as part of semi-structured questionnaire.

Round 2: Validate the additional factors that resulted from the first round.

Round 3: Revalidate the factors and subfactors from round 1 and round 2. Three parameters, namely mean[51], standard deviation[41] and Content Validity Ratio (CVR)[52] were used to eliminate the insignificant ones. The CVR is computed using the formula (equation 1).

$$CVR = \frac{(ne - N/2)}{N/2} \quad \ldots (1)$$

where, N = the total number of experts

ne = the number of experts indicating essential

The range of CVR using the equation varies between −1.00 and +1.00.

Through Delphi analysis, seven complexity factors and 18 subfactors were revealed. Project “X” encountered six complexities, whereas in Project “Y” an additional complexity: infrastructural was found (Table 6).

Discussion

The article aimed to explore PC factors in railway projects in the Indian context. The study adopted a

Table 5 — Sample of Delphi Questionnaire- Round 1

Name					
Email Id					
Name of Organization					
Years of experience					
Job position					
Name of the project					
Cost of the projects in crores					
Duration of project in years					
Project complexity factors and subfactors	1	2	3	4	5
The *attitude of stakeholders* is an important factor that leads to cultural complexity.					
The s*ocio-economic condition* is a significant factor that affects the cultural complexity.					
The *attitude of stakeholders is* an important factor that affects the project output.					
The *socio-economic condition* is an important factor that affects the project output.					
Please *state the factors* of cultural complexity other than those mentioned above explaining them in brief.					
The c*ontractual agreements* are an important factor contributing to complexity in stakeholder management.					
The *interrelation between the stakeholders* is an important factor that contributes to complexity due to stakeholder management.					
The *varied interest of the stakeholder* is an important factor that contributes to complexity due to stakeholder management.					
The *contractual agreements are* a significant factor that affects the project output.					
The *interrelation between the stakeholder*s is a critical factor that affects the output of the project.					
The *varied interest of the stakeholder* is a critical factor that affects the project output.					
Please *state the factors of stakeholder management complexity* other than those mentioned above explaining them in brief.					
The *interdependencies between the sites, departments and companies, resources and raw material* is a significant factor that leads to organizational complexity.					
The *availability of resources* is an important factor contributing to organizational complexity.					
The *diversity of staff with variety of required skills* is an important factor that affects the project output.					
The *interdependencies between the sites, departments and companies, resources and raw material* is a significant factor that affects project output.					
The *availability of resources* is an important factor is a significant factor that affects project output.					
Please *state the factors of organizational complexity* other than those mentioned above explaining them in brief.					

Table 6 — PC factors and subfactors in Railway project

PC factors	Subfactors	Case 1: Project "X"	Case 2: Project "Y"
Organizational complexity	Availability of resources (people, material)	√	√
	Inter-dependencies between the sites, departments and companies, resources and raw material	√	√
Cultural complexity	Attitude of stakeholders	√	√
	Socio-economic condition	√	√
Communication complexity	Bidirectional communication	√	
	Timely availability of information	√	
	Information completeness		
Environmental complexity	Sustainable environment	√	√
	Adverse weather conditions	√	√
	Environment of changing policy and regulation	√	√
Technological complexity	Technological compatibility/integration	√	√
	Newness of technology	√	√
	Degree of innovation		√
Stakeholder management complexity	Contractual agreements	√	
	Interrelationships among the stakeholder	√	√
	Variety of stakeholders	√	√
Infrastructural complexity	Site compensation and clearance		√
	Transportation system		√

case-based approach and analyzed the two select doubling line brownfield projects. Two cases highlighted seven PC factors in doubling projects.

In project "X" mainly, six PC factors emerged resulting in an extension of the initial completion timelines of the project- environmental, technological, organizational, communication, cultural, and stakeholder management complexities. In project "X", environmental complexity was found as one of the most contributing factors resulting in a delay of the project. Stringent and changing environmental laws and regulations to acquire forest land delayed inviting EPC tenders. This was mainly due to a lack of clarity about laws and regulations and awareness among the project team members and other stakeholders. Further, the tunnels in the mountain ranges (ghat sections) were constructed using the New Australian Tunnel Method (NATM), particularly suitable for constructing tunnels through geologically challenging areas.

Moreover, innovative machines and equipment are being used for tunnel construction in the country. This technology needed sound technical knowledge and past experience. The lack of experienced staff, contractors and the use of advanced machinery further enhanced the technological complexity in the project. In addition, the use of such technology required a huge amount of coordination, cooperation, and communication with other methods and parties contributing to organizational, communication, and stakeholder management complexities. Identifying the right contractor by looking at its skills and qualifications was critical for the implementation of this project which was done through a bidding process by addressing contractor qualifications and pricing. Further, for 267 km of the section (railway line length), project site offices were scattered all along the length resulting in organizational complexity. As the project has jurisdiction over two states of India: Maharashtra and Madhya Pradesh, it required coordination among various departments of the two-state governments contributing to stakeholder management complexity. It was found that the railway projects under consideration involved various stakeholders: both external and internal. Stakeholder complexity increased because a large number of stakeholders with diverse interests were involved in the project. The power/interests for the doubling railway line project are shown in Fig. 3. Most of stakeholders are found in high power high interest and high-power low interest region. They make the biggest impact on the project success requiring close management and understanding their expectations. Further, the passing region of the line in the state Madhya Pradesh, (Dharakoh-Itarsi) is a backward area which created a challenge among the project team members in dealing with the local people highlighting cultural complexity. This complexity was caused by the nuances of the socio-economic condition of the region. The involvement of rural and tribal communities, each having a unique culture made this project complex as they relied on local resources for their livelihoods and any disruption caused impacted their socioeconomic well-being.

Also, to address local concerns, delay in decision took place due to coordination issues of two different states for smother implementation of project. In Project "Y" one of the major work package dealt with rail transport tracks that branched off from the main railway line for storage or operational purposes (sidings) to facilitate the transportation and handling of coal, was done in large quantities by freight trains. Such coal sidings are typically located at or near a coal mine or a power plant (Wardha-Ballarshah), where trains carrying coal can be loaded or unloaded.

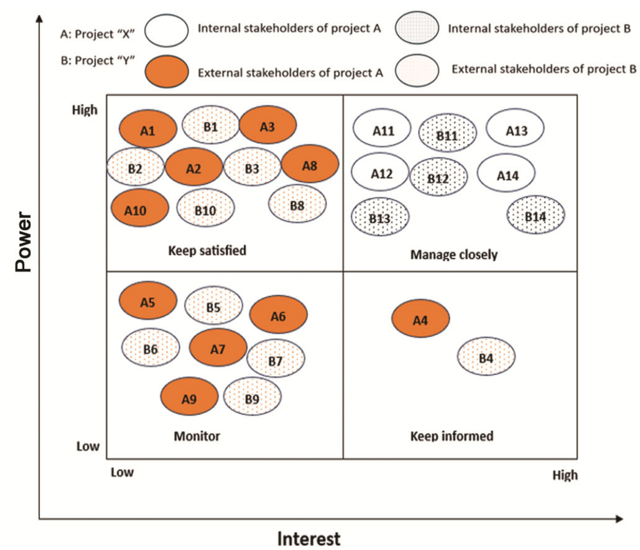

Fig. 3 — Stakeholder matrix (power vs interests) [A1: B1: Ministry of Environment, Forest and Climate Change; A2:B2: Government of Maharashtra; A3: B3: Railway Slum Dweller Federation; A4: B4: Suppliers; A5: B5: Media; A6: B6: local community; A7: B7: End users; A8: B8: Maharashtra State Electricity Distribution Co. Ltd; A9: B9: Landowners; A10: B10: Maharashtra Industrial Development Corporation; A11:B11: Central Railway; A12:B12: Ministry of railways; A13:B13: Consultants; A14:B14: Contractors; A15: Government of Madhya Pradesh]

These sidings are often used to temporarily store railway wagons waiting to be loaded with coal or after unloading it, allowing trains on the main line to pass by without obstruction. The higher traffic requirement due to the availability of many coal sidings has led to yard remodelling at every station (requiring more land in the station area), enhancing the infrastructural complexity. The project required yard remodeling involving complex electronic interlocking having a large number of routes, shifting of service buildings, good shed, use of tamping and turnout laying machinery (turnout laying machinery, tamping machinery), and block working (suspending traffic for carrying different work such as connecting track and overhead equipment work). Further, due to the availability of coal belts and difficult-to-access locations transportation of raw materials (aggregate and crushed sand) to lay the railway line was challenging which further enhanced the infrastructural complexity resulting into cost overrun. In project "Y", the management faced resistance (local communities and state government) in Chandrapur district, requiring coordination between project-based organizations and local governments. Delays in resolving conflicts with local communities cascaded across sites and departments. The negative attitude of local communities led to resistance and protests, which complicated project execution. The project involved the relocation of utility infrastructure (e.g., overhead lines) and required the involvement of utility companies and government agencies thus enhancing the infrastructure complexity. In addition, any delay in their cooperation impacts the project's timeline. This indicated that stakeholder management is very critical for railway projects.

Conclusions

The study focused on identifying PC factors in doubling railway projects in a developing country perspective. This qualitative methodology was undertaken in two phases using interviews and Delphi. The study validated seven complexities namely, organizational, technological, environmental, cultural, infrastructural, communication and stakeholder management. It was also found that project "Y" was riskier and complex than the project "X".

To cater to the increase in demand for a huge population and alleviate traffic congestion, doubling projects are essential for transporting passengers and freights. Considering the identified complexities and devising the appropriate management strategies to tackle the above complexities will help project managers in the effective planning and execution of similar railway projects in countries having similar socio-economic profiles. The current study focuses on PC considering two specific doubling projects in India. The study can be extended by considering analogous projects in other countries of similar socio-economic background. Further, diverse railway projects cases can be considered in future to explore any new PC factors.

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.

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