Anusandhanvallari
Vol 2025, No.1
January 2025
ISSN 2229-3388

Managing Complexity in Mega Steel Projects: Leveraging Digital Technologies in India's Steel Industry

Biplab Kumar Dey[1], Dr. Souren Sarkar[2], Dr. Bishwajeet Bhattacharjee[3]
[1]Research Scholar, Chhattisgarh Swami Vivekanand Technical University, Bhilai; bdey.steel@gmail.com
[2]Profesor & Head, Shri Shankaracharya Technical Campus, Bhilai; drsourensarkar@gmail.com
[3]Associate Professor, Shri Shankaracharya Technical Campus, Bhilai; bhbishwajeet@gmail.com

Abstract: The growing size and technologic advancement of the industrial projects have contributed greatly to the complexity of project management especially in the industries which are capital intensive like the steel industry. During large steel projects, there is a high level of engineering integration, a complicated supply chain, regulatory limitations and a number of stakeholders interaction, which often results in schedule delays, cost increases and coordination issues. This paper explores structural factors that cause project management complexity in the Indian steel sector and suggests a combined model to enhance the effectiveness of project management. The research design was mixed-method involving a qualitative assessment and quantitative survey analysis. A total of 412 professionals working in steel sector projects such as project managers, engineers and senior management personnel were used as a source of primary data. The study used SWOT analysis, descriptive statistics, and structural relationship analysis to determine the major project management challenges and the causal factors behind the challenges. The results have shown that project planning and scheduling (Composite Score = 4.26), cost management (4.21), procurement management (4.20), and risk management (4.17) are the most significant challenges in project management. Root cause analysis reveals that these challenges arise from interconnected factors related to human competencies, organizational processes, and external environmental conditions. Statistical validation confirms that the People dimension ($\beta = 0.412$) has the strongest influence on project management effectiveness, followed by Process ($\beta = 0.385$) and Business Environment ($\beta = 0.327$). On the basis of these results, the proposed study is the Three Arm Clock Model of Project Management Effectiveness, which frames project performance as the dynamic interplay of People, Process, and Business Environment dimensions. Moreover, the study presents an AI-powered Project Management and Monitoring System (APMS) to increase risk prediction, decision support, and real-time project monitoring using digital technologies. The paper can add to the project management body of knowledge through offering a unified analytical approach towards comprehending the complexity of projects in a large industrial-scale infrastructure and also through offering a feasible contribution on how to enhance the performance of projects in the steel industry through digital transformation and data-driven management practices.

Keywords: Project management complexity; steel industry projects; industrial project management; SWOT analysis; project planning and scheduling; cost overrun management; procurement management; risk management; stakeholder coordination; digital transformation in project management; artificial intelligence in project management; Industry 4.0; AI-driven project monitoring; project decision support systems; Three Arm Clock Model.

1. Introduction

The steel industry is very important in economic growth as well as the industrial base of the emerging economies, especially in the countries like India where the development of industries and infrastructure development is intertwined with the production and use of steel. Projects in the steel industry, such as greenfield projects, brownfield projects, and modernization projects are traditionally highly capital-intensive, complicated supply chains, long implementation times, and high levels of regulation (Gamidullaeva et al., 2024). These projects have to be handled with advanced project management practices that have the capacity to deal with technical complexity, diversity of stakeholders, regulatory and market volatility. Although the steel industry has experienced much technological growth and is becoming more digital ready, project execution in the steel industry still remains beset with a series of delays, cost overruns, procurement inefficiencies and coordination challenges among various project participants (Sońta-Drączkowska & Krogulec, 2024).

1.1 Background of the Steel Industry and Large-Scale Projects

The steel industry is a pillar of the industrial economies of the world, as it is a key supplier of inputs to other industries including infrastructure, construction, transport, energy, and other manufacturing industries. The steel industry in India has seen a tremendous growth in the last 20 years due to the high rate of urbanization, infrastructure growth and policy measures set forth to enhance the manufacturing capacity of India (Van der Meij et al., 2023). Big steel projects, such as integrated steel plants, and capacity expansion projects, are multi-stage processes: feasibility analysis, plant design, heavy equipment acquisition, construction, commissioning, and integration of operations. Such ventures are usually associated with many stakeholders such as the government authorities, engineering firms, contractors, equipment suppliers, financial institutions, and local communities. The size and complexity of such programs pose significant issues in the areas of coordination, accuracy of planning, risk management and regulatory compliance (Yin et al., 2024).

1.2 Project Management Complexity in the Steel Sector

The steel industry has an inherent complexity in the project management because of the technical complexity and interdependence of the operations in the large-scale industrial projects. Designing steel plants involves combining various engineering disciplines, innovative manufacturing technologies, environmental compliance systems, and widespread supply chains (Álvarez-Pozo et al., 2024). Besides technical complexity, the project managers have to deal with the changing prices of raw materials, changing environmental laws, difficulties in obtaining land, and changing demand conditions in the market. All these factors make the environment where the outcomes of the project are very sensitive to the accuracy of planning, the coordination of the organization, and the efficiency of decision making. Conventional project management models tend to be incapable of tackling these interrelated issues and thus, there is a need to develop integrated analytical methods where technical, organizational and environmental issues are taken into consideration at the same time (Elsherbeny et al., 2025).

1.3 Research Objectives

To address the research gap identified, this study will conduct a systematic and empirically based research to explore the complexity of project management practices in the Indian steel industry. The research aims at achieving two main goals. First, it aims to determine and rank the key project management issues faced on the large steel sector projects through analysing the views of industry experts. Second, the research will analyze these challenges in their underlying causes and seek strategic solutions that could be effective to address the challenges, such as digital and technology-based solutions that can be used to improve the effectiveness of project management. The study tries to come up with a general knowledge of the structural factors that would affect project performance in the steel industry by combining SWOT analysis, empirical evidence through surveys and statistical analysis.

2. Literature Review

The rapid expansion and technological advancement of the industrial projects of modern times has greatly amplified the complexity of project management practice in various sectors. Project implementation in capital intensive business like steel manufacturing consists of several inter-linked activities such as engineering design, acquisition of specialized equipment, and construction management, regulatory compliance, and operational integration. These actions have to be organized in different organizational departments and external parties, making the project environment very dynamic (Uğural & Aghili, 2026). Consequently, the elements that affect the performance of a project and the difficulties involved in the process of the management of complex industrial projects have come under critical academic and professional investigation. The project management literature sheds a lot of light on the diverse structural, organizational, technological and environmental factors that affect the project outcomes. This part examines the major themes in the literature regarding project management issues in large industrial projects, complexity in infrastructure and steel sector projects, and the increased role of digital technologies in boosting the effectiveness of project management (Chen et al., 2026).

2.1 Project Management Challenges in Large Industrial Projects

Massive industrial projects have long been considered to be one of the most complex types of project implementation as it has high capital requirements, is technologically advanced, and requires a large amount of co-ordination between several stakeholders. Industrial projects are usually characterized by long planning periods, huge investment amounts, and complicated engineering systems that need to be incorporated within stringent costs, time, and performance limits (Usman et al., 2026). This has necessitated highly sophisticated planning skills, robust governance frameworks and efficient coordination systems between organizational and functional boundaries in the project management of such settings.

Among the most commonly experienced issues in big industrial projects are delays in time schedule and cost increase. The causes of these problems typically include poor planning assumptions, poor estimation of the complexity of the project, and lack of integration between different stages of a project including design, procurement and building (White et al., 2026). Moreover, there are uncertainties that large projects are mostly susceptible to disruption of supply chains, regulatory authorization, and integration of technology, which also makes the execution of the projects more complex. Effective risk management practices thus become critical in anticipating possible disruptions and providing the corrective measures in time in implementing the project.

Coordination and communication among stakeholders is another issue of concern (Vergara et al., 2025). Major industrial projects are characterized by a varied cast of participants such as engineering companies, contractors, equipment vendors, regulatory bodies, and organizations. Variations in the organizational priorities, the contractual arrangements, and decision-making structure may pose coordination challenges that influence project performance. There must be proper communication systems and governance systems to make sure that there is alignment among the project participants and in order to ensure the transparency in the project execution (Salimimoghadam et al., 2025).

2.2 Complexity in Infrastructure and Steel Projects

Project complexity has received quite a bit of focus in infrastructure and industrial project management research. Project complexity is typically the existence of a number of inter-dependent elements, uncertainty in project environments and the existence of a number of stakeholders whose activities affect the results of the project. The complexity of a project is especially high in such industries as steel manufacturing where projects are large-scale integrated facilities with mechanical, electrical, chemical, and environmental systems (Abdullah et al., 2026).

Projects in the steel industry often involve the development or upgrading of blast furnace, rolling mill, continuous casting facilities and related logistical facilities. All these elements demand expert engineering skills and close coordination throughout project phases. The combination of heavy industrial machinery, environmental protection, and lengthy procurement process is another element contributing to the complexity of project implementation (Joshua et al., 2024). Moreover, steel projects are usually implemented under conditions of changing prices of raw materials, evolving demand conditions in the market, and altering regulatory environments.

The combination of technical complexity and organizational complexity complicates project management in the steel sector. Technical complexity is caused by the necessity to combine advanced technologies of production and engineering systems, and organizational complexity is caused by the coordination of various project teams, contractors, and regulatory entities (Almalki, 2025). Together these factors lead to a high probability of delays, escalation of costs and inefficiency in operations in case the project management processes are not robust enough.

2.3 Digital Transformation in Project Management

Due to the increased complexity of industrial projects, organizations operating in various industries have progressively embraced the use of digital technologies to enhance the process of project planning, monitoring and decision making. Digital transformation in project management incorporates integration of advanced information systems, data analytics tools, and digital platform which allows real-time coordination and sharing information among project stakeholders (Vergara et al., 2025). Such technologies contribute to the increased transparency, better monitoring of risks, and more sound predictions of the project results.

The adoption of integrated digital platforms which bring together project information across various sources into integrated management systems, represent one notable advancement in the field. These platforms enable project managers to track the project schedules, resource allocation, cost trends, and emerging risks more efficiently (Van der Meij et al., 2023). Moreover, the digital dashboards and data visualization tools also give the decision-makers real-time information on the performance of the project, making it possible to react to the information faster and make more informed decisions.

New technologies like artificial intelligence, machine learning, and advanced analytics are also under consideration as a way of enhancing the performance of project management. They can be used to assist in predictive scheduling, cost estimation, and risk identification through the analysis of large amounts of project data by these technologies (Almalki, 2025). As industrial organizations further develop digital facilities, the adoption of these technologies is likely to become even more relevant to the project management process, and the chances of project failure will decrease.

2.4 Research Gap Identification

Although a significant literature has been developed on the practices of project management and the complexity of projects, there are still some significant gaps in the steel industry. A significant part of the literature that is available deals with broad principles of project management or infrastructural projects without specifically analyzing the peculiarities of large-scale steel sector projects. The steel industry is a unique project environment that is marked by intensive industrial operations, high capital investments, sophisticated regulatory compliance and highly specialized supply chain (Usman et al., 2026). These features pose project management issues that can vary greatly as compared to those experienced in other industries.

Additionally, numerous research papers analyse the project management challenges in isolation and concentrate on particular areas like cost management, risk management, or coordination of the stakeholders. Nonetheless, project management issues in large industrial projects are usually a result of a combination of factors as opposed to a singular factor. A more cohesive analysis method is thus required to be able to see how organizational capabilities, project management processes, and external environmental conditions interact to determine project outcomes (Gamidullaeva et al., 2024).

The second weakness in the current literature is that there are a few empirical studies that integrate quantitative analysis and qualitative understanding to analyze the problems of project management in the steel industry. The empirical study that includes the opinions of professionals working in the industry can give some valuable information on the practical challenges that arise in the course of the project implementation and the methods that are employed to cope with them (Chen et al., 2026).

Against this background, the current research is based on a mixed method research methodology to analyze the complexity of project management in the Indian steel industry. Combining SWOT analysis, empirical evidence which is based on the survey and statistical analysis, the study aims to build a coherent view on the main issues impacting project management practices and to suggest a systematized model of enhancing the effectiveness of project management in the large projects of steel industry (Sońta-Drączkowska & Krogulec, 2024).

3. Research Methodology

The research takes a systematic approach to methodology to examine the complexity of project management in the Indian steel industry, and to determine the most significant challenges affecting project performance. A mixed-method research design was used because of the multidimensional character of the problem of project management in a large industrial project. To ensure that the research is able to not only record the quantifiable trends in the application of project management practices, but also contextual information pertaining to the actual cause of project problems, both qualitative and quantitative methods will be used (Abdullah et al., 2026). The methodological framework incorporates literature-based analysis, survey-based empirical study, and statistical methods to come up with a holistic view of the structural, organizational and environmental aspects that influence project management effectiveness in steel sector projects.

The study is designed methodologically in a sequential analytical format. We first conducted qualitative analysis to determine the key strengths, weaknesses, opportunities and threats that affect project management practices in steel industry. Such observations were used to build systematic survey tools to investigate the significant issues and possible solutions in project management practices (Joshua et al., 2024). The collected empirical data of industry professionals were analyzed through statistical methods to find out the patterns, relations and the underlying dimensions of project management complexity.

3.1 Research Design (Mixed-Method Approach)

The study is based on a mixed-method research that involves the qualitative exploration and quantitative validation. This method was deemed suitable as industrial sectors project management issues tend to arise due to multifaceted interactions among technical systems, organizational processes and the external environment. Qualitative analysis is used to determine and conceptualize these issues, whereas quantitative approaches are used to measure and prioritize these issues, using empirical evidence.

The qualitative phase of the study involved the comprehension of the structural peculiarities of the project management practices in the steel industry. This phase entailed surveying industry behavior, analyzing the project characteristics at the sector level, and the most critical dimensions, which determine the project management effectiveness. Qualitative insights gained in this step were utilized to come up with the conceptual basis of the SWOT analysis framework.

The quantitative phase entailed gathering empirical information by use of structured surveys to the professionals in the projects of the steel sector. The survey questions were structured in such a way that they would determine the perceptions of the project management challenges, causal factors, and possible solutions using standardized rating scales. Analysis of the obtained data that was performed statistically helped to identify the main areas of challenges and analyze the associations between various variables of project management.

3.2 Data Sources and Data Collection

The research is based on primary and secondary sources of information. The first phase of the study involved the use of secondary information to come up with a concept of the project management practices and complexity drivers in large industrial projects. This knowledge assisted in determining the overall themes that informed the construction of the analytical framework of the research.

The main empirical object of the research is primary data. The sample was gathered among professionals, who are actively engaged in the project management activity in the Indian steel industry. Data collection was carried out using structured survey instruments that were created to elicit the perception of respondents on project management issues, their cause, and the possible strategic interventions. The questionnaires were used in both online and offline approach to achieve wide representation in various organizations and project positions.

The survey design was designed into two phases. The initial survey aimed at determining and ranking project management issues in the various functional domains of project implementation. The second survey was focused on the possibility of identifying the solutions and interventions to enhance the effectiveness of project management, especially in reference to digital technologies and high-tech project management tools.

3.3 Sampling Strategy and Respondent Profile

The research focused on the professionals who were directly engaged in the planning, implementation, or management of the projects in the steel sector. The respondents were a representative sample of organizations, such as the public sector enterprises, the Indian steel industry private steel companies and the multinational organizations. The variety of organizational backgrounds provided the survey with a large scope of project management experiences and views.

The last dataset was the responses of 412 professionals who were involved in project management activities in different capacities that included, project managers, project engineers, functional managers, and senior management personnel. The respondents were also reflective of various categories of professional experience as well as different kinds of projects such as green field plant development, brownfield expansion projects and modernization projects.

This was facilitated by incorporation of professionals operating in various organizational settings and project roles, which facilitated the sampling of the data to include the operational realities of the project management practices in the steel industry. Such a variety of respondents makes the empirical results more reliable and makes the results more generalizable in the framework of large industrial projects.

3.4 Survey Design and Instruments

In the quantitative research process, two structured survey tools were created. These instruments were designed based on the information that was gained in the course of the qualitative analysis phase and the SWOT model that was created to help the study.

The initial survey tool was aimed at determining the main project management issues in the key functional areas of project implementation. The survey covered questions regarding the project planning, cost management, procurement processes, risk control, the contract administration, and the coordination of the stakeholders. The respondents were requested to rate the severity of these challenges on standardized rating scales that quantified the frequency of occurrence, effect on the project outcomes, and the difficulty of managing.

The second survey instrument aimed at coming up with the possible solutions and strategic interventions that might help in solving the challenges identified in the first survey. Special emphasis was put on the importance of digital technologies and sophisticated analytical tools to enhance project management performance. The respondents were requested to assess possible interventions basing on their feasibility and the anticipated effects on the project outcomes.

The systematic nature of the surveys, facilitated by their structured design, allowed systematic data collection, and also ensured consistency in measuring project management variables among the respondents.

3.5 Analytical Methods

A combination of descriptive and inferential statistical methods was used to analyze the empirical data obtained using the surveys. The first analysis step included an overview of the main features of the survey participants and the distribution of the answers to the various project management variables. The descriptive statistics identified the key areas of challenges raised by the respondents and how different issues in project management are important.

Additional statistical techniques were used to further analyze the relationships between the variables of project management. These consisted of analysis of variance to investigate the differences in the perceptions in the various types of organizations, regression analysis to study the effect of the organizational and project attributes on the severity of challenges and factor analysis to determine the underlying dimensions of project management complexity.

Combination of these analysis methods enabled the research to go beyond descriptive observations and generate a more in depth comprehension of the structural interrelationships between project management problems, causal influences and solutions. These analyses lead to the conceptual framework and strategies that will be provided in the following sections of the paper.

4. Results and Analysis

This part will give the empirical results based on the quantitative and qualitative aspects of the research. The findings are arranged in a systematic order to make the information gathered among the industry professionals to be logically interpreted. The analysis will start with the SWOT analysis of project management practices in the steel industry, and the identification of key project management issues (Van der Meij et al., 2023). The section then looks at the underlying causes of these issues and how the various dimensions of project management are related to structures.

The analysis combines descriptive statistics, comparative analysis, and analysis interpretation so as to give a holistic view of project management complexity in steel industry projects. Tables and graphical representations are provided to summarize the empirical results and indicate some key patterns in the data (Uğural & Aghili, 2026).

4.1 SWOT Analysis of Project Management in the Steel Industry

The SWOT analysis was done to determine the internal strengths and weaknesses and the external opportunities and threats to project management practices within the steel industry. The analysis gives a strategic perspective of the organizational strengths and the environment factors that affect the performance of the project.

Table 1: Quantitatively Rated Strengths in Project Management

Strength	Mean Rating (1–5)	Standard Deviation	Frequency of Mention (%)
Technical expertise and knowledge	4.21	0.68	87.3
Availability of skilled workforce	3.86	0.79	76.2
Established organizational processes	3.72	0.91	73.5
Adaptability to changing conditions	3.65	0.88	69.4
Cost competitiveness	3.58	0.92	64.8
Experience with complex projects	3.53	0.85	61.2

Strong vendor ecosystem	3.41	1.02	58.7
Leadership commitment	3.37	1.12	55.3

Source: Primary survey data collected from steel industry professionals (N = 412).

The findings show that technical skills and engineering knowledge are the most formidable internal strength in steel industry projects. The fact that many of the responses are related to these strengths indicates that industry practitioners are viewing the presence of technical competence and specialized workforce as significant determinants of the project implementation capacity.

Table 2: **Identified Weaknesses in Project Management**

Weakness	**Mean Rating (1–5)**	**Standard Deviation**	**Frequency of Mention (%)**
Inadequate project planning	4.28	0.72	89.6
Poor risk management practices	4.17	0.68	85.2
Weak contract management	4.05	0.81	82.8
Ineffective communication channels	3.92	0.77	79.1
Siloed organizational structure	3.88	0.83	77.4
Resistance to new technologies	3.81	0.91	74.5
Insufficient stakeholder engagement	3.79	0.86	71.8
Bureaucratic decision-making	3.72	1.04	68.7

Source: Primary survey data collected from industry respondents (N = 412).

The results indicate poor planning of projects and poor risk management practices as the most serious internal weaknesses impacting project management performance in steel sector projects.

Table 3: **Identified Opportunities for Project Management**

Opportunity	**Mean Rating (1–5)**	**Standard Deviation**	**Frequency of Mention (%)**
Digital transformation and Industry 4.0	4.35	0.64	91.7
Government infrastructure initiatives	4.18	0.73	85.4
Knowledge exchange with global players	4.07	0.69	82.0

Growth in domestic steel demand	3.94	0.82	78.9
Standardization of project practices	3.85	0.78	76.2
Green technology integration	3.79	0.87	72.8
Public–private partnerships	3.65	0.92	67.5
Capacity building initiatives	3.51	0.88	63.1

Source: Primary survey data collected from Solutions Survey responses (N = 412).

The most rated opportunity is associated with the project of digital transformation and Industry 4.0 technologies, which means that the impact of digital tools on enhancing the project management practices is highly anticipated.

Table 4: **Identified Threats to Project Management**

Threat	**Mean Rating (1–5)**	**Standard Deviation**	**Frequency of Mention (%)**
Regulatory uncertainties	4.31	0.67	88.3
Raw material price volatility	4.24	0.72	86.7
Market demand fluctuations	4.12	0.75	83.5
Land acquisition challenges	4.03	0.86	81.1
Environmental compliance complexities	3.95	0.79	77.7
Shortage of specialized skills	3.86	0.84	74.3
Global competition	3.72	0.93	68.9
Technological disruptions	3.58	0.97	64.6

Source: Primary survey data collected from Survey-1 and Survey-2 responses (N = 412).

The most problematic external risks as far as the implementation of projects in the steel sector is concerned are seen as regulatory uncertainty and price fluctuation of the raw materials.

4.2 Identification of Key Project Management Challenges

A three dimensional rating scale of frequency, impact and difficulty was used to determine the most important project management challenges by asking the respondents to rate different functional areas of project implementation.

Table 5: Key Challenge Areas in Project Management

Challenge Area	Frequency	Impact	Difficulty	Composite Score
Project planning and scheduling	4.32	4.58	3.87	4.26
Cost management	4.21	4.49	3.92	4.21
Procurement management	4.05	4.36	4.18	4.20
Risk management	3.97	4.42	4.13	4.17
Contract management	3.89	4.31	4.25	4.15
Scope management	4.24	4.39	3.68	4.10
Stakeholder management	3.81	4.27	4.09	4.06
Quality management	3.74	4.33	4.02	4.03
Human resource management	3.92	4.06	3.84	3.94
Communication management	4.03	4.12	3.64	3.93

Composite Score = (Frequency + Impact + Difficulty) / 3

Source: Primary survey data collected from steel industry professionals (N = 412).

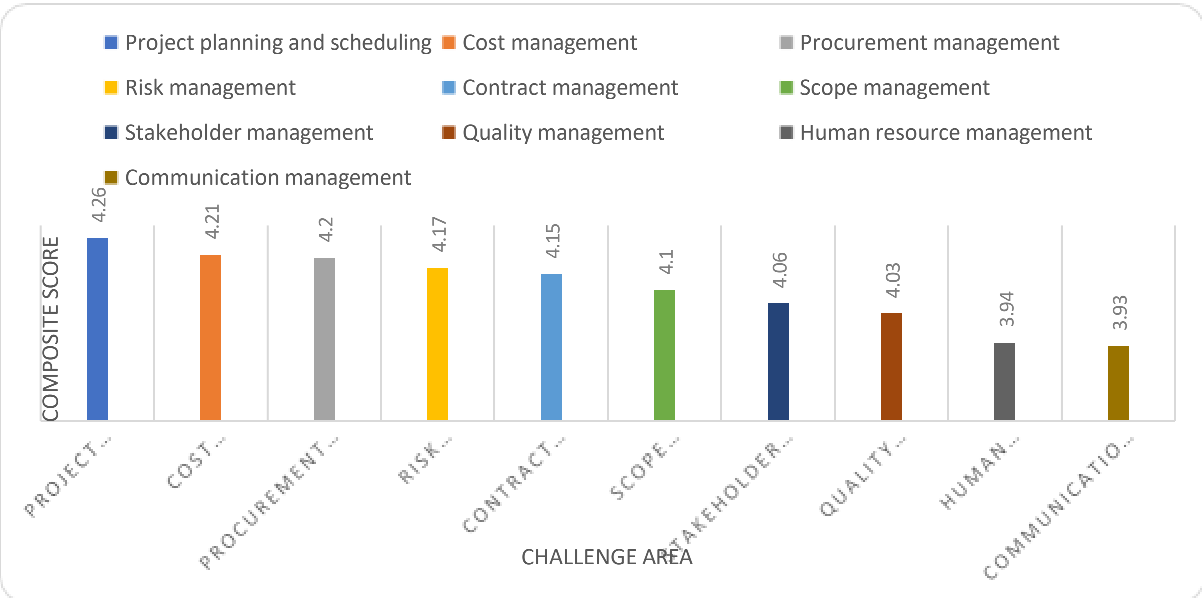

Figure 1: Severity of Project Management Challenges

Source: Generated from primary survey data (N = 412).

Anusandhanvallari
Vol 2025, No.1
March 2025
ISSN 2229-3388

The findings show project planning and scheduling are the most critical areas of challenge in projects in the steel sector.

4.3 Root Cause Analysis of Project Challenges

To gain insight into the latent causes of the project management issues, the respondents rated different causal elements pertaining to organizational capabilities, project management processes and external environmental conditions.

Table 6: Causal Factors Framework

Dimension	Category	Causal Factor	Frequency (%)
People	Competency	Insufficient project management expertise	78.6
People	Competency	Limited technical specialization	64.3
People	Competency	Inadequate risk management skills	72.1
People	Leadership	Short-term focus of leadership	81.3
People	Leadership	Ineffective decision-making structures	75.2
People	Behavioral	Optimism bias in planning	82.8
Process	Planning	Rushed planning phases	87.4
Process	Planning	Inadequate feasibility studies	76.9
Process	Systems	Fragmented information systems	71.4
Process	Methods	Limited use of modern PM tools	79.1
Business Environment	Market	Price volatility of inputs	83.5
Business Environment	Regulatory	Complex approval processes	84.7
Business Environment	Regulatory	Changing regulatory requirements	79.3
Business Environment	Organizational	Hierarchical decision structures	77.9

Source: Primary survey responses and qualitative validation (N = 412).

The analysis reveals that expedited planning processes, regulatory complexity, and market volatility are the most commonly cited causes of the project management challenges.

5. Model Development

The results of the SWOT analysis, prioritization of challenges and the evaluation of causal factors give the basis of the creation of a coherent conceptual framework of the enhancement of project management effectiveness in the steel sector projects. The discussion carried out in the sections of the paper above suggests that the challenges of project management are not operational problems in isolation but occur due to the interplay of a variety of structural dimensions such as organizational capabilities, project management processes, and external environmental conditions (Vergara et al., 2025).

To understand these interrelationships conceptually, the study hypothesizes a structured model, which is known as the Three Arm Clock Model of Project Management Effectiveness. The conceptual model considers project management performance to be a coordinated operation of three major dimensions of People, Process, and Business Environment. These dimensions work concurrently and affect the results of projects in terms of constant interaction (Sońta-Drączkowska & Krogulec, 2024). The model demonstrates that the success of sustainable projects is not only a result of the operational project management practices but also organizational leadership, institutional governance structures, and external environmental conditions that influence the project implementation.

The model is conceptualized based on the empirical findings that most of the project failures take place where organizations lay too much emphasis on operational processes and forget human capabilities or regulatory measures imposed externally (Elsherbeny et al., 2025). The model points out the necessity of a balanced synchronization of these factors as they are interdependent components of a clock mechanism in order to create successful project execution.

5.1 The Three Arm Clock Model for Project Management

The Three Arm Clock Model is a conceptualization of project management effectiveness that is a dynamic system where three core dimensions interact in the same way that the arms of a clock do. All the dimensions have a certain role to play and are still linked to each other. The clock metaphor is employed to explain the concept that proper time keeping involves all the arms moving in harmony; project management needs all the human capabilities, operational processes and the external environment to be balanced.

Dimension 1: People (Second Arm – Operational Driver)

The People dimension is the human and behavioral dimension of project management that has an immediate impact on the actual day to day project implementation. This dimension encompasses the skills, leadership potential, communication systems and cooperative actions of people engaged in project undertakings. All the project managers, engineers, contractors and organizational leaders add to this dimension by their capability to coordinate the activities, make sound decisions and react to the new challenges that arise in the project.

The second arm of the clock can be described as one that moves continuously and represents the activities and decisions that take place in real time during the project lifecycle. The presence of skilled professionals, high level of leadership orientation and team dynamics are therefore crucial to effective project performance.

Dimension 2: Process (Minute Arm – Operational Structure)

The Process dimension is the formal systems and methodological frameworks through which the project activities are planned, executed, monitored and controlled. This covers project planning processes, scheduling processes, cost management process, risk management processes, and performance monitoring.

The minute hand of the clock represents the systematic flow of activities in the project with time. Effective project management procedures ensure that activities are implemented in a coordinated order and allow organizations to be consistent, transparent and predictable in project implementation. The poor or fractured processes tend to result in poor planning, poor coordination and slow project implementation.

Dimension 3: Business Environment (Hour Arm – Strategic Context)

The Business Environment dimension is a more generalized aspect that denotes external and institutional components that have an impact on project implementation. These aspects encompass regulatory systems, market conditions, supply chain strengths, policy environments, and organizational governance systems.

The hour arm in the clock moves slower but defines the general direction of the project activities and the long term context. Opportunities and constraints under which projects are run are influenced by the external environmental conditions. The regulatory approvals, economic conditions, and industry competition are thus very critical in determining the feasibility of projects and timelines of their implementation.

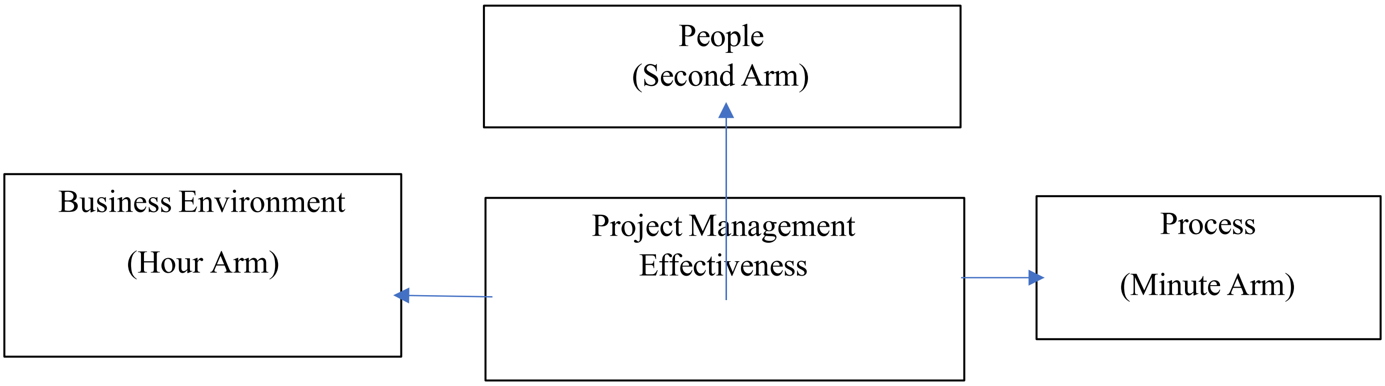

Figure 2: **The Three Arm Clock Model of Project Management Effectiveness**

Source: Conceptual framework developed from empirical analysis of survey data (N = 412).

5.2 Statistical Validation of the Model

The structural relationships of the three dimensions were tested statistically to assess the empirical validity of the Three Arm Clock Model. The purpose of analysis was to find out whether the dimensions that were found in the conceptual framework play a significant role in the effectiveness of project management.

Table 7: Structural Relationships Between Model Dimensions

Path Relationship	Standardized Coefficient	Standard Error	p-value
People → Project Management Effectiveness	0.412	0.048	<0.001
Process → Project Management Effectiveness	0.385	0.052	<0.001
Business Environment → Project Management Effectiveness	0.327	0.057	<0.001
People ↔ Process	0.463	0.061	<0.001
Process ↔ Business Environment	0.428	0.064	<0.001
People ↔ Business Environment	0.372	0.068	<0.001

Source: Statistical analysis based on primary survey data (N = 412).

The findings show that, statistically, the three dimensions are related to project management effectiveness. The People dimension is the most direct, which is why, of the three, it indicates the strongest impact, implying that leadership qualities, professional skills, and collaboration are essential factors that contribute to the success of project performance.

Table 8: **Model Fit Indicators**

Model Fit Index	Value
Chi-square / df	2.37
Comparative Fit Index (CFI)	0.941
Tucker-Lewis Index (TLI)	0.928
Root Mean Square Error of Approximation (RMSEA)	0.058
Standardized Root Mean Square Residual (SRMR)	0.042

Source: Structural analysis results derived from survey dataset (N = 412).

The model fit statistics show that the model has an acceptable level of statistical performance, meaning that the conceptual framework has provided a satisfactory representation of empirical relationship in the dataset.

6. Strategic Implications and Digital Transformation

The empirical results described in the sections above show that the problem of project management in the steel industry is the result of the complex interplay of organizational, operational, and environmental factors. The SWOT analysis, challenge prioritization, and causal factor assessment all show that the traditional project management methods tend to fail to tackle the systemic nature of the challenges (Usman et al., 2026). Specifically, challenges like poor planning, disjointed information systems, regulatory complexity, and poor coordination among project stakeholders remain problematic to project performance within large industrial projects.

To address these results, the research comes up with a number of strategic implications in enhancing project management practices in the steel industry. These implications are aimed at enhancing the organizational capabilities, improving the integration of the processes, and using digital technologies to enhance the planning, monitoring, and decision-making of the project. The increased presence of digital tools, data analytics systems, and artificial intelligence applications is a major opportunity to evolutionize traditional project management systems into more intensive and smart management systems (Álvarez-Pozo et al., 2024).

This section thus explains the strategic implication of the research results and discusses the possibility of digital transformation to help solve the project management issues identified during the empirical analysis. It especially focuses on the creation of a unified digital project management system that is capable of facilitating data-driven decision-making throughout the project lifecycle (Almalki, 2025).

6.1 Digital Transformation Opportunities in Steel Projects

The current trend of elevating the use of digital technologies in industrial sectors has brought about new opportunities in the aspect of enhancing project management practices. Digital transformation helps organizations to interconnect project information systems, automate data collection processes, and improve real-time monitoring of project activities. These functions are especially useful in big industrial projects where there are many teams, contractors, and suppliers to coordinate their efforts over long project durations.

Digital transformation initiatives in the steel industry could involve the implementation of integrated project management systems, high-quality data analytics systems, and automated monitoring systems that monitor projects in real-time. These technologies give the project managers access to centralized project data, trends on project performance and detect risks emerging at an early stage. Digital platforms also help to improve the communication between stakeholders of a project and enable quicker decision-making due to the increased transparency offered by these tools.

The responses to the survey questions that were received during the current work suggest that professionals in the industry consider digital transformation as one of the most promising areas to enhance the performance of project management. The use of new digital technologies in project management, however, is not uniform in organizations. Although there are a few organizations that have initiated the use of digital project management tools, most of the projects continue to use disjointed information systems that restrict the ability to coordinate and enhance the effectiveness of decision-making processes.

Table 9: **Assessment of Digital Technology Applications in Project Management**

Technology	Application Area	Current Adoption (1–5)	Potential Impact (1–5)	Implementation Challenges
Artificial Intelligence & Machine Learning	Risk prediction and scheduling	2.31	4.52	4.18
Internet of Things (IoT)	Real-time equipment monitoring	2.65	4.37	3.85
Building Information Modeling (BIM)	Design coordination	2.87	4.21	3.76
Cloud-based project management platforms	Centralized data integration	3.28	4.43	3.53
Advanced analytics systems	Project performance dashboards	2.92	4.31	3.42

Source: Primary survey data from Solutions and Digital Technology Survey (N = 412).

The findings indicate that there is a major disconnect between the present degree of technology use and the perceived potential of digital solutions. Advanced analytics technologies and artificial intelligence demonstrate an exceptionally great promise in enhancing the performance of project management.

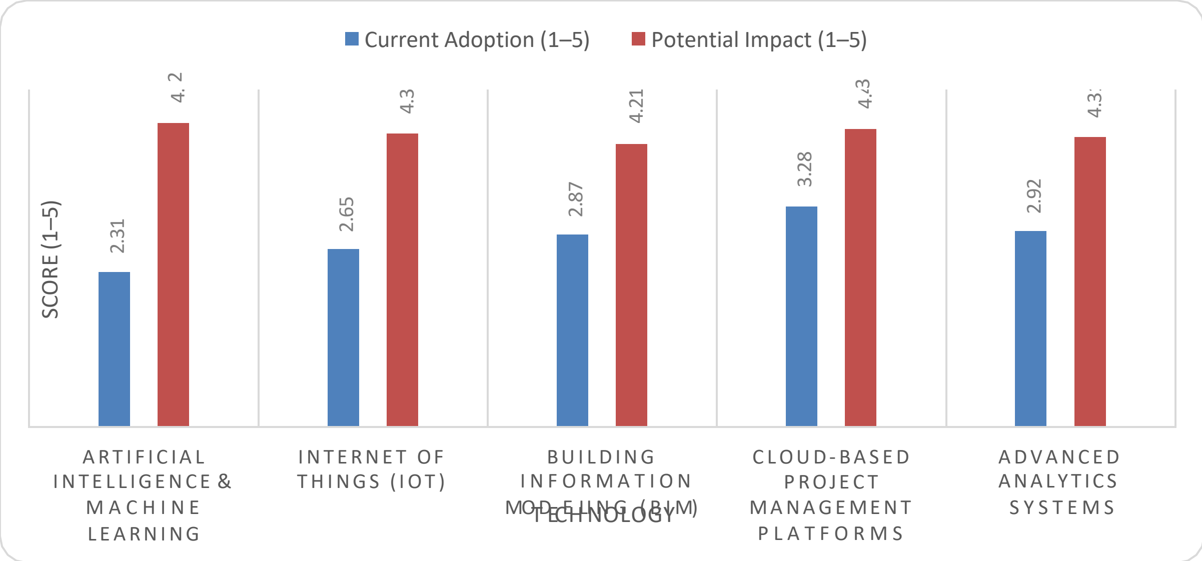

Figure 3: **Current Adoption vs Potential Impact of Digital Technologies**

Source: Generated from primary survey data (N = 412).

6.2 AI-Driven Project Management and Monitoring System (APMS)

Following the results of the research, the study suggests the creation of an AI-based Project Management and Monitoring System (APMS) as the strategic measure that could be used to cope with the identified structural issues in the projects of the steel sector. The APMS framework is set out to be a cohesive digital platform that has the capacity to integrate a variety of project information systems and deliver project decision-makers with real-time analytical insights.

The proposed system will combine the information of the project planning systems, procurement systems, financial management systems, and site monitoring systems into a single digital architecture. The integrated dataset can then be analyzed with artificial intelligence algorithms to identify emergent risks, anticipate schedule delays, estimate cost variations, and enable proactive decision-making.

The APMS model coincides with the Three Arm Clock Model that was suggested in the section above. The system allows organizations to be aligned in the People, Process and Business Environment dimensions of project management by incorporating data that concerns project teams, operational processes and external environmental conditions.

Table 10: **Core Functional Components of APMS**

APMS Module	Integrated Systems	Key Functions
Project Planning Engine	Scheduling tools, feasibility analysis systems	AI-based schedule optimization and planning analysis
Procurement Integration Layer	Vendor management systems	Vendor performance monitoring and procurement analytics
Execution Monitoring Module	Site reporting systems, IoT devices	Real-time progress tracking and performance monitoring
Financial Integration Module	ERP and finance systems	Cost forecasting and budget monitoring

Risk Intelligence Engine	Historical project databases	Predictive risk identification and mitigation alerts
Decision Support Dashboard	Integrated data systems	Real-time analytics and scenario simulation

Source: Conceptual framework developed from empirical analysis of survey data.

Table 11: **AI Functionalities in APMS**

AI Capability	Application Area	Expected Project Benefit
Predictive scheduling analytics	Planning and scheduling	Early identification of potential project delays
Machine learning cost estimation	Cost management	Improved accuracy of cost forecasts
Risk pattern recognition	Risk management	Proactive identification of emerging risks
Automated progress validation	Project monitoring	Reduction of reporting errors and delays
Vendor analytics	Procurement management	Improved supplier selection and performance tracking
Decision recommendation engine	Project governance	Data-driven strategic decision-making

Source: Analytical framework developed from survey findings and project management analysis.

6.3 Implementation Roadmap for Digital Project Management

Digital project management systems implementation needs a planned transformation strategy to be executed successfully. Companies should slowly transform the current project management processes to use digital technologies and make sure that project teams acquire the required digital skills.

The proposed roadmap will map a step-by-step process of integrating digital project management systems in the projects in the steel sector.

Table 12: **Phased Implementation Roadmap for Digital Project Management**

Phase	Focus Area	Key Activities	Timeline
Phase 1	Digital foundation	Integration of existing project information systems and creation of centralized dashboards	0–6 months
Phase 2	Analytical transformation	Deployment of predictive analytics tools and automated monitoring systems	7–18 months
Phase 3	Intelligent automation	Implementation of AI-based decision support systems and advanced project analytics	19–36 months

Source: Strategic implementation framework developed from research findings.

Anusandhanvallari
Vol 2025, No.1
March 2025
ISSN 2229-3388

The strategic analysis, which is provided in this section identifies that there is a great opportunity to improve the performance of the project management in the steel industry due to the digital transformation. Leveraging organizational capabilities and project management processes through the integration of digital technologies will enable organizations in the steel sector to promote transparency, minimize operational inefficiencies, and decision-making across the project lifecycle.

7. Conclusion

This paper has explored the intricacy of project management activities within the Indian steel industry and has determined the key elements that affect the performance of projects within large scale industrial projects. To achieve a comprehensive picture of the challenges in project management, the causes, and possible strategic solutions, the research had a mixed-method approach consisting of a qualitative analysis and quantitative survey data (Joshua et al., 2024). The results give empirical evidence on the structural challenges to project implementation and suggests a holistic model of enhancing the effectiveness of project management in the steel sector project.

7.1 Summary of Key Findings

The review showed that the project management in the steel sector is practiced in a very intricate environment that is technical sophistication, huge capital investment, regulatory restraints and involvement of many stakeholders. The SWOT analysis revealed that the industry has high technical skills, labor force competencies, and well-established experience in its operations, but a number of internal weaknesses still influence the project implementation (White et al., 2026). Specifically, poor project planning, poor risk management behavior, disjointed communication systems, and bureaucratic decision making were found to be significant internal limitations.

The empirical survey also determined the most important areas of project management challenges within the projects in the steel sector. The most significant challenge was project planning and scheduling, and next, there were cost management, procurement management, and risk management. These results suggest that a lack of proper planning of an early project stage is likely to have a ripple effect on the later stages of the project, eventually impacting project schedules and budgets (Yin et al., 2024).

The root cause analysis showed that project management challenges are complex, based on the complex of factors connected with human capabilities, operations, and external conditions in the environment. The critical drivers in the People dimension were found to be leadership orientation, levels of professional competency and collaborative behavior. In the same vein, there were hastened planning processes, disjointed information systems and inadequate utilization of contemporary project management tools that were noted to be major weaknesses in the Process dimension (Álvarez-Pozo et al., 2024). The regulatory complexity, supply chain volatility, and market uncertainty were found to be important factors in the Business Environment dimension.

According to these findings, the research came up with a Three Arm Clock Model of Project Management Effectiveness that conceptualizes project performance as the product of balanced interaction between People, Process, and Business Environment dimensions. The empirical validation of the model showed that all the three dimensions have a significant effect on the effectiveness of project management with the strongest direct effect on project outcomes being the People dimension (Salimimoghadam et al., 2025).

7.2 Managerial Implications

The results of this research have a number of significant implications on managers that are involved in planning and implementation of big industrial projects in the steel industry. First, the findings point to the necessity to enhance the project planning skills at the early phases of the project development. To minimize uncertainties in implementing projects, organizations must invest in better feasibility analysis, proper scheduling practices, and elaborate risk assessment frameworks (Uğural & Aghili, 2026).

Second, the paper has highlighted the role of building effective organization capacity in project teams. Collaboration between the project stakeholders can be greatly improved with the help of leadership development, professional training, and better communication mechanisms. The organizations are hence advised to concentrate on development of project management competencies in addition to enhancing the technical expertise (Abdullah et al., 2026).

Third, the study emphasizes the increased significance of digital technologies in improving the project management practices. The offered AI-Driven Project Management and Monitoring System (APMS) shows how unified digital platforms can be used to conduct real-time project tracking, predictive analytics, and make decisions based on the data (Elsherbeny et al., 2025). Such technologies can be utilized to assist organizations to enhance transparency, increase coordination between the project participants and minimize organizational inefficiencies.

7.3 Policy Implications

The implications of the study findings on the policymakers and regulatory bodies with regard to industrial development and infrastructure planning are also important. The regulatory systems, which govern large industrial projects, are important in determining the project implementation schedules and effectiveness of their operations (Chen et al., 2026). Streamlining the approval process, better coordination between regulatory agencies and increasing transparency in regulatory procedures can greatly decrease the time lag of projects and administrative overheads.

Moreover, the integration of innovative project management technologies within the steel industry can be supported by national programs that encourage digital transformation and modernization of industries (Gamidullaeva et al., 2024). The technological capacities needed in the current project management practices can be enhanced through government assistance in regard to digital infrastructure and technology innovation as well as training programs in skills.

7.4 Limitations and Future Research

Despite the fact that the study offers important information about the complexity of project management in the steel industry, a number of limitations must be mentioned. The empirical study is founded mainly on the survey data collected among the professionals working in the projects in the steel sector (Salimimoghadam et al., 2025). Although the data is very enriching in terms of how businesses in the industry operate, the outcome can be biased by the perceptions and experience of the respondents.

Moreover, the research concentrates on the Indian steel business largely and this might restrict the applicability of the results to other industrial settings or locations. The study can also be furthered in the future by exploring comparative studies in a range of industrial areas or international steel markets to determine whether the same patterns of project management can be observed in other settings (Yin et al., 2024).

Future studies may also focus on the application of digital project management systems in industrial projects in practice and the impact that new technologies, including artificial intelligence, sophisticated analytics, and digital twins, have on project performance (White et al., 2026). Longitudinal studies on the long-term effects of the digital transformation on the effectiveness of project management can also be of value to the researcher and practitioners alike.

REFERENCES

[1] Abdullah, N. F., Heidary, S., Zulkifli, I. H., Abu-Samah, A., Ibrahim, R., Subhi, N., & Zennaro, M. (2026). Micro-credential for Industry 4.0: Engineering safety and reliability with integrated machine learning and soft skills. *Cogent Education, 13*(1). https://doi.org/10.1080/2331186X.2025.2598923

[2] Almalki, S. S. (2025). AI-driven decision support systems in agile software project management: Enhancing risk mitigation and resource allocation. *Systems, 13*(3), 208. https://doi.org/10.3390/systems13030208

[3] Álvarez-Pozo, A. H., Parma-García, M. I., Ortiz-Marcos, I., Bautista, L. F., & Atanes-Sánchez, E. (2024). Analysis of causes of delays and cost overruns as well as mitigation measures to improve profitability and sustainability in turnkey industrial projects. *Sustainability, 16*(4), 1449. https://doi.org/10.3390/su16041449

[4] Chen, X., Liu, Y., Locatelli, G., He, Q., & Zhang, X. (2026). Exploring dynamics of stakeholder salience and functional roles in megaproject collaborative innovation system: Insights from the Hong Kong–Zhuhai–Macao Bridge. *Engineering, Construction and Architectural Management, 33*(2), 1424–1451. https://doi.org/10.1108/ECAM-09-2023-0915

[5] Elsherbeny, H. A., Gunduz, M., & Ugur, L. O. (2025). A hybrid model for enhancing risk management and operational performance of AEC (Architectural, Engineering, and Construction) consultants: An integrated partial least squares–artificial neural network (PLS–ANN) approach. *Sustainability, 17*(4), 1467. https://doi.org/10.3390/su17041467

[6] Gamidullaeva, L., Shmeleva, N., Tolstykh, T., Guseva, T., & Panova, S. (2024). The complex approach to environmental and technological project management to enhance the sustainability of industrial systems. *Systems, 12*(7), 261. https://doi.org/10.3390/systems12070261

[7] Joshua, S. R., Yeon, A. N., Park, S., & Kwon, K. (2024). Solar–hydrogen storage system: Architecture and integration design of university energy management systems. *Applied Sciences, 14*(11), 4376. https://doi.org/10.3390/app14114376

[8] Salimimoghadam, S., Ghanbaripour, A. N., Tumpa, R. J., Kamel Rahimi, A., Golmoradi, M., Rashidian, S., & Skitmore, M. (2025). The rise of artificial intelligence in project management: A systematic literature review of current opportunities, enablers, and barriers. *Buildings, 15*(7), 1130. https://doi.org/10.3390/buildings15071130

[9] Sońta-Drączkowska, E., & Krogulec, A. (2024). Challenges of scaling agile in large enterprises and implications for project management. *International Journal of Managing Projects in Business, 17*(2), 360–384. https://doi.org/10.1108/IJMPB-11-2023-0244

[10] Uğural, M. N., & Aghili, S. (2026). Addressing stakeholder dynamics in megaprojects: A framework for governance. *Engineering, Construction and Architectural Management*. Advance online publication. https://doi.org/10.1108/ECAM-07-2025-1219

[11] Usman, N., Javed, A., Ullah, A., Iftikhar, R., & Chaudhry, M. O. (2026). Deployment of a green hydrogen-based energy solution for the hard-to-abate steel sector. *International Journal of Hydrogen Energy, 207*, 153540. https://doi.org/10.1016/j.ijhydene.2026.153540

[12] Van der Meij, R. J. B., Edwards, D. J., Roberts, C., El-Gohary, H., & Posillico, J. (2023). Performance management within the Dutch steel processing industry. *Journal of Engineering, Design and Technology, 21*(4), 1230–1251. https://doi.org/10.1108/JEDT-04-2021-0201

[13] Vergara, D., del Bosque, A., Lampropoulos, G., & Fernández-Arias, P. (2025). Trends and applications of artificial intelligence in project management. *Electronics, 14*(4), 800. https://doi.org/10.3390/electronics14040800

[14] White, C., Lees, J. M., & MacAskill, K. (2026). Bridging the information gap using targeted digital transformation: Process mapping large-scale concrete activity. *Building Research & Information, 54*(1), 24–43. https://doi.org/10.1080/09613218.2024.2380331

[15] Yin, Z., Caldas, C., & de Oliveira, D. (2024). Identification of business–project management processes that improve capital efficiency of downstream and chemical projects. *International Journal of Construction Management, 24*(1), 1–9. https://doi.org/10.1080/15623599.2022.2132352