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Strategic Theory and Practice

Edited by Samuel Adeyinka-Ojo

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Aims and Scope of the Series

This series will provide a comprehensive overview of recent research trends in business and management, economics, and marketing. Topics will include asset liability management, financial consequences of the financial crisis and covid-19, financial accounting, mergers and acquisitions, management accounting, SMEs, financial markets, corporate finance and governance, managerial technology and innovation, resource management and sustainable development, social entrepreneurship, corporate responsibility, ethics and accountability, microeconomics, labour economics, macroeconomics, public economics, financial economics, econometrics, direct marketing, creative marketing, internet marketing, market planning and forecasting, brand management, market segmentation and targeting and other topics under business and management. This book series will focus on various aspects of business and management whose in-depth understanding is critical for business and company management to function effectively during this uncertain time of financial crisis, Covid-19 pandemic, and military activity in Europe.

Meet the Series Editor

Prof. Choudhry holds a BSc degree in Economics from the University of Iowa, as well as a Masters and Ph.D. in Applied Economics from Clemson University, USA. In January 2006, he became a Professor of Finance at the University of Southampton Business School. He was previously a Professor of Finance at the University of Bradford Management School. He has over 80 articles published in international finance and economics journals. His research interests and specialties include financial econometrics, financial economics, international economics and finance, housing markets, financial markets, among others.

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Contents

Preface

This preface of *Digital Project Management – Strategic Theory and Practice* serves as an introduction, laying the foundation for understanding this book's scope, audience, and unique contributions. It sets the tone for the content, highlights its relevance, and provides an overview of its structure and key features. By catering to a diverse audience, emphasising digital innovation, and connecting digital project management strategic applications, the book positions itself as a forward-thinking resource for learners and professionals alike.

Introduction, Purpose and Relevance of the book

The book addresses the evolving landscape of project management in the Digital Age, where technological advancements and strategic considerations have become integral to project management deliverables. While rooted in classical project management methodologies and principles, the book emphasises integrating digital tools and strategies to enhance critical success factors of government and private sector project execution. The text explores how digital advancements, such as artificial intelligence (AI), machine learning, and innovative approaches, reshape project management. The book caters to researchers and practitioners across diverse fields of project management body of knowledge.

Synopsis and Structure of the Book

The book is structured to provide a comprehensive yet accessible exploration of digital project management.

The book is divided into two sections, each addressing a critical aspect of digital project management.

Section 1, "Digital Technologies and Artificial Intelligence in Project Management", consists of 4 chapters.

1. The Role of AI in Enterprise Risk Management and Operational Efficiency

2. The Role of Disruptive Digital Technologies in Global Project Management

3. Agile Transformation: Business Strategies and Best Practices for VUCA and BANI World

4. Project Model Standardization with Dual DSP COD

Section 2, "Leadership, Public Infrastructure and Project Management Maturity Model", has 5 chapters.

5. Developing a Sustainable Framework for Government Funded Infrastructure Projects in Malaysia

6. 5D BIM Use by Contractors

7. Organisational Factors as Building Blocks in Project Management Maturity Model (PMMM) Concept Development: The Case of the South African Power Sector

8. Real-Time Physical and Financial Monitoring of Cross-Country Natural Gas Pipeline Infrastructure Projects: A Digital Way

9. Leadership in Digital Project Management World

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Section 1

Digital Technologies and Artificial Intelligence in Project Management

Chapter 1

The Role of AI in Enterprise Risk Management and Operational Efficiency

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Abstract

Business management in recent years has been experiencing a revolution generated by artificial intelligence, which offers innovative tools, especially in Enterprise Risk Management (ERM) and operational efficiency. This chapter explores how AI integration redefines traditional risk management methodologies and optimizes operational processes. To obtain results and a theoretical framework, the research questions were reformulated to address separately: (1) How does artificial intelligence (AI) contribute to Enterprise Risk Management (ERM)? (2) What are the strategic and operational implications of its adoption? Artificial intelligence allows risk management and improves companies' decision-making capabilities, also through the transformation of raw data into predictive insights in financial, operational, and environmental contexts. Even in the context of ERM, AI stands out for its predictive analytics capabilities. From an operational perspective, AI automates repetitive processes through various tools, such as Robotics Process Automation (RPA) and Intelligent Process Automation (IPA), improving productivity, reducing errors, and enhancing demand forecasting and customer personalization. The literature has highlighted the gaps in how AI directly impacts project management and operational efficiency, especially in the context of digital transformation. This research aims to fill the gaps by reviewing academic outputs from 2014 to 2024 from Scopus and Wos. The aim is to ensure a comprehensive and robust analysis that is also up to date. In this regard, the theoretical implications are for improving AI-integrated ERM, while the practical ones are mostly oriented toward strategies that managers can implement to leverage AI in optimizing their operations. They also address the well-being of society while addressing all concerns related to data management and transparency. The limitations of this study include relying solely on literature-based evidence with recommendations for future research.

Keywords: artificial intelligence (AI), enterprise risk management (ERM), operational efficiency, management, sustainability

1. Introduction

Artificial Intelligence (AI) has demonstrated in recent years that it can improve Enterprise Risk Management (ERM) and optimize operational efficiency with the help of its advanced analytical capabilities. In fact, AI allows you to transform even the most complex data into useful information for strategic decisions, anticipating risks. In this context, this chapter addresses two key research questions: (1) How does AI contribute to ERM? (2) What are the strategic and operational implications of its adoption?

The analysis is carried out in the context of "Digital Project Management" by applying the study to the broader theme of the book which is related to efficiency from a strategic and operational point of view with regards to project management. This chapter explores how the integration of AI is redefining traditional processes and allowing organizations to respond more effectively to the challenges of this dynamic and global context. The innovation that artificial intelligence brings is not limited to technological improvement alone but tends to redefine the approach to operational management as it determines changes at the global market level by allowing rapid and precise responses to changes. The adoption of technologies such as intelligent automation and predictive models, all based on artificial intelligence, is revolutionizing the manufacturing, financial, and logistics sectors as these innovations improve resilience and business continuity and ensure business sustainability. For example, predictive maintenance and digital twins in the manufacturing sector are reducing downtime costs and contributing to improved production, while in the logistics context, advanced algorithms are optimizing flows and reducing bottlenecks, making the system more efficient. However, the literature suggests that the intersection of AI with digital project management remains underexplored. This chapter aims to address this gap by investigating the role of AI in improving project-related operational efficiencies.

It should be noted, however, that the integration of AI is not without challenges, including the management of algorithmic biases, data quality, and the need for a cultural change within organizations. Artificial intelligence needs advanced technology and specific skills among both leaders and employees, as otherwise, it would encounter a significant obstacle in terms of large-scale adoption.

The chapter focuses on two main aspects: the strategic impact of AI in ERM and its contribution to operational efficiency. The aim is to provide an overview of both the practical and theoretical implications related to these transformations, while outlining the opportunities and critical issues of an informed adoption of AI. The benefits brought by artificial intelligence in promoting business models focused on the management of environmental risks, and therefore oriented toward sustainability, will be analyzed.

To achieve this, the chapter discusses how AI can be strategically leveraged in project management to achieve operational goals while addressing barriers such as cultural resistance and ethical considerations.

In this context, the need for technical skills and a cultural change emerges, which sometimes represent barriers that require strategic attention to improve sustainability and moving toward increasingly innovative operating models. With the growing combination of sustainability and competition, artificial intelligence is positioning itself as a tool for adaptability for businesses so that they can grow in the long-term.

2. Literature review

This section reports the literature review has shown that artificial intelligence (AI) has become an indispensable resource to address contemporary business challenges, thanks to its ability to optimize processes, manage complex risks, and promote operational efficiency. This section is based on a systematic literature review aimed at analyzing the role of artificial intelligence in digital project management and operational efficiency across multiple industries. Moreover, its integration into digital project management has been increasingly recognized as a key enabler of operational efficiency and risk mitigation [1]. In fact, multiple studies have highlighted the importance of AI in manufacturing, logistics, financial, and environmental sectors. Furthermore, recent research underscores its transformative potential in project management [2] particularly in resource allocation, decision-making, and process optimization [3]. In the manufacturing sector, AI has demonstrated its ability to transform industrial operations [4]. For example, applying machine learning models in industries such as oil and gas can help improve production efficiency by reducing operational risks [5]. Similarly, the integration of artificial intelligence and automation within factories has led to a significant increase in productivity [6]. Digital twin technology, on the other hand, studied in the context of Industry 5.0, has improved operational safety, and has enabled a more seamless collaboration between humans and machines, thus simplifying processes [7]. AI algorithms have also become essential strategies for optimizing logistics flows, solving bottlenecks, and increasing efficiency in global supply chains [8]. The application of the Virtual Geographic Information System (VGIS) Digital Twin system has further demonstrated how virtual data and geographic data integration can optimize even the most complex operations and improve risk management [9]. In digital project management, these capabilities translate into more effective coordination and monitoring of project activities, ensuring timely delivery and resource optimization. In the financial sector, AI is transforming the management of economic resources [10]. Through automation and predictive analytics, companies can make more informed decisions and anticipate complex risks. For instance, AI helps mitigate financial risks and improve business competitiveness [11]. Moreover, the use of machine learning models to identify and mitigate risks in financial markets has proven highly effective, enhancing the precision and responsiveness of strategies [12]. AI has also been fundamental in optimizing business resources, improving decision-making processes, and reducing overall costs [13]. In the area of financial innovations, advanced technologies like blockchain have been integrated to improve information management, regulatory compliance, and operational efficiency [14].

AI is revolutionizing environmental risk management, mitigating the impacts of climate change through predictive models that anticipate critical events, allowing companies to adapt processes to reduce environmental consequences and improve sustainability [15]. This characteristic element has also found application in the maritime sector, where artificial intelligence can be used to optimize resources and for what concerns the management of sustainability risks [16]. Furthermore, systems based on artificial intelligence allow for the monitoring and management of risks by intervening to improve the quality of products and reduce safety incidents [17].

In this context, supply chain management also benefits from innovations related to artificial intelligence. Indeed, during the COVID-19 pandemic, the use of technologies such as generative artificial intelligence has helped address disruptions in logistics flows as well, optimizing inventory management [18]. Innovative strategic models that integrate AI and blockchain are now recognized for their improvement in operational efficiency [19]. Similarly, in project management, AI-driven tools have demonstrated their capacity to enhance collaboration, streamline workflows, and provide predictive insights for better decision-making [20]. In the context of digital project management, these strategies align with the need for adaptive and sustainable approaches to address the growing complexity of projects [21]. Even in digital marketing, the use of neural networks has proven effective in analyzing critical factors for startups, improving customer engagement and optimizing company resources [22]. Machine learning-based technologies have also been fundamental in understanding and optimizing industrial production processes, contributing to greater precision and sustainability [23].

2.1 Gap of literature review

From the literature review, some gaps have been identified. The lack of focus on some specific contexts has emerged, such as healthcare, where AI now plays a fundamental role, especially in the management of clinical data, allowing predictive analysis. AI is also involved in the urban mobility and agriculture sectors, where it intervenes, respectively, in the optimization of traffic and the reduction of waste. Therefore, more sectoral studies would be appropriate to obtain a 360-degree vision. Another aspect that has emerged is the lack of empirical analysis on specific cases of failure. In fact, the literature is particularly focused on cases of success, but no cases emerge in which the implementation of artificial intelligence models has led to cases of unsatisfactory or unexpected results. In a delicate and constantly evolving context, an analysis of what went wrong would allow us to better understand both the technical and organizational barriers and minimize the associated risks.

In the field of digital project management, there is a gap in understanding the impact of AI on the outcomes of long-term oriented projects, especially when it comes to failures that arise from poor applications or inadequate resource allocation. Closing these gaps could lead to the implementation of more precise strategies that can make more targeted future decisions.

Furthermore, another gap is the lack of analysis on how to incorporate sustainability goals into AI-based business models, as companies need strategies to balance the energy-intensive use of AI with sustainable practices. This is especially relevant in project management, where sustainability objectives are increasingly integrated into project lifecycles, requiring AI solutions that are both effective and environmentally responsible.

3. Methodology

The methodology followed to conduct this study is mainly based on a literature review aimed at identifying and selecting all the scientific and relevant contributions on the integration of artificial intelligence (AI) in Enterprise Risk Management (ERM) and operational optimization.

The research question that guided the contribution was: (1) How does artificial intelligence (AI) contribute to Enterprise Risk Management (ERM)? (2) What are the strategic and operational implications of its adoption?

As for the papers, they were collected from two platforms which are Scopus and Wos, known for the quality and completeness of their academic contents. This claim is supported by their recognition as leading academic databases ensuring high-quality indexed literature.

Precise selection criteria were followed in order to guarantee the relevance and quality of the contributions.

Articles published in the last 10 years (2014–2024) in the English language were selected. This period was chosen to focus on recent advances while maintaining data robustness and to include current studies in the field of operational optimization.

On Wos, there were duplicates of the papers chosen on Scopus, so we report the search string used on Scopus, which combines keywords related to the topics of AI, ERM, and operational optimization, using Boolean operators. The complete query is the following:

("Artificial Intelligence" OR "AI") AND ("Enterprise Risk Management" OR "ERM" OR "Risk Management") AND ("Operational Efficiency" OR "Business Efficiency" OR "Process Optimization")

After downloading the data, all articles were examined through title and abstract to verify their relevance to the topic and research question (RQ).

The selection and analysis process were supported by Systematic Literature Review (MySLR) tool developed by Ammirato et al. [24], a tool designed to conduct systematic literature reviews. MySLR facilitates the organization, screening and extraction of relevant articles, ensuring greater efficiency in the evaluation of the collected articles.

Irrelevant articles were excluded if after preliminary evaluation they were not found to be consistent with the study objectives.

Only articles that explicitly addressed the application of AI for operational risk management or optimization were included, and consequently articles that did not meet these requirements or did not provide significant contributions were excluded from the analysis.

A total number of 220 articles was initially identified which, after removing duplicates and irrelevant articles, decreased to 85 articles. Of these, 50 were included in the final analysis as they were deemed relevant based on the research questions.

So, overall, in the selection process, the following were excluded:

Articles not relevant to the main themes of the chapter.

Duplicate contributions between platforms.

Publications not accessible in full text.

Non-peer-reviewed documents, such as company reports or opinion pieces.

The articles that have been selected are considered essential and relevant for the analysis, generation of results and practical implications related to the integration of AI in different processes related to the various sectors.

The article selection process was based on topics such as artificial intelligence tools, sectors involved, and operational improvements observed. This identification strategy allowed us to understand the current state of the literature and identify gaps.

4. Findings and discussion

The analysis of the results generated a graph (**Figure 1**) of the distribution of scientific publications over time, highlighting annual variations. Each bar represents the quantity of articles year after year, showing the evolution of scientific production. In recent years, there has been an increase in production, both topical and certainly due to various factors, including the evolution of research technologies, an increase in

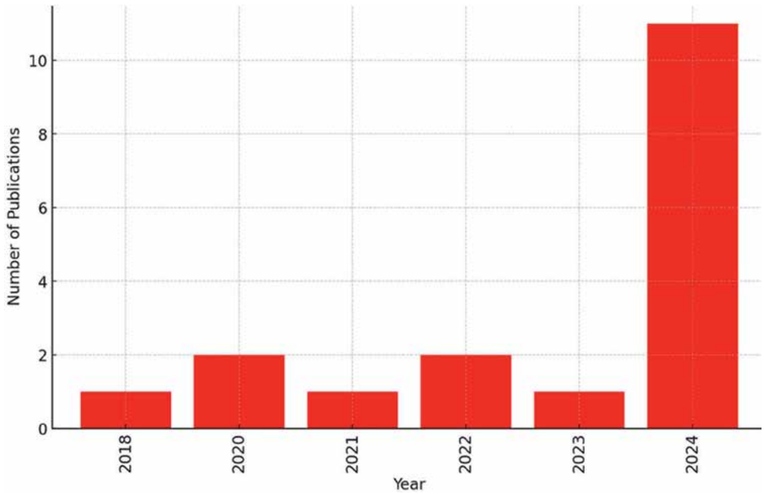

Figure 1.
Publication over time. Source: own elaboration.

investments in research and development, and a greater interest in scientific topics of global relevance.

The growth of scientific contributions over time reflects how research ambitions are constantly evolving, with an increase in the number of researchers and institutions interested in everything related to artificial intelligence. From 2020 onwards, the graph shows that there has been a significant increase in scientific production on the topic especially in the post-pandemic period.

Therefore, the distribution of annual publications allows us to directly show temporal trends in scientific research, and the peaks in certain years are indicative of significant developments and events that have influenced academic research. This reflects the rising importance of AI in addressing global challenges, such as operational disruptions, sustainability, and risk management.

Machine learning-based technologies have also been fundamental in understanding and optimizing industrial production processes, contributing to greater precision and sustainability. These technologies have enabled companies to mitigate risks through real-time monitoring and predictive analytics, significantly enhancing Enterprise Risk Management (ERM).

The analysis of the literature has highlighted, in addition to what is already known about the increase in the use of AI during the pandemic period (2020), how it is now an indispensable resource for corporate risk management (ERM) and for operational optimization, as it improves the effectiveness and efficiency of corporate organizations.

Artificial intelligence is a valid ally in increasing operational efficiency, especially thanks to some tools, such as Robotic Process Automation (RPA) and Intelligent Process Automation (IPA). All these tools automate repetitive processes, resulting in an increase in resources available for strategic and management activities. Furthermore, improving market demand forecasts and optimizing logistics. Instead, in financial markets, AI has proven effective in detecting anomalies, predicting market trends, and reducing risks.

There is another front which is that of security, where machine learning models improve fraud detection and prevention and strengthen protection against financial threats and cyberattacks.

Artificial intelligence is a valid ally in increasing operational efficiency, especially thanks to some tools, such as Robotic Process Automation (RPA) and Intelligent Process Automation (IPA). All these tools automate repetitive processes, resulting in an increase in resources available for strategic and management activities. Furthermore, improving market demand forecasts and optimizing logistics. Instead, in financial markets, AI has proven effective in detecting anomalies, predicting market trends, and reducing risks.

However, the integration of AI is not without challenges. Algorithmic biases and issues related to data quality remain significant barriers. Organizations must invest in robust frameworks and ethical guidelines to ensure transparency and fairness in AI-driven decision-making processes.

Additionally, the adoption of AI in digital project management represents a new frontier, where its impact on resource optimization, real-time collaboration, and risk mitigation strategies is only beginning to be understood. This connection between AI and project management highlights the need for more sector-specific analyses and empirical studies.

5. Implications, summary and conclusion

From the literature review and the findings, the implications of AI adoption in organizations are drawn from different strategic, operational, and cultural aspects.

At a strategic level, artificial intelligence also helps companies respond more quickly to regulatory changes, economic challenges and issues directly related to environmental sustainability.

From an operational perspective, AI, through automation and process optimization, increases productivity and drives innovations in customer experience and human resources management. In this regard, both tools, such as AI-based chatbots capable of offering quick and personalized responses, and AI-based learning systems designed to enhance employees' skills and professional development. At the same time, these advances bring challenges, including the need for technical skills within organizations and ethical issues such as algorithmic bias and user privacy, which must be addressed.

But all these innovations come with challenges, including the need to develop technical expertise within organizations and address ethical issues such as managing bias and protecting privacy. These challenges require strategic investments in training and infrastructure to ensure organizations are prepared for large-scale AI implementation.

The creation of a scalable and secure technological infrastructure therefore becomes a prerequisite to be able to fully exploit the potential of AI. Companies that adopt AI as a strategic tool will obtain sustainable competitive advantages and will also contribute to redefining traditional business models, promoting a culture of innovation in which technology and sustainability merge to address current and especially future challenges.

Based on what has emerged so far, the implications can be categorized as follows:

5.1 Strategic implications

- AI enables companies to respond more promptly to regulatory changes, economic challenges, and environmental pressures.

- AI allows companies to adapt quickly in increasingly uncertain contexts through predictive capabilities.

- Adopting AI as a strategic tool helps redefine traditional business models, promoting sustainability and innovation goals.

5.2 Operational implications

- AI enhances productivity and reduces errors through tools like Robotic Process Automation (RPA) and Intelligent Process Automation (IPA).

- AI-powered chatbots and tools personalize customer interactions, improving satisfaction and service efficiency.

- Machine learning systems support personalized training pathways, fostering continuous skill improvement.

- Developing robust technological systems is essential to ensure operational effectiveness and full AI utilization.

5.3 Cultural implications

- Investing in training for employees and business leaders is necessary to ensure effective and strategic use of AI.

- Topics such as algorithmic bias and privacy protection must be addressed to ensure fair and transparent AI implementation.

- AI adoption requires a cultural shift in organizations, integrating technology and sustainability as core pillars. Thus, these implications can be summarized and categorized as reported in the following **Table 1**.

In addition to the literature analysis itself, gaps also emerge in the formulation of implications that clearly also in this case become guidelines for future research. First, studies on issues such as algorithm bias, transparency, and privacy issues in the cultural and ethical context are limited and generic, so it would be appropriate to have a

Category	Implication
Strategic	AI also enables companies to respond quickly to regulatory changes, economic challenges, and environmental and social pressures.
Strategic	AI enables traditional business models to be redefined, promoting sustainability goals and intelligent innovation.
Operational	AI enables the reduction of errors and increases productivity through the use of automation tools aimed at optimizing resources.
Operational	Machine learning supports employee development through personalized training paths.
Cultural	Challenges require structured organizational strategies aimed at preventing bias.
Cultural	A cultural change is necessary in order to effectively integrate AI into existing business models.

Source: own elaboration.

Table 1.
Implications.

practical framework for risk management that uses Explainable AI (XAI) models and implements more targeted regulatory frameworks.

The differences in AI adoption between different geographical areas and corporate cultures have not been analyzed either. A comparative analysis would also be appropriate to take ideas on strategies that highlight how regulatory and cultural factors can impact the effectiveness and speed of integration of the most sophisticated artificial intelligence techniques.

Last, but not least, is the training context as employee preparation and training are topics that have been little studied for now and that require further study and certainly investment.

6. Conclusion

In this chapter, the research question wanted to analyze how artificial intelligence (AI) contributes to Enterprise Risk Management (ERM) and operational efficiency, and the strategic and operational implications of its adoption. This chapter has highlighted that both research questions have been addressed by analyzing the role of artificial intelligence in two main areas, which are risk management and operational efficiency. The answer is divided into two main areas: risk management and operational efficiency. Artificial intelligence supports risk management through predictive models that allow organizations to predict financial, operational and environmental risks, enabling continuous monitoring of data in real-time and optimization of business strategies. Regarding operational efficiency, artificial intelligence automates repetitive processes, for example, with Robotic Process Automation (RPA) and Intelligent Process Automation (IPA), increasing productivity and reducing errors, thus optimizing both interaction with customers and demand forecasting. The strategic and operational implications of AI adoption extend to enhancing organizational resilience, enabling companies to respond quickly to external changes, and fostering innovations in both resource management and business strategy. The findings are consistent with the demand for increased adaptability and innovation within ever-changing markets.

This context clearly poses challenges related to data quality, the management of algorithmic biases, and the need for cultural as well as regulatory change within organizations and consequently at a global level.

In conclusion, it has been seen that artificial intelligence (AI) has established itself as a transformative element in Enterprise Risk Management (ERM) and operational optimization, offering advanced tools for predictive analysis, process automation, and decision support, through the ability to anticipate financial, operational, and environmental risks, allowing organizations to adopt proactive strategies, improving effectiveness and efficiency.

The implementation of artificial intelligence presents several challenges. Among these, for example, those based on the quality of data, or the ethical implications and the need for adequate connections with systems in order to ensure that the potential of AI is exploited correctly and to its full potential. The limitations highlight the need for an approach that can mix technological strategies with ethical and organizational ones. Furthermore, the adoption of these technological tools also requires a change from a cultural point of view within organizations, promoting training and the development of adequate technical skills. Despite the progress made, this study has some limitations as it is based on a literature review but lacks empirical validation through case studies or quantitative data, therefore, future research should address these limitations to provide more comprehensive contributions on the practical applications of artificial intelligence. Looking to the future, artificial intelligence represents an opportunity to improve business performance and is a strategic element for achieving sustainability, innovation and competitiveness objectives in a long-term perspective. Its ability to transform processes and strategies makes AI an ally for all types of organizations working in ever-changing environments. Despite the progress in the application of AI in Enterprise Risk Management (ERM) and operational processes, there are several areas that still need further exploration. Future studies should focus on Explainable AI (XAI), which improves transparency and trust, so as to ensure that automated decisions are understandable and reliable from the perspective of end users. Further research could explore how AI can support the transition to more sustainable business models, such as optimizing natural resources, reducing waste, and predicting environmental impacts. As AI usage increases, it is essential to understand and mitigate potential biases in data and algorithms. This highlights the need to focus on creating regulatory and technical frameworks to ensure fair and ethical use of AI. Artificial Intelligence (AI) can help organizations develop capabilities to prevent, manage, and overcome crises, improving emergency management and ensuring business continuity. It also offers great opportunities when integrated with technologies such as blockchain and the Internet of Things (IoT). In addition, future research should investigate how AI can address sector-specific challenges. For example:

- In healthcare, AI could optimize clinical data management and enable predictive analysis for patient care.
- In agriculture, AI could reduce waste and improve resource management.
- In urban mobility, AI could improve traffic safety and efficiency.

It is therefore necessary to develop customized solutions to meet the needs of each sector, and it is essential to invest in training to prepare leaders and employees to use AI. Targeted programs can bridge the skills gap, ensuring informed and effective adoption, and promoting the strategic and innovative use of AI to address future challenges.

Conflict of interest

The authors declare no conflict of interest.

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References

[1] Elapanda S, Adinarayana Rao UV, Sravan KE. Application of artificial intelligence in improving operational efficiency in telecom industry. International Journal on Emerging Technologies. 2020;**11**(3):65-69

[2] Davahli MR. The last state of artificial intelligence in project management. arXiv preprint. 2020. DOI: 10.48550/arXiv.2012.12262

[3] Dam HK, Tran T, Grundy J, Ghose A, Kamei Y. Towards effective AI-powered agile project management. In: Proceedings of the 41st International Conference on Software Engineering: New Ideas and Emerging Results (ICSE-NIER '19). Montréal, Canada: IEEE Press; 2019. pp. 81-84

[4] Li G, Li N, Sethi SP. Does CSR reduce idiosyncratic risk? Roles of operational efficiency and AI innovation. Production and Operations Management. 2021;**30**(7):2027-2045

[5] Hyoung J, Lee Y, Han S. Development of machine learning-based production forecasting for offshore gas fields using a dynamic material balance equation. Energies. 2024;**17**(21)

[6] Zhang L, Li Y, Chen Z. AI-driven smart factory operations: Applications and future trends. Journal of Industrial Automation. 2023;**39**(6):201-215

[7] Martusewicz R, Wierzbic T, Łukaszewicz B. EFQM 2025 model and AI: A strategic framework for resilient organizations. Total Quality Management & Business Excellence. 2024;**35**(9):910-934

[8] Lin H, Chang K. AI-based solutions for bottleneck analysis in global supply chains. Supply Chain Management Review. 2024;**23**(2):45-58

[9] Alabbasi A, Aljabery MA, Bölük PS. Application of VGIS digital twin platform for enhanced oilfield disaster management and environmental protection. Informatics (Slovenia). 2024;**48**(14):27-42

[10] Al-Haji YK, Bakar SB. Factors that influence AI investment decisions in Oman's hydrocarbons industry: A review of the theoretical literature and proposed theoretical model. Quality - Access to Success. 2024;**25**(200):94-113

[11] Kalkan G. The impact of artificial intelligence on corporate governance. Journal of Corporate Finance Research. 2024;**18**(2):17-25

[12] Malpani R, Singh P. Machine learning applications in financial market risk assessment. Journal of Financial Innovation. 2024;**12**(4):347-367

[13] Almustafa E, Assaf A, Allahham M. Implementation of artificial intelligence for financial process innovation of commercial banks. Revista de Gestão Social e Ambiental. 2023;**17**(9)

[14] Ali M, Razaque A, Yoo J, Kabievna UR, Moldagulova A, Ryskhan S, et al. Designing an intelligent scoring system for crediting manufacturers and importers of goods in industry 4.0. Logistics. 2024;**8**(1)

[15] Kumar R, Patel S, Yadav A. Leveraging artificial intelligence to mitigate climate risk in business. Journal of Environmental Management. 2024;**329**:117091

[16] Kong L, Yuen C. AI-driven solutions for maritime risk management and

stakeholder engagement. Maritime Policy & Management. 2024;**51**(3):400-419

[17] Tsang WY, Ng ET, Chan TL, Lee AP. IoT and AI integration in cold chain risk management. Journal of Food Safety & Technology. 2018;**9**(2):142-157

[18] Jackson S, Ivanov D, Dolgui A, Namdar R. Resilience in supply chains through AI-driven digital twins during crises. International Journal of Production Economics. 2024;**246**:113431

[19] Wu Q, Zhang N, Xie X. The Clinicopathological characteristics of POLE-mutated/ultramutated endometrial carcinoma and prognostic value of POLE status: A meta-analysis based on 49 articles incorporating 12,120 patients. BMC Cancer. 2022;**22**(1)

[20] Dacre N, Kockum F, Senyo PK. Transient information adaptation of artificial intelligence: Towards sustainable data processes in complex projects. arXiv preprint. 2021. DOI: 10.48550/arXiv.2104.04067

[21] de Matas M, Shao Q, Shukla R. Artificial intelligence: The key to process understanding. Pharmaceutical Technology Europe. 2007;**19**(1):44-48

[22] Rahim NM, Ahmad R, Hassan A, Khan S. Neural network applications in digital marketing for startups. Journal of Digital Business Strategy. 2020;**14**(3):192-210

[23] Daneshpajouh A, Taboada I, Toledo N, de Vass T. Artificial intelligence enabled project management: A systematic literature review. Electronics. 2024;**13**(8):5014

[24] Ammirato et al. MySLR: A Systematic Literature Review Tool. 2022. Available from: https://myslr.unical.it/homepage

Chapter 2

The Role of Disruptive Digital Technologies in Global Project Management

Faeyz Abuamria, Imad Alzeer and Mousa Ajouz

Abstract

The rapid integration of disruptive digital technologies, including AI, blockchain, and IoT, has significantly transformed global project management, particularly in the realms of planning, execution, and communication. Despite the potential of these innovations to streamline processes and enhance decision-making, there exists a research gap in understanding the challenges these technologies introduce, particularly in cross-cultural communication and interpersonal skills development. This chapter addresses this gap by analyzing case studies across the construction, energy, healthcare, and IT sectors to assess the impact of these technologies. The findings reveal that while disruptive technologies offer substantial opportunities for efficiency and complexity management, they also necessitate new strategies for managing cultural diversity and enhancing team collaboration. The study emphasizes the need for project managers to develop new competencies and organizations to invest in continuous training to leverage disruptive technologies. Policymakers should create regulatory frameworks that support technological adoption while addressing risks like data security. Additionally, the study highlights both the societal benefits of improved efficiency and the ethical concerns, such as job displacement, that must be addressed.

Keywords: disruptive technologies, digital transformation, global project management, tech innovation, emerging tech

1. Introduction

The advent of disruptive digital technologies has significantly transformed various aspects of business operations, including global project management. These technologies have revolutionized the way projects are planned, executed, and monitored. The development of innovative software solutions and platforms has enabled project managers to streamline their processes and collaborate with teams across different countries in real time [1]. Disruptive technologies, such as artificial intelligence (AI), blockchain, the Internet of Things (IoT), and advanced analytics, have introduced new ways to enhance efficiency, communication, and decision-making in project management on a global scale. These technologies are reshaping traditional project management practices, enabling organizations to manage complex, multi-national projects more effectively [2, 3].

Emerging technologies such as blockchain, big data, and artificial intelligence are changing the unique mix of science and art—the combination of tools, talents, and techniques—that defines project management [4]. Project managers have traditionally balanced technical, administrative, and interpersonal knowledge and skills. This combination enabled them to orchestrate the resources needed to address complex, uncertain, and unique requirements. The integration of disruptive digital technologies into project management has revolutionized the way organizations approach complex projects [5].

The conceptual framework for this study is based on the integration of theories related to digital transformation, project management, and disruptive innovation. This framework draws on the work of Christensen [6] on disruptive technologies, which highlights how innovations can reshape industries and practices. Additionally, the framework incorporates insights from recent literature on the adoption of AI, blockchain, and IoT in various sectors [2, 3]. By examining the interaction between technological advancements and project management practices, this framework provides a structured approach to understanding how disruptive technologies influence project outcomes and the necessary adaptations for project managers.

Therefore, the basic research questions of this study are: How do disruptive digital technologies, particularly AI, blockchain, and IoT, impact global project management? and What are the challenges and opportunities associated with their integration in various industries, including construction, energy, healthcare, and IT? The study also seeks to examine how project managers can adapt their skills and strategies to effectively leverage these technologies.

This essay explores the implications of the rise of disruptive digital technologies for global projects. It will examine how these technologies are changing the landscape of project management and the challenges and opportunities they present. The introduction will also provide an overview of the key disruptive digital technologies and their impact on global project management [7, 8]. The impact of innovative digital technologies on worldwide project management is highly significant. So far, the different changes caused by digital technologies have proven difficult to define in simple terms. However, it is already evident that project managers will have to acquire new interpersonal skills to complement the advanced digital capabilities of artificial intelligence, especially when overseeing complex projects [9].

1.1 Definition and concept

Digital disruption in project management refers to the transformative effect that emerging digital technologies have on the traditional processes, tools, and methodologies used to manage projects. This phenomenon occurs when innovative technologies such as cloud computing, AI, machine learning, big data, and automation challenge and reshape established methods, leading to a fundamental shift in how projects are planned, executed, and delivered. The disruption affects all aspects of project management, including communication, collaboration, risk management, and overall project delivery [5, 10].

The idea of disruptive technology has undergone significant growth over time, impacting not just entire industries, but also the realm of project management. The evolution of this concept and its major contributions to understanding and applying disruptive technology in project management are outlined below. Concept

Emergence (1995): The term "disruptive technology" was first introduced by Clayton Christensen, a professor at Harvard Business School, in his influential book "The Innovator's Dilemma" (1997) [6].

Christensen defined it as an innovation that creates a new market and eventually disrupts existing markets, often overtaking dominant technologies. Although the focus at this stage was broader than project management, Christensen's work established the foundation for comprehending how innovations can overturn established industries. One key contribution was the recognition that technologies like cloud computing, artificial intelligence, and digital tools could eventually disrupt traditional methods of managing projects by enhancing efficiency, reducing costs, and enabling new management approaches [6, 11]. Digital disruption in project management (2000s–2010s): With the emergence of the internet, cloud technologies, and digital communication tools, the field of project management underwent a transformation. Tools such as Microsoft Project and web-based collaboration platforms (e.g., Asana, Jira) started to dominate, altering how teams managed timelines, risks, and communications. These platforms facilitated real-time data sharing and remote project management, significantly disrupting traditional approaches. Key technological contributions included cloud computing enabling global collaboration in real time, overcoming geographical boundaries, and automation tools streamlining routine tasks, allowing managers to focus more on strategic decision-making. As digital technologies continue to advance, they are reshaping the landscape of project management by introducing new challenges and opportunities [6].

1.2 Key technologies driving digital disruption

In the past ten years, digital disruption has redefined global project management. Social media tools emerged, such as Facebook, Twitter, and WhatsApp, shifting the power dynamics of communications. Machine learning-based analytics and sensors supplied the power of fine-grained predictive analytics marked by IBM's Watson, PwC's Halo, and ScienceLogic. It allows us to anticipate outcomes in managing complex, interrelated projects. The quantum jump in distributed control systems permits massive resource optimization inspired by distributed ledger technologies, i.e., blockchains, driving resource management practices such as tendering, procurement, and performing by P2P technologies [5, 10].

Robotics, 3D printing, nanotechnologies, and advanced materials are transforming whole industry sectors, providing us with new construction, manufacturing, transportation, healthcare delivery, and financial industry options, thus redrawing supply and demand parameters [1]. At the same time, big data, machine learning, and AI are catalyzing another transformation by fundamentally transforming the nature of risk management and innovation portfolio decision-making [5]. Blockchains and smart contracts are driving a different type of disruption by enhancing facilitating transactions ranging from a broad array of modes, including financial from bitcoins to mortgages, orchestration such as for IoT networks or other resources, as well as authenticating software code transaction steps.

Wisdom of crowds, social media interactivity, and IoT are important disruptive forces behind rising collaborative activities and an open innovative-based economy. Each of these technologies converts how, where, when, and from whom we access, manage, and create the resources necessary for project initiation, deployment, monitoring and control, risk analysis, knowledge transfer, team building, and composition, as well as contractual orchestration [1, 12].

The purpose of the following section is to pave the road to a deep understanding of how these technologies might impact project management practices by analyzing their features, functionalities, applications, transformative capabilities, and uptake to date.

2. Methodological process

This study adopts the descriptive-analytical method to explore the impact of disruptive digital technologies on global project management. The descriptive-analytical method is well-suited for this research as it allows for a detailed examination of existing practices, identification of challenges, and analysis of opportunities presented by these emerging technologies in various industries.

The research begins by conducting an extensive review of the relevant literature on disruptive digital technologies and their influence on project management practices. This includes analyzing previous studies, theoretical frameworks, and real-world applications to provide a comprehensive understanding of the current state of knowledge. The literature review serves as the foundation for identifying the key concepts, trends, and research gaps that this study aims to address.

Following the literature review, the study focuses on specific case studies from industries such as construction, energy, healthcare, and IT. These case studies are selected to illustrate how disruptive technologies have been implemented in different sectors and to assess their impact on project planning, execution, and communication. By comparing these industries, the research highlights both the opportunities and challenges associated with integrating these technologies into project management practices.

The findings from the literature review and case studies are synthesized to draw conclusions and develop recommendations for project managers and organizations. These recommendations focus on strategies for effectively adopting disruptive technologies, overcoming the associated challenges, and enhancing overall project management performance. The study concludes by offering insights into future trends and directions for research in the field of global project management.

This methodology provides a systematic approach to analyzing the role of disruptive digital technologies in project management, offering practical insights that can be applied across different industries.

3. Results and discussions

3.1 Global project management challenges and the impact of emerging technologies

Global project management is evolving rapidly due to both the increased complexities of managing international projects and the rapid development of emerging digital technologies. These technologies present both opportunities and challenges, necessitating that project managers adapt their strategies to stay competitive in the evolving business landscape.

3.1.1 Global project management challenges

Globalization and remote work have introduced significant hurdles for project management. One of the primary challenges is managing remote and distributed teams. This often involves coordinating across time zones, different work environments, and various cultures, which necessitates effective communication tools and collaboration strategies [4, 13]. Another major challenge is cultural differences and diversity. Project managers must navigate cross-cultural teams by understanding local business practices and customs to avoid potential conflicts (Project Management Nerd). Regulatory and compliance issues also present obstacles, as managing projects across borders requires an understanding of diverse legal and regulatory frameworks. Without careful attention to these factors, project execution can be severely impacted. Finally, sustainability and ethical practices have become increasingly important, adding new layers of complexity as project managers must ensure alignment with global sustainability goals [14].

3.1.2 Impact of emerging technologies

Emerging technologies are reshaping project management by automating and streamlining various tasks. Artificial intelligence (AI) and automation are reducing the burden of routine tasks like scheduling and resource management, allowing managers to focus on more strategic aspects [15]. In addition, big data and predictive analytics offer real-time insights that help anticipate risks and optimize decision-making [16]. Cloud computing has revolutionized collaboration by enabling seamless management of distributed teams through platforms like Asana and Microsoft Teams (Project Management Nerd). Furthermore, blockchain technology is improving transparency and accountability, particularly in contract management and tracking deliverables [1].

3.1.3 Future trends in project management and the role of technology

As technology evolves, project management practices must adapt to new challenges. Smart cities, virtual construction, and machine learning introduce complex variables for project managers. Motivational tools and behavioral applications are more integrated, along with simulations for tackling complex project issues. Technologies such as radio-frequency identification (RFID) and advanced analytics are reshaping project management, providing enhanced data dashboards and real-time updates [17, 18].

These advancements facilitate just-in-time delivery and automate time-consuming tasks, allowing project managers to allocate resources more efficiently. However, the uptake of these technologies poses new challenges as managers must develop proficiency with these tools to maximize their potential [3].

Historically, between 20% and 50% of global projects have failed to meet their intended objectives. According to the PMI's 2018 report [19], this scenario is being increasingly disrupted by new technologies. Innovations like robotic or intelligent automation, the Internet of Things (IoT) big data analytics, and crowdsourcing are becoming crucial enablers of project success. By leveraging these technologies, companies can address the unique challenges posed by the international environment. As technology improves, project failure rates have significantly decreased [20].

The adoption of radical digital enablers has not only reduced project waste but has also led to creative solutions for age-old problems. By embracing a technology-driven approach, project management has the potential to significantly improve both efficiency and success rates on a global scale. In conclusion, while emerging technologies present challenges, they also offer opportunities for innovation and efficiency in project management. The ability to navigate these shifts will be critical for the future of global project management.

3.2 Cultural diversity and communication barriers in global project management: Challenges and technological solutions

3.2.1 Cultural diversity and communication barriers

Cultural diversity and closely related, communication differences, constitute another major issue that complicates global project management. Cultures differ immensely in how they communicate, with some preferring a direct approach, such as in the United States and Germany, where people tend to speak clearly and openly. Such cultures are often referred to as low-context, as opposed to high-context cultures like Japan and South Korea, which prefer indirect communication that depends a lot on context [13, 21].

These differences are frequent sources of conflict and misunderstanding between the members of an international team, which can jeopardize the final result of a project. Therefore, project managers should acknowledge and properly mediate these cultural differences to ensure a conflict-free working environment and, therefore, a better final result [22]. Digital technology mitigates the negative impact of the aforementioned cultural differences by providing efficient means for members of a virtual team to communicate. Nevertheless, integrating new technologies will not be sufficient without a comprehensive understanding of the deep-rooted cultural approaches [23].

Time can serve as a perfect illustration of the problem: in the US and Germany, being late is considered unprofessional and disrespectful, whereas in countries like Mexico or India, time is usually flexible, and people postpone scheduled events due to more pressing matters This results in delays and increased costs and risks if not managed properly, and, again, the solution is possible only with the help of cutting-edge digital tools [24].

However, by themselves, they will not be enough to secure truly satisfactory results. Indeed, as relevant research shows, the level of cultural awareness achieved via proper training significantly facilitates knowledge transfer and success of an international project [25, 26].

3.2.2 Time zone and geographical differences

Time zone differences have been identified as a significant obstacle in the smooth progress of global software development (GSD) or global resource development (GRD). Relying on traditional methods such as in-person project meetings or teleconferencing to discuss tasks synchronously can be, at best, a laborious process. At worst, it may result in conflicts among stakeholders due to a lack of understanding regarding the core issues related to time differences and their impact on communication and collaboration [27].

For example, literature reports that the time difference between India and the US East Coast ranges between 9.5 and 13.5 hours, depending on daylight savings, with an average time difference of 12.5 hours. To have interaction with a US office that does not start work before 10:00 am means that a manager will have to make a conference call at 9:30 pm, well after standard working hours. In this situation, a manager will have to stay at work on a daily basis until 9:30 pm to be part of the conference call, stretching a nine-hour workday to 12 hours. Thus, an immediate effect appears to be a loss of personal/family time, inconducive by managers [28].

In the United States, supervisors in charge of work trailers often find themselves working late into the evening to align with the Indian workday. At the same time, employees in India have to start their day early in order to communicate with clients in the US or attend early meetings requested by customers. This creates an imbalance, putting unnecessary pressure on both sets of employees [29].

In cases where a project has strict time constraints, the varying local time zones can result in one part of a distributed team completing their portion of the work earlier in the day, potentially creating added pressure for the team working in a different time zone. This not only causes conflict due to the out-of-sync working hours of the global team but also creates challenges in balancing work and family time [27].

Despite the use of various communication technologies such as email, telephone, and faxes, addressing timely communication issues in the presence of multiple time zones remains an ongoing concern in global project management. As organizations increasingly adopt distributed structures, the geographical distance between project stakeholders and team members becomes a significant boundary, although digital networks can help bridge this gap. However, geographical separation, when compounded by time differences, can lead to heightened stress. While some sources highlight the benefits of technology and communication tools for globally distributed projects, few address the disruptive impact of digital technologies on global projects and the challenges of implementing them [30].

3.3 The impact of disruptive digital technologies on global project management

3.3.1 Enhanced collaboration and communication

Innovative digital technologies have revolutionized the way global project management operates by improving communication and collaboration among teams that are located in different geographical areas. These tools allow instant access to project information, which fosters productive teamwork and the sharing of knowledge, both of which are vital to the success of virtual teams [31]. For example, the European Cybercrime Center uses digital collaboration to combat cybercrime, and similar tools have been successful in high-tech projects throughout Europe, where teams work remotely to cut down on travel expenses and increase productivity. These technologies also facilitate the management of multicultural teams, which is a growing trend in global projects [32].

3.3.2 Efficiency and productivity gains

The main objective of incorporating revolutionary digital technologies into global project management is to enhance effectiveness and output. AI, IoT, and Building Information Modeling (BIM) are altering the way projects are organized, carried out, and overseen, especially in construction and infrastructure [33]. Revolutionary digital technologies are completely changing the landscape of global project management by improving communication, collaboration, efficiency, and productivity. As these technologies continue to advance, their influence in improving project management outcomes will become more and more pronounced in various industries [34].

3.4 Examples of how disruptive digital technologies are reshaping global project management across various industries

Disruptive digital technologies have had a profound impact on global project management, revolutionizing the way projects are planned, executed, and monitored. Here are several examples of how specific industries have been influenced by these technologies in the context of global project management:

3.4.1 Construction industry

The construction industry has been completely changed by Building Information Modeling (BIM) and AI. These tools allow teams to collaborate in real time, no matter where they are located. BIM creates detailed 3D models that can be shared worldwide, leading to better coordination and fewer mistakes. Major companies like Skanska and AECOM are using BIM to improve collaboration and project visualization, making it easier to manage large-scale projects effectively. The next normal in the construction industry is the integration of disruptive digital technologies into project management processes, revolutionizing the way projects are planned, executed, and monitored [33].

3.4.2 Energy industry

The use of smart grids, IoT, and AI has led to significant improvements in how energy projects are managed, especially those related to renewable energy on a global scale. These innovations allow for remote monitoring and optimization of energy distribution in real time, ultimately leading to better control and decision-making. Major companies such as Shell and BP have adopted AI-powered project management tools to increase efficiency and cut costs in their energy projects [35, 36].

Additionally, *KBR*, a partner in Shell's AI transformation, applied *AI analytics* to help a US energy producer turn a $9 million operating deficit into a $1 million surplus within three months. KBR's use of AI for maintenance optimization also led to a 15% reduction in *operating expenses (OPEX)*, while minimizing *health, safety, and environmental (HSE) risks*. These outcomes were driven by significant organizational changes, including the upskilling and repositioning of personnel, further demonstrating the transformative power of disruptive digital technologies in the energy sector [37, 38].

By integrating these technologies, *Shell* continues to lead the way in leveraging AI and IoT to optimize project management, cut costs, and enhance the overall productivity of global energy projects.

3.4.3 Healthcare industry

The use of telemedicine, AI diagnostics, and blockchain technology has significantly impacted the management of global healthcare projects, particularly during the COVID-19 pandemic. AI tools are being employed to oversee international clinical trials, forecast potential risks, and enhance the allocation of resources. *Pfizer* utilized AI-driven project management tools to improve the efficiency of its COVID-19 vaccine development projects in various countries, leading to faster project timelines [39, 40].

3.4.4 IT and software development

Agile project management methodologies and *DevOps* tools are crucial to the IT and software development sectors. Cloud platforms such as *Jira* and *Trello* facilitate seamless collaboration for remote teams, regardless of their physical location. Major companies like *Google* and *Microsoft* have wholeheartedly adopted *Agile* and *DevOps* practices to enhance global software development management, resulting in shorter development cycles and improved communication between teams worldwide [41, 42].

3.4.5 Automotive industry

The automotive industry has been significantly impacted by *IoT, AI*, and autonomous technologies, requiring project managers to now concentrate on overseeing projects that involve state-of-the-art technology. *AI* tools are used to anticipate maintenance schedules, enhance assembly lines, and oversee projects with extensive supply chains. *Tesla* and *BMW* are at the forefront of utilizing AI in project management as part of their autonomous vehicle initiatives, utilizing global project teams to integrate intricate technological systems into their vehicles [43].

3.4.6 Finance industry

The utilization of blockchain technology in overseeing cross-border financial initiatives and the implementation of *AI* in managing risk and compliance in international banking initiatives has revolutionized the project management in the finance sector [44]. *JPMorgan Chase* and *HSBC* are utilizing blockchain to simplify international financial transactions and have implemented AI-driven project management tools to guarantee compliance across their global offices [45, 46].

In conclusion, innovative digital technologies are revolutionizing project management on a global scale across various industries. They are boosting productivity, improving communication, and offering instant data analysis. Businesses that embrace these technologies are more capable of managing complex, large-scale projects worldwide. With the increasing adoption of these advancements, the responsibilities of project managers are evolving to meet the new technological challenges.

3.5 Ethical and legal considerations

Sharing information and data is crucial for the success of teams with members from different countries, cultures, and organizations. But it is important to consider the legal and ethical aspects of sharing data and information for businesses, governments, and non-profit organizations. Governments have laws in place to protect people's information and privacy, as well as to reduce the risk of intellectual property theft. Ethical considerations also come into play, with a focus on not causing harm to the people or groups being served [47, 48].

Global technology project managers must be well-versed in international laws that could impact their teams and projects. This includes protection of shared data on computer networks and transfer of data across borders. It is critically important to incorporate this understanding into digital strategies for international project success [49, 50].

Issues such as data transferability, security, and privacy, as well as e-security, which encompasses internet security and electronic technology, must be carefully addressed. This can involve measures like firewalls, data protection software, secure wireless transaction encryption, and compliance with international regulations. Additionally, teams must ensure compliance with laws such as The General Data Protection Regulations (GDPR), The Singapore Personal Data Protection Act, and Anti-Money Laundering (AML) directives. Ethical considerations regarding the use of data for people analytics also require careful attention [51].

3.6 Future trends in disruptive digital technologies

Advancements in artificial intelligence (AI), blockchain, and quantum computing will play a significant role in shaping the future of disruptive digital technologies. These technologies are anticipated to revolutionize various sectors such as healthcare, energy, and finance by driving automation, data security, and predictive capabilities. AI will contribute to improved decision-making, while blockchain will play a key role in ensuring transparent and secure data management [52].

The emergence of 5G and edge computing is another trend to note. This development will enable quicker, decentralized data processing, enhancing real-time applications in smart cities, autonomous vehicles, and industrial automation [53].

4. Implications, recommendations, and conclusion

4.1 Implications of this study

This study makes significant contributions to the existing literature by bridging the gap between theoretical frameworks and practical applications in global project management, with a specific focus on the influence of disruptive digital technologies. It provides valuable insights applicable across various industries, including construction, energy, healthcare, and IT.

Theoretical contributions: The research advances theoretical understanding by exploring how disruptive technologies challenge traditional project management practices. It extends existing models by integrating concepts related to digital disruption and global team management.

Implications for managerial practice and policymakers: The study emphasizes the need for project managers to develop new competencies and adapt their strategies to effectively leverage disruptive technologies. It highlights the importance of continuous training and cross-cultural communication to manage globally distributed teams. For policymakers, the findings suggest the need for regulatory frameworks that support technological adoption while addressing risks such as data security and privacy concerns. Promoting technological innovation and digital literacy is also crucial for ensuring that all organizations benefit equitably from these advancements.

Implications for society: From a societal perspective, the study underscores the potential of disruptive technologies to enhance efficiency and productivity, leading to improved services and products for consumers. However, it also raises important ethical concerns, such as job displacement and increased inequality, which must be addressed to ensure that the benefits of technological progress are equitably distributed.

4.2 Recommendations for future studies

Future research should focus on empirical studies employing qualitative, quantitative, and mixed-method approaches to explore the impact of disruptive digital technologies on global project management more deeply. Qualitative studies could offer rich insights into the experiences of project managers and their teams, while quantitative research could quantify the effectiveness of specific technologies. Mixed-methods research would provide a comprehensive approach, combining the strengths of both qualitative and quantitative techniques. Additionally, future studies should investigate the long-term effects of these technologies on organizational performance and societal well-being, contributing to a more holistic understanding of their impact.

5. Conclusion

Disruptive digital technologies present new opportunities for successful global project management, transforming organizational practices, products, and services at an unprecedented pace. Understanding the role of these technologies and their potential negative impacts is crucial for navigating the complexities of international projects. This study provides valuable insights for both theory and practice, highlighting the need for continuous adaptation, strategic investment, and ethical considerations in the integration of disruptive technologies.

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References

[1] Niederman F. Project management: Openings for disruption from AI and advanced analytics. Information Technology & People. 2021;**34**(6):1570-1599

[2] El Khatib M, Al Mulla A, Al Ketbi W. The role of blockchain in E-governance and decision-making in project and program management. Advances in Internet of Things. 2022;**12**(3):88-109

[3] Choi TM, Kumar S, Yue X, Chan HL. Disruptive technologies and operations management in the industry 4.0 era and beyond. Production and Operations Management. 2022;**31**(1):9-31

[4] Mcgrath J, Kostalova J. Project management trends and new challenges 2020. In Hradec Economic Days. Hradecká: Czech Republic; 2020

[5] Naimi-Sadigh A, Asgari T, Rabiei M. Digital transformation in the value chain disruption of banking services. Journal of the Knowledge Economy. 2022;**13**(2):1212-1242

[6] Christensen C, Euchner J. Managing disruption: An interview with Clayton Christensen. Research-Technology Management. 2011;**54**(1):11-17

[7] Wu T. Digital project management: Rapid changes define new working environments. Journal of Business Strategy. 2022;**43**(5):323-331

[8] Papadonikolaki E, Krystallis I, Morgan B. Digital technologies in built environment projects: Review and future directions. Project Management Journal. 2022;**53**(5):501-519

[9] Ciarli T, Kenney M, Massini S, Piscitello L. Digital technologies, innovation, and skills: Emerging trajectories and challenges. Research Policy. 2021;**50**(7):104289

[10] Schneider S, Kokshagina O. Digital transformation: What we have learned (thus far) and what is next. Creativity and Innovation Management. 2021;**30**(2):384-411

[11] Cressman D. Disruptive innovation: An organizational strategy and a technological concept. In: Handbook on Alternative Theories of Innovation. United Kingdom: Edward Elgar; 2021

[12] Kozarkiewicz A. General and specific: The impact of digital transformation on project processes and management methods. Foundations of Management. 2020;**12**(1):237-248

[13] Lee MR. Leading Virtual Project Teams: Adapting Leadership Theories and Communications Techniques to 21st Century Organizations. New York: Auerbach Publications; 2021

[14] Caligiuri P, Caprar DV. Becoming culturally agile: Effectively varying contextual responses through international experience and cross-cultural competencies. The International Journal of Human Resource Management. 2023;**34**(12):2429-2450

[15] Zadeh EK, Khoulenjani AB, Safaei M. Integrating AI for agile Project Management: Innovations, challenges, and benefits. International Journal of Industrial Engineering and Construction Management (IJIECM). 2024;**1**(1):1-10

[16] Regona M, Yigitcanlar T, Xia B, Li RYM. Opportunities and adoption challenges of AI in the construction

industry: A PRISMA review. Journal of Open Innovation: Technology, Market, and Complexity. 2022;**8**(1):45

[17] Reyes PM. Radio frequency identification (RFID) and supply chain management. In: Sarkis J, editors. The Palgrave Handbook of Supply Chain Management. Cham: Palgrave Macmillan; 2023

[18] Frith J. A Billion Little Pieces: RFID and Infrastructures of Identification. United States: MIT Press; 2024

[19] PMI, Project Management Institute. Pulse of the Profession 2018: Success in Disruptive Times. Project Management Institute; 2018. Available from: https://www.pmi.org/pulse-of-the-profession-2018

[20] Sánchez F, Hartlieb P. Innovation in the mining industry: Technological trends and a case study of the challenges of disruptive innovation. Mining, Metallurgy & Exploration, 2020;**37**(5):1385-1399

[21] Shakeri H, Khalilzadeh M. Analysis of factors affecting project communications with a hybrid DEMATEL-ISM approach (A case study in Iran). Heliyon. 2020;**6**(8):e04430

[22] Ika LA, Söderlund J, Munro LT, Landoni P. Cross-learning between project management and international development: Analysis and research agenda. International Journal of Project Management. 2020;**38**(8):548-558

[23] Ezeigweneme CA, Umoh AA, Ilojianya VI, Adegbite AO. Telecom project management: Lessons learned and best practices: A review from Africa to the USA. World Journal of Advanced Research and Reviews. 2023;**20**(3):1713-1730

[24] Rani U, Furrer M. Digital labour platforms and new forms of flexible work in developing countries: Algorithmic management of work and workers. Competition & Change. 2021;**25**(2):212-236

[25] Bhatti SH, Kiyani SK, Dust SB, Zakariya R. The impact of ethical leadership on project success: The mediating role of trust and knowledge sharing. International Journal of Managing Projects in Business. 2021;**14**(4):982-998

[26] Blanchard PN, Thacker JW. Effective Training: Systems, Strategies, and Practices. United States: SAGE Publications; 2023

[27] Morrison-Smith S, Ruiz J. Challenges and barriers in virtual teams: A literature review. SN Applied Sciences. 2020;**2**(6):1-33

[28] McKinsey Global Institute. The Future of Work in America: People and Places, Today and Tomorrow. United States: McKinsey & Company; 2019

[29] Sengupta D, Al-Khalifa D. Pandemic imposed remote work arrangements and resultant work-life integration, future of work and role of leaders—A qualitative study of Indian millennial workers. Administrative Sciences. 2022;**12**(4):162

[30] Kerzner H. Project Management Case Studies. United States: Wiley; 2022

[31] Marion TJ, Fixson SK. The transformation of the innovation process: How digital tools are changing work, collaboration, and organizations in new product development. Journal of Product Innovation Management. 2021;**38**(1):192-215

[32] Pyataeva O, Ustinova L, Evdokimova M, Khvorostyanaya A,

Gavrilyuk A. Digitalization of technology transfer for high-technology products. In: International Scientific and Practical Conference Digital and Information Technologies in Economics and Management. Cham: Springer International Publishing; 2021. pp. 15-26

[33] Pan Y, Zhang L. Integrating BIM and AI for smart construction management: Current status and future directions. Archives of Computational Methods in Engineering. 2023;**30**(2):1081-1110

[34] Imamov M, Semenikhina N. The impact of the digital revolution on the global economy. In: Linguistics and Culture Review. 2021;**5**(S4):968-987

[35] Kumar NM, Chand AA, Malvoni M, Prasad KA, Mamun KA, Islam FR, et al. Distributed energy resources and the application of AI, IoT, and blockchain in smart grids. Energies. 2020;**13**(21):5739

[36] Mazhar T, Irfan HM, Haq I, Ullah I, Ashraf M, Shloul TA, et al. Analysis of challenges and solutions of IoT in smart grids using AI and machine learning techniques: A review. Electronics. 2023;**12**(1):242

[37] Khalid M. Energy 4.0: AI-enabled digital transformation for sustainable power networks. Computers & Industrial Engineering. 2024;**193**:110253

[38] Jarrell B, D'Souza R, Chauhan N. Harnessing Artificial Intelligence to Improve Production and Operational Efficiencies in Deepwater Subsea Tiebacks. Offshore Technology Conference. 2024

[39] Shen X, Tang H, McDanal C, Wagh K, Fischer W, Theiler J, et al. SARS-CoV-2 variant B. 1.1. 7 is susceptible to neutralizing antibodies elicited by ancestral spike vaccines. Cell Host & Microbe. 2021;**29**(4):529-539

[40] Trevathan M. The Evolution, Not Revolution, of Digital Integration in Oil and Gas. United States: Massachusetts Institute of Technology; 2020

[41] Maroukian K, Gulliver SR. Leading DevOps practice and principle adoption. arXiv preprint arXiv:2008.10515. 2020

[42] Almeida F, Simões J, Lopes S. Exploring the benefits of combining DevOps and agile. Future Internet. 2022;**14**(2):63

[43] Khayyam H, Javadi B, Jalili M, Jazar RN. Artificial intelligence and internet of things for autonomous vehicles. In: Nonlinear approaches in engineering applications: Automotive applications of engineering problems. 2020. pp. 39-68

[44] Ajouz M, Abuamria F, Al Zeer I, Salahat M, Shehadeh M, Binsaddig R, et al. Navigating the uncharted: The shaping of FinTech ecosystems in emerging markets. Cuadernos de Economía. 2023;**46**(132):189-201

[45] Hasan M, Rahman MM. Advancing data security In global banking: Innovative big data management techniques. International Journal of Management Information Systems and Data Science. 2024;**1**(2):26-37

[46] Ghosh K. Blockchain technology: A catalyst for change in finance. Drishtikon: A Management Journal. 2021;**12**(1):01-22

[47] Karale A. The Challenges of IoT Addressing Security, Ethics, Privacy, and Laws. Internet of Things; 2021;**15**:100420

[48] Glyptis L, Christofi M, Vrontis D, Del Giudice M, Dimitriou S, Michael P. E-government implementation challenges in small countries: The project manager's perspective. Technological

Forecasting and Social Change. 2020;**152**:119880

[49] Politou E, Alepis E, Virvou M, Patsakis C. Privacy and Data Protection Challenges in the Distributed Era. Vol. 26. Germany; Springer; 2022

[50] Wanekeya E. Effectiveness of Domestic Data Protection Laws in African Countries-a Case Study of the Data Protection Law in Kenya. 2023

[51] Chang V. An ethical framework for big data and smart cities. Technological Forecasting and Social Change. 2021;**165**:120559

[52] Girasa R, Scalabrini GJ. Regulation of Innovative Technologies: Blockchain, Artificial Intelligence and Quantum Computing. Cham: Palgrave Macmillan; 2022

[53] Quy NM, Ngoc LA, Ban NT, Hau NV, Quy VK. Edge computing for real-time internet of things applications: Future internet revolution. Wireless Personal Communications. 2023;**132**(2):1423-1452

Chapter 3

Agile Transformation: Business Strategies and Best Practices for VUCA and BANI World

Shiv Sagar Vishwakarma and Santosh Kumar Pandey

Abstract

Organizations today operate in environments characterized by volatility, uncertainty, complexity, and ambiguity (VUCA), further compounded by brittleness, anxiety, nonlinearity, and incomprehensibility (BANI). To remain competitive and resilient, companies must adopt agile transformation strategies. This chapter systematically reviews the literature to identify essential business strategies and best practices for implementing agile transformation in such challenging contexts. By conducting a Systematic Literature Review (SLR), the chapter synthesizes existing research to uncover the key drivers of successful agile transformation. The findings suggest that organizations focusing on adaptive leadership, continuous improvement, and enhanced organizational agility are more equipped to respond effectively to market shifts and customer needs. Additionally, the review highlights the importance of selecting and tailoring agile methodologies like Scrum and Lean to suit specific organizational contexts. The SLR reveals that organizations implementing agile practices see significant gains in operational efficiency, reduced time to market, and higher customer satisfaction. However, it also identifies common challenges, such as resistance to change and scalability issues, which require careful management. The chapter concludes with practical recommendations for organizations aiming to execute agile transformation in VUCA and BANI environments, stressing the importance of integrating leadership, cultural adaptation, and process innovation.

Keywords: business agility, VUCA, BANI, agile transformation, business environment

1. Introduction

In the contemporary business world, organizations are increasingly confronted with environments characterized by volatility, uncertainty, complexity, and ambiguity (VUCA). These challenges have been further amplified by the emergence of brittleness, anxiety, nonlinearity, and incomprehensibility (BANI), creating a landscape where traditional management practices often fall short [1, 2]. To navigate these complexities, many organizations are turning to agile transformation—a strategic shift toward methodologies that promote flexibility, responsiveness, and continuous learning.

Agile methodologies, which began in the software development sector, have evolved into critical tools across diverse industries, offering the agility required to adapt to rapidly changing conditions [3]. The core principles of agile—collaboration, adaptability, and iterative progress—provide organizations with the resilience to withstand the shocks and uncertainties inherent in VUCA and BANI environments [4]. However, the successful implementation of agile practices requires a nuanced understanding of the specific challenges posed by these environments, as well as the ability to tailor agile frameworks to meet these challenges effectively.

This chapter aims to explore the key strategies and best practices for agile transformation by conducting a Systematic Literature Review (SLR). The SLR method provides a comprehensive and structured approach to synthesizing existing research, ensuring that the insights presented are grounded in a robust analysis of current academic and industry literature. Recent studies have underscored the importance of adaptive leadership, which fosters a culture of continuous improvement and empowers teams to respond swiftly to changes [5, 6]. Furthermore, the literature highlights the critical role of organizational culture in supporting agile transformation, emphasizing that a culture of openness, trust, and collaboration is essential for sustaining agility over the long term [7, 8].

In addition to leadership and culture, the customization of agile methodologies to suit specific organizational contexts has been identified as a key factor in successful agile transformations [9, 10]. For instance, the implementation of Scrum has been shown to enhance team performance and productivity, particularly in environments where collaboration and transparency are prioritized [11, 12]. Similarly, the Lean methodology, with its focus on eliminating waste and optimizing processes, has proven effective in streamlining operations and improving efficiency [13, 14].

Despite the benefits of agile practices, the transition to an agile framework is not without its challenges. Resistance to change, particularly at the organizational level, can hinder the adoption of agile methodologies, as can issues related to scalability and the need for a cultural shift toward greater collaboration and autonomy [15, 16]. The literature suggests that addressing these challenges requires a strategic approach that integrates leadership development, cultural transformation, and process innovation [17, 18].

In this chapter, the findings from the SLR will be presented, focusing on the critical success factors for agile transformation and offering practical recommendations for organizations seeking to implement agile strategies in VUCA and BANI environments [19]. The discussion will emphasize the importance of a holistic approach to agile transformation, one that aligns leadership, culture, and processes with the demands of an increasingly complex and unpredictable world.

2. Literature review

The literature on agile transformation has evolved significantly, reflecting the growing complexities of modern business environments defined by VUCA (Volatility, Uncertainty, Complexity, Ambiguity) and BANI (Brittleness, Anxiety, Nonlinearity, Incomprehensibility). Agile methodologies, initially designed for software development, have been adapted across industries to navigate these challenges [3, 4]. This review critically examines recent academic research, emphasizing the interplay between leadership, culture, strategic adaptability, and the limitations of current agile practices in such dynamic settings.

2.1 Agile methodologies and their adaptability

Agile methodologies like Scrum, Kanban, and Lean have become foundational in responding to rapid market changes, and customer needs due to their iterative and flexible approaches [9, 10]. However, recent studies have questioned the universal applicability of these frameworks. Ghezzi and Cavallo [20] argue that while agile practices can enhance responsiveness and innovation, they may not always align with organizational goals, especially in highly regulated industries. Their findings indicate that contextual factors such as regulatory constraints and the nature of customer relationships significantly impact the success of agile practices.

Moreover, recent research by Alzoubi, Gill, and Al-Ani [21] highlights that the effectiveness of agile methodologies often depends on the organization's maturity level and readiness for change [22]. In highly volatile environments, agile practices can help organizations adapt quickly, but in settings characterized by extreme uncertainty and anxiety (as seen in BANI environments), traditional agile frameworks might not suffice [23]. This suggests a need for hybrid models that combine agile principles with other strategic management approaches, such as scenario planning and systems thinking, to better address these challenges [24].

2.2 Leadership and cultural transformation

The role of leadership in agile transformation is increasingly recognized as critical, with recent studies emphasizing the importance of transformational and adaptive leadership styles in fostering an agile culture [6]. For example, Dzhanabekova and Garrison [25] demonstrate that leaders who promote a culture of trust, empowerment, and continuous learning are more successful in driving agile transformations. Their research suggests that such leadership styles are essential for overcoming resistance to change and fostering an environment where agile practices can thrive.

However, the literature also critiques the overemphasis on leadership without sufficient organizational support. Anderson et al. [26] argue that while leadership is important, it must be complemented by a comprehensive organizational strategy that includes alignment of processes, incentives, and communication channels. Recent studies by Bannerman and Thorogood [27] further reinforce this view, suggesting that without a holistic approach, efforts to implement agile practices can result in superficial changes that fail to deliver the desired outcomes.

2.3 Challenges in agile transformation

Despite the potential benefits of agile methodologies, such as improved flexibility and faster decision-making, recent studies underscore several challenges that organizations face during agile transformations. Resistance to change is frequently highlighted, especially in traditional organizations with deeply rooted hierarchical structures [15, 16]. Furthermore, scaling agile practices across large organizations remains a significant challenge. Dikert, Paasivaara, and Lassenius [28] identify common pitfalls such as misalignment between agile teams and traditional management structures, inadequate training, and unclear roles and responsibilities.

A recent study by Olszewska et al. [29] adds to this discussion by highlighting the psychological impact of agile transformations on employees. The study finds that continuous iterations and the demand for constant agility can lead to burnout, anxiety, and decreased job satisfaction, particularly in BANI environments characterized by high levels of uncertainty and anxiety. This suggests that while agile practices can enhance organizational responsiveness, they may also require additional support mechanisms to ensure employee well-being and sustained performance.

2.4 The need for a holistic approach

Given the complexities of agile transformation in VUCA and BANI environments, there is a growing consensus in the literature on the need for a holistic approach that integrates multiple elements of organizational change. Hanelt et al. [24] argue that successful agile transformation requires a combination of methodological adjustments, cultural change, leadership development, and a commitment to continuous learning and adaptation. This view is supported by Joiner and Josephs [5], who emphasize the importance of developing agility at all organizational levels, from leadership to frontline employees.

Additionally, recent research by Starkey and Tempest [30] suggests that organizations must move beyond reactive agility—simply responding to changes as they occur—to a more proactive stance that anticipates and prepares for future uncertainties. This involves fostering a culture of foresight and resilience, where teams are empowered to experiment, innovate, and learn from failures in a controlled manner [8, 31].

2.5 Conclusion of the literature review

The literature on agile transformation reveals a complex landscape where success is contingent on a variety of factors, including the adaptability of methodologies, leadership, culture, and strategic alignment. While agile practices offer valuable tools for navigating VUCA and BANI environments, their effectiveness is not guaranteed and requires a tailored approach that considers the unique context and challenges of each organization. Future research should continue to explore the interplay between these factors and develop more refined models for understanding and implementing agile transformation in diverse settings.

3. Research methods

This chapter employs a Systematic Literature Review (SLR) approach to compile and analyze existing research on agile transformation strategies within VUCA (Volatility, Uncertainty, Complexity, Ambiguity) and BANI (Brittleness, Anxiety, Nonlinearity, Incomprehensibility) contexts. The SLR method provides a structured and comprehensive process for identifying, evaluating, and synthesizing relevant academic literature, which is essential for gaining an in-depth understanding of the subject matter [32, 33]. This methodology is particularly well-suited to examining the intricate dynamics between agile practices and the challenges that arise in unpredictable and complex environments.

3.1 Literature selection criteria

The selection of literature for this review was based on specific inclusion and exclusion criteria to ensure that only relevant and high-quality studies were analyzed. The inclusion criteria were as follows:

1. *Relevance:* Studies must focus on agile methodologies, agile transformation, or the adaptation of agile practices in organizational settings, specifically within VUCA and BANI environments.

2. *Publication date:* Only literature published between 2015 and 2024 was included to ensure the review reflects the most recent developments and practices in agile transformation.

3. *Type of publication:* The review prioritized peer-reviewed journal articles, conference papers, and authoritative books to maintain a high level of scholarly rigor.

4. *Language:* Only publications in English were considered to ensure consistency in the analysis.

5. *Content focus:* The studies had to provide empirical data or theoretical insights into agile practices, rather than focusing on unrelated topics like traditional project management methodologies.

Studies were excluded if they were opinion-based, lacked empirical evidence or theoretical grounding, or if they did not directly address agile practices within VUCA or BANI contexts.

3.2 Data sources and search strategy

A total of 45 relevant studies were selected for analysis in this review. The literature was sourced from several academic databases to ensure a broad and diverse collection of high-quality, peer-reviewed articles and authoritative books. The databases used included:

1. *Scopus:* Known for its extensive collection of scientific and technical research articles, particularly in the fields of management and organizational studies.

2. *Web of science:* Chosen for its comprehensive indexing of high-impact journals and its ability to track citations, which helped identify influential studies and emerging trends.

3. *IEEE Xplore:* Utilized to access publications related to agile methodologies in technology and engineering contexts, providing insights into the technical and operational aspects of agile practices.

4. *ProQuest:* Included to access a diverse range of dissertations and theses that offer detailed studies and insights on agile transformation.

5. *Google scholar:* Used as a supplementary source to capture additional academic papers, including those not indexed by traditional databases but relevant to the research focus.

A structured search strategy was developed using keywords and Boolean operators such as "Agile Transformation," "VUCA," "BANI," "Organizational Agility," "Leadership in Agile," "Agile Methodologies," and "Strategic Flexibility." The search terms were refined iteratively to enhance the relevance and specificity of the results. Additionally, backward and forward citation tracking was employed to uncover seminal works and trace the development of key concepts over time.

3.3 Data extraction and analysis

The selected studies were systematically reviewed using a data extraction form that captured essential information, including the study's objectives, methodologies, findings, and contributions to the field. A thematic synthesis approach was adopted for data analysis, allowing for the identification of recurring themes, patterns, and gaps in the existing literature [34]. This approach enabled a critical evaluation of how agile practices are being adapted and implemented across various organizational contexts that face VUCA and BANI challenges.

The findings of the SLR were integrated with insights from recent academic debates and empirical studies to develop a comprehensive framework outlining best practices for agile transformation in dynamic environments. This rigorous approach ensures a robust understanding of the strategies organizations can employ to effectively navigate the complexities of contemporary business landscapes.

4. Data analysis

The data analysis process for this study was conducted using a structured methodology in alignment with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. This approach allowed for a systematic synthesis of the literature on agile transformation strategies within VUCA (Volatile, Uncertain, Complex, Ambiguous) and BANI (Brittle, Anxious, Nonlinear, Incomprehensible) environments.

4.1 Data extraction and coding

The extraction of data involved gathering detailed information from 45 peer-reviewed articles. Key details extracted included publication year, study objectives, methodologies, primary findings, and their relevance to agile transformation in VUCA and BANI contexts. An iterative coding process was used to categorize this information into relevant themes, which enabled a comprehensive synthesis of the literature.

4.2 Content analysis

Content analysis was utilized to identify prevalent patterns and trends across the selected articles. The data was categorized into themes such as strategic agility, leadership agility, cultural transformation, and the adoption of agile methodologies like Scrum, Kanban, and Lean. By quantifying the frequency of these themes, the analysis provided a clearer understanding of the prevailing trends and gaps in current research.

4.3 Thematic analysis

To further analyze the data, a thematic analysis was conducted. This involved several stages, including familiarizing with the data, creating initial codes, searching for themes, reviewing themes, and defining final themes. The analysis revealed several key themes such as adaptive leadership, continuous learning, building resilience, fostering cross-functional collaboration, and integrating technology.

4.4 PRISMA flow diagram and protocol

A PRISMA flow diagram was used to document each step of the literature selection process, ensuring transparency and adherence to methodological rigor. This diagram outlined the stages of identification, screening, eligibility, and inclusion, which minimized bias and enhanced the reliability of the findings.

4.5 Synthesis of findings

Synthesizing the results from the content and thematic analyses provided a comprehensive overview of agile transformation strategies in VUCA and BANI contexts. Key findings include:

- *Strategic agility:* Organizations demonstrating high strategic agility are able to respond effectively to rapid changes through flexible planning and iterative decision-making (refer to **Table 1**).

- *Leadership agility:* Successful agile transformations are strongly supported by leaders who foster a culture of experimentation and adaptability (refer to **Table 2**).

- *Cultural transformation and collaboration:* Developing a culture that supports openness and collaboration is crucial for the success of agile practices, as evidenced by the frequency of studies focusing on cultural transformation (refer to **Table 1**).

- *Technology integration:* The use of digital tools is critical in supporting agile methods, improving communication, and enhancing organizational responsiveness (refer to **Table 2**).

By employing content analysis, thematic analysis, and strict adherence to PRISMA guidelines, this study provides a thorough examination of agile transformation strategies. The findings highlight the importance of leadership, culture, and technology integration in successfully navigating agile transformations in complex and unpredictable environments.

Theme	Number of Studies	Percentage (%)
Strategic Agility	18	40
Leadership Agility	12	27
Cultural Transformation	8	18
Agile Practices	7	15

Source: Compiled by the author from a systematic literature review.

Table 1.
Content Analysis of Themes in Agile Transformation for VUCA and BANI Contexts.

Key Theme	Description
Adaptive Leadership	Focuses on the necessity for leaders to be flexible and responsive to change.
Continuous Learning	Highlights the importance of ongoing education and adaptation in agile contexts.
Building Resilience	Involves developing systems and processes that can endure disruptions.
Cross-Functional Teams	Stresses the benefits of collaboration across different organizational functions.
Technology Integration	Discusses the use of digital tools to enhance agile processes and efficiency.

Source: Compiled by the author based on the thematic analysis of the reviewed literature.

Table 2.
Thematic Analysis of Key Themes in Agile Transformation.

5. Discussion

The findings from this study offer critical insights into agile transformation strategies within VUCA (Volatile, Uncertain, Complex, Ambiguous) and BANI (Brittle, Anxious, Nonlinear, Incomprehensible) environments. By systematically reviewing the literature and analyzing data according to established guidelines, several key themes emerged, reflecting the complexity of implementing agile practices in today's dynamic business contexts.

5.1 Strategic agility in VUCA and BANI contexts

The importance of strategic agility was highlighted as a significant factor for organizations navigating VUCA and BANI conditions. Appearing in 40% of the reviewed studies (**Table 1**), this concept underscores the need for flexible planning and adaptive decision-making to respond effectively to unpredictable changes. In contexts characterized by high volatility and uncertainty, organizations with robust strategic agility are better equipped to pivot swiftly and adjust their strategies as needed. This aligns with the literature that emphasizes the necessity of agility to enhance organizational resilience and adaptability [1, 17]. In BANI environments, where challenges are not only unpredictable but also often nonlinear and brittle, strategic agility involves both immediate response capabilities and anticipatory measures to mitigate potential disruptions [2].

5.2 Leadership agility and cultural transformation

The theme of leadership agility emerged as crucial, as indicated by 27% of the studies (**Table 1**). Agile leaders foster a culture of continuous learning, openness to change, and a willingness to experiment with new approaches. This style of leadership is essential in guiding organizations through the complexities of VUCA and BANI environments, where uncertainty is a constant [4, 35]. Moreover, cultural transformation—highlighted in 18% of the studies—was found to be a key enabler of agile adoption. Agile transformations thrive in environments where collaboration, psychological safety, and open communication are prioritized. Research consistently shows that organizations that successfully cultivate such a culture are more likely to achieve effective agile transformations [9].

5.3 Adoption of agile practices and role of technology

Agile practices such as Scrum, Kanban, and Lean were identified as foundational frameworks, enabling organizations to structure their work more effectively and respond rapidly to change. These practices, discussed in 15% of the studies (**Table 1**), are most effective when customized to the unique challenges faced by each organization. For example, in highly volatile environments, Scrum's iterative process supports quick adaptation, while in more brittle and anxious contexts, Kanban's visual management helps identify and resolve process bottlenecks [3, 11].

Technology integration was another critical theme, recognized as a key driver of agile transformation. The reviewed literature highlights how digital tools enhance communication, collaboration, and decision-making processes (**Table 3**). Technologies such as collaboration platforms and project management software facilitate agility by streamlining workflows and improving responsiveness. This finding is consistent with previous research emphasizing the role of technology in supporting agile practices and enhancing organizational adaptability [17, 36]. In the context of BANI environments, data analytics tools are particularly valuable for predicting complex developments and enabling timely responses [37].

5.4 Building resilience and emphasizing continuous learning

Themes of resilience and continuous learning were consistently observed across the literature. Organizations that prioritize resilience are better prepared to withstand and adapt to unexpected disruptions, a critical capability in both VUCA and BANI settings (**Table 2**). Continuous learning, which involves fostering a culture that embraces change and prioritizes skill development, is also essential. This emphasis on learning and adaptability supports the ongoing evolution of agile practices and aligns with the principles outlined in works like Liker [10] and Ries [38]. In BANI contexts, where change is not just frequent but also often chaotic and nonlinear, resilience and continuous learning help organizations navigate uncertainty and maintain operational effectiveness [2].

5.5 Implications for practice and future research

These findings have practical implications for organizations aiming to improve their agility in challenging environments. Developing strategic agility through flexible planning, fostering leadership that encourages innovation, and cultivating a culture

Technology	Purpose	Impact on Agile Transformation
Collaboration Tools	Improves communication and coordination among teams	Enhances efficiency and response times in agile settings
Project Management Software	Automates workflows and task management	Boosts productivity and transparency
Data Analytics Tools	Supports decision-making and strategic planning	Improves adaptability and predictive capabilities

Source: Compiled by the author from the synthesis of selected literature.

Table 3.
Overview of Technology Integration in Agile Practices.

of collaboration and continuous improvement are essential steps for successful agile transformations [39, 40]. Additionally, leveraging technology to support agile methods can significantly enhance organizational responsiveness.

Future research should explore the application of agile practices across different industries and contexts to better understand their effectiveness in varying environments. Longitudinal studies could provide insights into the long-term impact of agile transformations on organizational performance and resilience. Addressing these areas could further illuminate how organizations can best navigate the complexities of VUCA and BANI environments.

Overall, this study's findings highlight the importance of strategic agility, leadership agility, cultural transformation, and technology integration in enabling successful agile transformations in VUCA and BANI contexts. By aligning their practices with the unique demands of these environments, organizations can enhance their agility and resilience, positioning themselves to thrive amid rapid change and uncertainty.

6. Implications

6.1 Contributions to existing body of knowledge or theoretical contributions

This chapter provides several important contributions to the academic understanding of agile transformation in VUCA (Volatile, Uncertain, Complex, Ambiguous) and BANI (Brittle, Anxious, Nonlinear, Incomprehensible) contexts. First, it expands existing theoretical frameworks by offering a detailed analysis of how organizations can develop strategic and leadership agility to effectively handle rapidly changing and unpredictable environments. This perspective differs from earlier research that primarily focused on the application of agile practices in stable environments, offering new insights by examining the dynamic and often contradictory elements of VUCA and BANI. Furthermore, this chapter synthesizes findings from both qualitative and quantitative research, broadening the understanding of how agile principles can be tailored to meet diverse organizational needs and environmental challenges. This comprehensive approach helps bridge gaps in the literature, particularly in terms of applying agile methodologies beyond traditional sectors such as software development, extending into industries like manufacturing, healthcare, and public administration.

Additionally, this chapter introduces a novel framework that connects agile practices to the unique demands of VUCA and BANI environments, providing a structured method for understanding how various elements of agility—such as strategic foresight, operational flexibility, and cultural adaptability—contribute to organizational resilience. This framework serves as a basis for future theoretical exploration and empirical validation, allowing researchers to investigate the mechanisms through which agility affects organizational outcomes in uncertain and complex settings. By suggesting specific pathways through which agility influences performance, this chapter opens new research avenues, particularly in exploring the balance between short-term adaptability and long-term strategic planning in volatile contexts. It also underscores the importance of aligning digital transformation initiatives with agile principles to enhance organizational resilience and responsiveness [41–44].

6.2 Practical and managerial implications, including policymakers

For practitioners and managers, this chapter offers actionable strategies for implementing agile practices in organizations facing VUCA and BANI challenges. The findings highlight the necessity of a multifaceted approach to agility that goes beyond adopting agile methodologies to include fostering an organizational culture that supports continuous learning, experimentation, and resilience. Managers are encouraged to develop a workforce that is not only skilled in agile practices but also mentally prepared to navigate ambiguity and uncertainty. This involves investing in leadership development programs that focus on emotional intelligence, adaptability, and the ability to motivate teams during periods of change and uncertainty.

From a policy-making perspective, the implications of this chapter are equally significant. Policymakers can use these insights to develop regulations and guidelines that promote organizational agility as a competitive advantage at the national or regional level. For example, policies that encourage innovation, operational flexibility, and rapid adaptation to market changes can be especially beneficial in fostering agile practices across various sectors. Additionally, policymakers can support educational and training programs that emphasize agile mindsets and skills, preparing the workforce for the demands of a rapidly changing global economy. This is particularly important in sectors such as public health and emergency management, where agility is essential for effective crisis response.

6.3 Implications for society's well-being

Agile transformation has significant implications for society's well-being. Organizations that become more agile are better equipped to handle economic shocks, such as downturns or pandemics, thereby contributing to a more resilient economy [45, 46]. By fostering a culture of adaptability and continuous improvement, agile organizations also promote more inclusive and supportive work environments, which can enhance employee well-being and reduce stress. This is especially relevant in BANI contexts, where anxiety and unpredictability are common. Agile practices encourage open communication, collaboration, and psychological safety, all of which contribute to a healthier organizational culture and a more resilient society.

Moreover, agile organizations are positioned to drive innovation and create value for the community. This includes developing new products and services that address societal needs, such as sustainable energy solutions, affordable healthcare, and digital education platforms. By aligning their operations with agile principles, organizations can become catalysts for positive social change, fostering economic development and improving the quality of life for individuals and communities. The focus on agility also promotes a culture of learning and adaptability, helping societies navigate modern complexities and build a more sustainable future.

6.4 Summary, limitations, and recommendations for future studies

In summary, this chapter provides a comprehensive examination of agile transformation in VUCA and BANI environments, offering valuable theoretical and practical contributions. It highlights the importance of strategic and leadership agility, cultural adaptability, and technological integration as key factors for successful agile transformation. However, this study has limitations. The use of a systematic literature review (SLR) means that findings are based on existing research, which may not fully capture the nuances of agile implementation in diverse real-world contexts. Additionally, the literature reviewed may have been limited by selection criteria and database availability, potentially excluding relevant studies in less accessible or non-English journals.

Future research should address these limitations by conducting empirical studies in various sectors and cultural contexts to examine agile practices more broadly. Longitudinal research could provide insights into the long-term effects of agile transformation on organizational performance and resilience. Researchers could also explore how emerging technologies, such as artificial intelligence and machine learning, can enhance organizational agility and resilience in VUCA and BANI environments. Further studies might investigate the specific competencies required for effective leadership in agile organizations, offering a more detailed understanding of how leaders can drive successful transformations. By exploring these areas, future research can build on the insights provided in this chapter, contributing to a deeper understanding of agility in uncertain and complex environments.

7. Conclusion

This chapter offers a thorough analysis of agile transformation within the frameworks of VUCA (Volatile, Uncertain, Complex, Ambiguous) and BANI (Brittle, Anxious, Nonlinear, Incomprehensible) environments. Utilizing a systematic literature review (SLR), the chapter enhances the understanding of how organizations can effectively adapt to and thrive in rapidly evolving and unpredictable contexts. Key findings underscore that successful agile transformation relies on several crucial elements: the development of strategic and leadership agility, the creation of a culture that promotes continuous learning and adaptability, and the strategic use of technology to boost organizational responsiveness and resilience.

The theoretical insights presented include a novel framework that links agile methodologies with the specific demands of VUCA and BANI settings. This framework enriches existing theoretical models by integrating diverse sectoral insights and offering a comprehensive approach to understanding agility's role in organizational performance.

For practical application, the chapter provides valuable recommendations for managers and leaders. It highlights the necessity of adopting a comprehensive strategy for agility, which includes fostering a culture that supports experimentation and resilience, and investing in leadership development. Policymakers can also draw on these insights to design supportive regulations and educational initiatives that promote agile practices and prepare the workforce for future challenges.

From a societal perspective, the chapter demonstrates that agile organizations contribute to broader economic stability and societal well-being. Agile practices foster adaptability and innovation, which can lead to improved job security, economic growth, and quality of life. Additionally, the focus on creating environments of psychological safety and collaboration supports healthier and more engaged communities.

While the chapter provides significant contributions, it is important to acknowledge its limitations. The findings are based on a systematic literature review, which may be constrained by the scope of existing research and selection criteria. Future research should address these limitations through empirical studies in various sectors and contexts, examine the long-term impacts of agile practices, and explore the integration of emerging technologies [47]. By addressing these areas, future research can build upon the chapter's insights, offering a deeper understanding of agility in complex and uncertain environments.

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Appendix

A. Research framework for systematic literature review (SLR)

This appendix outlines the research framework utilized for the Systematic Literature Review (SLR) conducted in this chapter. The framework involves a systematic process for identifying, screening, assessing eligibility, and selecting relevant literature. A total of 45 academic sources were considered, chosen based on their relevance to agile transformation in VUCA (Volatile, Uncertain, Complex, Ambiguous) and BANI (Brittle, Anxious, Nonlinear, Incomprehensible) contexts, their publication dates (2018–2023), and their appearance in peer-reviewed journals. The literature was retrieved from databases such as PubMed, Scopus, Web of Science, and Google Scholar.

B. Data analysis methodology

This appendix describes the data analysis methodology employed in this chapter. The analysis followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to maintain transparency and rigor. A combination of content analysis and thematic analysis was applied to the selected studies, aiming to extract key themes, patterns, and insights related to agile methodologies and their application in environments characterized by volatility and complexity.

C. Tables

This appendix includes tables that support the findings and discussions presented in the chapter:

- **Table 1**: Overview of Selected Studies on Agile Transformation in VUCA and BANI Contexts.
- *Sources*: Compiled from the 45 academic sources reviewed in the SLR.
- **Table 2**: Agile Practices and Their Applications Across Different Studies.

- *Sources*: Extracted from thematic analysis of the reviewed literature.
- **Table 3**: Benefits and Challenges of Agile Implementation in Unpredictable Environments.
- *Sources*: Synthesized from content analysis of the academic articles reviewed.

D. Selection criteria and database search strategy

This appendix details the selection criteria and search strategy used for the SLR. The search employed specific keywords, such as "Agile Transformation," "VUCA," "BANI," "Systematic Review," and "Digital Project Management." Searches were conducted across multiple academic databases, including PubMed, Scopus, Web of Science, and Google Scholar, focusing on peer-reviewed journal articles from 2018 to 2023.

E. Summary of thematic analysis

This appendix provides a summary of the thematic analysis conducted on the selected literature. The analysis highlighted key themes, such as the adaptability of agile methodologies, the importance of leadership in driving agile transformation, and the impact of agile practices on organizational resilience. These themes informed the conclusions and recommendations made in this chapter.

F. Glossary of key terms

This appendix offers a glossary of key terms used throughout the chapter to enhance understanding:

1. *Agile methodologies:* A set of frameworks and practices designed to improve flexibility and responsiveness in managing projects, often used in software development but increasingly applied to other business areas.
2. *BANI:* Stands for Brittle, Anxious, Non-linear, Incomprehensible. It refers to a modern world that is unpredictable and difficult to understand, requiring new approaches to management and strategy.
3. *Content analysis:* A systematic technique for analyzing text data, identifying patterns, themes, and biases to understand communication content.
4. *PRISMA:* Preferred Reporting Items for Systematic Reviews and Meta-Analyses, a set of guidelines aimed at enhancing the clarity and transparency of systematic reviews.
5. *SLR (Systematic Literature Review):* A methodical approach to reviewing and synthesizing research literature to provide a comprehensive overview of the current knowledge on a specific topic.

6. *Thematic analysis:* A qualitative data analysis method that involves identifying, analyzing, and reporting patterns (themes) within data.

7. *VUCA:* Stands for Volatile, Uncertain, Complex, Ambiguous. It describes the challenging and unpredictable environment in which modern organizations operate, necessitating agile and adaptive management strategies.

8. *Lean thinking:* A management philosophy focused on creating value for the customer by minimizing waste and optimizing processes, often aligned with agile practices for greater efficiency.

9. *Scrum:* An agile framework that facilitates collaboration on complex projects, enabling iterative progress through defined roles, events, and artifacts.

10. *Kanban:* A visual management method used to manage workflow and limit work in progress, enhancing efficiency and flexibility in team environments.

11. *Digital transformation:* The process of integrating digital technologies into all aspects of a business, fundamentally altering how it operates and delivers value.

12. *Organizational resilience:* The capability of an organization to adapt, recover, and grow amidst adverse conditions and disruptions.

13. *Change management:* The structured approach to transitioning individuals, teams, and organizations from a current state to a desired future state, critical for successful agile transformation.

14. *Cross-functional teams:* Teams composed of members from various departments or specialties, leveraging diverse perspectives and expertise to solve complex problems in agile environments.

15. *Iterative development:* A development approach that involves repeated cycles of planning, execution, and review, allowing for continuous improvement and refinement of a product or solution.

16. *Feedback loops:* Mechanisms used in agile environments to adjust actions or processes based on feedback, ensuring alignment with customer needs and organizational goals.

17. *Risk mitigation:* Strategies developed to reduce or manage risks associated with agile transformation in unpredictable environments such as VUCA and BANI.

18. *Adaptive leadership:* A leadership style that promotes flexibility and adaptability in response to changing conditions, fostering a culture of innovation and continuous learning.

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References

[1] Bennett N, Lemoine GJ. What VUCA really means for you. Harvard Business Review. Jan-Feb 2014;**92**(1-2):27-33

[2] Kraaijenbrink J. What Does the BANI Acronym Mean? Forbes. 2020 [cited 2024 Sep 15]. Available from: https://www.forbes.com/sites/jerseykraaijenbrink/2020/05/22/what-does-the-bani-acronym-mean/

[3] Denning S. Understanding Agile: The Best Way to Make Software. Forbes. 2016 [cited 2024 Sep 15]. Available from: https://www.forbes.com/sites/stevendenning/2016/03/22/understanding-agile-the-best-way-to-make-software/

[4] Rigby DK, Sutherland J, Takeuchi H. Embracing Agile. Harvard Business Review. May 2016;**94**(5):40-50

[5] Joiner B, Josephs S. Leadership Agility: Five Levels of Mastery for Anticipating and Initiating Change. Jossey-Bass; 2007

[6] Nason RS, Goldstein J. The Complexity of Innovation in Organizations. Cambridge University Press; 2020

[7] Yusuf Y, Gunasekaran A, Dan G. Agile manufacturing: The drivers, concepts and attributes. International Journal of Production Economics. 2007;**62**(1-2):33-43

[8] Schneider S. Agile transformation: A model for organization-wide adoption of Agile. Business Horizons. 2017;**60**(6):765-774

[9] Schwaber K, Sutherland J. The Scrum Guide. Scrum Inc.; 2020. Available from: https://www.scrum.org/resources/scrum-guide

[10] Liker JK. The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer. New York, NY: McGraw-Hill; 2004

[11] Schwaber K. Agile Project Management with Scrum. Redmond, WA: Microsoft Press; 2004

[12] Moe NB, Dingsøyr T, Dybå T. A teamwork model for understanding an agile team: A case study of a Scrum project. Information and Software Technology. 2010;**52**(5):480-491

[13] Womack JP, Jones DT. Lean Thinking: Banish Waste and Create Wealth in your Corporation. New York, NY: Free Press; 2003

[14] Bhamu J, Singh Sangwan K. Lean manufacturing: Literature review and research issues. International Journal of Operations & Production Management. 2014;**34**(7):876-940

[15] Cohn M. User Stories Applied: For Agile Software Development. Boston, MA: Addison-Wesley Professional; 2004

[16] Leffingwell D. Agile Software Requirements: Lean Requirements Practices for Teams, Programs, and the Enterprise. Boston, MA: Addison-Wesley Professional; 2011

[17] Westerman G, Bonnet D, McAfee A. Leading digital: Turning technology into business transformation. Harvard Business Review Press. 2014

[18] Barlow J. Agile management: Working with Agile teams. Project Management Journal. 2011;**42**(1):73-87

[19] Beck K, Beedle M, van Bennekum A, Cockburn A, Cunningham W, Fowler M,

et al. Manifesto for Agile Software Development [Internet]. 2001. Available from: http://agilemanifesto.org/

[20] Ghezzi A, Cavallo A. Agile business model innovation in digital entrepreneurship: Lean startup approaches. Journal of Business Research. 2020;**110**:519-537

[21] Alzoubi YI, Gill AQ, Al-Ani A. Agile enterprise architecture: A systematic review and research agenda. Journal of Systems and Software. 2022;**183**:111068

[22] Rigby DK, Sutherland J, Takeuchi H. Agile at scale: How to go beyond a pilot and deliver value across the Enterprise. Harvard Business Review. May-Jun 2018;**96**(3):88-96

[23] Conboy K, Carroll N. Implementing large-scale agile frameworks: Challenges and recommendations. IEEE Software. 2019;**36**(2):44-50

[24] Hanelt A, Bohnsack R, Marz D, Antunes Marante C. A systematic review of the literature on digital transformation: Insights and implications for strategy and organizational change. Journal of Management Studies. 2021;**58**(5):1159-1197

[25] Dzhanabekova A, Garrison G. Agile transformation in global IT firms: Balancing efficiency and flexibility. Information Systems Journal. 2022;**32**(3):453-478

[26] Anderson D, Crabtree B, Steele DJ, McDaniel R. Applying complexity theory to Agile development in healthcare organizations. Journal of Organizational Behavior. 2020;**41**(1):1-21

[27] Bannerman PL, Thorogood A. Patterns of agile adoption and agile maturity in software development. Journal of Systems and Software. 2021;**175**:110892

[28] Dikert K, Paasivaara M, Lassenius C. Challenges and success factors for large-scale agile transformations: A systematic literature review. Journal of Systems and Software. 2016;**119**:87-108

[29] Olszewska M, Heidenreich R, Babb J, Stol K-J. Understanding the impact of agile practices on project success: A meta-analysis. Empirical Software Engineering. 2021;**26**(2):1-42

[30] Starkey K, Tempest S. Agile organizations and the future of work. Management Learning. 2020;**51**(3):321-337

[31] Yusuf Y, Sarhadi M, Gunasekaran A. Agile manufacturing: The drivers, concepts and attributes. International Journal of Production Economics. 2007;**62**(1-2):33-43

[32] Nguyen Q, Tran T. Agility in VUCA and BANI environments: A literature review and future research directions. Journal of Management and Strategy. 2023;**14**(1):30-45

[33] Tranfield D, Denyer D, Smart P. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management. 2003;**14**(3):207-222

[34] Thomas J, Harden A. Methods for the thematic synthesis of qualitative research in systematic reviews. BMC Medical Research Methodology. 2008;**8**:45

[35] Sutherland J. Scrum: The Art of Doing Twice the Work in half the Time. New York, NY: Crown Business; 2014

[36] Schwaber K, Sutherland J. The Scrum Guide: The Definitive Guide to

Scrum: The Rules of the Game. Scrum.org; 2017. Available from: https://www.scrum.org/resources/scrum-guide

[37] Sutherland J, Bateh B. The impact of agile methodologies on organizational resilience. Journal of Management Studies. 2021;**58**(3):700-725

[38] Ries E. The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses. New York, NY: Crown Publishing Group; 2011

[39] Kautz K, Wæhrens B, Høst M. Agile transformation: Case studies and theoretical insights. European Journal of Information Systems. 2022;**31**(5):497-510

[40] Jansson A. Strategic agility in times of crisis: A systematic review. Strategic Management Journal. 2022;**43**(6):1203-1218

[41] Garcia R, Quiros M. Leveraging agile for digital transformation: A systematic review. Journal of Digital Innovation. 2023;**8**(4):134-148

[42] Morrison D, Choudhury V. Managing agile transformations in the digital age: Challenges and solutions. Business Horizons. 2023;**66**(1):43-55

[43] Sutherland J, Schwaber K. Scrum: A framework for managing complex projects. Agile Project Management Journal. 2023;**11**(1):22-38

[44] Roberts P. Strategic agility in uncertain times: Theoretical and practical perspectives. Strategic Organization. 2023;**21**(4):405-424

[45] Lauer T, Mayer K. Systematic literature review on agile practices in VUCA environments. Journal of Systems and Software. 2022;**175**:110-125

[46] Walters M, Carter M. Agile and lean: Transforming organizations in the digital age. Technology and Innovation Management Review. 2022;**12**(6):78-92

[47] VersionOne. 12th Annual State of Agile Report [Internet]. 2016. Available from: https://www.versionone.com/state-of-agile-report/

Chapter 4

Project Model Standardization with Dual DSP COD

Vladimir Križaić

Abstract

The digital ICT revolution, with the new applications BIM, DT and AI package tools, reaches the organizational processes after the design and technology processes. That is, the management of business systems with complex processes is essential for ongoing projects to improve economic principles as components of the business system. With the advent of ISO standardization, companies are standardizing business communication flows to improve processes and facilitate the work of managers during idle periods. However, it has been found that the transition from the previous manual static technology to software does not bring about a significant change in business performance. Therefore, the recommendation is to change the model of the organizational structure with mathematical modeling to a dynamic vector organization, which is upgraded to a process system as a by-product of the computerization of the project production economy. By adding the matrix structure of the project organization and the function in addition to the process, a fourth resource dimension is added. This results in an nD vector organization system that enables a "daily monitoring" system, i.e., daily management of the business system. But even this method of ICT technology proves to be insufficient in the old costing or tendering system. Therefore, for mathematical modeling, the dynamic structure programming (DSP) method is proposed, which creates a model standardization of the bill of quantities, bid constructions, and standards as elements of the project. Križaić's DSP method is a logical induction equation that, in cooperation with vector norms and a modified Gaussian S-curve equation (MGSC), creates a digital twin (DT) for a business system for monitoring project resources. With the upgrade to BIM and DT tools, it is possible to close the loop of the business system and create an AI system for project management, which in turn creates an intelligent manager and an organizational differential (OD).

Keywords: model standardization project, vector standard and organization BS, ≙ DSP dual cod - organization differential, digital twin organization DSP-MGSC cod, smart manager – daily monitoring

1. Introduction

Every business system has a functional, project-related and process-related dimension. The accelerated evolution of project management (PM) has been enabled by the rapid development of business process management technology with management tools such as global SAP, Oracle BPM, Abacus and now locally oriented AI internet platforms for communication aids such as ClickUP, Teamwork, Claim, Smartsheet, etc. Global systems first solve the design and finance part of projects with CAD and SAP software. Then the production function with ERP, PCR or CPM method through the well-known Primavera tool and MSP Gantt charts and histograms, which today are revolutionarily solved with BIM, DT and AI tools. However, all these global connections are still a fairy tale. However, every system strives for compatibility with other systems, so graphic design technology and architecture are linked to the IFC code. While the Internet XML code is suitable for the general connection of all tools, software intervention solutions for the connection of all databases, such as the Oracle database, are required for the management of large enterprise systems. These solutions are very expensive, so small companies do not even think about it. However, there are also attempts by the government to intervene in subsidizing expensive tools to increase business productivity and follow the global AI trend. However, the key function of any business system is the management function that develops the fourth resource dimension of the business system within the technology and organization with the help of the ITC system with the most important sub-function of planning the development of the production process and managing the regulation of the production processes that lie in the function of the security of the marketing logistics system [1] that connects the systems with the environment and optimizes them. Thus, new tools and SMART technologies and methods within integrated information systems (IIS) contribute to the development of the method of daily monitoring [2] of enterprise and project management systems. The main problem of current project realization is the static preparation of works, therefore there is a need for vectorial [3] or parametric [4] modeling and the transformation of static construction organization project (POG) and PM documentation into dynamic scientific documentation with Yust in time logistics [5]. The first change from static to dynamic is necessary for standardization because the current static tabular system has a number of disadvantages that are negated by dynamic vector standards, but the creation of vector models of standards is a long-term process. By combining these models with probabilistic stochastic and simulation behavior with modern research tools, they lead to digital twin systems in process production, i.e., mimicking resource requirements, especially human resources in the process. By developing other dynamic Križaić models (AK, DSP, MGSC, SC), he dynamizes economic-organizational systems and transforms commercial ones into dynamic calculation methods, i.e., dynamic tools of optimal logistic project management. Software modeling and simulations such as BIM and Digital Twins (DT) tools aim to complement the lack of decision-making in processes with cyber-physical systems (CPS) [6], which is an introduction to artificial intelligence (AI) systems. However, automation is not yet possible due to a lack of high-quality software algorithms, i.e., equations for logistics management. The key to solving the problem lies not only in the automation of existing management but in the standardization of new models and the standardization of business processes, especially in the area of process supply, i.e., the design cost sheet. This dynamization of project documents as key documents is made possible by Križaić's new DSP method, i.e., the dual COD method [7], which creates an iteration differential of cyclic production processes. Here, with the help of mathematical and cybernetic methods, organizational histogram structures are transformed into differential histogram structures as the main components of logistic artificial intelligence. The model standardization of business processes eliminates the problems of non-standardized estimates and quotations and aims to optimize the economic and organizational elements in the business system defined by the financial case-flow curve. This process of approximating organizational solutions to the technological achievements of FEM [8] and IEM or RK∞ [9] in order to eliminate their gap leads to the creation of the financial MGSC [10] as a simulation element of a modern production CPS model. The purpose of DSP_MGSCNr automation is softwareization, i.e., model standardization of production processes using mathematical and statistical methods to reduce the financial risks of the investment to the optimum. Today's iterative mathematical and software engineering period, supported by the ICT system, is creating a new renaissance, the digital age of AI systems [11].

The contribution of DSP_MGSCNr project management is primarily the transformation of a static process into a dynamic financial logistics process with the S-curve. Then the model standardization of the project with dual code, which enables digital twin monitoring of the logistics processes and guarantees the quality of the project, i.e., the profit for the project and the company.

The management objectives of the DSP_MGSCNr method are to promote a different way of recording process logistics as a basis for mobile management standardization to achieve standards for management according to the PM methodology. This in turn leads to a competitive price and the desired product quality with the ability to simulate management. A team manager who has dynamic data on a daily level in intelligent technology becomes a manager for daily monitoring [12], i.e., an intelligent manager.

2. Literature review

The fundamentals of the organizational structures of business systems are defined by [13, 14], while the fundamentals of the process of economic reproduction [15] define the structures of business systems from the production functions to the modern management functions of today. For the marketing and finance functions, they emphasize the knowledge society [16], i.e., the transition from hardware to software, and the emergence of the global economy, i.e., the global enterprise. Through the decomposition of production systems with the method of new product development – NPD [17] and the use of ICT, the information system (IS) is enabled, which leads to the creation of integrated information systems (IIS). These are modeled in a dynamic way and structurally created by today's Cyber-Physical System (CPS) trend [18, 19]. The interaction of dynamic calculation and planning with a vector standard gives these processes the necessary precision in combination with Enterprise Resource Planning (ERP) [20]. This is modeled through an application programming interface (API) [21] and tools are created that can help facilitate research related to BIM tools [22]. Modern CPS, ERP, BIM and augmented reality (AR) [23] are therefore technologies that create IT logistics managers. Examples include exploring the benefits of CPS for the progress of project execution, and scenarios for the application of CPS in potential areas of the construction industry, such as component management. For example, today there are several scattered attempts to automate construction projects [24] in order to reduce the huge losses directly attributable to the inefficiency of integrating existing systems by linking virtual models and physical construction. Therefore, vectorial, automatic and progressive structural models are still being investigated as CPS structures in production. The DSP method is similar to the CPM method in its hierarchical structure and standardizes a new data set of the cost sheet or project with a vectorial approach. Operational research [25] is a great mathematical tool for the optimization of the production system, so they are at the beginning of this research on the optimization of construction production, i.e., construction supply. The iterative method of dynamic programming simply records all the states of a system with its equation and therefore proved to be optimal for the present research. Then, computer technology opens up the structural linking of processes such as WBS structures [26] through the use of Delphi tools for structural software programming [27]. By connecting these components, i.e., by integrating the equation of dynamic programming into the structural domains of computer technology, i.e., into the mathematical algebra of logical wood [28], a method of dynamic structural programming – the DSP method – emerges. The answer to these problems is given by modeling the processes that create the construction offer, but in a dynamic way and structurally created by today's trend of CPS systems. Further definitions of the DSP–CPS system have been developed in other industries by validating the metamodel of the construction process of the system, inspired by the research progress on the metamodel of the software process and the system modeling language to invigorate the execution control and production monitoring of the process industry [29]. However, so far there has been little research specifically focused on the direct problem of modeling and defining positional descriptions of construction bids. Today, BIM modeling provides a link between the specification of project resources and the bid in cost modeling and planning due to the early incorporation of known project and execution technologies [30] to increase profits [31] and also to be competitive in the construction project bidding process [32]. Just as the machine process industry strives for automation and artificial intelligence [33], so does the DSP method. Such an application of the PM paradigm leads to the innovation and definition of new organizational structures and communication channels [34] as well as modern simulation labs to optimize the efficiency of PM [35]. This paper attempts to show the advantages and disadvantages of dynamic PM in a vector organizational structure with the new standard modeling bid construction bid items using the DSP-e method as a new method of production standardization.

2.1 Status of the static PM methodology

The industrial production society with its organizational structure was enthroned by Adam Smith in 1776 and is only now being replaced by the information society, today in the digital renaissance period. However, the organizational structures do not follow the rapid changes in technology and the theory of Scientific Management (SM). Nevertheless, hierarchical structures have been created [36], which prescribe process control at management levels. Hierarchy is linked to natural social arrangements. Thus, from the individual to the basis of decision-making and command communication, it passes through the levels or stages of the system with more or less elementary components involved in the realization of the purpose of the system. Classical departmental structures also include the project organization, which includes organizational structures subordinate to the object (product, project, geographical area, etc.), so that all jobs, regardless of their type or functional affiliation, are directly related to a specific object (output) grouped in a department (project). The matrix form of organizational structure is a hybrid form of organizational structure in which functional and divisional forms are crossed in order to eliminate weaknesses and confirm the advantages of both forms. Today's construction companies have emerged from functional structures and use this matrix structure most frequently. More complex changes in the business environment led to the creation of flexible organizational structures –

from network-like, non-hierarchical structures to virtual organizational structures, i.e., suprastructures that are geographically dispersed nodes, each specialized in a specific field of activity and connected across spatial, and temporal. Organizational boundaries are usually *via* an information technology network to enable efficient and flexible collaboration and knowledge sharing. Communication then quickly moves from the manual approach of administration to a software flow, with the aim of moving to online work without paperwork, which banks already use. However, the fundamental basis of communication is the design quotation, i.e., the cost position, which has been maintained for many years through a traditional template or template. Lester Thurow has proven that in the twenty-first century, the most important resource in tenders is the knowledge of the employees, i.e., the know-how of the company using theories of business excellence. For example, the methodology of JIT and TQM emerged in Japan as early as the 1980s, and then the German concept of Lean Management (LM) with the scientific process concept of production put the knowledge base at the center of attention. The latest thinking is based on BPR as the backbone of today's society, and the company is viewed with new eyes, that is, there is a new systemic, model and abstract view. Also in practice, new improvements are being introduced by adding costs to activity-based costing to generate profits. Today, the IIS software for managing the entire business system based on Oracle's relational database, developed with designer developer tools, is causing confusion in managing all the data of medium and large companies. Various global SAP and local software companies have emerged in the market, focusing only on the cost area. Production planning is a key process for project management as part of a business system. The Microsoft project has simplified the critical path method to various graphical representations. The Pert method stochastically monitors the deviations of the realization from the plan, i.e., the creation of an interval of the fluctuation range and the standard deviation of the observed quantity. This has created a prerequisite for faster and more precise planning and reduction of business risks, which complements MGSC methods. The project is a systematic technological-organizational process of conscious actions to achieve the goal of the action with a predominantly static PM, which we are trying to make dynamic (**Figure 1**).

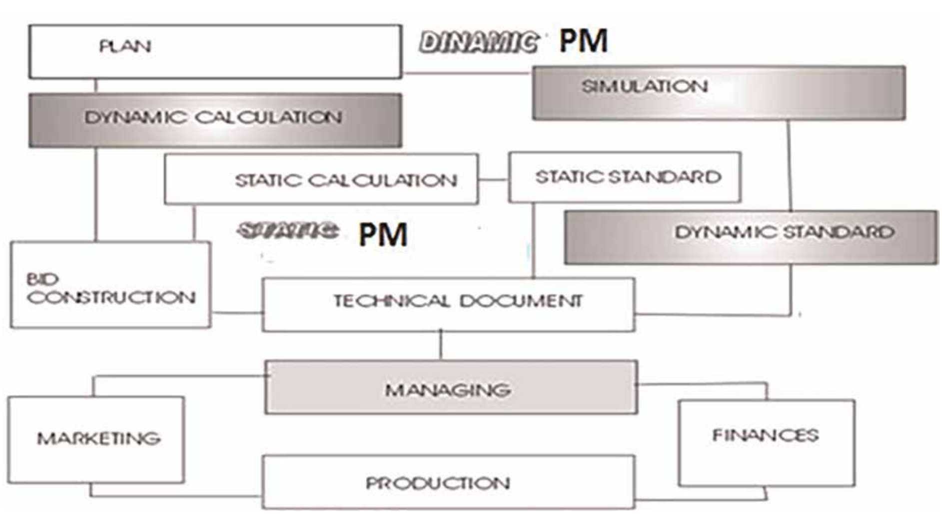

Figure 1.
Static and dynamic PM (author).

It can be seen that the static standard and calculation dominate production management, and the cost sheet and quotation construction are very inaccurate both financially and qualitatively as a product. However, with dynamic, vectorial or parametric modeling of the standard and costing, this problem is greatly reduced. Therefore, vectorial and parametric models of standards are created, that are used to create digital twin systems for graphical and analytical representation of production through dynamic logistics documentation.

3. Dynamic PM methodology

The dynamic definition of the project has so far taken place in planning, where the activities in a time unit are normally monitored dynamically. Standardization and costing are fixed as the main elements of production and trading or marketing of the business system and are dynamized with parametric or vector variables, resulting in dynamic PM.

3.1 Vector PM in PS

The management of the business logistics system, or PM, is carried out by three, four and five management functions with continuous decision-making that is constantly burdened with risks as uncertain events or situations that may occur in the future and disrupt a project goal, temporally, financially or qualitatively and reduce it to a tolerable risk. Therefore, risk mitigation is enhanced by the logistical preparation of the work of the Vector organization system (**Figure 2**).

Vector management emerges as a by-product of the development of a business systems management software program. By transferring the management documentation into the IT system as a result of relational databases, a vector organizational structure [37] of the company is created, which is upgraded to a matrix organizational structure with a third axis, namely the resource variables. In this way, the histogram data is stored in the database and enables data access down to the resource level. By elaborating the vector structure of the business system at the level of the construction bidding process through the tendering and construction site and situation documentation to the operational level [38], i.e., working with the same human resources, a process elaboration of the management is created. Thus, the static POG becomes a dynamic PM systematized by the logical algorithm of functions and the IBM BS syntax of designing entities and attributes with file links *via* Oracle database keys (**Figure 3**).

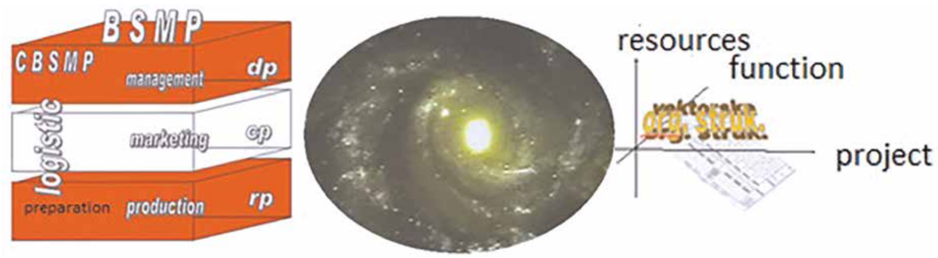

Figure 2.
IIS construction company with cyclo-space vector structure (author).

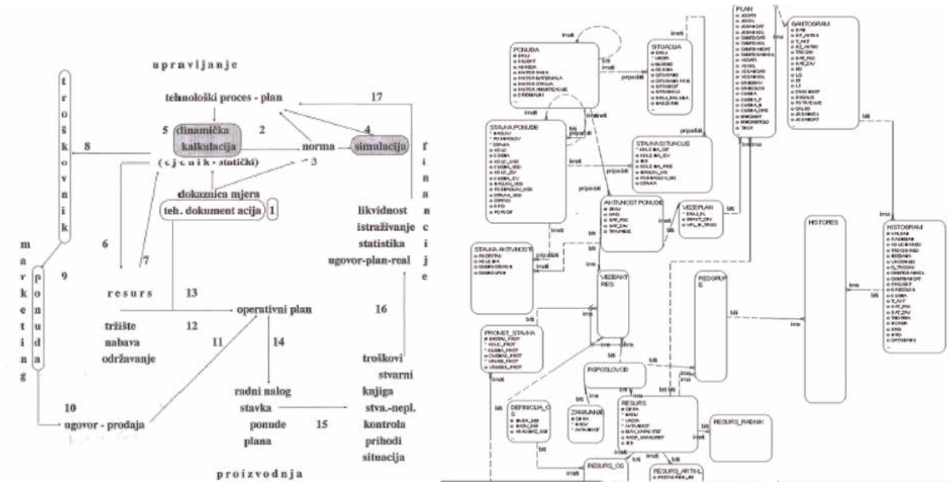

Figure 3.
PS nivo procesnih podfunkcija – operacija (author), IIS data planning model on Just in time IPC Međimurje company in Čakovec.

3.1.1 Vectorial norma (VN)

The parametric or functional linking of standards is the tendency and image of companies in the development of new technologies, that widely promote the technology in brochures in order to make it as useful as possible for the user in the form of specifications and technological possibilities.

3.1.1.1 Model VN

By analyzing and systematizing the description of the process of old norms, the variables of design, technology and organization can define the hypothesis of vector norm. The normative time can be represented as a resource effect in a three-dimensional formula. The variables are elements of project construction (Xc) and technology (Yr), which are defined by the categorized variable of organization (Zo) (**Figure 4**).

Thus, using the example of concrete technology, there are tables in the function of resources (r), i.e., the technology of execution and construction of the structure (k) and the dimensions of the structure (kd_i), which influence not only the time resource, but also the material part of the standard. With the help of these variables and the

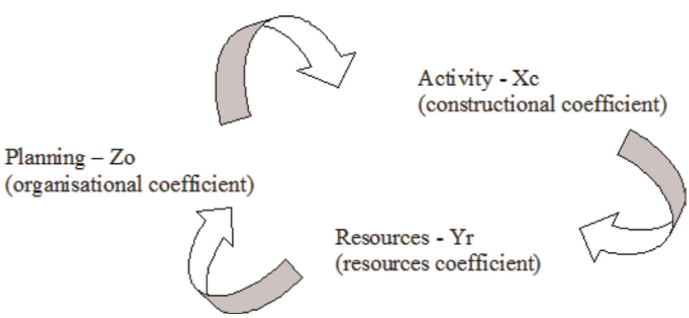

Figure 4.
Idea for the creation of a VN in the building industry (author).

definition of the basic construction (coke), all discrete tabular representations of formwork systems can be reduced to a graphical vector image and the structural Eq. (1). By excluding the basic or initial construction, which is the simplest and most frequently carried out, the beginning of the VN is defined, and depending on this, the other constructions are written with the given coefficients.

$$VN = f(kd, ko, k, r) = kd_i ko_i f(k, r) \tag{1}$$

3.1.1.2 VN concrete technology

For a specific element of the Arena Zagreb project (**Table 1**), a dynamic dual DSP modeling of the classical offer is performed.

An example of concrete technology is implemented by the work in the new equations of VN technology (**Figure 5**), which are defined by the old static standards for concreting [39, 40].

From the presented VN, the standard equation for concreting walls k = 3 and ko = 1.25, while kd = 0.6 for a wall d of 20 cm is defined by the Gauss method of least squares Eqs. (2)–(5).

	Perimeter walls of the basement:				
3.2.2.	Construction of double-sided smooth formwork for the perimeter walls of the basement, with a thickness of 20 cm and height up to 4.00 m, including the installation of waterproof concrete grade C30/37. Billing based on cubic meters (m^3) of concrete delivered and installed, and square meters (m^2) of formwork completed.				
3.2.22	Installation by pump	m^3	350	45,30	15.855,00
3.2.2.3.	Installation by crane	m^3	100	90,59	9.059,00
	Perimeter walls of the basement:	**m3**	**450,00**		**24.914,00**

Table 1.
Cost sheet for the Arena Zagreb project—a grandiose project—one item.

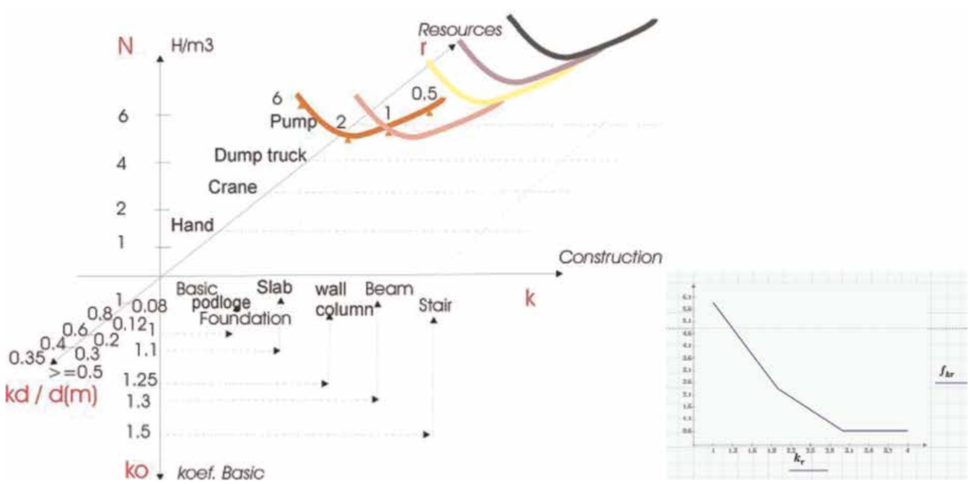

Figure 5.
Functional dependence of VN concreting of walls (author).

$$x = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \end{bmatrix} y = \begin{bmatrix} 6 \\ 2 \\ 1 \\ 0.5 \end{bmatrix} b = \begin{bmatrix} b1 \\ b2 \\ b3 \end{bmatrix} b1 = \sum_{x=1}^{n} x, b2 = \sum_{x=1}^{n} xy, b3 = \sum_{x=1}^{n} x^2 y \tag{2}$$

$$\begin{bmatrix} n & \sum_{x=1}^{n} x & \sum_{x=1}^{n} x^2 \\ \sum_{x=1}^{n} x & \sum_{x=1}^{n} x^2 & \sum_{x=1}^{n} x^3 \\ \sum_{x=1}^{n} x^2 & \sum_{x=1}^{n} x^3 & \sum_{x=1}^{n} x^4 \end{bmatrix} \mathbf{x} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} b1 \\ b2 \\ b3 \end{bmatrix} \tag{3}$$

$$X = bA^{-1}, X = \begin{bmatrix} 11.125 \\ -6.125 \\ 0.875 \end{bmatrix}, a_i = X_i \tag{4}$$

$$Nr = \frac{\Delta nr}{\Delta t} = a_1 + a_2 x + a_3 x^2 \tag{5}$$

The dynamic norm for the original, i.e., basic, construction of the foundation wall is, therefore, the value of Eq. (6).

$$Nr = f_r = y' = 11.125 - 6.125r + 0.875r^2 \tag{6}$$

The norm equation for the given example r = 2, Nr = 2.375 h/m^3 from VN is therefore Eq. (7).

$$VN = f(kd, ko, k, r) = kd_i ko_i f(k, r) = 0.6 \cdot 1.25 \cdot 2{,}375 = 1.78\text{h/m}^3 \tag{7}$$

The given data are used for the direct cost method of cost calculation. To determine the optimal production phase, a dynamic calculation is defined with fixed and variable data of the cost plan, whose equations provide the answer to the given problem.

3.1.2 Dynamic calculation

To define the optimal phase of the activity, you must divide the resource costs into fixed and variable variables, that correspond to the direct and indirect variables of the activity costs, i.e., the items of the cost sheet. The direct resource costs are visible in the histogram. They consist of labor R, material M and machines S. Eq. (4), which is used for the direct cost calculation method. However, it is not favorable for the optimization of the time or production phase, and the Križaić A-K method (KAK) calculation (**Figure 6**) [41] is introduced, which creates equations from the function of operations to the production project as a complex process.

3.1.2.1 KAK method

The calculation method using the fixed and variable costs of the resources used at the process level, which are summarized in the cost price of the process, operation, process and object, is used to determine the optimal production phase and thus the optimal dimensioning of resource requirements.

A. price of capacity, CAPITAL

B. transportation and assembly costs (part)

C. fixed labor costs

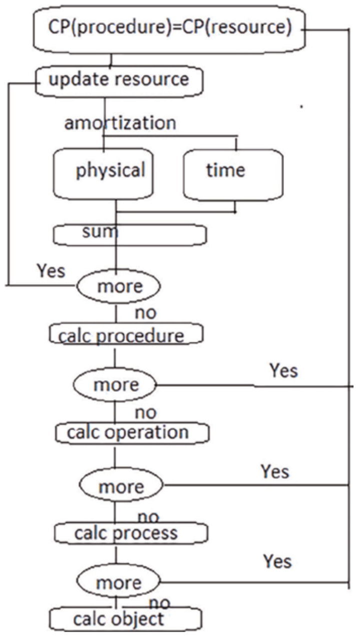

Figure 6.
Dynamic calculation algorithm of the A-K method (author).

D. fixed depreciation costs

E. Fixed costs (insurance, maintenance, interest)

F. transportation and assembly costs (part)

G. variable labor costs

H. variable energy costs

I. And variable costs of fixed assets (part)

J. variable costs for physical depreciation

K. price of auxiliary material

The summarizing equation—"A - K" method defines the cost price (CK) as the sum of fixed (CKf and CKv)

$$CK = CKf + CKv \tag{8}$$

The sums are determined depending on the number of work phases nf.

$$CKf = Qfnpf(A + B) + C + Quk(DE) + F \tag{9}$$

The sum variables are a function of Qf, the quantity of the phase.

$$CKv = Quk\left(\left(\frac{1}{Qf}\right)(G+H) + IJ + K\right) \tag{10}$$

$$CK = Qf\ nf(A+B) + C + Quk(DE) + F + Quk\left(\left(\frac{1}{Qf}\right)(G+H) + IJ + K\right) \tag{11}$$

3.1.2.2 Dimensioning the optimum cycle size of the execution according to the minimum cost method

The variables depending on the time and the total number of works are:
Quk - the total quantity of work.
Qf - the size of the work cycle time.
nf - total number of work cycles.
npf - number of initial work cycles in one cycle (cycle).
Tfconj - fixed cost constant.
Tf - phase costs.
nn - number of workers in the phase h - working hours qjm - standard amount of resources per jm.
The depreciation variables in the "A - K" method function are.
X - depreciation value of resources (FS, nmax).
Y - constant with the values (0, 1).
Z - constant with the values (0, 1).
Summarized fixed costs defined by the unit costs (4) and the additional fixed asset (OS) variables (4) (NV, ios, iod, ks), i.e., acquisition value, insurance index, maintenance index and interest rate. Then the labor cost variables (4) are defined (nr, BSr, fr, hr) as the number of workers, gross hourly wage, local labor factor and daily hourly wage. The constant cost variables (4) (Css, Tmon, Tpr), i.e., the cost of stopping the OS, assembly and transfer time or manipulation costs Eqs. (12)–(16).

$$\mathrm{Tj} = \mathrm{FTj} + \mathrm{VTj} \tag{12}$$

$$FTj = Fosj + Frj + Fconj \tag{13}$$

$$Fos = fosj = \sum_{i=1}^{n}\left(\left(\left(\frac{NV_i}{X_i}\right)qjm_i\right)\right)(Y + ios + iod + ks)\ Quk \tag{14}$$

$$Frj = frj = \left(nr\ BSr\, fr\ hr\ \frac{Quk}{Qf}\right)Qf \tag{15}$$

$$Fcon = fconj = Qf\ nf\ \ Tfconj = Qf\ nf\ \left(\sum(qijm\ NVi)(\,pm + Lpcm) + Css + Tmon + Tpr\right) \tag{16}$$

Summary variable triples defined by the unit costs of labor, material and fixed assets (Rj, Mj, Vosj) (4) with new variables for material (4) (Pi, Gsg, gsg, ko, Cg, Pe, Ce, tr, qpm, CPM), engine power, fuel consumption, specific fuel consumption, organization coefficient, fuel price, engine power, energy price, working time, specific material consumption and material price. The new variables OS Vosj (4) are (Z, nei, nmax) the constant of the KAK method, the number of elements OS and the maximum number of revolutions OS Eqs. (17)–(20).

$$VTj = vj = Rj + Mj + Vosj \tag{17}$$

$$Rj = rj = nrfhfBS(1+fr)/Qf \tag{18}$$

$$Mj = mj = (Pi\ Gsg\ gsg\ ko\ Cg + Pe\ Ce\ tr\ ks)/Qf + \sum_{i=1}^{n}(qpm_i Cpm_i) \tag{19}$$

$$Vosj = vosj = (Z + iod + ne)\sum_{i=1}^{n}\left(\left(\frac{NV_i}{nmax_i}\right)qjm_i\right) \tag{20}$$

It can be seen that the fixed and variable costs are functions of the variables Quk and Qf in Eqs. (21), (22).

$$\mathrm{FTj} = \mathrm{fj} = \mathrm{fosj(f(Quk))} + \mathrm{frj\ (f(Qf))} + \mathrm{fconj(f(Qf))} \tag{21}$$

$$\mathrm{VTj} = \mathrm{vj} = \mathrm{rj(f(Qf))} + \mathrm{mj\ (f(Qf))} + \mathrm{vosj(f(Quk))} \tag{22}$$

3.1.2.3 Unit costs using the minimum costs

By summing the fixed and variable unit costs, the total unit costs are defined by Eq. (23). By deriving this equation by the quantity of the work phase, the optimal quantity of work or production cycle for the total quantity of production is obtained.

$$Tj = \sum_{i=1}^{n}(fosj_i + vosj_i)Quk + (frj_i + fconj_i)Qf + (rj_i + mj_i)/Qf \tag{23}$$

It can be seen that the optimal phase now lies in the iteration equation of the square of the ratio of the fixed labor costs to the variable direct labor and material costs. The DT method has direct and indirect costs Eqs. (24), (25).

$$f\ Tf = T = \sum_{i=1}^{n}(1+f)\ DT \tag{24}$$

$$Qfj\ nfj\ Tfj = Tj = \sum_{i=1}^{n}(1+f)\ DTj \tag{25}$$

Equating both calculation methods results in the quadratic cost equation Eqs. (26)–(31).

$$\sum_{i=1}^{n} Qf\ nf\ Tf = \sum_{i=1}^{n}(fosj_i + vosj_i)\ Quk + (frj_i + fconj_i)Qf + (rj_i + mj_i)/Qf \tag{26}$$

$$\sum_{i=1}^{n} Qf\ nf\ Tf = \sum_{i=1}^{n}(fosj_i + vosj_i)\ Quk + \sum_{i=1}^{n}(frj_i + fconj_i)Qf + \sum_{i=1}^{n}(rj_i + mj_i)/Qf \tag{27}$$

$$\sum_{i=1}^{n} Qf\ nf\ Tf - \sum_{i=1}^{n}(frj_i + fconj_i)\ Qf - \sum_{i=1}^{n}(rj_i + mj_i)/Qf = \sum_{i=1}^{n}(fosj_i + vosj_i)\ Quk \tag{28}$$

$$Qf\ \sum_{i=1}^{n}\ nf\ Tf - frj_i - fconj_i - \sum_{i=1}^{n}(rj_i + mj_i)/Qf = \sum_{i=1}^{n}(fosj_i + vosj_i)\ Quk \tag{29}$$

$$Qf^2\ \sum_{i=1}^{n}\ nf\ Tf - frj_i - fconj_i - \sum_{i=1}^{n}(rj_i + mj_i) = \sum_{i=1}^{n}(fosj_i + vosj_i)\ Quk\ Qf \tag{30}$$

$$Qf^2\ \sum_{i=1}^{n}\ nf\ Tf - frj_i - fconj_i - Qf\sum_{i=1}^{n}(fosj_i + vosj_i)\ Quk - \sum_{i=1}^{n}(rj_i + mj_i) = 0 \tag{31}$$

The quadratic equation Qf has two solutions Eqs. (32)–(36).

$$a = \sum_{i=1}^{n} nf\ Tf\ - frj_i\ - fconj_i \tag{32}$$

$$b = \sum_{i=1}^{n} \left(fosj_i + vosj_i\right)\ Quk \tag{33}$$

$$c = \sum_{i=1}^{n} \left(rj_i + mj_i\right) \tag{34}$$

$$a\ Qf^2 + b\ Qf + c = 0 \tag{35}$$

$$Qf = \left(-b \pm b^2 - \sqrt{b^2 - 4ac}\right)/2a \tag{36}$$

The optimum phase for the given activity is defined by inserting an observed element. In the given example, labor, energy and depreciation are used. If for the given item Quk is 2845 m^3 and fcon = 1/3 Tf. By filling the mentioned variables with the values nf = 10, frj = 15.7, fconj = 1/3 Tf, Quk = 2845 Vosj = 2, fosj = 1/3 vosj and rj = 15.7 and mj = 1.53 from VN. For the given transaction in the cost sheet, Tf is 2845 × 17.43 or 49588.35 € Eq. (37).

$$Qf = 60 \tag{37}$$

This would mean that we are pouring 60 m^3 per day, which is a realistic capacity, even though Arena Zagreb was working at an impressive 1000 m^3/day for the foundation slab with a thickness of several meters. By iterating the number of phases, the quantity of the phase is created according to the resource cost method, and there is also a resource utilization method.

4. Model standardization of the project Križaić dual DSP code

The DSP method is a combination of dynamic programming from operations research and object or structure-oriented software programming. The use of keywords creates the name of a new method that introduces us to cyber systems. Iterative mathematical methods have evolved since the induction equation, which is simply ∀n ∈ N, s(n) = s[n](1) [42]. Then by iteration equations for linear equations by Gauss from 1823 [43] and linear programming in the form of classical programming [44] or similar to the finite element method with displacement addition [45] or by creating meshes in conjunction with BIM tools [8]. However, the emergence of structural or object programming, i.e. Turbo Pascal or later Delphi, plays a crucial role in defining the DSP dual code upgrade to dynamic programming.

4.1 Križaić DSP cod management

The dual DSP code is derived from the iteration equation of the operational research method of dynamic programming and structural programming within Pascal or Delphi programming. Mathematically, it is represented in such a way that the structure field occupies a variable in the iteration of the target function Eq. (38).

FC = BMP = min, max ∪ (S).

$(S)_{i,j} = \cup f_{n+1}(S)_{i,j}$;

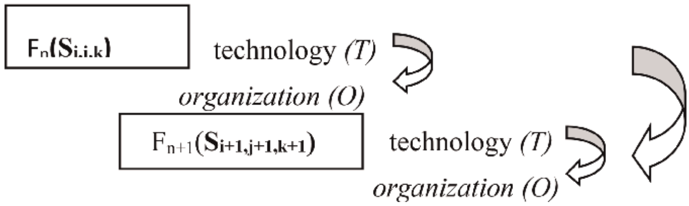

Figure 7.
DSP vector iteration organizational differential (author).

$$S = f\ (i, j, k, r, R, t); i, j, k, r, R, t > 0 \tag{38}$$

That is, by the method of recurrent equations, whose characteristic is the iteration of the functional equations of the state of the system f_n (S_n) in the sum of the observed function g_n and the function of the previous state f_(n-1) (S-x_n) with all possible changes in the value of the variables in the given functions or processes is Eq. (39).

$$f_n(S_n) = max_{\,0 \le x_n \le S}\left(g_n(x_n) + f_{n-1}(S - x_n)\right) \tag{39}$$

For multidimensional vector dynamic programming, the equations are identical, only with more variables (x,y). The organizational differential is marked as follows (**Figure** 7).

The mathematical methods of logical and inductive optimization and the programming methods define the dual DSP structure. TREE wood plus the induction equation, i.e., dynamic programming with object programming, defines the idea of the DSP equation for modeling the production process, i.e. building bid construction with DSP code (5) and TROSKO code and NORM COD on standard.

4.2 BID construction COD

By linking and extending the above models with iteration software technology, a DSP model was developed that helped to solve the problem of defining production and products. Thus, the product of offer construction or MSN. MSN = MSP = Σ Fn (S) = f (T, O) as a function of the data set of technology (design) and execution organization and T ≈ O = f (A, R, D), i.e., defined as a function of the variables A activities, R resources and D dimensions of design and resource performance. A unique code for defining the construction product is created by jointly coordinating the description of the item in the offer, i.e., the text of the bill of quantities, i.e., the standard. A product dataset is formed by layers and distribution of complex processes to procedures and the construction production dataset is modeled using the combinatorics and linking of these datasets through model standardization (**Figure 8**). A record of the elements formed by the project MSP Eqs. (40)–(42) definition of the structure with a specific resource and a description of the operational elements, from activities, processes and operations for construction production and other advanced production to the movement of robotization of production, the equation of the model standardization standard [46].

$$MSP = \sum A = \sum Pe = \sum O = \sum Pd = \sum M \tag{40}$$

$$MSP = \sum p = \sum c = \sum r = \sum d \tag{41}$$

$$BC = U\ \left[f_n(T_n, O_n) = f_{n+1}(T_{n+1}, O_{n+1})\right] \tag{42}$$

Figure 8.
Standardization of activities: Elements of the description of the items norms (author).

The norm N forms the left-hand side with the variable process Pe, the operation O, the procedure Pd and the movement M, while A is the activity, c the construction, r the resources and d the dimension. Modular and variant components can simulate all practical processes and operations up to the procedure by CPS, MindJet graphics technology or the software DSP method Eq. (43).

$$DSP\ COD = U\ [f_n([A|R|D||]) = f_{n+1}([A|R|D||]) \tag{43}$$

While the substitution of identical structures TO O generates the iterative DSP CODE of the product or standard (**Figure 9**).

The offer data set is therefore defined by the same items and the item description can be assigned to the costing structure. The DSP model shows the description of the item by the activity dataset the next level of the resource construction and the level of the resource dimension of the construction. Here, the first data record of the structure defines the other components of the quotation item, such as the unit of measure, the quantity and the price, which is the sum of the lower levels of the linearly linked

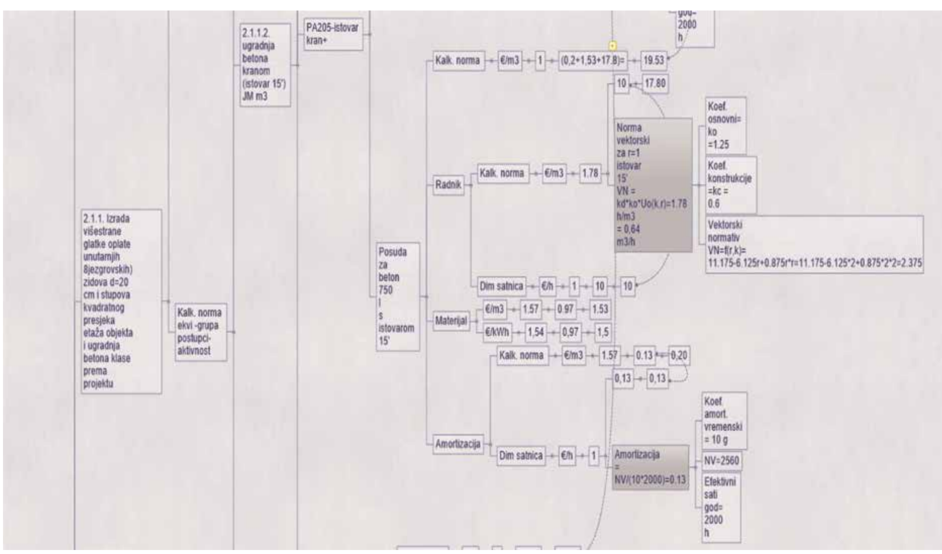

Figure 9.
Example of the Atrena Zagreb project (concrete work)—Minđet technology—Phd (author).

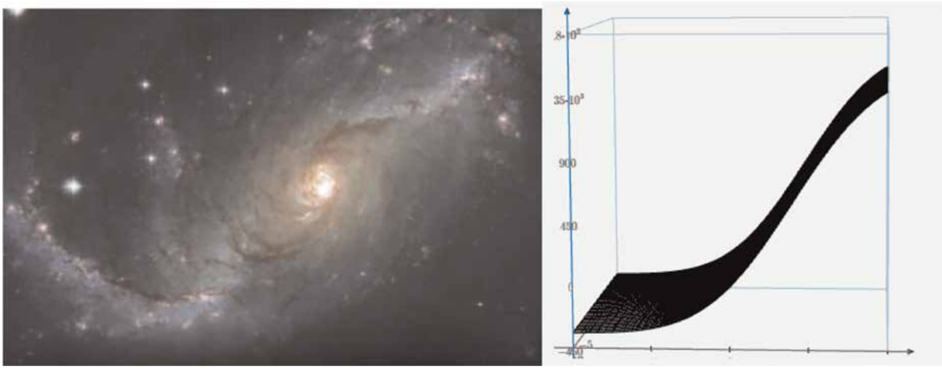

Figure 10.
Galaxy NGC 1672 [47], MGSC Arena Zagreb (author).

components and the value as the product of the specified values in the first syllable. In addition to the standard records, the lime-norm structure of the equivalent service group is also given, which normatively corrects the organizational model for the given item of the offer with all the old elements of the structure of the cost sheet, i.e., the module containing the component name, jm, quantity, unit price and value.

5. Digital twin system using the DSP-MGSC method as a path to the OD

The MGSC curve has a galactic trace (**Figure 10**), as do many natural phenomena that have the most frequent distribution according to the Gaussian distribution, which cumulatively yields an S-curve.

5.1 Financial planning management with the DSP-MGSC method

Recently, probabilistic forecasts of project performance and the use of stochastic S-curves with a program package for generating stochastic S-curves and a simulation approach have defined the scatter deviation of MGSC project finances and time as a function of the density distribution of cost and time. Expected monetary value (EMV) diagrams or S-diagrams are very popular today and are complemented by the functional MGSK Eq. (44).

$$skvGr(x, T) = \lambda r\ \lambda kv \int_0^x \frac{1}{(a \cdot T + b) \cdot \sqrt{2 \cdot \pi}} \bullet e^{\frac{-(x-\mu)^2}{kv \bullet (a \bullet T + b)}} dx \qquad (44)$$

For the Arena Zagreb contract for €1,200,000, the variables and coefficients are defined by values. The S-curve is defined for n = 8, μ = 4, T = 1200, kv = 104, a = 3.81104, b = 0.004 and λr = 1,λkv = 1.652. For alternating monitoring of resource and financial indicators with different reports. Thus, it is possible to define the estimation of the deviation of the total budget EAC and the estimation of the deviation of the time of the total duration of the project BAC from the planned cash curve Eqs. (45)–(48) for Δt = 1 (30). Za Arenu Zagreb ugovor od 1,200,000 € varijable i koeficijenti definirani su vrijednostima.

$$T_{x+1} = T_x + \Delta T_{x+1} \qquad (45)$$

$$T' = \frac{\Delta T}{\Delta x} = \frac{\Delta T}{\Delta t} = \frac{EAC - (T_{proc} - T_p)}{BAC} \tag{46}$$

$$BAC(T_{x+1} - T_x) + (T_{proc} - T_p) = EAC \tag{47}$$

$$\boldsymbol{T_{x+1} - T_x + (T_{proc} - T_p)_{x+1} = EAC} \tag{48}$$

By introducing the MGSC equation into the iteration series of the S-curve, the EAC query (**Figure 11**) was solved.

5.2 Management of resource planning with MSP and MGSCNr

With the vector organization, the resource receives its coordinate axis through the project, so that in combination with the planning, i.e., the time axis, a daily planning is created. Several related, leveled projects generate histograms that suggest that the MGSC method can be used for both project financing and optimal management of MRSCNr resource logistics (**Figure 12**).

The Gaussian method of least squares is used to define the distribution curve of a concrete worker on a construction site over the course of 3 months. And the

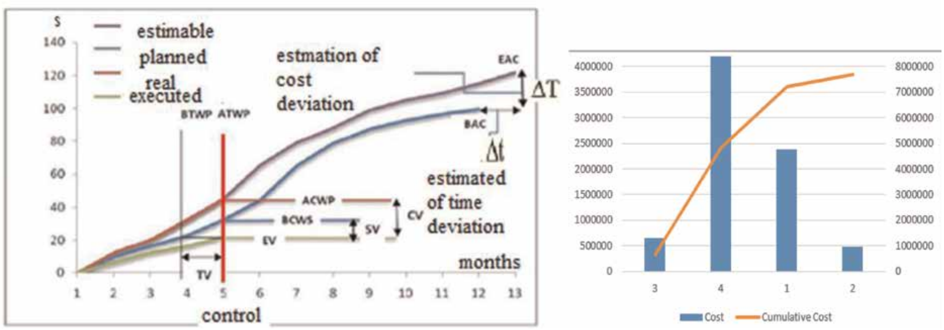

Figure 11.
Cash flow curve with risk in all states (author).

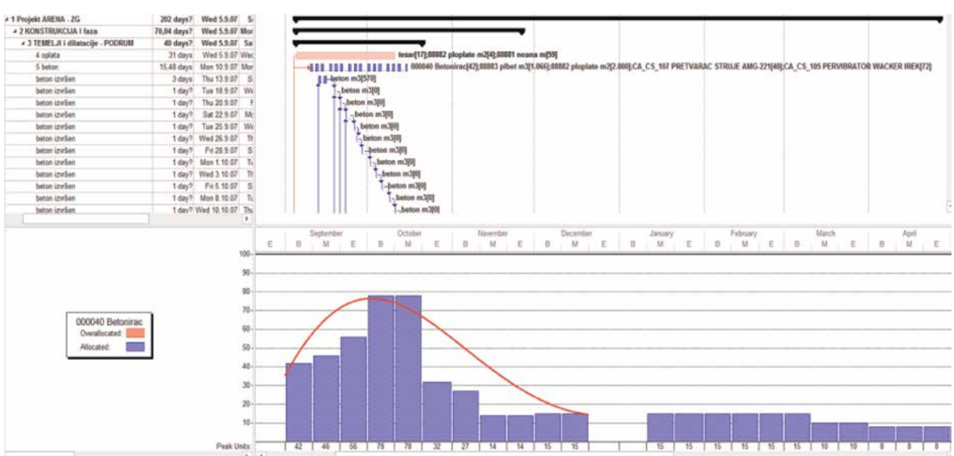

Figure 12.
Arena Zagreb S-curves of MSP software (work, material, machine) (author).

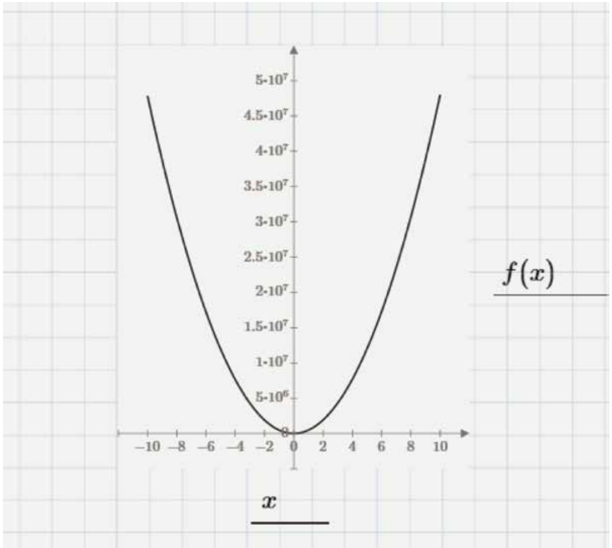

Figure 13.
Functional (fx)—derivation curve (nr = y´) of the resource histogram for concrete work from the cumulative MGSCNr curve (author).

distribution of the nr function is the derivative function y´, i.e., MGSCNr´ in relation to MGSCNr (**Figure 13**), Eqs. (49)–(53).

$$x = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \end{bmatrix} y = \begin{bmatrix} 42 \\ 46 \\ 56 \\ 78 \\ 78 \\ 32 \\ 27 \\ 14 \\ 14 \end{bmatrix} b = \begin{bmatrix} b1 \\ b2 \\ b3 \end{bmatrix} b1 = \sum_{x=1}^{n} x, b2 = \sum_{x=1}^{n} xy, b3 = \sum_{x=1}^{n} x^2 y \tag{49}$$

$$\begin{bmatrix} n & \sum_{x=1}^{n} x & \sum_{x=1}^{n} x^2 \\ \sum_{x=1}^{n} x & \sum_{x=1}^{n} x^2 & \sum_{x=1}^{n} x^3 \\ \sum_{x=1}^{n} x^2 & \sum_{x=1}^{n} x^3 & \sum_{x=1}^{n} x^4 \end{bmatrix} \mathbf{x} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} b1 \\ b2 \\ b3 \end{bmatrix} \tag{50}$$

$$X = bA^{-1}, X = \begin{bmatrix} 27.214 \\ 17.592 \\ -2.279 \end{bmatrix}, \qquad a_i = X_i \tag{51}$$

$$nr = \frac{\Delta nr}{\Delta t} = a_1 + a_2 x + a_3 x^2 \tag{52}$$

$$nr = f_x = y' = 27.214 + 17.592x - 2.279x^2 \tag{53}$$

5.3 Digital twin simulation optimization management project

Financial simulations are carried out using the KAK and MGSC methods.

5.3.1 Management by the KAK method

Japanese and American process control in business manufacturing processes have developed standards for product quality management. To reduce the risk, the optimal

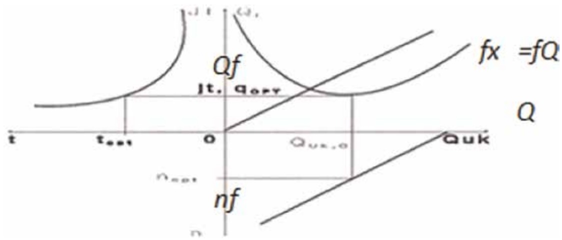

Figure 14.
Optimal takt or phase of production (author).

size of the clock or production phase is also introduced. By deriving unit costs by the amount of work, the optimal amount of work or production cycle is obtained Eqs. (54)–(60) (**Figure 14**).

$$Tj = \sum_{i=1}^{n} (fosj_i + vosj_i) Quk + (frj_i + fconj_i) Qf + (rj_i + mj_i)/Qf \tag{54}$$

$$dTj/dQuk = 0 \tag{55}$$

$$Quk = \sum_{i=1}^{n} (fosj_i + vosj_i) = 0 \tag{56}$$

$$dTj/dQf = 0 \tag{57}$$

$$\sum_{i=1}^{n} (frj_i + fconj_i) - (rj_i + mj_i) Qf^{-2} = 0 \tag{58}$$

$$\sum_{i=1}^{n} (frj_i + fconj_i) - \sum_{i=1}^{n} Qf^{-2} (rj_i + mj_i) = 0 \tag{59}$$

$$Qf^{-2} \sum_{i=1}^{n} (rj_i + mj_i) - \sum_{i=1}^{n} (frj_i + fconj_i) = 0 \tag{60}$$

Thus, for the simulations, we have two quadratic equations for the optimal production phase Qf, Eqs. (65), (66).

$$a = \sum_{i=1}^{n} nf\ Tf - frj_i - fconj_i \tag{61}$$

$$a = \sum_{i=1}^{n} nf\ Tf - \sum_{i=1}^{n} frj_i + fconj_i \tag{62}$$

$$a - \sum_{i=1}^{n} nf\ Tf = - \sum_{i=1}^{n} frj_i + fconj_i \tag{63}$$

$$a - nf\ Tf = - \sum_{i=1}^{n} frj_i + fconj_i \tag{64}$$

Thus, for the simulations, we have two quadratic equations for the optimal production phase Qf, Eqs. (65), (66).

$$Qf^2 + b\ Qf + c = 0 \tag{65}$$

$$c\ Qf^{-2} + 0 - (a - nf\ Tf) = 0 \tag{66}$$

By entering the simulation data into variables and constants, a quadratic equation of unit costs is obtained. So nf = 10, Tf = 49,588, fconj = Tf*1/3 and vosj = 2. Then the constants of the quadratic equation take the values a = 479,300, b = 7587 and c = 17.23. For Q_{opt} = Qf = 60 × is 0.0045.

The second equation confirms the value of the phase number n_{opt} = nf = 9.333 Eqs. (67), (68).

$$Qf\ c^2 + 0 - A^2 = 0 \tag{67}$$

$$nf = (a - A)/Tf \tag{68}$$

5.3.2 Digital twin simulation of the MGSC project with DSP code as OD

By simulating the given project Arena Zagreb with a derivative shift in the term or the cost increase of the equation, the future realization caused by a certain risk in the project Eq. (69).

$$\begin{aligned} MGSc\ DSP\ COD: = \Big[f_{n+1}\Big(\Big[skvGr(x,T)_{ijk}\Big]\Big) &= f_n\Big(\Big[skvGr(x,T)_{ijk}\Big]\Big)\Big] \\ &+ \Delta f_{n+1}\Big(\Big[skvGr(x,T)_{ijk}\Big]\Big) \end{aligned} \tag{69}$$

In the implementation, the main problem is to define the change in the EAC, BAC S-curve caused by different risks or changes in labor intensity, i.e., resource consumption. This is solved by numerical iteration, i.e., by induction and iteration of the cost estimation equations Tproc using the planned normative costs Tp and their derivation. The derivative of the MGSC valuation curve is therefore the value of the difference between EAC, BAC and the value of the valuation cost (Tproc) and plan (Tplan) functions, i.e., the normative costs T [Eqs. (12)–(14)] of the standard MGSC curve plus the differential costs T Eqs. (70)–(77).

$$T_{x+1} = T_x + \Delta T_{x+1} \tag{70}$$

$$T' = \frac{\Delta T}{\Delta x} = \frac{\Delta T}{\Delta t} = y' \tag{71}$$

$$T_{x+1} = skvGr(x,T) = \lambda r \bullet \lambda kv \bullet \int_0^x \frac{1}{(a\cdot T + b)\cdot\sqrt{2\cdot\pi}} \bullet e^{\frac{-(x-\mu)^2}{kv\bullet(a\bullet T+b)}} dx + T'\Delta x \tag{72}$$

$$x = \begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \end{bmatrix} y = \begin{bmatrix} 124.838 \\ 145.906 \\ 161.892 \\ 170.53 \\ 170.53 \\ 161.906 \\ 145.906 \\ 124.838 \end{bmatrix} b = \begin{bmatrix} b1 \\ b2 \\ b3 \end{bmatrix} b1 = \sum_{x=1}^{n} x, b2 = \sum_{x=1}^{n} xy, b3 = \sum_{x=1}^{n} x^2 y \tag{73}$$

$$\begin{bmatrix} n & \sum_{x=1}^{n} x & \sum_{x=1}^{n} x^2 \\ \sum_{x=1}^{n} x & \sum_{x=1}^{n} x^2 & \sum_{x=1}^{n} x^3 \\ \sum_{x=1}^{n} x^2 & \sum_{x=1}^{n} x^3 & \sum_{x=1}^{n} x^4 \end{bmatrix} \mathbf{x} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} b1 \\ b2 \\ b3 \end{bmatrix} \tag{74}$$

$$X = bA^{-1}\ X = \begin{bmatrix} 94.5 \\ 33.75 \\ -3.75 \end{bmatrix} a_i = X_i \tag{75}$$

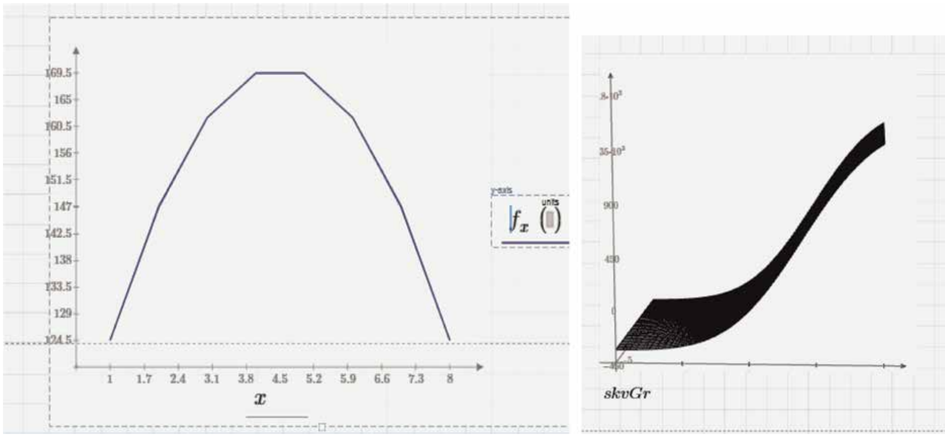

Figure 15.
Derivative function and cumulative MGSC curve, extended by half a month (author).

$$y' = \frac{\Delta T}{\Delta t} = a_1 + a_2 x + a_3 x^2 \tag{76}$$

$$y' = skvGrplus = f_x = 94.5 + 33.75\,x - 3.75\,x^2 \tag{77}$$

By including it in MGSC, the future cash flow curve is defined by Eq. (78) (**Figure 15**).

$$skvGr(x,T) = \lambda r\ \lambda kv \bullet \int_0^x \frac{1}{(a \cdot T + b) \cdot \sqrt{2 \cdot \pi}} \bullet e^{\frac{-(x-\mu)^2}{kv \bullet (a \bullet T + b)}} dx + \left(94.5 + 33.75\,x - 3.75\,x^2\right) dx \tag{78}$$

By numerically deriving the given curve skvGr(x, T) or Tp, the derivative of the function is created by tens parts of the function and approximated by Newton's tangent method, with the possibility of using steps of the degree of rotation or the intensity of resource consumption. The derivative function MGSC of the planned curve is defined with the Gaussian method of the sum of least squares.

5.3.3 Simulations of resource logistics DSP_MGSCNr by deriving the histogram curve

By the numerical derivative of the given curve skvGr(x, T) or Tp, the derivative of the function is created by tens of the function and approximated by Newton's tangent method, with the possibility of using steps of the degree of rotation or intensity of resource consumption. The derivative function MGSC of the planned curve is defined with the Gaussian sum of least squares method. The total number of concrete workers as a dimension of the project T is replaced by the total number of the given resource Nr, and partially by the given number of workers nr. Since Δt = Δx = 1, thus Nr\` = Δnr. Thus, the distribution or derivative curve of the resource demand consists of a series of Δnri Eq. (79).

$$Nr = \int y' = \int nr = \int \frac{\Delta nr}{\Delta t} = \int \Delta nr = \sum \Delta nr = 387 \tag{79}$$

For several projects in the same year interval, an approximately Gaussian distribution or a wave function of the quantitative data of a certain resource such as the labor of a carpenter, material or machine resources can be observed. The transformation of the financial MGSC curve into the MGSCNr curve is defined by replacing the T variable, i.e., the summarized financial by the Nr variable, i.e. the summarized quantity of resources, Eq. (80).

$$MGSCNr(x, Nr) = \lambda r\ \lambda kv \int_0^x \frac{1}{(a \cdot Nr + b) \cdot \sqrt{2 \cdot \pi}} \bullet e^{\frac{-(x-\mu)^2}{kv \bullet (a \bullet Nr + b)}} dx \tag{80}$$

The logistics team gets a great tool for the ability to define the probability and reliability of resources in the process cycle. For the specific worker n = 9, μ = 4.5, T = 389, kv = 104, a = 3.81104, b = 0.008 and λr = 1,λkv = 0.918 the S-curve is defined (**Figure 16**).

5.3.4 Resource reliability DSP_MGSCNr by derivative histogram curve

In this way, the probability or reliability of the system of future events can be defined with the optimization of the same and related to the reliability frequency of the resource elements (**Figure 17**), which is a function corresponding to the difference one and MGSCNr01 Eqs. (81), (82).

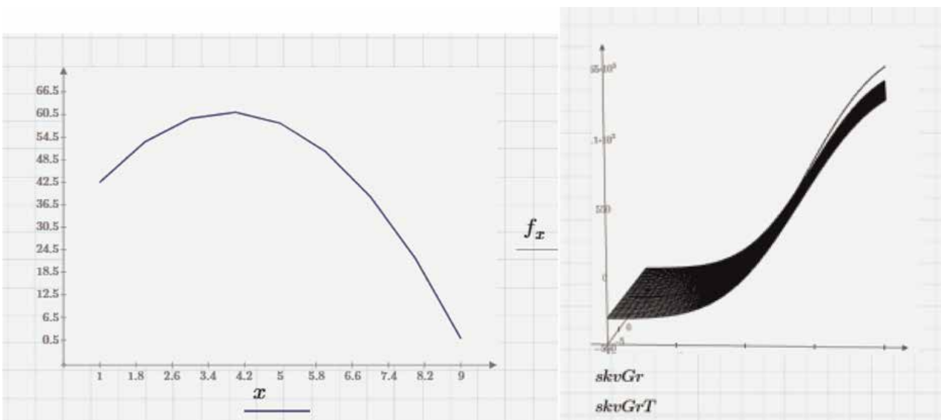

Figure 16.
Functional (fx), MGSC derivative curve (nr = y´) of the histogram of resources for a carpenter and cumulative MGSCNr curve from the distribution nr or derivative curve (author).

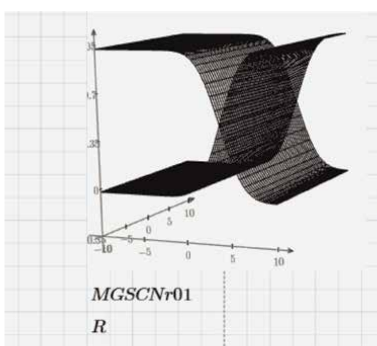

Figure 17.
Cumulative S-curve and resource reliability curve (author).

$$R(x, R, Nr01) = 1 - MGSCNr01'(x, R, Nr01) \tag{81}$$

$$R(x, R, Nr01) = 1 - \lambda kv \bullet \int_0^x \frac{1}{(\sigma) \cdot \sqrt{2 \cdot \pi}} \bullet e^{\frac{-(x-\mu)^2}{kv \bullet (\sigma)}} dx \tag{82}$$

6. AI system DSP-MGSC OD and Križaić software Combinatorics (KSC) method

6.1 Quantitative dependence of resources KSC method

The methods of logistics management that make use of operational research are a continuation of linear programming, optimal booking, Lagrange multipliers, gradient methods, dynamic programming, the transportation method, the allocation method, etc.

6.1.1 Iterative KSC equations

It defines all combinatorial data sets with a precisely defined number of combinations which are defined by known mathematical formulas of combinatorics [48]. Thus, permutations can also be represented graphically as the addition of the next number to all intermediate columns and as the first and last columns of the previous data set. The appearance of the notation equation is a permutation with repetition of Eqs. (83), (84).

$$P = \begin{bmatrix} U[[X_{n-1}]U[n_i]] \rightarrow 1 \hookleftarrow n_{\max} \\ n_{\max} \hookleftarrow \end{bmatrix} \tag{83}$$

$$P = U \begin{bmatrix} n_i \rightarrow 1 \hookleftarrow n_{\max} \\ n_{\max} \hookleftarrow \end{bmatrix} \tag{84}$$

P permutation, K combination, V variation.
U unija In the union still the.
n_i number in the sequence.
n_{max} max number in the sequence.
→ Movement of the sequence from row to column.
↵ Movement of the string to a row or in a column.
The equation of the combination set with the repetition of Eqs. (85)–(87).

$$K = U \begin{bmatrix} n_i \rightarrow 1 \hookleftarrow n_{\max} \; n_i \neq n_{\mathrm{ik}_i} \\ n_{\max} \hookleftarrow \end{bmatrix} \tag{85}$$

i_th channel.
The equation for recording variations with repetition Eq. (86).

$$V = U \begin{bmatrix} n_i \rightarrow 1 \hookleftarrow n_{\max} \\ n_{\max} \hookleftarrow \end{bmatrix} \tag{86}$$

Equation notation of combinations with repetitions in channels for the transport method ™ Eq. (87).

$$K = U\begin{bmatrix} n_i \rightarrow 0 \hookleftarrow n_{k\,\max} \\ n_{k_n\,\max} \hookleftarrow \end{bmatrix} \tag{87}$$

k channel, origins.

n_{kmax} maximum number of strings in k channel.

n_{k_nmax} maximum number of strings from all channels.

KSC equation of recording combinations without repetition, channels with the same dimensions Eqs. (88), (89). gives a record of all iteration syllables iterated with arrows in loops to specific values of numbers within the indicated dynamic (open intervals) determinants.

$$k_i = k$$

$$K = \left| \begin{matrix} n_1 \rightarrow & k_{max}-1 \\ \uparrow & \downarrow \\ \leftarrow & n_{max} \end{matrix} \left| n_2 \overset{\rightarrow}{\underset{\leftarrow}{\uparrow}} \quad \overset{1}{\downarrow} n_1 - k_i \,|\, n_{i \rightarrow} n_i + 1 \downarrow \rightarrow \quad n_k \downarrow k_i \,|\, \overset{\leftarrow}{\uparrow} n_k \rightarrow \quad \overset{n_{max}}{\downarrow} n_1 + 1 \right| \right| \tag{88}$$

Placing the iteration equation in a Delphi procedure with about one hundred lines, solves all problems of combinatorics and fast writing of all possible sequences. KSC equation of the data sets of combinations without repetition and channels with different dimensions Eq. (40).

$$k_i \neq k$$

$$K = \left| \begin{matrix} n_1 \rightarrow & k_{max} \\ \uparrow & \downarrow \\ \leftarrow & n_{max} \end{matrix} \left| n_2 \overset{\rightarrow}{\underset{\leftarrow}{\uparrow}} \quad \overset{1}{\downarrow} n_{max} - k_i \,|\, n_{i \rightarrow} n_i + 1 \downarrow \rightarrow \quad n_k \downarrow k_i \,|\, \overset{\leftarrow}{\uparrow} n_k \rightarrow \quad \overset{n_{max}}{\downarrow} n_1 + 1 \right| \right| \tag{89}$$

The transport method and the assignment method can be easily developed from this.

6.1.2 Iterative KSC equations with the assumption of critical path activity

By determining the number of critical activities, it is possible to determine which critical path is the most optimal. A record of all combinations by critical activities is similar to a lottery draw and would give the cost for each time point and the minimum cost can be easily determined. But the critical path activities also have conditions that are the future of the given research.

6.2 Automation and AI systems for management maintenance DSP_MGSCNr and KSC method as OD

The automation of the logistical preparation process is achieved through the softwareization of the given model. Thus, the procurement plan and the installation plan are transferred from Yust to time production logistics. Planning with the DSP code is achieved by with a combinatorial equation to define all paths during product creation. The DSP code is therefore a universal equation that can be used for all equations, including CPM equations or DSPiP modeling. Simulating the MSP project model with a Gantt chart and an S-curve over the key resources given by the ABC curve, amounts to defining the labor hours of the resources with the cost Eqs. (90)–(92) using the directional coefficient (a) of the linear direction of the representation of the resource cost plus the product with the intensity of the resource input (i), i.e., the double directional coefficient.

$$\Delta t\left(R_j\right) = \Delta Nr\left(R_j\right)/Nr^{\prime} \tag{90}$$

$$\Delta t_i\left(R_j\right) = \Delta Nr\left(\sum\nolimits_{i=1}^{nr} a_{ri} i_{ri} t_{ri}\right)/Nr_i^{\prime} \tag{91}$$

$$MGSCNr(x, R, Nr) = \lambda r\ \lambda kv \bullet \int_0^x \frac{1}{(a \cdot Nr + b) \cdot \sqrt{2 \cdot \pi}} \bullet e^{\frac{-(x-\mu)^2}{kv \bullet (a \bullet Nr + b)}} dx + \Delta Nr_i\left(R_j\right) \tag{92}$$

In the planned example itself, the ABC curve restricts the normative resource risk, which is involved in about 80% of the project, to a pair of resources, while only one resource can be responsible for almost half of the costs. Another estimation method is possible by creating a step according to the mathematical iteration methods of Eqs. (93)–(97) with the variables BACNr equal to 1 and EACNr.

$$\boldsymbol{Nr_{x+1} = Nr_x + \Delta Nr_{x+1}} \tag{93}$$

$$Nr' = \frac{\Delta Nr}{\Delta x} = \frac{\Delta Nr}{\Delta t} = \frac{EACNr - \left(Nr - Nr_p\right)}{BACNr} \tag{94}$$

$$\boldsymbol{Nr_{x+1} = Nr_x + \left(EACNr - \left(Nr_{proc} - Nr_p\right)_{x+1}\right)} \tag{95}$$

$$\boldsymbol{Nr_{x+1} - Nr_x + \left(Nr_{proc} - Nr_p\right)_{x+1} = EACNr} \tag{96}$$

BACNr different from one.

$$\boldsymbol{BACNr(T_{x+1} - T_x) + \left(T_{proc} - T_p\right) = EACNr} \tag{97}$$

By introducing the MGSC equation into the iteration series of the S-curve, the question EACNr was solved (**Figure 18**).

While project management bWhile project management by increasing the BACNr rating curve with risk without extending the project duration will cost the company more, which is a big warning by EACNr or by DSP-MGSC-OD method Eq. (98) for management.

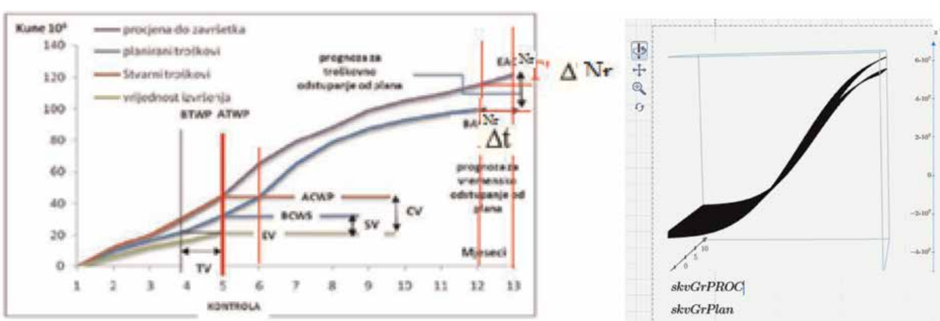

Figure 18.
Cash flow curve in all states (author).

$$\triangleq DSP\_COD = MGSCNr(x,R,Nr) = \sum\left(MGSC(x,R,Nr) + \Delta Nr\left(\sum_{i=1}^{nr} a_{ri} i_{ri} t_{ri}\right)/Nr_i\right) \tag{98}$$

$\triangleq$ is an organizational differentiation function in dual DSP Cod.

6.3 Automation and AI systems for management maintenance DSP_MGSCNr method with relative MGSCNr quantum plan

The relative plan defines the development of project activities in a certain time t and in a certain space with a certain intensity of activity development. The Cyclogram graphical plan also separates the activities according to space and intensity, but in absolute time. By simulating the MSP project model with a Gantt chart and an S-curve over the key resources given by the ABC curve, it amounts to defining the working hours of the resources with the costs Eqs. (99)–(101) using the directional coefficient (a) of the linear direction of the representation of the resource costs plus the product with the intensity of the resource input (i), i.e., the double directional coefficient.

$$\Delta t(R_j) = \Delta T(R_j)/T' \tag{99}$$

$$\Delta t_i(R_j) = \Delta T\left(\sum_{i=1}^{nr} a_{ri} i_{ri} t_{ri}\right)/T_i' \tag{100}$$

$$MGSCNr(x,R,Nr) = \lambda r \bullet \lambda kv \bullet \int_0^x \frac{1}{(a \cdot Nr + b)\cdot\sqrt{2\cdot\pi}} \bullet e^{\frac{-(x-\mu)^2}{kv \bullet (a \bullet Nr + b)}} dx + \Delta Nr_i(R_j) \tag{101}$$

Power in the physical sense is the work done per unit of time, and effect in the organizational sense is also the work done per unit of time Eqs. (102)–(104).

$$\frac{W}{t} = P = U = \frac{W}{t} \tag{102}$$

$$U = VU = U_{k,r,ko,kd} = kd_i\left(ko_k\left(f_i(k,r)\right)\right) \tag{103}$$

The combination of physical work with organizational work results in the Eq. (102).

$$m\omega^2 f = F * h = W = U = VU = U_{k,r,ko,kd} = kd_i\left(ko_k\left(f_i(k,r)\right)\right) \tag{104}$$

The quantum plan defines the imaginary development of the project activities in a certain time t and a certain space with a certain frequency of activity development. The frequency is defined by a known physical equation related to the mechanics of the material, i.e., the strength of the material, and it is a function of the effect, i.e., the norm Eqs. (105), (106).

$$m\omega^2 f = W = VU = kd_i\left(ko_k\left(f_i(k,r)\right)\right) \tag{105}$$

$$f = kd_i\left(ko_k\left(f_i(k,r)\right)\right)/m\omega^2 \tag{106}$$

The effect of the resource defined by the capacity Q with the MGSCNr curve defines the Eqs. (107), (108).

$$m\omega^2 f = W = VU = Q = MGSCNr(x, R, Nr) \tag{107}$$

$$f = MGSCNr(x, R, Nr)/m\omega^2 \tag{108}$$

7. Conclusions

The results of mathematical project modeling with Križaić methods efficiently raise the organization to the level of technologically differentiated theory (FEM and IEM technologies), and thus, with the advent of computer and software support, the desire to define a dynamic PM business system is realized. VN models and the support of digital work monitoring [49] also create dynamic standards, and the KAK method defines a dynamic calculation with the determination of the optimum phase using a quadratic equation in which the minimum of the function can be defined. The use of the MGSC curve for the MGSCNr curve of the cumulative resource histogram representation proved to be justified because the annual de-leveling resource histogram can be easily interchanged with the MGSCNr curve. When predicting the future in logistics maintenance according to technological processes, the MGSCNr curve, supported by the economic calculation of the production price with the KAK method and the probabilistic KSC methods within the DSP code, enables optimization games of logistics inside and outside the business system. The DSP code is identical to the CPS system and can define all states or all paths in the process with the KSC method. This also enables the definition of the optimal production phase and creates an idealized and automated process simulation through AI in maintenance logistics. A PM dynamic and a digital twin system are also created, and in the organization we simulate the reality of the projects through the model standardization recommended by the DSP_MGSCNr OD method or ≜ which is an organizational differentiation function in the dual DSP COD. In addition to the PM probability calculation of the derivative of the MGSCNr distribution curve, the Monte Carlo simulation [50] or KSC is used, for example, which is an approximation of the FEM and IEM-RK∞ models. This creates a probability range using statistical curves so that better risk management of the resources in the project is possible. The MGSCNr curve opens up a new research area in the field of BACNr and EACNr dimensions in the project. The idea of the KSC models can be transferred to other methods of operational research, so that the entire branch of science is based on the combinatorics of numbers. Limitations exist in the reliability of the data, especially from the field, which can be replaced by process automation [51] with AR [52] communication. This, in turn, aims to support the business model with AI [53] and CPS [54] systems to initiate new discoveries in defining the development of technology standards and organization with DSP_MGSC-OD technology or ≜. Also for system optimization with SMART technology, for automation and robotization through large infrastructural logistics investments in a sustainable circular economy. Further research on model standardization of projects and vectorial standards is recommended to more realistically define risk in the PM logistics process project system. A team of theories develops the practice, and the practice complements the theory. The final result refers to the idea ≜ of organizational differential with the theory of relativity in defining the intensity of the work process in conjunction with the definition of the wave function of logistic analysis data.

Conflict of interest

The authors declare no conflict of interest. 16.02.2007. The author deposited the software called dynamic structural programming - cybernetic programming in the Croatian copyright agency.

Notes/thanks/other declarations

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References

[1] Kevin A, Sebayang AKT, Afrianto I. Penerapan Cloud Computing untuk keamanan logistic. 2023. Available from: https://www.researchgate.net/publication/368543814. DOI: 10.13140/RG.2.2.18757.93925

[2] Križaić V, Hranj D. Daily monitoring by IIS. In: 11th OTMC. Dubrovnik: Croatian Association for Construction Management; 2013. ISBN 978-953-7686-03-1, str. 26

[3] Križaić V. Application of norms models with vectoral system in construction projects. Journal of Civil Engineering an Architecture. 2014;**8**:722-728. USA, ISBN 1934-7359 str. 722-728

[4] Abdelhady MI, Abdelgadir AK, Al-Araimi F, AL-Amri K. Using Algorithm in Parametric Design as an Approach to Inspire Nature in Architectural Design. Cham: Springer Nature; 2022. DOI: 10.1007/978-3-030-97196-0_10

[5] Cheng L-CV. Logistics strategies to facilitate long-distance just-in-time supply chain system. In: Supply Chain Management. London, UK: IntechOpen; 2011. DOI: 10.5772/15534

[6] Falera C, Höftmanna M. Service-oriented communication model for cyber-physical-production-systems. Procedia CIRP. 2019;**67**:156-161

[7] Križaić V, Završki I. Modelska standardizacija građevinske ponude metodom dinamičkog strukturnog programiranja, 5. simpozij doktorskog studija građevinarstva, Zagreb: Zbornik radova, Štirmer, Nina (ur.). Zagreb: Građevinski fakultet Sveučilišta u Zagrebu, 2019. 117-126 doi: 10.5592/CO/PhDSym.2019.10

[8] Qiu Y, Wang J, Zhang C, Zhou Z. Numerical simulation study on the impact of excavation on existing Subway stations based on BIM-FEM framework. Buildings. 2024;**14**(5):1444

[9] Križaić V, Rodiger T, Križaić N, Križaić J. Ritter-križaić iteracion method of truss construction. In: 16th World Congress on Computational Mechanics and 4th Pan American Congress on Computational Mechanics Vancouver. Kanada; 2024

[10] Križaić V, Rodiger T, Baksa S. Simulation project management by modified Gaussian S-curve. In: 14th WCCM-ECCOMAS Congress. Paris; 2021. DOI: 10.23967/wccm-eccomas.2020.309

[11] Padmanaban S, Nasab MA, Samavat T, Nasab MA. Artificial intelligence techniques for smart power systems. In: Book IoT and Analytics in Renewable Energy Systems (Volume 1). 2023. DOI: 10.1201/9781003331117-9

[12] Križaić V, Rodiger T, Buč S. Digitally literate manager in a vector organization. Journal of Civil Engineering and Architecture. 2021;**15**(8):419-428. DOI: 10.17265/1934-7359/2021.08.003

[13] Belak V. Menadžment u teoriji i praksi. Zagreb: Biblioteka Excelens; 2014

[14] Buble M. Management, Split. Ekonomski fakultet Split; 2000

[15] Katavić M. Osnove ekonomike za graditelje. Zagreb: Hrvatska Sveučilišna naklada; 2009

[16] Šundalić A. Između društva rada i društva znanja media. Culture and Public Relations. 2012;**3**(2):120-130

[17] Smulders F, Boer H, Hansen P, Gubi E, Dorst K. Configurations of NPD –

Production interfaces and Interface integration mechanisms. Creativity and Innovation Management. 2003;**11**:62-73, Available from: https://www.researchgate.net/publication/229620012

[18] Chelyshkov P. Computer-Aided Design of Cyber-Physical Building Systems. Russia: Moscow State University of Civil Engineering; 2019. DOI: 10.1051/e3sconf/20199701012

[19] Horváth I. Cyber-physical systems design section. Designs. 2018;**3**(1):1. DOI: 10.3390/designs3010001

[20] Huang C, Fisher N. An alternative methodology for selecting enterprise resource planning (ERP) systems in a typical architecture/engineering/construction (AEC) company. International Journal of Construction Management. 2014;**5**(1):39-57

[21] Oti AH, Tizani W, Abanda FH, Yaly-Zada A, Tah JHM. Structural sustainability appraisal in BIM. International Research Journal Automation in Construction. 2016;**69**(5):44-58

[22] Eber W. Artificial intelligence in construction management – A perspective. In: Creative Construction Conference, 2019, Budapest, Hungary. 2019

[23] Kim J, Cha H. Design criteria-based probabilistic estimation method for aged apartment remodeling projects in Korea. In: Creative Construction Conference, 2019, Budapest, Hungary. 2019. pp. 275-283

[24] Anumba CJ, Akanu AA, Mesner JI. Towards a cyber-physical systems approach to construction. In: Construction Research Congress. 2010. DOI: 10.1061/41109(373)53

[25] Petrić J. Opreaciona istraživanja. Beograd: Naučna Knjiga; 1998

[26] Taylor D, Mischel J, Penman J, Goggin T. Velika snaga Delphy 3 programiranja. Zagreb: Znak; 1998

[27] Eslinger S. The Position of Software in the Work Breakdown Structure (WBS) for Space Systems. In: Space and missile systems center air force space command 483 N. Aviation Blvd. El Segundo: The Aerospace Corporation; 2006

[28] Vranjković P. Booleova algebra. Zagreb: Element; 1998

[29] Jakjoud A, Zrikem M, Baron C, Ayadi A. SysPEM: Toward a consistent and unified system process engineering meta model. Journal of Intelligent Manufacturing. 2014;**25**(2):1-18. DOI: 10.1007/s10845-014-0886-7

[30] Mota P, Machado F, Biotto C, Mota R, Mota B. BIM for production: Benefits and challenges for its application in a design-bid-build project. In: Pasquire C, Hamzeh FR, editors. 27th Annual Conference of the International. Group for Lean Construction (IGLC). Dublin, Ireland; 2019. pp. 687-698. DOI: 10.24928/2019/0243

[31] Yin YL, Qian K. Construction project cost management based on BIM technology. Applied Mechanics and Materials. 2013;**357-360**:2147-2152

[32] Wei L. Application of BIM technology in construction bidding. Earth and Environmental Science. 2017;**100**:012178. DOI: 10.1088/1755-1315/100/1/012178

[33] Kholopov VA, Kashirskaya EN, Shmeleva AG, Kurnasov EV. An intelligent monitoring system for execution of machine engineering

processes. Journal of Machinery Manufacture and Reliability, ResearchGate. 2019;**48**(5):464-475

[34] Daaboul J, Duigou J, Eynard B. Strategic lean management: Integration of operational performance indicators for strategic lean management. IFAC-PapersOnLine. 2016;**49**:65-70. Available from: https://www.researchgate.net/publication/306068896

[35] Turk Ž, Klinc R, Mac Z. Towards a parsimonious information management for energy retrofitting of buildings. In: Creative Construction Conference, 2019, Budapest, Hungary. 2019

[36] Widhiastuti H. The effectiveness of communications in hierarchical organizational structure. International Journal of Social Science and Humanity. 2012;**2**(3):185-190

[37] Križaić V. System adjustments through vector organization and technology, Proceedings of the Creative Construction Conference 2019. Budimpešta, Skibniewski, Miroslaw J, Hajdu, Miklos (ur.), 2019. 440-445. doi: 10.3311/CCC2019-061

[38] Križaić V. Optimizacija izvođenja oplata, magistarski rad. Zagrebu: FGZ; 1994

[39] IRO Građevinska Knjiga. Normativi i standardi u građevinarstvu. Beograd: Građevinska knjiga; 1982

[40] Vukomanović M, Kolarić S, Radujković M. Priručnik organizacije građenja. Zagrebu: Sveučilište u Zagrebu, Građevinski fakultet; 2018

[41] Križaić V. Dinamička kalkulacija "A-K" metoda. In: V simpozij – Organizacija i management u graditeljstvu. Zagreb: GFZ; 1993. pp. 219-224

[42] Guljaš B. Matematička analiza I & II, skripta. Zagreb: PMF; 2018

[43] Ciramela G, Gander JM. Iterative Methods and Preconditioners for Systems of Linear Equations. USA: Society for Industrial and Applied Mathematics; 2022

[44] Schellhorn H, Kong T. Machine Learning for Asset Management and Pricing. USA: Society for Industrial and Applied Mathematics; 2024

[45] Wang Y, Zhao Y, Liu BM, Wang N, Le C. Key technologies and future development trends of intelligent earth–rock dam construction. Journal of Intelligent Construction. 2023, 2023;**1**(3):9180018

[46] Križaić V, Hranj D. Project management by modified Gaussian S-curve, conference proceedings. In: 14th International Conference Organization, Technology and Management in Construction and 7th International Project Management Association Research Conference. 2019. pp. 208-213

[47] Benz A. Svemir znanje i čuđenje. In: Astrofizičke spoznaje i vjerska iskustva. Zagreb: Krščanska sadašnjost; 2022

[48] Križaić V, Hranj D, Rodiger T. Utjecaj softverske matematike na modeliranje u graditeljstvu, Inovacije, tehnologije, edukacija i menadžment. In: 5. međunarodna konferencija, Sv. Martin na Muri. 2018. pp. 173-178

[49] Šopić M, Vukomanović M, Car-Pušić D, Završki I. Estimation of the excavator actual productivity at the construction site using video analysis. Organization, Technology and Management in Construction. 2021;**13**: 2341-2352. DOI: 10.2478/otmcj-2021-0003

[50] Wilches-Visbal JH, Apaza-Veliz DB. Validation of the spectral reconstruction of an electron beam by comparison with spectrum from MonteCarlo. Biomedical Engineering. 2023;**25**(1):2-12. DOI: 10.25100/iyc.25i1.12051

[51] Funaki K. Product automation and innovation. In: Springer Handbook of Automation. Cham: Springer; 2023. pp. 561-584

[52] Park J, Chang S, Lee H, Cho Y. Inspection Data Exchange and Visualization for Building Maintenance Using AR-Enabled BIM. The International Association for Automation and Robotics in Construction; 2022. pp. 483-490

[53] Marrapu AK, Chinthamu N, Pokhriyal S. Development of product quality with enhanced productivity in industry 4.0 with AI driven automation and robotic technology. In: Second International Conference on Augmented Intelligence and Sustainable Systems (ICAISS). 2023. DOI: 10.1109/ICAISS58487.2023.10250736

[54] Verma M. Cyber-physical systems: Bridging the digital and physical realms for a smarter future. International Journal of Trend in Scientific Research and Development (IJTSRD). 2023;**7**(6): 296-302. November-December 2023, e-ISSN: 2456 – 6470. Available from: www.ijtsrd.com

Section 2

Leadership, Public Infrastructure and Project Management Maturity Model

Chapter 5

Developing a Sustainable Framework for Government Funded Infrastructure Projects in Malaysia

Samuel Adeyinka-Ojo

Abstract

This chapter is aimed at developing a sustainable framework for critical success factors (CSFs) and critical failures factors (CFFs) for government funded infrastructure projects in Malaysia. The research gaps show that there is a lack of empirical studies on the sustainable framework for CSFs and CFFs in the implementation of government projects. The research case scenario is placed within a theoretical framework discussing the process involved in a government-funded project underpinned by both resource-based theory and stakeholder theory. This chapter has adopted a qualitative case study and relied on 26 in-depth interviews conducted with the study's participants. A thematic analysis framework was adopted to analyse the participants' responses and views. Key findings identified three main constructs that were conceptualised to develop a sustainable framework. Theoretical contributions, implications for managerial practice, policymakers, and society's wellbeing are identified. Transferability to similar projects is presented. Finally, the limitations of the study and directions for future studies are discussed.

Keywords: government-funded projects, sustainable framework, CSFs, CFFs, infrastructures

1. Introduction

In recent time the successful implementation of any infrastructure projects bankrolled by the government has attracted the business practitioners and researchers [1]. Over the years, due to the importance attached to the success of public sponsored projects has led to the crafting and development of different models or frameworks of managing project management success [1]. It should also be known that the donor bankrolled or funded infrastructure projects is different from the specific projects funded by the local government, state and national government. These types of projects are mainly sponsored as developmental infrastructures from not-for-profit organisations or non-government organisations (e.g., Red Cross, United Nations agencies, Rotary Club International, Lioness Club etc.) [2]. The purpose of donor funded project is to improve the quality of life and well-being of the host communities where such infrastructural facilities are located [2]. Notably, for every successful government funded projects and donor funded projects, the key success factors include the project iron triangle components of project quality (meeting customer expectations), project cost, and project time management or schedule.

Previous extant literature specifically on project management paradigm has focused on project failure factors. These failures have been from the generic perspective. Studies that have been specifically on government funded projects failure and success factors have been growing in the extant literature work [3]. However, in the current era, there exist lack of academic interest on sustainable critical success factors and critical failures factors of government projects especially in the developing countries [3] and Malaysia is not exempted.

1.1 Current scenario and government policies in Malaysia

The government project infrastructure sector provide services for other industries as all economic infrastructure of a country depends on the successful execution of these government funded projects. In comparison to other economic sectors, the government funded infrastructure projects have not embraced technological development as expected [4]. It should be noted that automation has begun to replace the traditional way of doing things. This necessitates the Malaysian workforce to move towards technical and internet-based work systems for a sustainable project execution and management [4].

In Malaysia, the current National Construction Policy (NCP) 2030 is one of the key initiatives by the Government in transforming the whole construction sector and government funded infrastructure projects towards a sustainable and digitalisation era [4]. This policy is designed to guide both government projects and private construction business in order to achieve sustainable national development by 2030 [4]. The NCP has four main objectives to be achieved. In order to embrace paradigm shift which, the National Policy on Construction (2030) provide specific focus on the innovation of technological integration with the nine (9) pillars of the Industrial Revolution 4.0. The NCP 2030 is designed to restructure the economy in order to handle the wealth inequality era [4]. Therefore, the main aim of this study is to explore government funded infrastructure project sustainable critical success factors and critical failures factors in Malaysia.

1.2 Understanding the issues with government funded infrastructure projects

Despite the large amount of money allocated to government funded infrastructure projects, study indicates due to lack of a framework for sustainable critical success factors in the execution of government projects it caused economic problems. For example, when projects are not executed based on the project iron triangle (time, cost and quality), poor management of project will lead to delays in final deliverables causing about 11 per cent (10.30 per cent) of the entire project costs. Likewise, close to 90 per cent of government construction project in west Malaysia shows that government projects are confronted with cost overrun at about 10 per cent [5].

Researchers have provided evidences from different parts of the world that indicate government projects suffered delays these include countries like Malaysia, Slovenia, Jordan and Norway. These researchers have found 26 causes of project delay grouped into three key causes. These are contractors with nine (9) causes, from the clients' perspective five (5) and from the project consultants (12) twelve [5]. However, the lacks of sustainable critical success factors in government infrastructure project have been understudied by the academic researchers and practitioners alike [3]. This is because the issue of sustainability in government projects are still new and not that familiar in the country which led to the following research gaps in the government funded projects in Malaysia.

1.2.1 Research gap 1

The first research or study gap identified is the dimension of current state of the government sponsored or funded infrastructure projects in the country (Malaysia). Extant literature sources revealed the existence of lack of empirically research by both academic researchers, government and private led practitioners on the current state of government related projects [2]. This study is also related to the paucity of underpinning theories, managerial and theoretical gap perspectives as further justifications for this research.

1.2.2 Research gap 2

The second research gap deals with identifying and explaining the challenges of executing government funded infrastructure projects sustainably in Malaysia. This is well documented in the literature that this important dimension in government financed public project lacks academic and practitioner interest from empirical point of view [6].

1.2.3 Research gap 3

The final research gap is connected with the current global challenge in which Malaysia is not exempted in the comity of nations as a bonafide member of United Nations. As we face unprecedented challenges such as climate change and COVID-19 pandemic, industry players will now have to be more innovative and creative in mitigating these challenges to stay relevant and competitive. Currently government is managing available scarce resource. Therefore, it is imperative to identify and develop a framework for the sustainable critical success factors in the execution of government funded infrastructure projects in Malaysia and identify the critical failures factors. Besides all these, for the government funded project execution to remain sustainable it is indispensable to adopt digital technologies inclusion that are disruptive transformation for competitive benefits [4]. It is essential to mention that government projects in developing countries that are featuring sustainable critical success factors and critical failures factors are very scare [3].

Therefore, following the main aim of this study, it also asks a general question that is consistent with the stated aim*:* How could a sustainable framework and critical success factors for government funded infrastructure projects in Malaysia be developed? In other to support the general question, the following specific questions that are consistent or align with the specific research objectives are asked: (a). What is the current state of the government funded infrastructure projects in Malaysia? (b). What are the challenges of executing government financed infrastructure projects in Malaysia? and (c). How can a sustainable framework for critical success factors and critical failures factors of government funded infrastructure projects in Malaysia be developed?

2. Literature review

Recently, academic researchers and project management practitioners have developed interest on project failures and success factors. According to the Project Management Institute [7], project success has been described as meeting customer's expectations or requirements as contained in the project charter. In other words, project success is the fulfilment of project iron triangle which consists of cost, time, and cost. Importantly, a project is generally referred to from the academic and professional perspectives as a temporary business undertaken to construct a unique products or service that satisfy the unique requirements of the clients [7]. Similarly, project management is also viewed as the utilisation of knowledge, skills, tools and techniques to project activities designed to satisfy the expectations of clients in project execution [7].

2.1 Government-funded projects and infrastructures

Study conducted in a developing country like Kenya uncovered the determinants of completion rate of government infrastructure financed projects located in different counties in Kenya. Furthermore, examples of government-funded infrastructure projects include the following: transportation infrastructure, power and energy (electrical transmission, natural gas pipelines), water project, telecommunication infrastructure, healthcare (hospitals, clinics), education (schools, colleges, and universities), and social infrastructure [building prisons, court building, and sporting complex] [3]. The study conducted by [3] has identified the following critical success factors namely, availability of funds, effective project planning, human resources, and stakeholders' role and involvement. Based on the different success factors, it is imperative to identify underpinning theory for this study in the following section.

2.2 The perspective of theoretical framework

This study is underpinned by stakeholder theory [8], and resource-based view (RBV) theory [8]. For every government-funded project it requires large amounts of resources for its successful execution. It should be noted that there are multiple stakeholders in government funded-projects. A managerial framework known as the resource-based view (RBV) is used to identify the strategic resources a company might use to gain a competitive advantage over time [9]. The resource-based view model (RBV) otherwise known as resource-based theory (RBT) is considered to be the critical success factors in government funded infrastructure project deliverables [6]. The resource-based view (RBV) is a model that view resources as critical to excellent organisation performance which provide a sustainable competitive advantage.

For government funded infrastructure projects to develop sustainable critical success factors, it is important to focus on the availability of resources including funding, materials, human resources, and relevant synergy. In addition, core-competencies of those involved in the government funded projects are also important which should be leverage upon [10, 11]. The basic tenet of the stakeholder theory, as put forth by Freeman in 1984, is to completely restructure the company. According to Freeman, a manager in an organisation has two roles: first, they should run the business for the benefit of the stakeholders to make sure the management serves as the stakeholders' agent, ensuring that each group's stake in the business is protected and that each group's rights in decision-making are respected. In this study stakeholder's theory is adopted because government-funded projects involve several stakeholders. Most of the end users or beneficiary of the public infrastructures are members of society. Likewise, project sponsors or owners and project team members are the relevant stakeholders.

2.3 Project critical success factors (CSFs) and project critical failure factors (CFFs)

The issue of project success is to ensure that the content of the project charter regarding the meeting client expectations cannot be overemphasised [1]. Evidence from extant literature indicates government infrastructure projects and public-private-partnerships presents several critical success factors (CSFs). These will include following transparent procurement of materials, the importance of cost benefit analysis, receiving government support, provision of financial resources, effective risk allocation of the projects, good governance and rule of law [12]. Other study has identified factors that influenced success in government infrastructure funded projects to include application of information technology management, digitalization of project management and execution, engagement of core stakeholders, project monitoring and control [6]. Others include team members qualities, the role of project main contractor and sub-contractors [13].

Furthermore, a review of extant literature suggests 34 different critical failure factors (CFFs) connected with the government financed infrastructure projects. These critical failure factors have been categorised into ten (10) components namely: (i) lack of effective project communication, (ii) lack of continuous support and commitment by project sponsor, (iii) poor project supervision and inexperienced professional project management practitioners, (iv) inflated project contract, (v) corruption and bribery, (vi) poor project management planning, (vii) lack of funding by the project sponsor, (viii) failures to honour payment for already job certified by the project engineer, (ix) political interference and interest, and (x) change of political leaders in government and lack of continuity [3, 14]. A summary of the findings on critical success factors are presented in the following **Table 1** for better understanding.

In view of the extant literature work, the identified critical success factors indicate there exist lack of research on developing a sustainable framework for digital critical success factors of government infrastructure funded projects in Malaysia. The justification for the CSFs will help us to know how sustainable they are and identifying potential CFFs in the execution stage of government-funded projects in Malaysia and by extension other developing countries.

2.4 Conceptual framework

As a follow-up to the current state of the government funded infrastructure project in Malaysia, challenges of executing government funded infrastructure project, CSFs and CFFs identified from the literature sources. A conceptual framework was developed to present a diagrammatical illustration of concepts, variables, factors, to be researched in this study. A conceptual framework is important in qualitative case study research of this nature [17]. The conceptual framework is presented in **Figure 1**. The next section is focused on methodology adopted in this study.

Citations (Year)	Component factors	Dimension
[12]	Government support, transparency and legal framework	• Transparency • Cost benefit analysis • Government and political support • Financial resources • Legal framework and good governance • Sound risk management • Effective project leadership • Project feasibility study • Enabling business environment
[1]	Project manager team member, competencies, skills and emotional intelligence	• Project manager competencies and skills • Emotional Intelligence and soft skills • Project team capabilities and specialised skills • Project iron triangle • Organisational culture and structure
[6]	Technology application	• Project implementation, monitoring and control • Technology and software application • Project procurement strategy • Relevant stakeholder involvement
[13]	Strategic construction management	• Project contractor and • Sub-contractor involvement • Strategic and effective construction management
[15]	Stakeholders: role and multiple key resources	• Availability of funds, • Effective project planning, • Human resources • Stakeholders' role and involvement.
[16]	Critical success factors for Malaysian construction projects	• Managing the iron triangle: • Time • Cost • Quality
[16]	Critical success factors for Malaysian construction projects	• Initial investment, commitment for changing behaviours, policy implementation efforts, guidance for sustainable contract available of technology and materials and project procurement system.
Source: Compiled and developed for this study.		

Table 1.
Key findings on critical success factors on government projects.

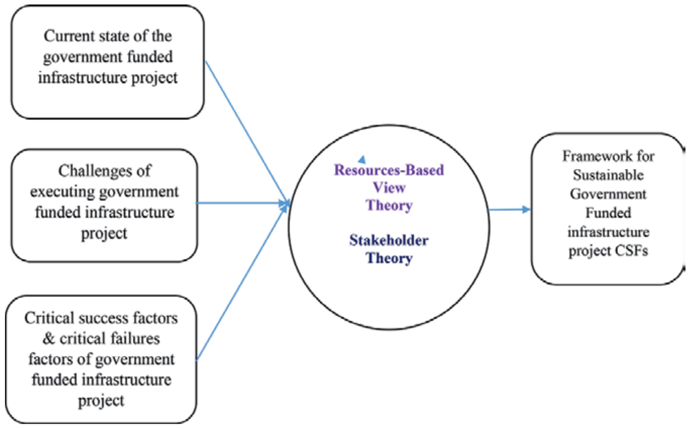

Figure 1.
Conceptual framework developed for this study.

3. Methodology

3.1 Preamble

In this study case study approach was adopted due to the nature of the proposed study aims and research questions. Based on the exploratory nature of this study into the sustainable framework of critical success factors in government infrastructure funded projects. Qualitative research methodology suggested by Creswell & Poth [18] was used in this study. The rationale for the selection of case study in this study is due to the need to produce an in-depth understanding of a case or phenomenon that has been researched. Literature work show there are single and multiple case studies [18]. It should be noted that the government-funded infrastructure projects in Malaysia is the study context or research case.

This study adopted single case study because the focus is on government project. This allowed researcher to undertake an in-depth study of the selected case. For a successful single case, the following procedures were followed as recommended by Miles and Huberman [17]. These stages include (a). be sure of the usefulness or suitability of the research problem, determine the suitability of using case study for the research problem; (b). ascertain the purpose of the case or event being studied; (c). develop the process of data collection and sustainability of data sources; (d). identify the analysis approach based on themes generate from the study; (e). present findings and provide interpretation of the case.

3.2 Data collection methods and participants

This study has applied in-depth interviews for data collection from the participants [19]. The participants in this study were chosen based on purposive sampling. This sampling technique was adopted so that the participants are those who can provide answers to the research questions. In this study, selected project directors, project managers, and officers of government ministries, departments, agencies, individual project contractors with the government, relevant stakeholders in the society, foreigners who has spent at least 5 years in Malaysia and those involved in government funded projects who were saddled with the responsibilities of government funded projects were interviewed.

The selection of these participants is consistent with previous studies on government funded projects [3, 6, 14]. The participants in this study were carefully chosen and sent a request letter to seek their consent for voluntary participation. Semi-structured interview protocol was developed to elicit data from the participants. There are 26 participants featured for the data collection. The number of participants interviewed was based on the saturation point where additional number of interviewees did not add no new data [20]. The focus is on the main question: *How could a sustainable framework for critical success factors and critical failures factors of government funded infrastructure projects in Malaysia be developed?*

4. Findings and discussion

Based on the comments obtained from the study's participants, the real study's findings were given and the study's participants' profiles are presented in **Table 2**. Additionally, findings from the analysis of the data collected are from three main perspectives based on the specific three research questions. The findings include

No.	Participant code No. (PCN)	Age	Gender	Country	Involvement in Government Projects
1	PCN01	41	Male	Malaysia	
2	PCN02	44	Female	Foreigner	
3	PCN03	38	Male	Malaysia	
4	PCN04	45	Male	Malaysia	Yes
5	PCN 05	25	Male	Malaysia	
6	PCN06	54	Male	Malaysia	
7	PCN07	55	Female	Malaysia	Yes
8	PCN08	77	Male	Malaysia	Yes
9	PCN 09	37	Female	Malaysia	
10	PCN10	23	Male	Malaysia	
11	PCN11	46	Male	Malaysia	
12	PCN12	23	Male	Malaysia	
13	PCN13	38	Male	Foreigner	Yes
14	PCN14	52	Male	Malaysia	
15	PCN15	26	Male	Malaysia	
16	PCN16	36	Female	Malaysia	
17	PCN17	48	Male	Malaysia	
18	PCN18	47	Female	Foreigner	
19	PCN 19	47	Male	Malaysia	Yes

No.	Participant code No. (PCN)	Age	Gender	Country	Involvement in Government Projects
20	PCN20	29	Female	Malaysia	
21	PCN21	45	Female	Malaysia	Yes
22	PCN22	56	Male	Malaysia	
23	PCN23	48	Male	Malaysia	Yes
24	PCN24	24	Female	Malaysia	
25	PCN25	41	Male	Foreigner	
26	PCN26	67	Male	Malaysia	Yes

Source: Developed for this study.

Table 2.
Demographic information of the participants.

(i). The current state of the government-funded infrastructure projects in Malaysia; (ii). The challenges of executing public infrastructure projects in Malaysia; and (iii). The critical success factors and critical failures factors of government-funded infrastructure projects in Malaysia. These are presented in **Tables 3**–**5**.

The goal of this study is to create a sustainable framework for Malaysian government-funded infrastructure projects' critical success factors (CSFs), and critical failures factors (CFFs). Findings from the qualitative case study, resource-based view (RBV) theory, and stakeholder theory used in this study are discussed further. Thematic analysis framework was applied to analyse the data collected from the participants. Thematic analysis is widely used in analysing qualitative data. This study also adopted the six stages of thematic data analysis, thematic map, and A-15 Point criteria of doing good qualitative analysis framework [21, 22]. Codes, sub-themes, and themes were generated from the analysis of the in-depth interviews conducted with the participants.

In this study, 26 participants were interviewed. There are eight (8) participants among the interviewees who have been involved in the execution of government-funded project in Malaysia (local or municipal council, state and federal governments). Among the participants there are 22 Malaysians and 4 foreigners who had lived in Malaysia for minimum of 5 years actually satisfied or met the selection criteria set for this study. Based on these criteria, foreigners living in Malaysia who are

Themes	New findings (contributions)
Identification of Government-funded infrastructures and projects.	• Pan Borneo Highway • East Coast Rail Line (ECRL)
Sources of finance or funding for government infrastructures projects in Malaysia	• Public projects are done as corporate social responsibility (CRS) by some private organisations. • The Pan Borneo Highway is funded by the federal government. • Soft loans by Chinese government agencies and contractor-financing.
Implementation and current state of public-funded projects in Malaysia	• Rooms for improvement by strengthening the tender selection process and project implementation process

Table 3.
The current state of the government-funded infrastructure projects in Malaysia.

Themes	New findings (contributions)
Challenges of implementation of public infrastructure project	• Covid-19 pandemic and infectious diseases
Causes of challenges in the execution of public-funded projects	• Government policy on bumiputra affirmation action • Not having the right people in government
Mitigating the challenges of executing government-funded projects	• Encourage Bumi Putra and non Bumi Putra joint venture • Less stringent immigration policies for foreign workers, health insurance for workers, personal protective equipment

Table 4.
The challenges of executing public infrastructure projects in Malaysia.

Themes	New findings (contributions)
Developing sustainable implementation of government-funded projects	• Increase number of monitoring agencies
Critical success factors of public project execution in Malaysia	• Sustainable project management • Good professional governance and controls
Digital technology, sustainable and successful execution of government-funded projects	• Digital technology support sustainable project through automation • Digital technology promotes transparency of projects
Failures of government-funded infrastructural projects	• Lack of awareness campaign • Lack of cutting-edge digital technology
Stakeholders and their roles in the execution of government-funded projects in Malaysia	• Roles - Monitoring the progress of the project [by all stakeholders]

Table 5.
The critical success factors of government-funded infrastructure projects in Malaysia.

participants shared their views, opinions, understanding, perceptions and lived experiences during the interviews. The participants involved and featured in this study are consistent with the stakeholders' theory adopted in this study. These participants are in the age range of 23 to 77 years. As a follow-up to the views obtained from the participants in this study, the summary of key findings are presented in **Tables 3–5** based on the thematic analysis framework developed by [21, 22].

4.1 The current state of the government-funded infrastructure projects in Malaysia

Findings on the current state of the government-funded infrastructure projects in Malaysia are presented in three themes as depicted in **Table 3**. This also addressed the first research question and first research objective. When asked to name or identify these infrastructures, a Malaysian lawyer who has worked on government-funded projects responded as follows:

> *Sarawak infrastructure, government buildings, public buildings that supports government operation in the country, schools, government offices, and government housing projects (PCN07).*

According to one of the participants, a Malaysian and an academic elite, he described government-funded projects in the following statement:

> *The east coast rail link project, which is expected to be completed in 2026; the rapid transit system project linking the Bukit Chagar Station in Johor Bahru with the Woodlands North Station in Singapore, construction of which will begin by end-2021; and the 5,500-kilometre Pan-Borneo Highway in East Malaysia which is intended to be completed by 2025 (PCN11).*

The sources of government sponsored projects are crucial for the successful execution of government identified infrastructural projects in Malaysia. Responses from the interviews conducted with the participants showed that there are several sources of funded for government related sponsored projects.

A Malaysian participant and a university don explained that the sources of funding for government project will include the following:

> *Ministry of finance; soft loans by Chinese government agencies and contractor-financing [PCN11].*

Likewise, a foreigner and a participant in one of the local universities who has lived more than 5 years in Malaysia commented on the sources of finance for government project as follows:

> *While some of the public projects are outsourced to private organisations, other are constructed by the government. In some cases, some of the public projects are done as corporate social responsibility (CRS) by some private organisations [PCN25].*

Next is the implementation or execution of government-funded infrastructures and projects is considered as one of the current states of government-funded projects. Comments from the participants illustrated their understanding on the implementation of these public related projects. For example, a Malaysian participant and one of the project managers for the Pan Borneo Highway covering 2325 kilometres said:

> *Implementation of projects are slow, imbalance allocation between urban and rural areas and not implemented according to development's priority. Most of government funded projects are slow and poor-quality due corruption, incompetent main contractor and bureaucracy issues at government departments. It became worst to a certain extent; the projects are only implemented at selected area for specific race of community. In Sarawak in particular, the natives Dayak are always being marginalized and deprived from receiving any government funded projects [PCN04].*

These findings have generated three constructs with potential contributions to existing studies on the current state of government-funded infrastructure projects in Malaysia. These new findings are conceptualised as components of developing a proposed sustainable framework for government-funded infrastructure projects in Malaysia.

4.2 The challenges of executing government-funded infrastructure projects in Malaysia

Findings from the challenges of executing government-funded infrastructure projects in Malaysia are presented in **Table 4**. Comments from the participants are highlighted in three sections and contrasted these findings with the extant literature working in other to ascertain the similarities, differences and potential contributions. A Malaysian and former employee of Shell Malaysia who has involved in the execution of government-funded project described the challenges of faced in the following statement:

> *The first is transparency and accountability of managing the funds and secondly having the right professionals in executing these projects [PCN26].*

A foreigner, a resident and stakeholder in government-funded project in Malaysia said:

> *The challenges could be frequent change in governance and policies which may slower the execution of the projects [PCN25].*

A project manager involved in the execution of the 2325 kilometres Pan Borneo Highway commented on the challenges of executing government-funded projects:

> *Slow project's execution, poor quality of materials and services and slow payment by the government to contractors [PCN04].*

Findings also indicate the causes of these challenges in the execution of government-funded infrastructure projects. When asked, the question on the causes of the challenges in the execution of projects sponsored by the government. One of the project managers who had worked with Pan Borneo Highway commented:

> *Cost overrun due to corruption at state and federal government, incompetent contractor, imbalance project execution between rural and urban area or most of the time projects with high impact are only allocated for certain race or implemented at areas linked to certain corrupted politicians making the projects does not achieve its main objective i.e., for development [PCN04].*

Furthermore, this section seeks to uncover views of the participants regarding potential mitigation towards the challenges of executing public sponsored projects. A foreigner who has been involved previously in the execution of public sponsored infrastructure projects in Malaysia on mitigations towards challenges affecting implementation of government projects, he echoed:

> *(a). Acquisition of land through proper legal processes and settlement of land owners before implementation of project; (b). Availability of foreign workers through less-stringent immigration policies; and (c) Provisions for health emergencies should be put in place which include health insurance, personal protective equipment (PPE), free vaccinations for workers etc. [PCN13].*

These findings have generated three constructs with potential contributions to existing studies on the challenges of implementing government-funded infrastructure projects in Malaysia. These new findings are conceptualised as components of developing a proposed sustainable framework for CSFs and CFFs for government-funded infrastructure projects in Malaysia.

4.3 Critical success factors and critical failures factors of government-funded infrastructure projects in Malaysia

This section seeks to answer research question three, research objective three, and the relevant component of the conceptual framework in **Figure 1**. Summary of the findings are presented in five themes in **Table 5**. These findings are compared and contrasted with the existing literature work to determine any similarities and differences to ascertain potential contributions that are important variables to achieve the aim of this study.

In order to achieve the objective of this section on CSFs, and provide credible answers to the interview question, a participant who had engaged in the execution of government-funded project in Malaysia; she said that the CSFs include:

> *Experience of the project manager in handling a critical project and good communication and governance [PCN21].*

In the similar direction, a participant who has executed government-funded infrastructure projects commented on the CSFs:

> *Good professional governance and controls [PCN26].*

One of the participants who had lived over 5 years in Malaysia and involved in the implementation of government projects stated:

> *Project support by the public; transparency; proper project procedures; modern technology; weather; and proper supervision [PCN13].*

Additionally, this section seeks to answer on why do government funded public infrastructures projects fail? For example, a participant who had involved in the execution of projects bankrolled by the government commented on the factors causing government-funded infrastructure projects to fail. As a project manager in government projects, he said project:

> *Failed due to corruption, cost overrun, lack of funds, inefficient of government agencies (project implementor) and incompetent contractors as most of the contractors awarded with large projects are politically linked contractors which are not technically capable executing and/or completing the works or projects. Non-transparency on procurement process and lack of skills or competency of government agencies [PCN04].*

One of the participants who was involved in government-funded project express his views on why government funded infrastructures projects fail in the following statements:

> *Mismanaged of funds because appointment of executor [project] contractors are mostly by politically connected people [PCN07].*

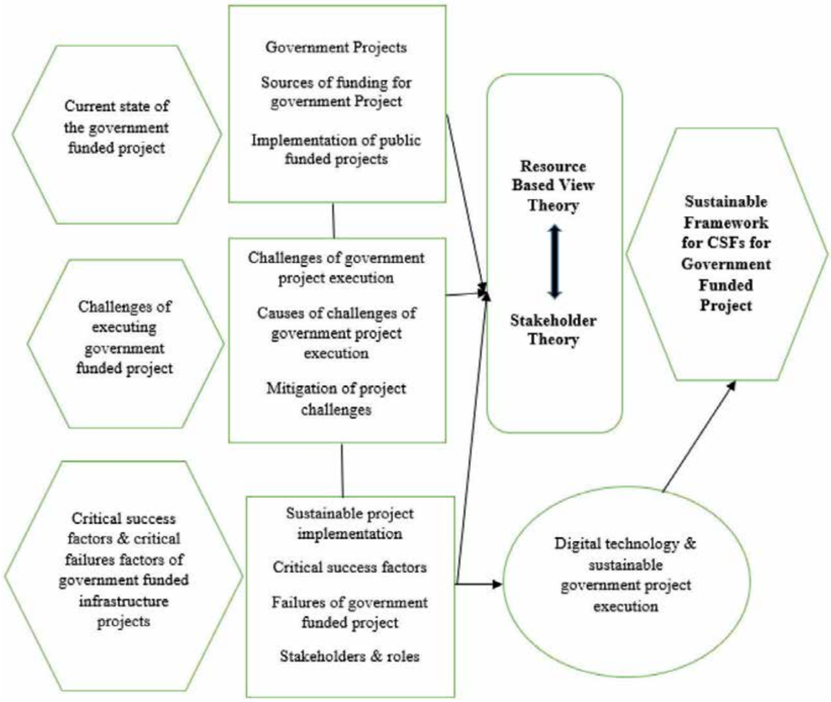

Figure 2.
Sustainable framework for critical success factors and critical failures factors for government funded infrastructure projects.

Similarly, a participant commented on the failures of government-funded projects as follows:

> *Lack of adequate fund and sustainability plans including right individuals to manage the projects [PCN25].*

These new findings depicted in **Table 5** are conceptualised as components of developing a proposed sustainable framework for CSFs and CFFs for government-funded infrastructure projects in Malaysia as presented in **Figure 2**.

5. Conclusion

This study is aimed at developing a 'Sustainable digital framework for critical success factors for government-funded infrastructure projects in Malaysia.' This study also adopted resource-based theory and stakeholder theory. This section presents the key lessons to be learned from this study. In other words, key findings of the study and contribution that addressed the basic three components of the three research questions. These findings were based on the analysis of the interviews conducted with the participants. A total number of 26 participants were interviewed. Of this, 22 were local residents or Malaysians and 4 were foreigners who has lived in Malaysians for over 5 years. In addition, 8 of these participants have been involved in government-funded infrastructures projects. The following section presented the implications of this study.

5.1 Theoretical implications

This study has generated several theoretical contributions. These contributions are divided into two namely, the main theoretical contribution which satisfies the main aim of this study of developing a sustainable digital framework for critical success factors for government funded infrastructure projects in Malaysia as presented in **Figure 2**. The stakeholder theory and resource-based theory were applied to this study as part of theoretical implications. Other contributions include the identification of the three themes and eleven sub-themes for critical success factors for government-funded infrastructures projects.

5.2 Managerial and policy implications

This dissertation has several practical implications for policy makers and industry professional practitioners. The sustainable digital framework provide guidance for both policy makers and industry practitioners regarding the applications of the study's findings on the critical success factors required to ensure the successful implementations of government funded project.

5.3 Implications to the society

The implications of this study to the society or citizens can be viewed from the following different perspectives.

a. Quality projects will be delivered to the public and society at large.

b. Competent contactors and project management team are awarded project execution

c. Awareness of the causes of government-funded projects are uncovered. This will help the society in terms of wasted funds and time on projects execution.

d. Numbers of abandoned projects will be reduced

e. Study's findings highlighted stakeholders and their roles

f. The role of digital technology in supporting the sustainable and successful execution of government-funded projects.

5.4 Summary of lessons learned

This study has contributed to the scholarship of critical success factors for public sponsored infrastructure projects in Malaysia in the following ways.

a. This study has generated a theoretical framework for critical success factors for government funded infrastructure projects in Malaysia.

b. It has adopted the stakeholder theory and resource-based theory to understand the three main components of the identified for this study.

c. It has identified three main themes, 11 sub-themes and processes involved in critical success factors for government-funded projects.

d. This study has developed a sustainable digital framework for critical success factors for government funded infrastructure projects in Malaysia.

e. It has also presented the theoretical contributions, practical implications to industry practitioners and policy makers, and the implications to the society.

f. The limitations of the study and direction for future studies are highlighted in this study.

g. Government, industry practitioners and larger society are the key beneficiary of this study.

The main aim of this study is to develop a sustainable digital framework for CSFs for government-funded projects in Malaysia based on the findings from this study. This represent the fundamental contribution to government-funded infrastructure projects. The key constructs and sub-themes identified in the case research are conceptualised to develop the framework as depicted in **Figure 2** as follows.

5.5 Transferability of the study's findings

The transferability of sustainable digital framework for critical success factors for government funded infrastructure projects in Malaysia can be transferred to other similar projects. These include projects funded by government in both developing and advanced countries, non-governmental organisations (NGOs), international donors, international institutions such as the World Bank (WB), IMF, WHO, African Development Bank (AfDB), and private sponsored projects.

5.6 Limitations and recommendations for future research

This study has limitations in terms of scope and focus. This study has adopted government-funded infrastructure projects. Therefore, it is recommended that future research should look into other sector of the economy and not government project only. Future research can also beam search light on projects from other government agencies such as education, government link companies, health, aviation, military, police, information and communication technology projects. Likewise, this study has adopted qualitative research methodology using interviews in the data collection. It is recommended similar research in future should adopt quantitative research methodology to compare the expected results with the findings from this study.

To sum up, the journey of a thousand miles starts with a step. This paper begins with a one general question and three research questions developed and aligned with aims of this study to extract detailed information from multiple participants involved in the execution of government-funded projects and other relevant stakeholders. Findings indicate that the main aim of the study has been achieved. Notably the three main constructs of (a) the current state of the government-funded infrastructure projects in Malaysia; (b) the challenges of executing government-funded infrastructure projects in Malaysia; and (c) critical success factors of government-funded infrastructure projects in Malaysia are conceptualised to develop the sustainable digital framework as contained in the main aim of this study. Relevant theoretical, managerial implications and to the society are mentioned. Limitations and directions for future studies, and transferability of the findings to similar projects are highlighted.

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References

[1] Radujković M, Sjekavica M. Project management success factors. Procedia Engineering. 2017;**196**:607-615

[2] Ouma OA, Kamaara M. Determinants of successful implementation of donor funded projects in Kenya: A case of pathfinder international. Journal of Entrepreneurship & Project Management. 2018;**2**(1):70-87

[3] Damoah IS, Kumi DK. Causes of government construction projects failure in an emerging economy: Evidence from Ghana. International Journal of Managing Projects in Business. 2018;**11**(3):558-582. DOI: 10.1108/IJMPB-04-2017-0042

[4] Ministry of Works Malaysia [MOW]. National Construction Policy 2030. Putrajaya, Malaysia: MOW; 2022. Available from: https://www.kkr.gov.my/public/Dasar%20Pembinaan%20Negara%20NCP2030.pdf

[5] Idrus NA, Ismail S, Sanusi FA. Delays in Malaysian Government Projects: Learning from Project Management Failure. Petaling Jaya, Malaysia: The Institution of Engineers Malaysia; 2019. Available from: file:///D:/IUMW%20PG%20Research%201%20-%20MBOC7074/Delays%20in%20Malaysian%20government%20projects-%20learning%20from%20project%20management%20failure.pdf

[6] Gilbert DK. Critical success factors in the implementation of donor funded projects in Tharaka Nithi County, Kenya. International Journal of Business and Social Science. 2021;**12**(4):1-94

[7] Project Management Institute [PMI]. A Guide to the Project Management Body of Knowledge (PMBOK). 6th ed. Newtown Square, PA: Project Management Institute; 2017

[8] Freeman RE. Strategic Management: A Stakeholder Approach. Boston, MA: Pitman; 1984

[9] Barney JB. Firm resources and sustained competitive advantage. Journal of Management. 1991;**17**:99-120

[10] Hamel G, Prahalad CK. Strategic intent. McKinsey Quarterly. 1990;**1**:36-61

[11] Hossain MS, Hussain K, Kannan S, Nair SKKR. Determinants of sustainable competitive advantage from resource-based view: Implications for hotel industry. Journal of Hospitality and Tourism Insights. 2021;**5**:79-98

[12] Almarri K, Abu-Hijleh B. Critical success factors for public private partnerships in the UAE construction industry - a comparative analysis between the UAE and the UK. Journal of Engineering, Project, and Production Management. 2017;**7**(1):21-32

[13] Obi LI, Awuzie B, Islam R, Gupta AD, Walton R. Critical success factors for cost management in public-housing projects. Construction Innovation. 2021;**21**(4):625-647. DOI: 10.1108/CI-10-2020-0166

[14] Damoah IS, Akwei C. Government project failure in Ghana: A multidimensional approach. International Journal of Managing Projects in Business. 2017;**10**(1):32-59. DOI: 10.1108/IJMPB-02-2016-0017

[15] Mutai F. Determinants of Completion Rate of County Government Funded Projects in Kenya; a Case of

Urban Infrastructure Projects in Kisii Town [Thesis]. Kenya: University of Nairobi; 2017

[16] Yong YC, Mustaffa NE. Critical success factors for Malaysian construction projects: An investigative review. International Journal of Built Environment and Sustainability. 2017;**4**(2):93-104. DOI: 10.11113/ijbes.v4.n2.180

[17] Miles MB, Huberman AM. Qualitative Data Analysis: An Expanded Sourcebook. Thousand Oaks, CA: Sage; 1994

[18] Creswell JW, Poth CN. Qualitative Inquiry and Research Design: Choosing among Five Approaches. 4th ed. Thousand Oaks, CA: Sage; 2018

[19] Puvenesvary M, Rahim RA, Naidu RS, Badis M, Nayan NFM, Aziz NHA. Qualitative Research: Data Collection and Data Analysis Techniques. Sintok, Malaysia: Universiti; 2011

[20] Strauss AL, Corbin JM. Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory. London: Sage Publications Limited; 2008

[21] Braun V, Clarke V. Using thematic analysis in psychology. Qualitative Research in Psychology. 2006;**3**:77-101

[22] Adeyinka-Ojo S. PRISMA statement and thematic analysis framework in hospitality and tourism research. University of South Florida M3 Centre Publishing. 2021;**2021**(5):9

Chapter 6

5D BIM Use by Contractors

Derek Thurnell

Abstract

The integration of 5D BIM into the construction industry presents both transformative benefits and significant challenges for contractors. A literature review was undertaken to identify the major benefits and challenges to successful 5D BIM implementation by contractors in the construction industry. An analysis of the findings suggest that 5D BIM, with its advanced cost modelling capabilities, enhances project efficiency, cost control, and stakeholder communication. Significant benefits are: enhanced cost control; improved collaboration; increased accuracy and efficiency; proactive risk management, and competitive advantage. Significant challenges are: cultural resistance; high initial costs; skill gaps; data and software compatibility, and lack of standardisation. To maximise the potential of 5D BIM, the construction industry must address these challenges through strategic investments and collaborative efforts, including promoting a culture of innovation, providing comprehensive training programmes, and developing standardised BIM protocols. Further research is needed to develop a framework for the utilisation of 5D BIM by contractors, in order to address and ameliorate the challenges identified in this study, as well as empirical research to establish BIM protocols in the construction industry, by investigating what information/data within BIM models supplied by the design team is of most benefit to main contractors when using 5D BIM on construction projects.

Keywords: 5D BIM, building information modelling (BIM), contractors, cost estimating, quantity surveying

1. Introduction

In the construction sector, integrating BIM (Building Information Modelling) for cost management (5D BIM) is vital for contractors. 5D BIM enables advanced cost modelling, empowering contractors with proactive decision-making capabilities to mitigate financial risks in dynamic project environments.

This desktop review of the extant literature aims to determine the key benefits of 5D BIM use by main contractors, and the challenges to successful 5D BIM implementation in contracting practice. The following research question is addressed: What are the benefits and challenges of 5D BIM use by main contractors? This is broken down into two sub-questions: (1) What are the potential benefits of BIM for main contractors? and (2) What are the challenges to more widespread BIM implementation by main contractors?

This analysis provides actionable insights for contractors to enhance cost control through efficient 5D BIM adoption, driving competitive advantage and improved project outcomes [1–3]. Secondary data was collected by the adoption of a traditional literature review, commencing with a literature search for previous research related to the use of 5D BIM by main contractors. The literature review procedure consisted of collection of as many relevant studies as possible, using a variety of search engines, including Google Scholar, as well as the Web of Science bibliographic database. Three search conditions were used: "Building Information Modelling" [or "BIM"]; "5D BIM", and "contractors". The search mainly aimed for scholarly articles published in journals in the construction management field. In order to ensure a comprehensive search, the References listed in the initial studies identified through the use of the keywords mentioned above were also examined, enabling the identification of further studies. The studies identified were then analysed, taking into consideration their academic quality, relevance to the theme of contractors' use of 5D BIM, and any subsequent discussion of the benefits of 5D BIM use by contractors and the challenges to their successful implementation of 5D BIM in practice. The findings were then categorised using the most common themes emerging from the literature, and are presented below.

2. BIM contextualised

BIM is a digital representation of a building's geometric and non- geometric data, and is used as a reliable, shared knowledge resource to make decisions on a facility throughout its lifecycle [4]. Various users can extract and use the invaluable data contained in the data-rich and intelligent 3D model objects.

Many construction projects internationally which are using BIM are operating at Stage 2A: "One-way Collaboration," which allows a single BIM model to be shared with everyone involved in the project for visualising, cooperation, interaction, assessment, evaluation, simulation, or order design. However, the original model is revised digitally separately from other domain models [5].

Parametric modelling facilitates the creation of a relationship between elements, and includes the specification and properties of individual elements and objects, potentially enabling the extraction of comprehensive and accurate information from the model which can be directly used for costing, i.e. '5D BIM' [6].

3. The role of 5D BIM in the construction industry

The fifth dimension (5D) of BIM, "cost," focuses on quantifying, modifying, and extracting data from the model to serve as the main information source for quantity surveying (QS) services [7]. 5D BIM involves the incorporation of cost-related data to BIM model objects, allowing for efficient quantification and pricing of the building work, usually by linking the BIM model to a cost database, using appropriate proprietary software [8]. Objects are coded in the model to ensure their correct costs are given during the pricing process. Generally, the model creator, the designer, codes objects with the expectation that this will be of assistance during the QTO stage for the cost estimator [6]. Cost management plays a significant role in construction project management. Advancements in the use of 5D BIM have opened new opportunities for enhancing efficiency, quality, and precision in cost management processes [2].

BIM and associated digital tools present vast opportunities for project cost managers to enhance their services' quality, speed, accuracy, and sophistication, ensuring their relevance in the BIM domain. With firms realising the necessity of embracing these technologies and observing competitors gaining market advantage through expertise in this area, momentum is increasing for widespread adoption. Realising the full potential benefits of BIM models hinges on their richness in comprehensive and accurate data. Achieving these demands considerable time and expertise from BIM modellers and teams [9]. Research indicates that stakeholder engagement throughout the implementation of Building Information Modelling (BIM) has the most advantageous financial benefit throughout the project's lifetime [1].

4. Benefits of 5D BIM for contractors

4.1 Time to bid

BIM makes price checking easier during the bid phase [10]. Even though more effort is needed to prepare the bid, BIM results in a better quality bid, which together with the benefits of the formulating of construction methodology and better visualisation, far outweighing the increased time and effort to bid using BIM. As contractors become more familiar with BIM, in the future, less time will be needed to prepare bids. Using 5D BIM, at present, a contractor's estimator spends valuable time having to recode, or at the least, spending time verifying that the BIM model objects are coded correctly, but it is hoped that as designers improve their object coding practices with regard to cost information, this time will be reduced [1, 11].

4.2 Alternatives and optioneering

BIM allows opportunities for alternative solutions to be considered during tendering stage, by offering more flexibility in 'optioneering', allowing the bid-team to virtually construct the building and being able to play-out 'what-if' scenarios, benefitting the project as a whole [12]. Alternative solutions to problems are more easily generated and comprehended, when compared with traditional design methods, and undertaking build simulations, including alternatives, in front of the Client, is a definite benefit at tender stage [7].

4.3 Clash detection and rework

Clash detection, or spatial coordination, is a significant benefit to main contractors. Resulting in reduced errors and omissions [12, 13]. 5D BIM improves coordination by integrating clash detection and specification, as centralised BIM models can consequently update changes and disburse these data to stakeholders [13].

Furthermore, it is purported that clash detection ius the single most significant driver for adopting BIM [1]. The ability for main contractors to utilise BIM tools for coordination of subcontracting trades prior to construction, with a resultant reduction in rework, is beneficial [12], and cost savings through reduced rework are a very strong driver for BIM implementation [1].

4.4 Communication and access to information

5D BIM helps to minimise costly errors during construction by recognising data incompatibilities between software in advance, saving time, money, and other issues.

Automated computerised models aid decision-making by evaluating alternative building methods, materials, and procedures without requiring real construction, allowing for the selection of the most efficient processes to save time and money [12].

BIM improves communication and access to information within the project team, and many contractors see the ability to work collaboratively with owners or design teams as being highly beneficial, and has been identified as one of the 'top 5' BIM benefits for contractors [14]. Better collaboration with other professionals in the industry has also been found to be a significant benefit of 5D BIM use [15].

4.5 3D visualisation, decision-making and coordination

Walk-through visualisations can assist clients in the decision-making process, and so can reduce 'preference' changes later on [6]. In a survey of U.S. contractors, it was found that clash detection and visualisation were the most commonly used BIM functions implemented by contractors [15]. Moreover, the improvements in design quality enabled by 3D visualisation are rated by BIM users as an important driver for BIM implementation [1]. Also, the 3D visualisation function of BIM can improve decision making and reduce inaccurate drawing interpretation [14]. Furthermore, the ability to get subcontractors to have input at an earlier stage, to avoid costly clash detection and rework on-site, is hugely beneficial [11].

Visualising a building project via the BIM model improves knowledge for every participant, particularly when communicating with investors. It provides dependable features for architects, engineers, contractors, and other stakeholders, resulting in a centralised model that is available to all parties and clearly defines each construction component. As a result, everyone may see any model modifications right away [16].

5. Challenges for main contractors using 5D BIM

5.1 Cultural resistance

There is a cultural resistance to the change from traditional tendering approaches to one incorporating BIM processes, and the scale of culture change required is a very significant barrier to BIM implementation [10]. Indeed, "culture resistance" is considered as the most major difficulty for BIM adoption [17].

Successful BIM projects need the commitment and buy-in from directors, and the change from traditional 2D to 3D BIM (and beyond) has been described as being a leap in technology, as well as a cultural and organisational change [15, 18].

Furthermore, the industry is changing, and the desire to become more efficient in all areas is a key driver. Contractors' use of BIM on their projects gives them a definite competitive advantage, in particular in areas of modelling looking at resources and programming; indeed, many main contractors who use BIM during pre-construction derive an improvement in trade coordination, and for main contractors, a benefit of making the decision to adopt BIM technologies into their businesses is to promote themselves as an industry leader [14].

5.2 BIM skills shortages

BIM models are rarely used to their full potential; models sometimes lack sufficient data to assist project cost managers and construction experts adequately. To ensure proper data entry, it is important to have enough workers with the requisite knowledge, experience, and skill, as well as suitable fees. Clients, developers, and contractors are the primary stakeholders who must invest in this data intake, and shortage of qualified and expert workers in the BIM area is one of the most serious BIM difficulties [9, 18]. A significant barrier to BIM adoption in current projects is the shortage of expertise within the project team and external organisations. This could explain why the advantages of 3D modelling and BIM have not been fully harnessed in construction, akin to their documented impact in other industries like car manufacturing and machinery design [1]. Artificial Intelligence (AI) and algorithms have significant promise for augmenting building projects as computer technology improves and BIM becomes more ubiquitous [19].

5.3 Implementation costs of BIM

The implementation of 5D BIM involves significant upfront investments in software, hardware, and training. Small-to-medium enterprises (SMEs) may find these costs prohibitive, limiting their ability to adopt BIM fully. However, the cost of software and training is not considered to be a major barrier to 5D BIM implementation among contractors [11]. The costs of implementation can be reduced if BIM is utilised from the outset, and that once the initial technology investment has been made, costs will not be such a negative factor [18].

5.4 Changes in business systems and processes

BIM is not felt to require a complete change to business systems and processes, and some negative effects of the cost of BIM implementation are less relevant than the positive effects brought about by updates in processes because of the implementation. However, the reluctance of some design consultants to share models or work with main contractors for project benefits; as well as late and/or uncoordinated designs can mitigate some BIM advantages [12, 18].

5.5 Demand for BIM-enabled projects

Some Clients are specifically requiring BIM – particularly on government projects. Also some private sector Clients now ask for BIM, which is coming through in tender documents, with Clients wanting to know of tenderers' BIM experience. However, much of the literature asserts that contractors consider that education of the Client, and getting them to have the right level of expectation, is a barrier. However, as has been done in Singapore and more recently in the UK, Clients' use of BIM can be enhanced by having a government mandate [12, 14, 16].

Although 5D BIM offers significant benefits for cost management in construction projects, implementing it poses challenges. Successful utilisation of 5D Building Information Modelling (BIM) for cost management demands a skilled and competent team of professionals [20]. The primary gap exists in comprehending the data/information flow after designers create 3D models and identifying shortcomings before implementing 5D BIM from the QSs' perspective. Understanding these potential issues is expected to strengthen the approach to cost-related considerations [21]. Key issues shedding light on prevalent challenges encountered during the implementation of 5D concepts include the level of development (LOD), coding standards, the absence of 5D BIM protocols, and the need to train the existing QS workforce.

5.6 Integrating 5D BIM into the contractor's existing cost control processes

BIM serves as a tool in facilitating the integration and coordination of various project disciplines, enabling stakeholders to collaborate more efficiently and make well-informed decisions [22]. Incorporating cost-related data into the 3D model ensures that cost projections align with the project's physical attributes [22, 23], resulting in more accurate and reliable cost estimates [20]. Professionals using 5D BIM for cost management should be knowledgeable in BIM software tools designed for cost integration, estimate, and tracking. They must be proficient in using the software's features and functions to effectively extract numbers, allocate costs, and provide detailed cost reports [20].

Uncertainties exist regarding the QS role in BIM Level 2, especially in contractor-led projects, hindering the applicable use of 5D BIM for cost management [22]. Presently, Quantity Surveyors are often not fully integrated into BIM [24], although QS practices involving appending object properties in estimating tools have been observed [25]. It is crucial to clarify 5D BIM implementation in contractor-led projects for consistent integration into Level 2 BIM.

BIM's capabilities and integration will help to reduce mistakes and improve project cost predictions in the future. With the integration of projects, the process can become better coordinated and interactions are boosted [26]. BIM can boost collaboration across construction industries, management teams, and owners by integrating relevant data and information for every person involved in the project [20]. Members of the project can integrate and team up through trust-based associations, better interaction, coordination, common objectives, shared commitment, and joint decision-making [27, 28]. The BIM initiative offers a research-based substitute to top-down BIM implementation policies, providing an innovative rapid answer to the opportunities and challenges of BIM adoption at all corporate levels; it uses an integrated methodology and modular language to evaluate performance and optimise processes [29].

Disparities are evident in the perceived barriers to BIM adoption between contracting organisations that have adopted BIM, and those that have not [11]. For organisations yet to adopt BIM, the most significant barriers include a lack of support from the supply chain, a substantial cultural shift required, a shortage of technical proficiency, and the expense associated with software. Conversely, the primary barriers among firms that have already adopted BIM are a limited understanding of BIM benefits, the magnitude of cultural adjustment needed, and the costs associated with training [11].

6. Conclusion

The integration of 5D BIM into the construction industry presents both transformative benefits and significant challenges for contractors. This comprehensive literature analysis reveals that 5D BIM, with its advanced cost modelling capabilities, enhances project efficiency, cost control, and stakeholder communication. By directly linking cost data to 3D models, 5D BIM allows for accurate quantity take-offs, real time cost monitoring, and proactive decision-making, thereby reducing financial risks and improving project outcomes. A summary of the benefits and challenges experienced by contractors using 5D BIM are outlined below:

6.1 Benefits of 5D BIM

Enhanced Cost Control: 5D BIM facilitates precise budget oversight and cost estimation, crucial for avoiding cost overruns and maintaining profitability. By providing accurate data on materials, scheduling, and quantities, contractors can make informed decisions and optimise resource allocation, thereby improving economic management and risk mitigation.

Improved Collaboration: The integration of cost data with BIM models fosters better collaboration among stakeholders, including designers, quantity surveyors, and contractors. Early involvement of contractors in the design phase ensures that cost considerations are integrated from the outset, leading to more efficient and coordinated project execution.

Increased Accuracy and Efficiency: Automated quantity take-offs and digital cost estimation significantly reduce errors associated with traditional manual methods. This not only enhances the accuracy of cost estimates but also streamlines the entire cost management process, saving time and reducing labour costs.

Proactive Risk Management: 5D BIM's ability to simulate various building methods and materials allows contractors to evaluate alternative solutions and select the most cost-effective options. This initiative-taking approach to risk management helps in identifying potential issues early in the project lifecycle, thereby mitigating risks and avoiding costly delays.

Competitive Advantage: As the construction industry increasingly adopts digital tools, contractors proficient in 5D BIM gain a competitive edge. The ability to provide sophisticated cost management services and deliver projects within budget and on schedule enhances a contractor's reputation and marketability.

6.2 Challenges to 5D BIM adoption

Cultural Resistance: Transitioning from traditional methods to BIM-based processes can be met with resistance from staff accustomed to conventional practices. Overcoming this cultural barrier requires a shift in mindset and the promotion of BIM's long-term benefits.

High Initial Costs: The implementation of 5D BIM involves significant upfront investments in software, hardware, and training. Small-to-medium enterprises (SMEs) may find these costs prohibitive, limiting their ability to adopt BIM fully.

Skill Gaps: Successful 5D BIM utilisation requires a skilled workforce proficient in BIM software and integrated cost management. The shortage of trained professionals poses a significant barrier, necessitating substantial investment in education and training programmes.

Data and Software Compatibility: Effective 5D BIM implementation depends on the seamless integration of data across different platforms and software. Incompatible systems and incomplete data can hinder the efficient use of BIM, leading to inaccuracies and delays.

Lack of Standardisation: The absence of standardised processes and protocols for SD BIM can create inconsistencies in its application. Establishing clear guidelines and standards is essential to ensure uniformity and reliability in BIM practices.

6.3 Recommendations to address the challenges to 5D BIM adoption

To maximise the potential of 5D BIM, the construction industry must address these challenges through strategic investments and collaborative efforts. This includes promoting a culture of innovation, providing comprehensive training programmes, and developing standardised BIM protocols. Additionally, enhancing the role of Quantity Surveyors within the BIM framework can further streamline cost management processes and improve project delivery. It is hoped that the following recommendations will enhance the benefits to be derived from contractors' use of 5D BIM, whilst simultaneously ameliorating the negative impact of challenges which contractors have experienced to date: improved education of Clients and design professionals of main contractors' needs and requirements for working on BIM-enabled projects; improved education of Clients as to what they can, and should, expect from the main contractor. This education process would ensure that realistic expectations of what can be achieved in the pre-construction period are set down before the tender process begins; increased collaboration between design professionals and main contractors - particularly in sharing BIM models at an early stage in the design process; an increased push from main contractors for Early Contractor Involvement- type methods of procurement to gain the most benefit from 5D BIM on a project, and lastly, urgent investment in technology, people and processes within the BIM-sphere to capture and transfer knowledge gained in the implementation of 5D BIM thus-far to assist with the lack of BIM experience found in many bid/pre-construction teams.

In conclusion, while the adoption of 5D BIM presents hurdles, the benefits it offers in terms of cost control, efficiency, and collaboration far outweigh the challenges. By embracing 5D BIM, contractors can not only improve project outcomes but also gain a significant competitive advantage in an increasingly digital construction landscape. This literature analysis underscores the importance of initiative-taking engagement with 5D BIM to drive sustainable growth and innovation in the construction industry.

6.4 Future directions

Future research should include the development of a framework to address the challenges identified in this literature review, together with empirical research, both qualitative and quantitative in nature, to establish BIM protocols in the construction industry, by investigating what information/data within BIM models supplied by the design team is of most benefit to main contractors when using 5D BIM on construction projects.

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References

[1] Eadie R, Odeyinka H, Browne M, McKeown C, Yohanis M. An analysis of the drivers for adopting building information modelling. Journal of Information Technology in Construction. 2013;**18**:338-352 http://www.itcon.org/2013/17

[2] Vigneault M, Boton C, Chong H, Cooper-Cooke B. An innovative framework of 5D BIM solutions for construction cost management: A systematic review. Archives of Computational Methods in Engineering. 2019;**27**(4):1013-1030. DOI: 10.1007/s11831-019-09341-z

[3] Hall AT, Durdyev S, Koc K, Ekmekcioglu O, Tupenaite L. Multi-criteria analysis of barriers to building information modeling (BIM) adoption for SMEs in New Zealand construction industry. Engineering Construction and Architectural Management. 2023;**30**(9):3798-3816. DOI: 10.1108/ecam-03-2022-0215

[4] NBIMS. National Building Information Modeling Standard [Internet]. 2010. Available from: http://www.wbdg.org/pdfs/NBIMSv1_p1.pdf

[5] Australian Institute of Architects. Towards integration. In: National Building Information Modelling (BIM) guidelines and case studies. Cooperative Research Centre for Construction Innovation (CRCCI) [Internet]; 2009. Available from: http://www.construction-innovation.info/images/pdfs/Brochures/Towards_Integration_Brochure_170409b.pdf

[6] Eastman C, Teicholz P, Sacks R, Liston K. BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. Hoboken, NJ: Wiley; 2011

[7] Stanley R, Thurnell D. The benefits of, and barriers to, implementation of 5D BIM for quantity surveying in New Zealand. Construction Economics and Building. 2014;**14**(1):105-117. DOI: 10.5130/AJCEB.v14i1.3786

[8] Forgues D, Iordanova I, Valdivesio F, Staub-French S. Rethinking the cost estimating process through 5D BIM: A case study. In: Proceedings of the Construction Research Congress 2012: Construction Challenges in a Flat World, ASCE. American Society of Civil Engineers Library; 2012. pp. 778-786. DOI: 10.1061/9780784412329.079

[9] Smith PN. Project cost management with 5D BIM. Procedia: Social & Behavioral Sciences. 2016;**226**:193-200. DOI: 10.1016/j.sbspro.2016.06.179

[10] Thurairajah N, Goucher D. Advantages and challenges of using BIM: A cost consultant's perspective. In: Proceedings of the 49th ASC Annual International Conference, CA Polytechnic State University (California Poly), San Luis Obispo, CA; Associated Schools of Construction; 2013

[11] Eadie R, Odeyinka H, Browne M, McKeown C, Yohanis M. Building information modelling adoption: An analysis of the barriers to implementation. Engineering & Architecture. 2014;**2**(1):77-101

[12] De Meyer K, Thurnell D. New Zealand main contractors' use of BlM during the pre-construction stage. In: Proceedings of the 40th Australasian Universities Building Education Association Conference Rockhampton.

Australia: Central Queensland University; 2016. pp. 447-456

[13] Harrison C, Thurnell D. BIM implementation in a New Zealand consulting quantity surveying practice. International Journal of Construction Supply Chain Management. 2015;**5**(1):1-15. DOI: 10.14424/IJCSCM501015-01-15

[14] McGraw Hill Construction. The business value of BIM in Australia and New Zealand: How building information modeling is transforming the design and construction industry. In: McGraw Hill Construction Research & Analytics [Internet]. McGraw Hill Construction; 2014. Available from: https://download.autodesk.com/temp/pdf/mcgraw_hill_business_value_of_bim_anz.pdf

[15] Ogunseiju O, Odeyinka HA, Yusuf AO. Usage of building information modelling in quantity surveying firms in Nigeria. Journal of Construction Business and Management. 2023;**6**(2). DOI: 10.15641/jcbm.6.2.1378

[16] Ku K, Taiebat M. BIM experiences and expectations: The constructors' perspective. International Journal of Construction Education & Research. 2011;**7**(3):175-197. DOI: 10.1080/15578771.2010.544155

[17] Katke SS. Time and cost control of construction projects using 5D BIM process. International Research Journal of Engineering and Technology (IRJET). 2020;**07**(08):3247-3257. Available from: https://www.irjet.net/archives/V7/i8/CRJET-V7I8547.pdf

[18] Hasan AN, Rasheed S. The benefits of and challenges to implement 5D BIM in construction industry. Civil Engineering Journal. 2019;**5**(2):412-421. DOI: 10.28991/cej-2019-03091255

[19] Bryde D, Broquetas M, Volm J. The project benefits of building information modelling (BIM). International Journal of Project Management. 2012;**31**:971-980. DOI: 10.1016/j.ijproman.2012.12.001

[20] Alzara M, Attia YA, Mahfouz SY, Yosri AM, Ehab A. Building a genetic algorithm-based and BIM-based 5D time and cost optimization model. IEEE Access. 2023;**11**:122502-122515. DOI: I0.1109/access.2023.3317137

[21] Mustafa MH, Mohd-Rahim FA, Chia L. The role of 5D building information modelling in construction project cost management: An overview and future directions. Journal of Project Management Practice. 2023;**3**(1):95-112. DOI: 10.22452/jpmp.vol3no1.5

[22] Mayouf M, Gerges M, Cox S. 5D BIM: An investigation into the integration of quantity surveyors within the BIM process. Journal of Engineering, Design and Technology. 2019;**17**(3):537-553. DOI: 10.1108/jedt-05-2018-0080

[23] Khosakitchalert C, Yabuki N, Fukuda T. Development of BIM-based quantity takeoff for light-gauge steel wall framing systems. ITcon. 2020;**25**:522-544. DOI: 10.36680/j.itcon.2020.030

[24] Moses T, Heesom D, Oloke D. Implementing 5D BIM on construction projects: Contractor perspectives from the UK construction sector. Journal of Engineering, Design and Technology. 2020;**18**(6):1867-1888. DOI: 10.1108/jedt-01-2020-0007

[25] Monteiro A, Martins JP. A survey on modeling guidelines for quantity takeoff-oriented BIM-based design. Automation in Construction. 2013;**35**:238-253. DOI: 10.1016/j.autcon.2013.05.005

[26] Taihairan RBR, Ismail Z. BIM: Integrating cost estimates at initial/

design stage. International Journal of Sustainable Construction Engineering & Technology. 2015;**6**(1):62-74. Available from: https://publisher.uthm.edu.my/ojs/index.php/IJSCET/article/view/1122/750

[27] Zanjirchi SM, Moredi M. Construction project success analysis from stakeholders' theory perspective. African Journal of Business Management. 2012;**6**(15):5218-5225. DOI: 10.5897/AJBM11.2437

[28] Olugboyega O, Edwards DJ, Windapo A, Omopariola ED, Martek L. Development of a conceptual model for evaluating the success of BIM-based construction projects. Smart and sustainable. Built Environment. 2020;**10**(4):681-701. DOI: 10.1108/sasbe-02-2020-0013

[29] Agostinelli S, Cinquepalmi F, Ruperto F. 5D BIM: Tools and methods for digital project construction management. WIT Transactions on the Built Environment. 2019;**7**(8):205-215. DOI: 10.2495/BIM190181

Chapter 7

Organisational Factors as Building Blocks in Project Management Maturity Model (PMMM) Concept Development: The Case of the South African Power Sector

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Abstract

This study focused on South Africa and focusing on improving the project management maturity model (PMMM). The purpose of this research is to determine whether to include organisational factors as building blocks in the conceptual development of a project management maturity model (PMMM) for the South African's power sector. A detailed literature review was conducted with an adequate research design and a case study approach. This chapter establishes organisational factors for SA's power sector through a literature review. A case study approach was used to confirm the proposed parameters with questionnaires. This chapter contributes to the discussion on constructing a conceptual PMMM in the South African's power sector. This research focused on the power sector. The analysis provides insight to practitioners and professionals on the current literature that exists on the organisational factors for the SA's power sector. It also provides a foundation in understanding building block to a conceptual PMMM development. The contribution identifies the organisational factors for the SA power sector, and the case study provides analysis to determine whether the organisational factors should be incorporated into the PMMM measurement for the SA power sector.

Keywords: project management, projects management maturity, organisational factors, organisational project culture, organisational project strategy

1. Introduction

Improving the maturity of an organisation was found to be extremely correlated with project success [1]. The greater the project management maturity the greater the project performances and that a high project management maturity is more likely to deliver projects on time and on budget and align with the original business goals [2]. Therefore, there is a link between PMMM and the organisational factors that need to be explored.

The following gaps in the current project management maturity models (PMMM) exist on organisational factors:

- Viana et al. [3] indicate in their research that organisational project management maturity models have been criticised as being ineffective as firms continue to face difficulties in improving their project management practices.
- Alam et al. [4] indicate that there was a lack of organisational factors in PMMM, and the social-cultural skills required by project managers managing projects successfully are under examined.
- Hulya [5] state that organisational culture was also largely under examined in project management research.
- Hillson [6] suggests that while knowledge and processes are important contributors to project management capability, they are not the only crucial elements to assess an organisations project management maturity.
- Research conducted by Skulmoski [7] affirms the lack of research on the competencies that is most important for certain types of projects.
- Further empirical studies should be built for the mechanisms by which superior PM practices can be developed over time [8].

The gaps indicate that literature is lacking on what factors contribute to success for a PMMM in SA's power sector. The current challenges SA faces and the gaps listed indicate appropriate reasons for investigating whether organisational factors influence PMMM for the SA's power sector.

Therefore, the purpose of this study is to understand whether organisational factors influence the PMMM measurement in SA's power sector. The research objectives include the following:

- Determine the organisational factors for the SA's power sector,
- Determine whether organisational factors affect PMMM,
- Assess whether to include the organisational factors into SAF's PMMM.

This chapter is divided into five sections. Section 2 provides the literature review regarding the organisational factors for SA. Section 3 provides the research methodology, and Section 4 provides the analysis and discussion. The conclusion is provided in Section 5. A study to determine the organisational factors for the SA's power sector is presented next.

2. Literature review

The findings by Gareeb and Rwelamila [9] indicate that the current project management maturity models are not completely suitable for SA's power sector. The authors list the current maturity models and provide an analysis of twenty-eight models for suitability for the SA's power sector. The current literature indicates that there is a gap pertaining to a PMMM in the SA's power sector. Project management maturity models are important for project-based organisations because large multinational projects taking place in SA need to consider the SA environment before entering SA markets. The researchers would like to acknowledge that this study is based on a large study towards developing a PMMM for the South African power sector.

Earlier research focuses narrowly on the definition of project success as project cost, time, and quality, but current literature has adapted this definition to include other factors. Hartman and Skulmoski [10] state that elements that affect maturity will include technical, business, and social issues. Zwikael [11] comments that different industries face different challenges while managing projects. The author refers to some examples like the software development organisations that must deal with high-technology uncertainty, while construction organisations that are usually more troubled with engineering and financial problems. Crawford [12] demonstrates that the competence of project personnel is important as they are having major impact on project performances and ultimately also impact the business performance.

Crawford [12] develops a framework to reconcile the competence model and competency standards and provides a basis for identifying and measuring aspects of competence against standards. The model indicates that competence can be inferred from attributes by Heywood et al. 1992 in the model as input competences. The output competencies are represented upon demonstrable performance of practice in the workplace in accordance with occupational, professional, or organisational competency standards. This model indicates that agility and flexibility represent the way to achieve organisational performance and that maximum project performance is accomplished when efforts are tied together to improve leadership factors and organisational factors. Studies by De Oliveria et al. [13] reveal that improvement actions should focus upon achieving a maximum level of individualised consideration and median intellectual stimulation that are associated with redistribution of tasks among team members and consequently a reduction of human resource sharing among projects. During low intellectual stimulation, it becomes essential to ensure a low level of task overlapping to ensure maximum project performance. An important organisational success measure is the respondent's perceived rate of project success of their organisations compared with competitors' organisations in the same sector of activity [14]. Gareis and Huemann [15] show that project management competencies must describe, assess, and further develop for the organisation, teams, and individuals in the organisation. Brush et al. [16] describe the resource pyramid of value creation. The base of the pyramid represents the generic resources that are often easy to identify and access. The generic resource becomes a capability that enhances the firm's ability combined with other resources. Brush et al. [16] define capability as a combination of proprietary resources, knowledge, and skills. The specialised core competencies allow firms to outperform rivals combine into strategic assets. Firms can have a unique advantage when assets become valuable, rare, inimitable, and non-substitutable. Jugdev and Thomas [17] use this basis to conceptualise maturity models in the context of resource-based view (RBV).

Fitsilis et al. [18] suggest that one of the main reasons that contribute to project management is lack of maturity and further suggests that many organisations, approximately 22%, were not capable of managing projects, and an even larger percentage from 30 to 65% are not using efficient project management practices.

The need for incorporating the appropriate organisational factors into PMMM can have the following benefits:

- Findings from Yazici [19] demonstrate the impact of the successful integration of corporate sustainability and organisational PMM efforts on organisational success and indicate that project management capability strengthens the effects of sustainability efforts, specifically in economic and social sustainability.

- Andersen and Jessen [20] claim that the types of projects the organisation is handling are of importance in determining the level of maturity and indicate that projects have as their objective to create fundamental changes within the organisation. The authors analysis can be extended to cover a study of which factors explain the level of maturity.

- Görög [21] indicates that one of the theoretical contributions in their research includes providing conceptual bases for organisational project management maturity assessment.

- Langston and Ghanbaripour [22] indicate that any project management environment needs to support the business for successful project, program, and/or portfolio delivery. The author indicates that the basis for achieving consistent excellence in project management is assisted by mature organisational systems and processes.

- Viana et al. [3] point out that PMMMs have significantly contributed to the field of project management as they heighten awareness of competence to assess organisational project management maturity and that an essential input to support organisational development.

From the literature review, organisational factors that support projects can be categorised into two broad categories, namely organisational project culture and second the organisational project strategy. **Figure 1** provides the focus of this chapter which entails the investigation of organisational factors that support projects and include the sub-parameters that are organisational project culture and organisational project strategy.

A conceptual model published by Gareeb and Rwelamila [23] included the full summarised conceptual PMMM for the SA's power sector. The detailed organisational project cultural factors are explored next and will be tested for validity.

2.1 Organisational project culture

Different organisations have unique characteristics. Cooke-Davies and Arzymanow's [8] definition put emphasis on "...underlying beliefs, values and principles that serve as a foundation for an organisations management practices and behaviour...", while Deal and Kennedy [24] define culture as "the way things are done around here". Nelson and Winter [25] strengthen the definitions organisational culture and add behaviour established through formal systems, procedures, informal routines, and norms.

Based on the literature review above and specifically from Cooke-Davis and Arzymanow [8], two important factors in organisational culture are:

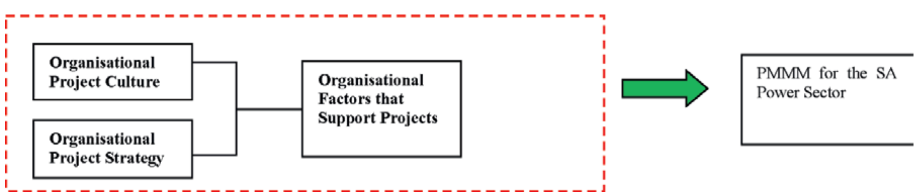

Figure 1.
Focus of this paper—organisational factors that support projects.

- If the culture is unhelpful, then it is important to change it; and
- Irrespective of whether culture helps or hinders and that the effects of culture must be considered throughout the project.

Cooke-Davis and Arzymanow [8] also suggest that the leadership style of a project manager needs to be adapted to the organisational culture and confirms through the literature review that there is a clear correlation between high trust and low cost, and between low trust and high cost.

Killen and Hunt [26] suggest that project portfolio management can act as a dynamic capability to improve organisational flexibility; resource agility; and performance by providing a holistic and responsive decision-making environment while ordinary capabilities permit organisations to "make a living" in the short term. Branson [27] interprets organisational culture as an alignment between individual and organisational values that drive an alignment of everyone's efforts towards the common purpose, and therefore, there is a less need for overt management and control.

Another view on organisational culture was Simons [28] that argues companies have used belief systems for years to articulate the values and direction that senior managers want their employees to embrace. Thamhain [29] results show that despite cultural differences among organisations a general agreement exists on the factors that drive team performance, one of the most striking findings is the large number of performance factors that are derived from the human side where organisational components that satisfy personal and professional needs seem to have a strong effect on cooperation, commitment, and risk management, and ultimately drive overall team performance. Other influences are derived from the organisational process, which often has their locus outside the project organisation. Individuals who find their assignments professionally challenging, leading to accomplishments, acknowledgment, and professional growth, also seem to function more successfully in a complex and technology-intensive team environment. Such a professional environment also lowers communication barriers, increases the tolerance for conflict and risk-taking, and enhances the desire to succeed [29].

Diallo and Thuillier [30] mention that project success and success dimensions depend on project type and sector. Performance problems on technology-intensive projects involve largely management, and behavioural and organisational issues, rather than technical complications [31, 32]. Dvir et al. [33] suggest that project success factors are not common for all projects; different types of projects are affected by different sets of success factors. Therefore, a project-specific approach is appropriate for following studies into the practice and theory of project management [34].

The summary from the literature review of the themes that affect the organisational culture in a project environment is summarised in **Table 1**.

2.1.1 Organisational culture that supports project management process

Roberts et al. [36] comment that organisational culture develops cognitively through vision, strategies, and tactics and tacitly develops through experience, including psycho-motor learning and habits. Crawford [12] indicates that agility and flexibility represent the way to achieve organisational performance and that maximum project performance is accomplished when efforts are tied together to improve leadership factors and organisational factors.

Themes	References
Organisational culture that supports project management process	Cooke-Davies [8]. Diallo and Thuillier [30]. Killen and Hunt [26]. Mishra, Dangayach, and Mittal [35]. Roberts et al. [36]. Crawford [12]
Support employees to understand cultural diversity	Thamhain [29]. *Belassi and Tukel [31]. *Hartman and Ashrafi [32]. **Branson [27]. Andersen et al. [37] Deal and Kennedy [24]. Diallo and Thuillier [30]
Organisational Structures that support project	*Dvir et al. [33]. **Hyvari [34]. Mishra et al. [35]
Top Management Support for Organisational Project Culture	Killen and Hunt [26]. Zwikael [11]. *Simons [28] **Cooke-Davies [8];

Gareeb and Rwelamila [23].

Table 1.
Organisational project culture.

2.1.2 Support employees to understand cultural diversity

Studies by Andersen et al. [37] suggest that organisational culture is a wide concept covering many aspects, rationality is one part of the culture, and being part of an organisation means that the thinking, ideas, and values of the organisation adapt the activities of the individual. The authors Deal and Kennedy [24] define culture as "the way things are done around here" which includes behaviour established through formal systems, procedures, informal routines, and norms. Diallo and Thuillier [30] comments that performance problems on technology-intensive projects involve largely management, and behavioural and organisational issues, rather than technical complications [31, 32]. Branson [27] interprets that organisational culture should be aligned between individual and organisational values to drive an alignment of everyone's efforts towards the common purpose.

2.1.3 Organisational structures that support project

Studies by Mishra et al. [35] indicate that the important factors related to organisation were found to be organisation structure that needs to support the project.

2.1.4 Top management support for organisational project culture

Killen and Hunt [26] literature review outlines that other factors and approaches to improve the quality and consistency of project and portfolio management execution include gaining top management support, demonstrating the benefits, changing incentive, and reward structures; thus in summary, the literature shows how project portfolio can provide organisational agility and assist organisations create value in dynamic environments. Zwikael [11] study indicates that different industries have different critical top management support processes. The results of the authors study confirm that unique CSPs exist in different industries, cultures, and claims that one should tailor the type of project involvement to the industry and culture.

2.2 Organisational project strategy

The understanding of what organisational project strategy will be covered, Albu and Panzar [38] state that maturity alignment is a concept referring to the extent to which the organisational components (strategy, structure, systems, processes, etc.) reflect similar or close maturity levels, acting in synergy towards the achievement of organisational objectives. Christenson and Walker's [39] study concludes that project vision is a critical project success factor. The more immediate contribution remains demonstrating a protocol for getting project teams to focus on the project vision and the likely impact upon that for PM success. Fitsilis et al. [18] suggest that programmes and projects are recognised as one of the most important means of achieving organisation strategic plans. To become durably successful, an organisation should realise its maturity alignment [40]. Project management maturity level cannot be attained or sustained if a certain level of organisational maturity is not reached [41].

Cooke-Davies et al. [42] argue that strategic drivers influence the nature of value expected from project management, and a project management system should be adapted to the specific strategic positioning of each organisation to deliver maximum value. Their study demonstrates that the effort to close the gap improved the overall project performance.

Aspects by Andersen et al. [37] suggest the following:

- Organisational culture is a wide concept covering many aspects.
- Rationality is one part of the culture.
- Being part of an organisation means that the thinking, ideas, and values of the organisation adapt the activities of the individual. That is taken further when the organisation introduces rules, standards, and procedures that administer the work and the decision-making.

Aspects by Andersen et al. [37] study reveal that more of the formal organisational rationality results in more of the task perspective, which means that if an organisation would like to see an organisational perspective prevailing among their projects, the base organisation with the more formal organisational rationality must work harder and more consciously to achieve such an approach. Therefore, the study found support for the proposition that there is a relationship between project perspectives applied in project management and formal organisational rationality.

The summary from the literature review indicated in **Table 2** shows the themes for organisational project strategy in a project environment. The following themes for strategic organisational project management from the literature review are summarised in **Table 2**.

Themes	References
Aligning Project Objective with Business Objective *Scorecards **Project Vision	Albu and Panzar [38]. Selders and Markle [43]*. Christenson and Walker [39] **. Fitsilis, et al. [18]. Meyer [40]. Andersen et al. [37]
Sustainability of the Organisation and Best practices *Strategic Drivers	Power [41]; Gareis and Huemann [15]. Cooke-Davies et al. [42] Crawford [12]
Gareeb and Rwelamila [23].	

Table 2.
Organisational project strategy.

2.2.1 Aligning project objectives with business objectives

There is an importance of linking the project objectives to the overall business strategy of the organisation. There is a need to have synergy and alignment with the organisational components and the organisation [38].

2.2.2 Sustainability of the organisation and best practices

Power [41] comments that project management maturity level cannot be attained or sustained in the organisation if a certain level of organisational maturity is not reached. Crawford [12] framework indicates that the output competencies in the model rely upon demonstrable performance or use of best practice in the workplace in accordance with occupational, professional, or organisational competency standards. Gareis and Huemann [15] show that project management competencies must describe, assess, and further develop for the organisation for both teams and individuals in the organisation.

Based on the above literature review on organisational factors that supports projects, there are strong indications to have an attribute to measure organizational factors that support a project in the PMMM.

3. Research methodology

The literature search in Gareeb and Rwelamila [9] categorised over a nineteen-year period using twenty-eight databases indicates that the current models are not completely suitable for SA's power sector.

The purpose of this study was to investigate whether organisation competencies that support project management from literature should be included in the development of a PMMM for the South African's power sector.

This research focused on investigating the SA's power sector. There is only one utility provider in SA that is: the SA's power utility. SA's power utility and the principal contractor involved in the largest construction projects for the sector will be used in this study. The principal subcontractor (the service provider) was chosen due to their contract to build the biggest power stations in SA for the power utility (Company A). The current SA's power environment consists of SA's power utility (Company A). Company A generates approximately 95% of the electricity used in South Africa [44], and the Independent Power Producers (IPP) contribute 5% of SA's supply; therefore, the SA's power utility was chosen to be sampled. However, the supply and demand of energy in South Africa have shown to be very incompatible. IPP assists in bridging the gap between supply and demand since Company A has suffered with ageing infrastructure, maintenance challenges, and financial difficulties, which have led to regular power shortages and load shedding. South Africa hopes to achieve its environmental obligations, promote economic growth, diversify its energy mix, and increase energy security by bringing in private power producers. Strong government regulations, financial incentives, and the operational achievements of multiple private power projects all support these endeavours.

A case study approach was used with questionnaires to collect the information. The respondents for the questionnaire included 37 respondents from Company A and 24 from Company B which was the total number of personnel working together from both organisations in SA.

The concept of accuracy uses two components, that is reliability and validity. Reliability refers to the consistency of the operations meaning the replicable of the results and validity refers to the connection of the results and reality [45].

The ethical issues through all phases of the research process were considered where anonymity was an important factor for the organisations taking part in the study. The findings and analysis are provided together with the concluding remarks showing the contributions of this study in the PM field.

4. Analysis and discussion

The organisational factors were covered in Section 2, and the research method was provided in Section 3.

The questionnaires were issued to all project management personnel in the respective PMO's. This study sampled 37 respondents from Company A and 24 from Company B for the questionnaires which was the total number of personnel working together from both organisations in SA.

Table 3 shows the majority of respondents (64%) indicate their role as project managers. Two of respondents (8%) indicate they are junior project managers. One of the respondents indicates project coordinator. Six of the respondents indicate that they fulfil a role other than that provided in the questionnaire.

Table 4 shows the majority of respondents (64.3%) indicate their role as project managers. Four (28.6%) of respondents indicate they are project directors. One (7.1%) respondent indicated they are a junior project manager.

The split between male and female is 64–36% for Company A and 85.7–14.3% for Company B. This distribution may indicate that males dominate power projects for Company A and Company B, but it is encouraging to note that the study is based on the views of both genders.

Table 5 indicates that the majority of respondents were between the ages of 31 and 40 years, followed by the age group 41–50 years, and only 2 respondents (8%) were in the range of 51–65 years of age.

Table 6 indicates that the majority of respondents were between the ages of 41 and 50 years, followed by the age group 31–40 years. The age groups 51–65 years contribute to double-digit percentages. Only one individual was in the category 21–30 years old.

Table 7 shows that respondents who have obtained a degree are 72% and make up the majority of the distribution. All of the respondents have formal qualification and a Grade 12. Similarly, 16% have diploma. Three of the respondents obtained a Master's degree (12%).

	No. of respondents	%
Junior Project Manager	2	8%
Senior Project Manager	0	0.0%
Project Co-ordinator	1	4.0%
Project Manager	16	64%
Project Director	0	0.0%
Other (specify)	6	24%

Table 3.
Company A's designation of the respondents.

	No. of respondents	%
Junior Project Manager	1	7.1%
Senior Project Manager	0	0.0%
Project Co-ordinator	0	0.0%
Project Manager	9	64.3%
Project Director	4	28.6%
Other (specify)	0	0.0%

Table 4.
Company B's designations of the respondents.

	No. of respondents	%
<20 yrs.	0	0.0%
21–30 yrs.	0	0.0%
31–40 yrs.	16	64.0%
41–50 yrs.	7	28.0%
51–65 yrs.	2	8.0%
> 65 yrs.	0	0.0%

Table 5.
Company A age group of participants.

	No. of respondents	%
<20 yrs.	0	0.0%
21–30 yrs.	1	7.1%
31–40 yrs.	4	28.6%
41–50 yrs.	7	50.0%
51–65 yrs.	2	14.3%
> 65 yrs.	0	0.0%

Table 6.
Company B Age group of participants.

	No. of respondents	%
No formal education / training	0	0.0%
Grade 12	0	0.0%
Project Management Certificate	0	0%
Diploma	4	16%
Degree	18	72%
Master's Degree	3	12%
PhD Degree	0	0.0%
Other (specify)	0	0.0%

Table 7.
Company A's respondents qualifications levels.

	No. of respondents	%
No formal education/training	0	0.0%
Grade 12	0	0.0%
Project Management Certificate	2	14.3%
Diploma	4	28.6%
Degree	2	14.3%
Master's Degree	5	35.7%
PhD Degree	0	0.0%
Other (specify)	1	7.1%

Table 8.
Company B's respondents qualifications levels.

Table 8 shows the distribution of the qualification levels of the respondents for Company B. Respondents who have obtained a Master's degree (35.7%) made up the majority of the distribution. Two of the respondents indicate that they have obtained a degree (14.3%). Similarly, 28.6% have diploma. Two respondents (14.3%) obtained a project management certificate.

5. Quantitative analysis: exploratory factor analysis

Exploratory factor analysis is a range of tests to identify a unified concept for decision-making. To achieve this, a fit between the items needs to be established as well as internal consistency and unidimensional.

5.1 Exploratory factor analysis criteria

The first step to assess the suitability of the data for factor analysis involves the following criteria:

- Calculating the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (KMO)—The KMO is a measure of sampling adequacy, and this index ranges from 0 to 1, with 0.6 suggested as the minimum value for good factor analysis.

- Barlett's test of sphericity—To assess the factorability of the data Bartlett's test of sphericity, Bartlett's test of sphericity should be significant ($p < 0.5$) for factor analysis to be considered appropriate and

- The anti-image correlation matrix must show that items >0.5.

Cronbach's alpha is a way to measure reliability or internal consistency of a psychometric instrument. "Reliability" is how well a test consistently measures what it is supposed to measure. The higher the Cronbach alpha, the better the reliability. Inter-item correlation is a crucial element in conducting an item analysis of a set of test questions. Inter-item correlations inspect the extent to which scores on one item are connected to scores on all other items in a scale. This offers an assessment of item redundancy: the extent to which items on a scale are assessing the same content [46]. Preferably, the average inter-item correlation for a set of items should be between 0.20 and 0.40, signifying that while the items are reasonably homogenous, they do contain sufficiently unique variance to not be isomorphic with each other. If this value is lower than 0.20, then the items may not be representative of the same content domain.

5.1.1 Organisational project culture

The exploratory factor analysis for the organisational project culture revealed the following

- The means and the standard deviations for each of the organisational project cultural factors are indicated in **Table 9**.

- This inspection for KMO was 0.64 indicating sampling adequacy.

- Bartlett's test shows that $p < 0.5$ indicating factor analysis can be considered.

- All diagonals were above 0.5 when conducting the anti-image correlation matrix.

Reliability—The Cronbach's alpha was calculated at 0.75, and the standardised items were calculated at 0.763. This Cronbach alpha is acceptable. The acid test

Descriptive Statistics			
Organisational Project Culture Factors			
	N	Mean	Std. Deviation
Top management support	39	4.46	.790
Organisational Structures	39	4.36	.707
Organisational culture	39	4.03	.903
Cultural diversity	39	3.74	.880
Organisational Strategies			
Strategies that align the project objectives with the business objectives	39	4.56	.641
Sustainability of the organisation	39	4.54	.682

Table 9.
Order based on priority for the organisational project culture factors and organisational strategies.

indicates the mean inter-item correlation needs to be above >0.2, and here, it was at 0.44, suggesting that while the items are reasonably homogenous, they do contain sufficiently unique variance. Based on the reliability and the mean item correlation, it is determined that all variables were acceptably correlated.

5.1.2 Organisational project strategy

The exploratory factor analysis for the organisational project strategy factors revealed the following:

- The means and the standard deviations for each of the organisational project strategy factors s are indicated in **Table 9**.

- This inspection for KMO was 0.5 indicating sampling adequacy.

- Bartlett's test shows that $p < 0.5$ indicating factor analysis can be considered.

- All diagonals were above 0.5 when conducting the anti-image correlation matrix.

Reliability—the Cronbach's alpha was calculated at 0.803, and the standardised items were calculated at 0.804. This alpha is acceptable. The acid test indicates the mean inter-item correlation, this needs to be above >0.2, and here, it is 0.67, suggesting that while the items are reasonably homogenous, they do contain sufficiently unique variance.

Based on the reliability and the mean item correlation, it is determined that all variables were acceptably correlated. Therefore, the results indicate that "organisation project culture" factors qualify as building blocks for PMMM, and these include organisational culture that supports project management process, supports employees to understand cultural diversity, organisational structures that support project and top management support for organisational project culture. The next building block is "organisation project strategy" composed of strategies that align the project objectives with the business objectives and sustainability of the organisation and management of best practices.

6. Conclusion

Earlier definitions of what project management success and what contributed to PMMM were limited. The contribution to what PMMM is and its importance to PBOs has evolved, and now, we understand that it is better to have models that fit the company's need rather than the company adapting to the model [47]. We also understand that a single PMMM cannot be applied in all cases and there is a need to understand what other parameters can affect PMMM for different organisations.

The objectives of this research were to determine whether PMMM should incorporate organisational factors as building blocks in the conceptual development of a project management maturity model (PMMM) for the South African's power sector. To achieve this, a literature review was conducted to determine the organisational factors that affect the PMMM power sector.

The first contribution of this study was to determine the organisational factors that support project taking place in SA, this was determined through a literature review, and these are listed in **Tables 1** and **2**. The questionnaire was used to collect data. The core findings from the questionnaire were presented.

The following objectives of the research study were achieved:

First, the organisational factors that affect PMMM were determined in Section 2 in detail, thus addressing research objective one.

The questionnaire was used to collect data. The findings from the questionnaire for the organisational factors revealed that these factors should be included in the PMMM.

The analysis indicates that for the SA power sector, PMMM should include organisational factors that support projects, and this is composed of two building blocks—organisational project culture and organisation project strategy. These building blocks need to be incorporated into the measurement for the PMMM for the SA power sector.

Building blocks of organisational project culture include:

- Organisational culture that supports project management process
- Support employees to understand cultural diversity.
- Organisational structures that support project and
- Top management support for organisational project culture.

Building blocks of organisational project strategy include:

- Strategies that align the project objectives with the business objectives
- Sustainability of the organisation and management of best practices.

The contribution of the study contributes to the existing knowledge base and has suggestions for managerial and policymakers and the well-being of society.

6.1 Contributions of the study to the existing knowledge

i. can be used to refine existing frameworks as it offers additional dimensions to be considered.

ii. propose new constructs that challenge conventional thinking and open up new avenues for research.

iii. explores new data previously unavailable especially in under-researched areas.

6.2 Implications of the study for the managerial and policymakers

i. provide evidence that can inform policymaking the changes that can be implemented based on the findings.

ii. strategic planning and decision-making where managers can use study findings to make more informed strategic decisions.

iii. can inform human resource management the findings related to employee behaviour and motivation and can inform HR policies

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iv. workplace environment: the research on organisational culture can help managers create a more positive and productive workplace environment, leading to higher employee retention and satisfaction.

6.3 Implications of the study for the well-being of society

i. can guide policies that foster job creation and economic growth. This can lead to increased employment opportunities and higher standards of living.

ii. can inform economic policies that promote sustainable growth, benefiting society as a whole.

iii. can drive policies aimed at creating a more equitable society.

6.4 Implementation in the South African power sector and transferability of the study's findings in similar industries or countries

i. Developing Countries: Similar to South Africa, many developing countries face challenges in energy sector. The findings can inform their strategies for adopting and creating supportive policies.

ii. International Collaboration: The study's findings can facilitate international collaboration, where countries share knowledge and technologies to address common challenges in the energy sector.

iii. Adoption of Standards: Research can lead to the adoption of global best practices and standards in energy management, enhancing efficiency and sustainability worldwide.

These contributions collectively advance the field, guide future research, and often have real-world implications that extend beyond academia.

7. Future research

The study focused on one government organisation and one subcontractor implementing power projects on behalf of national government. The extendibility of the research finding provides the following opportunities for future research:

- The study only focused on SA's power sector; therefore, this research can be adapted by looking at other sectors.

- This study did not consider independent power suppliers because they only form 5% of the power generation and are recent in SA. Studies can be conducted considering this sector.

- The results of this study as well as the results from a study conducted from the independent power suppliers could provide valuable insight into the phenomenon of SA's power sector project management environment, specifically on PBOs.

- A further recommendation is to conduct a similar study by including other African countries' power sectors and compare the results.

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References

[1] Harter DE, Krishnan MS, Slaughter SA. Effects of process maturity on quality, cycle time, and effort in software product development. Management Science. 2000;**46**(4):451-466

[2] Swanson S. Measuring Maturity: An Organisations Project Management Maturity Is a Key Success Indicator –but Only if the Company Knows How to Gauge it. PM Network, Project Management Institute; 2012. pp. 42-45

[3] Viana JC et al. Enhancing organizational project focused thinking model. Production. 2016;**26**(2):313-329

[4] Alam MGA, Brown M, Khan AI. The importance of human skills in project management professional development. International Journal of Managing Projects in Business. 2010;**3**(3):496-516

[5] Hulya JY. The role of project management maturity and organisational culture in perceived performance. Project Management Journal. 2009;**40**(3):14-33

[6] Hillson D. Assessing organisational project management capabilities. Journal of Facilities Management. 2003;**2**(3):298-311

[7] Skulmoski G. Project maturity and competence interface. Cost Engineering, ABI/INFORM Global. 2001;**43**(6):11-18

[8] Cooke-Davies TJ, Arzymanow A. The maturity of project management in different industries, an investigation into variation between project management models: Selected papers from fifth biennial conference of the international research network for organising by projects, held in Renesse, Seeland, the Netherlands, 28-31 May 2002. International Journal of Project Management. 2003;**21**(6):471-478

[9] Gareeb N, Rwelamila PD. Rethinking project management maturity models for the South African power sector. African Journal of Science, Technology, Innovation and Development (AJSTID). 2021;**14**:759-773. DOI: 10.1080/20421338.2021.1899558

[10] Hartman FT, Skulmoski G. Project management maturity. Project Management. 1998;**4**(1):74-78

[11] Zwikael O. Top management involvement in project management exclusive support practices for different project scenarios. International Journal of Managing Projects in Business. 2008;**1**(3):387-403

[12] Crawford L. Senior management perceptions of project management competence. International Journal of Project Management. 2005;**16**(7):7-16

[13] De Oliveria MA, Valentina LVOD, Possamai O. Forecasting project performance considering the influence of leadership style on organisational agility. International Journal of Productivity and Performance Management. 2012;**61**(6):653-671

[14] Cooper RG, Edgett SJ, Kleinschmidt EJ. Benchmarking best NPD practices – I. Research Technology Management. 2004;**47**(1):31-43

[15] Gareis R, Huemann M. Project management competences in the project oriented organization. In: Turner JR, Simister SJ, editors. The Gower Handbook of Project Management Hampshire: Gower Publishing; 2000. pp. 709-721

[16] Brush CG, Green PG, Hart MM, Haller HS. From initial idea to unique advantage: The entrepreneurial challenge of constructing a resource base. The Academy of Management Executive. 2001;**15**(1):64-78

[17] Jugdev K, Thomas J. Project management maturity models: The silver bullets of competitive advantage. Project Management Journal. 2002;**33**(4):4

[18] Fitsilis P, Kirytopoulos K, Leopoulos V. Assuring the managerial capability of public organisations implementing projects: The Greek case. International Journal of Managing Projects in Business. 2011;**4**(2):329-344

[19] Yazici HJ. An exploratory analysis of the project management and corporate sustainability capabilities for organizational success. International Journal of Managing Projects in Business. 2020;**13**(4):793-817. DOI: 10.1108/IJMPB-08-2019-0207

[20] Andersen ES, Jessen SA. Project maturity in organisations. International Journal of Project Management. 2003;**21**(6):457-461

[21] Görög M. A broader approach to organisational project management maturity assessment. International Journal of Project Management. 2016;**34**:1658-1669

[22] Langston C, Ghanbaripour AN. A management maturity model (MMM) for project-based organisational performance assessment. Construction Economics and Building. 2016;**16**(4):68-85. DOI: 10.5130/AJCEB.v16i4.5028

[23] Gareeb N, Rwelamila PMD. A conceptual Project Management maturity model for the south African Power sector. In: Mircea M, Nguyen TMM, editors. Project Management - New Trends and Applications. (Working Title). London, UK, London: IntechOpen; 2022. DOI: 10.5772/intechopen.104384

[24] Deal TE, Kennedy AA. Corporate cultures: The rites and rituals of organizational life. In: Deal T, Kennedy A, editors. Reading. Vol. 2. Mass: Addison-Wesley; 1982. pp. 98-103

[25] Nelson RR, Winter SG. An Evolutionary Theory of Economic Change. Cambridge, MA: Harvard University Press; 1982

[26] Killen CP, Hunt RA. Robust project portfolio management: Capability evolution and maturity. International Journal of Managing Projects in Business. 2013;**6**(1):131-151

[27] Branson CM. Achieving organisational change through values alignment. Journal of Educational Administration. 2008;**46**(3):376-395

[28] Simons R. How new top managers use control systems as levers of strategic renewal. Strategic Management Journal. 1994;**15**(3):169-189

[29] Thamhain HJ. Linkages of project environment to performance: Lessons for team leadership. International Journal of Project Management. 2004;**22**(7):533-544

[30] Diallo A, Thuillier D. The success dimensions of international development projects: The perceptions of African project coordinators. International Journal of Project Management. 2004;**22**:19-31

[31] Belassi W, Tukel O. A new framework for determining critical success/failure factors in projects. International Journal Project Management. 1996;**14**(3):141-151

[32] Hartman F, Ashrafi R. Project management in the information systems

and technologies industries. Project Manage Journal. 2002;**33**(3):5-15

[33] Dvir D, Lipovetsky S, Shenhar A, Tishler A. In search of project classification: A non-universal approach to project success factors. Research Policy. 1998;**27**(9):915-935

[34] Hyväri S. And the changing relationships between professionals. In: Nylund M, Yeung AB, editors. Volunteering. Anti, Values and Inclusion. Tampere: Equipoise; 2005. pp. 214-235

[35] Mishra P, Dangayach GS, Mittal ML. An empirical study on identification of critical success factors in project based organizations. Global Business, and Management Research: An International Journal. 2011;**3**(3/4):356-368

[36] Roberts A, Kelsey J, Smyth H, Wilson A. Health and safety maturity in project business cultures. International Journal of Managing Projects in Business. 2012;**5**(4):776-803

[37] Andersen ES, Dysvik A, Vaagaasar AL. Organizational rationality and project management. International Journal of Managing Projects in Business. 2009;**2**(4):479-498

[38] Albu E, Panzar C. A new tool for assessing maturity alignment: The Enterprise maturity matrix. International Society for Performance Improvement. 2010;**49**(9):35-47

[39] Christenson D, Walker DHT. Using vision as a critical success element in project management. International Journal of Managing Projects in Business. 2008;**1**(4):611-622

[40] Meyer F. Using system dynamics to implement integrated sustainable excellence and performance management systems. 2005. Available from: http://www.afscet.asso.fr/ressystemica/paris05/meyer.pdf [Accessed: November, 2013]

[41] Power B. Michael Hammer's process and enterprise maturity model. 2007. Available from: http://www.bptrends.com/publicationfiles/07-07-ARTHammersPEMM-Power-final1.pdf

[42] Cooke-Davies TJ, Crawford LH, Stevens TGL. Project management systems: Moving project management from an operational to a strategic discipline. Project Management Journal. 2009;**40**(1):110-123

[43] Selders M, Markle L. Project scorecard. Project Magazine. 2003;**20**(1):15-23

[44] The Economist Intelligence Unit. Country Report South Africa. 2013. Available from: http://0-country.eiu.com.oasis.unisa.ac.za/South%20AfricaEditor:PratibhaThaker

[45] Gagnon YC. The Case Study as Research Method: A Practical Handbook Québec (Que.): Presses de l'Université du Québec, c2010. Saint-Lazare, Quebec: Gibson Library Connections; 2010

[46] Cohen RJ, Swerdlik ME. Psychological Testing and Assessment: An Introduction to Tests and Measurement. Mayfield Publishing Co; 2005

[47] Wheatley M. Maturity matters. PM Network. 2007;**21**(7):48-53

Chapter 8

Real-Time Physical and Financial Monitoring of Cross-Country Natural Gas Pipeline Infrastructure Projects: A Digital Way

Asim Prasad

Abstract

This chapter discusses the importance of project planning and introduces a new approach using mathematical models to track linear infrastructure projects' physical and financial progress, particularly cross-country natural gas pipeline (NGPL) initiatives. The chapter teaches readers how to develop project schedules using Work Breakdown Structures and "S" curves, which have been successfully implemented in complex NGPL projects. The researcher used an exploratory methodology, including a literature review, to synthesize his experience with cross-country NGPL project implementation. Natural gas (NG), which accounts for 23.3% of global primary energy consumption, requires transportation to the consumption site, with cross-country pipelines being the safest, most efficient, and most economical delivery method. The results provide a seven-step Excel-based mathematical model for Physical Progress Monitoring and a six-step model for Finance Monitoring. These models can help project sponsors and contractors forecast and detect delays, which can be mitigated by altering execution techniques to control time and cost overruns. This helps to keep the NG transportation tariff within affordable limits. The research has practical societal implications. The novelty of the models lies in their originality.

Keywords: natural gas pipelines, energy transition, physical progress, financial progress, work breakdown structure, risk management, net zero

1. Introduction

1.1 Climate change

Climate change is a cause of global concern and the point of discussion among leaders of advanced and developing nations. The subject is the most important one since its repercussions are global in Scope and unparalleled in scale. These implications range from altering weather patterns that threaten food production to rising sea levels that increase the likelihood of catastrophic flooding. Over time, it will be more difficult and expensive to adjust to these repercussions in the future if drastic actions are not taken today [1]. Perceiving the threat, the global leaders from 196 participating nations collectively agreed to the 2015 Paris Agreement at the United Nations Climate Change Conference, COP 21 [2]. It is a global accord addressing climate change, subsequently ratified in 2016, wherein global leaders agreed to limit "the increase in the global average temperature to well below 2°C above pre-industrial levels" and "to limit the temperature increase to 1.5°C above pre-industrial levels."

The Paris Agreement aims to reduce climate change's impact, adapt to its effects, and allocate financial resources. All member nations endorsed the 2030 Agenda for Sustainable Development, pledging to fulfill the 17 Sustainable Development Goals [3]. The agreement mandates countries to prepare and maintain nationally determined contributions (NDCs) to reduce emissions and adapt to climate change impacts, focusing on domestic mitigation measures [4]. However, there has been a 0.70% rise in global carbon dioxide emissions between 2013 and 2023, amounting to 35129.8 MT in 2023, caused by 504.8 Exajoules of fossil fuel consumption [5]. Analysis reveals that global fossil fuel consumption rose from 461.1 Exajoules in 2013 to 504.8 Exajoules in 2023, a global rise of 0.91%.

1.2 Energy transition with natural gas

The developed and developing nations have announced "Net Zero" targets to limit carbon dioxide emissions and meet the Paris Agreement 1.5°C global warming target by mid-century [6]. This requires shifting energy consumption from polluting fuels to clean natural gas (NG) and renewables. In 2023, global NG consumption increased by 1.75% from 2013 to 144.31 Exajoules, and renewable power primary energy input consumption rose by 13.6% to 45.84 Exajoules, indicating progress toward an energy transition with a global preference for NG and renewable consumption [5]. However, NG is the choicest fuel globally [7], with a 23.3% share in the global primary energy mix.

NG is the cleanest burning fossil fuel—colorless and odorless. A blue flame burns without particles. Its advantages over coal and oil, which comprise 58.1% of the world's primary energy use, offer climate change solutions. It provides the maximum fuel and feedstock versatility. It serves home, industrial, commercial, and transport needs [8]. The global NG-proven reserves are 188.1 trillion cubic meters (TCM), and 2023 production was 4059.2 BCM. The reserve-to-production ratio is 48.8. NG reserves are onshore or offshore, remotely located, and NG must be transported to the point of use to enhance consumption.

1.3 Natural gas transportation via pipelines

NG is transported from gas sources to demand centers in liquefied form as liquefied natural gas (LNG) and through buried pipelines in gaseous form. In 2023, the trade movement for LNG was 549.20 BCM, while it was 677 BCM through pipelines [5]. However, pipeline transportation is considered the safest and most economical means of transportation over large distances. Globally, the trunk/transmission pipeline network spans 2,270,526 km, including crude oil, petroleum products, natural gas, and NGL pipelines, with 5047 active and suspended pipelines as of November 2023 [9].
NG trunk/transmission pipelines are cross-country pipelines buried underground, constructed adhering to ASME B31.8 Gas Transmission and Distribution Piping Systems code requirements [10].

The construction of natural gas pipelines (NGPLs) is classified as a linear project due to the number of repetitive sections or units [11]. During construction, the NGPL route alignment encounters obstacle crossings like rivers, canals, waterways, roads, highways, utilities, forests, and sensitive zones, which poses challenges during pipeline construction. Additionally, pipeline project execution encounters known or unknown risks [12] that may impact project schedules, resulting in delays for several reasons [13]. These are detrimental to the project as they may increase the cost of gas transportation and, consequently, the delivered gas price to the customer. Therefore, a mechanism is required to quantify physical and financial progress and measure delay and impact.

1.4 Research gap, question, and objective

A concept-centric literature review manifests a large body of research on the cause of delay in linear projects [11, 14–23]. Research exists in areas like Modeling Organizational Project Management [24], global projects model to improve performance [25], reserve estimation [26], project performance critical success factors [27], critical chain project management methods for multi-project systems [28]. However, there is scant research on the domain related to the physical and financial monitoring of linear projects, including NGPL, to precisely quantify linear project delays in measurable terms. Therefore, a robust project management monitoring methodology is required to establish the physical and financial schedule, measure progress, and determine any delays. Considering this, the following are the research questions (RQ):

RQ 1: Are there any mathematical models for physical and financial progress monitoring for linear projects like NGPL projects?

RQ 2: How to measure delays in physical progress in linear projects like NGPL projects?

Accordingly, this chapter aims to establish mathematical models for monitoring linear projects' physical and financial progress. The model will help the project manager establish a schedule and monitor the project's progress against the schedule in real time.

1.5 Methodology

The researcher used an exploratory approach involving a literature survey to consolidate valuable knowledge and apply his experience with NGPL project execution to establish the model. The methodology is discussed in **Figure 1**.

The rest of the chapter is structured as follows: Section 2 is the project conceptualization. Section 3 is the project formulation and stakeholders analysis; Section 4 is the project decomposition. Section 5 is the mathematical model for physical progress monitoring, while the financial progress monitoring is in Section 6. The findings and discussions are in Section 7. The article ends with implications and conclusions in Section 8.

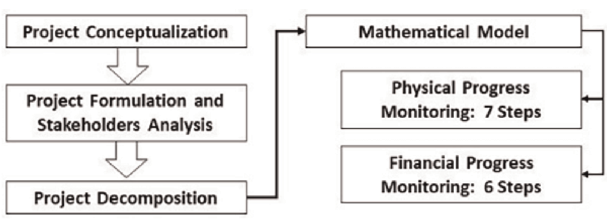

Figure 1.
Methodology. Source: Authors conceptualization.

2. Project conceptualization

Project management [29, 30] is the art and science of converting vision into reality. It involves utilizing knowledge, skills, tools, and procedures to carry out project activities to fulfill the project requirements [31]. It manages several interrelated activities by systematically applying knowledge and resources for tangible results. What all of us demand is fast, cheap, and robust projects. As a project matures, its interaction with the operating and remote environment increases, leading to increased complexity and challenges in delivering projects, as the operating and remote environment can hinder speedy execution.

Natural gas pipeline (NGPL) projects aim to benefit stakeholders, including gas transporters, customers, and stakeholders [32]. These linear projects are designed to create a distinct pipeline, service, and outcome. They are linear, dividing them into manageable sections for concurrent execution. Construction activities involve pipe stringing, trenching, welding, lowering, and backfilling, which are then integrated to commission the entire NGPL.

NGPL projects, based on Open System theory (**Figure 2**) [33], involve continuous interaction with remote environments [34] and are characterized by uniqueness, complexity, dynamicity, diversity, limited resources, and risk. They bring beneficial change by delivering cleaner NG. As projects are executed under stiff deadlines, organizations need real-time monitoring systems to assess the project's progress and performance accurately.

Mathematically, project characteristics are depicted as follows in Eq. (1).

$$\text{Projects Characteristics} = f\left(C^a, D_1{}^b, D_2{}^c, Lr^d, R^e, U^f\right) \tag{1}$$

Where

C: Complexity; D_2: Diversity; R: Risk D_1: Dynamism; L_r: Limited Resource; U: Uniqueness; a,b,c,d,e,f are real numbers greater than zero.

3. Project formulation and stakeholders analysis

The root causes of project issues are attributed to either neglecting or intentionally committing errors during the initial stages when the project objectives are being

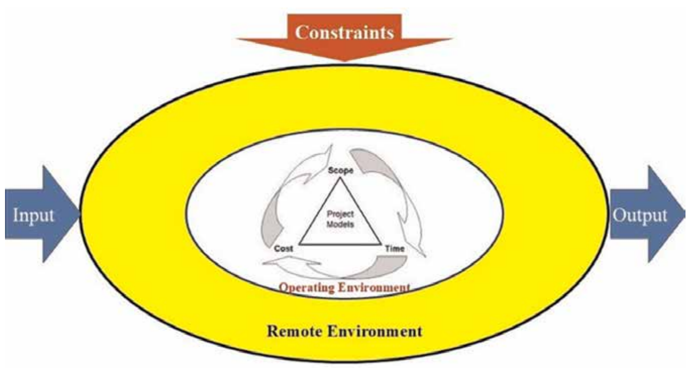

Figure 2.
Open systems approach. Source: Authors conceptualization.

defined and the project is being scheduled. This stage of the project is referred to as the Fuzzy Front End [35]. A project charter is prepared, which is a formal document provided by the project initiator or sponsor that grants the project manager the ability to allocate organizational resources to project activities and officially approves the project's existence [31]. After formulating the project and identifying its objectives and business value, the project management plan is developed, considering the stakeholders' demands and expectations. The project management plan is an integrated document that encompasses the sub-plans and sets forth the management controls and overall plan for effectively integrating and managing the separate components of the NGPL project.

Conducting a stakeholder analysis (**Figure 3**) at this stage is crucial for preparing a stakeholder engagement plan [31], which involves identifying stakeholders, categorizing them, and prioritizing them (**Table 1**) based on their significance, level of influence, and impact, and then integrating what they want and expect into the project plan. Often, after doing a thorough analysis of the stakeholders, it may be necessary to redefine the project objectives and plan. This task must be completed initially to preempt any issues arising during the project's execution. Mathematically, this is represented in Eq. (2).

Figure 3.
NGPL project stakeholders. Source: Authors analysis.

Stakeholder	Importance (1–10) [A]	Degree of influence (1–10) [B]	Impact (1–10) [C]	Prioritization score (P) [A + B + C]
S_1	A_1	B_1	C_1	P_1
S_2	A_2	B_2	C_2	P_2
S_3	A_3	B_3	C_3	P_3
S_4	A_4	B_4	C_4	P_4
S_5	A_5	B_5	C_5	P_5
S_i	A_i	B_i	C_i	P_i
Source: Authors analysis.				

Table 1.
Stakeholders prioritization.

$$\text{Project redefined objectives} = f\,(\textit{Stakeholders Demand}, \textit{Expectations}, \textit{Criticality}, \textit{Degree of Influence}, \textit{Extant of Participation}) \tag{2}$$

The variable Pi denotes the Prioritization score assigned to a particular Stakeholder (Si), and its mathematical representation is in Eq. (3).

$$P_i = A_i + B_i + C_i \tag{3}$$

Grouping of stakeholders is done to keep each type of stakeholder under one category. This helps to focus on the stakeholders and monitor their requirements, which are dynamic as they change with project maturity.

4. Project decomposition

NGPL projects are implemented in remote areas with varying topography, weather, and regional and local conditions. Thus, project modeling must include the execution methodology, project detailed plan, risk management plan, Work Breakdown Structure (WBS), resource breakdown structure, risk breakdown structure, and responsibility matrix [29]. The project agency must accurately identify risk factors and develop measures to mitigate them to complete the NGPL project within the approved schedule and cost to avoid time and cost overruns, which requires project decomposition to micromanage the project. Project decomposition is the hierarchical split of the project work scope into smaller components that the project team must execute to satisfy project goals and deliverables within schedule and budget.

A WBS simplifies project management by separating it into hierarchical levels, representing each generation [31]. WBS is hierarchical. The NGPL project title and final deliverable are typically level 1, which aligns with stakeholder concerns. The WBS supports scheduling, resource matrix preparation, responsibility identification, budgeting, cash flow management, risk breakdown structure, and workarounds during execution. It helps allocate resources, plan completion schedules, and address known-unknown risk issues [36] while allocating resources and effort throughout project implementation.

5. Mathematical model for physical progress monitoring

1. *Step 1*: The first step of the mathematical model is to identify the WBS elements for the execution of the cross-country NGPL project and assign a unique code to each element. The WBS elements, as per the authors understanding, are discussed in **Table 2** and **Figure 3**, respectively. This is the second level, called the “Controls account.” It provides a clear overview of the project’s major phases and essential outcomes.

2. *Step 2*: The second step is to assign weights to each WBS element, as shown in **Table 3**. The summation of weights is 100%, as depicted in Eq. (4). The WBS elements diagrammatically are in **Figure 4**.

$$\text{Total WBS weightage} = \sum \text{Wi}; i = 1 \textit{ to } 8 \tag{4}$$

Sl.	WBS element	WBS code (WBS_i)
1.	Statutory permissions, Right of Use(RoU), and land Acquisition	WBS_1
2.	Engineering	WBS_2
3.	Tendering	WBS_3
4.	Ordering	WBS_4
5.	Manufacturing, inspection, delivery	WBS_5
6.	Construction	WBS_6
7.	Commissioning	WBS_7
8.	Project Closeout	WBS_8
Source: Authors conceptualization.		

Table 2.
Typical WBS elements for NGPL project.

Sl.	WBS code (WBS_i)	WBS weights(W_i)
1.	WBS_1	W_1
2.	WBS_2	W_2
3.	WBS_3	W_3
4.	WBS_4	W_4
5.	WBS_5	W_5
6.	WBS_6	W_6
7.	WBS_7	W_7
8.	WBS_8	W_8
Source: Authors conceptualization.		

Table 3.
WBS elements weights.

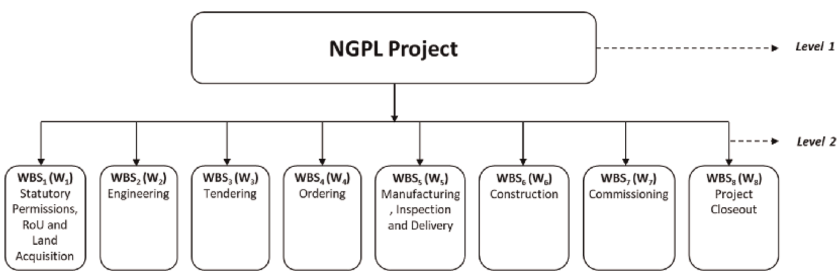

Figure 4.
NGPL project stakeholders. Source: Authors depiction.

3. *Step 3*: The third step relates to the operationalization of each WBS element. It involves the WBS element description and the further decomposing of the elements to the third and fourth levels. The third level is the task or work package level, while the fourth is the activity level. One task comprises several activities. The different elements are described as follows:

5.1 Statutory permissions, RoU, and land acquisition (W_1)

In India, the execution of NGPL projects requires permissions from statutory authorities such as the Ministry of Environment, Forest and Climate Change (MEFCC), and NoC from State Pollution Control Boards, apart from No Objection Certificates from different government-controlled departments for seeking obstacle-crossing permissions. For example, pipeline alignment may encounter obstacle crossings like water bodies, roads, highways, forest areas, wildlife sanctuaries, railway crossings, mangroves, and other pipelines, for which permission is required. Further, RoU and permanent land acquisition are also required to develop facilities. The RoU is required to lay the pipeline, while permanent land is required to establish stations like the gas dispatch terminal (DT), sectionalizing valve (SV), intermediate pigging (IP) stations, and gas receipt terminal (RT) along the pipeline alignment. Permanent land will also be required if the detailed engineering design requires any intermediate gas-boosting station. **Table 4** indicates the decomposition methodology for this WBS. Mathematically, this is given in Eq. (5).

$$W_1 = \sum \mathrm{Wij}; i = 1; j = 1\ to\ 5 \tag{5}$$

5.2 Engineering (W_2)

Executing any NGPL projects requires identifying the different engineering disciplines for which the primary and detailed engineering is done to finalize the design basis. The disciplines for which the engineering work is done include mechanical, civil, electrical, instrumentation, telecom, Supervisory Control and Data Acquisition Systems (SCADA), etc. Mathematically, the sub-WBS for this discipline is shown by Eq. (6).

$$W_2 = \Sigma W_{2k}; k = 1\ to\ n, \tag{6}$$

$n = number\ of\ engineering\ disciplines$

5.3 Tendering (W_3)

NGPL projects require many procurement and work packages for which tenders are prepared for procurement. A transparent, fair, and competitive bidding must be followed to attract bids from several prospective bidders. In general, a two-bid system is preferred. The first bid is the technical bid. The second bid is the price bid. The price

WBS_1 = Statutory permissions, RoU, and land acquisition (W_1)		**W_{ij}**
1.	RoU acquisition	W_{11}
2.	Permanent land acquisition	W_{12}
3.	MoEF clearance	W_{13}
4.	SPCB clearance	W_{14}
5.	Obstacle-crossing permissions	W_{15}
Source: Authors conceptualization.		

Table 4.
WBS sub-elements and weights for WBS1.

bids will be opened for the technically qualified bidders only. For high-value packages, the project implementing agency may follow a reverse auction wherein price negotiations with each of the technically qualified bidders are done concurrently on a virtual platform on a real-time basis. The procurement involves coated line pipes, valves, fittings, flanges, metering skids, power sources, pipeline laying, Supervisory Control and Data Acquisition Systems (SCADA), Telecom, etc. However, the project implementation agency may decide the procurement method and the number of packages based on their management decision. Mathematically, the sub-WBS for this WBS is given in Eq. (7).

$$\mathrm{W}_3 = \Sigma \mathrm{W}_{3l}; l = 1 \textit{ to } m \tag{7}$$

m = *number of procurement packages*
Subweights for different packages can be assigned considering the cost, criticality, and delivery schedule.

5.4 Ordering (W_4)

After the bids have been received, the technical and commercial bid analysis is done. The orders are placed with the bidder who has quoted the lowest price, provided their bids have qualified technically. A transparent and fair methodology is followed. Each tender package may have more than one order, depending on the methodology outlined under the special conditions of the contract. Mathematically, the sub-WBS for this discipline is in Eq. (8).

$$\mathrm{W}_4 = \Sigma \mathrm{W}_{4\mathrm{p}}; p = 1 \textit{ to } q \tag{8}$$

q = *number of purchase and work orders*
Subweights at WBS level 3 for different orders can be assigned considering the cost, criticality, and delivery schedule.

5.5 Manufacturing, inspection, and delivery (W_5)

NGPL projects require different items to be manufactured per the project engineering requirement since all items may not be available off-shelf. Such items are manufactured by different vendors located geographically far away from the project site or even in a foreign country. The items are manufactured to adhere to the requirements of national/international codes and standards, during which stage inspections are conducted. After manufacturing and inspection are completed, the finished material is delivered by any economic means of transportation to the project site. Mathematically, the sub-WBS for this discipline is given in Eq. (9).

$$\mathrm{W}_5 = \Sigma \mathrm{W}_{5\mathrm{r}}; r = 1 \textit{ to } s \tag{9}$$

s = number of orders where item inspection is required
Subweights can be assigned considering the cost, criticality, and delivery schedule.

5.6 Construction (W_6)

Every NGPL project requires extensive construction activities carried out in challenging environments. A team of contractors, comprising personnel with specialized equipment, highly skilled, moderately skilled, and unskilled workforce, and occasionally expatriates, works at the site despite the challenges presented by its remote locations. The construction of pipeline laying and station work, which includes the receipt/dispatch station SV/IP stations, is conducted concurrently. The pipeline is divided into smaller sections for easier management. Every section length is planned to have comparable levels of complexity in terms of topography, number of obstacle crossings to traverse, and geographical conditions. Extra precautions are implemented to ensure that a particular section of the pipeline terminates at the state boundary to avoid any administrative complexities and law enforcement at the state level during the construction phase. NGPL is a linear infrastructure project; the construction works in distinct sections are carried out concurrently. The primary tasks carried out during pipeline construction are RoU Opening, RoU Grading, Pipe Stringing, Trenching, Welding and Inspection, Joint Coating, Optical Fibre Cable (OFC) laying, Lowering of welded sections, Backfilling, Hydrotesting, and Dewatering. Each task may have multiple activities. The OFC laid along the pipeline helps with communications, data transmission, real-time monitoring, and NG leak detection [37]. As the release of NG poses a significant risk to public safety, leak detection is essential as it increases the reliability and resilience of the NGPL infrastructure [38].

With the completion of successful hydrotesting, the sections are declared mechanically complete. The mechanically completed sections are joined through a Gloden Tie-In Joint. The "Golden Joint" is a distinct weld joint, usually the last weld that connects pre-existing piping sections with new ones. The term "golden" is used to describe it due to its crucial character and the significance of its quality. The **Table 5** illustrates the construction work of the pipeline in multiple sections. The total Scope and real-time total task completion progress are given in Eqs. (10) and (11), respectively.

Here,

- "TA" is the distinct task at WBS level 3. Each task may have multiple activities at WBS level 4.
- "S" is the Scope corresponding to each task in each section (S_1, S_2 … .).
- "C" is the work completion progress made for each task (TA_1, TA_2 … .).

		Section-1		***Section-2***		***Section-S***		***Total***	
Sl.	**Distinct task**	**Scope**	**Physical progress**	**Scope**	**Physical progress**	**Scope**	**Physical progress**	**Scope**	**Physical Progress**
i.	TA_1	S_{11}	C_{11}	S_{21}	C_{21}	S_{s1}	Cs_1	S_{T1}	C_{T1}
ii.	TA_2	S_{12}	C_{12}	S_{22}	C_{22}	S_{s2}	Cs_2	S_{T2}	C_{T2}
iii.	TA_3	S_{13}	C_{13}	S_{23}	C_{23}	S_{s3}	Cs_3	S_{T3}	C_{T3}
iv.	TA_4	S_{14}	C_{14}	S_{24}	C_{24}	S_{s4}	Cs_4	S_{T4}	C_{T4}
v.	TA_5	S_{15}	C_{15}	S_{25}	C_{25}	S_{s5}	Cs_5	S_{T5}	C_{T5}
vi.	TA_s	S_{1s}	C_{1s}	S_{2s}	C_{2s}	S_{ss}	C_{ss}	S_{Ts}	C_{Ts}

Source: Authors conceptualization.

Table 5.
Pipeline construction in multiple sections.

- "S_T" is the total Scope against each task (S_{T1}, S_{T2} … .).
- "C_T" is the total work completion progress corresponding to the task (C_{T1}, C_{T2} … .).

$$Sss = S_{1s} + S_{2s} + S_{3s} \ldots .. + S_{xy} \tag{10}$$

$$C_T s = C_{1s} + C_{2s} + C_{3s} \ldots + C_{xy} \tag{11}$$

5.7 Commissioning (W_7)

The pipeline pre-commissioning and commissioning checks [39] of NGPL are undertaken to verify that all pipeline construction has been completed satisfactorily and fulfills the required standards and safety requirements. A safety audit is also conducted as per the predefined checklist. Further, the pipelines must be cleaned thoroughly before injecting natural gas. It is possible to perform pipeline cleaning services throughout both the pre-commissioning and commissioning stages of final testing. NGPLs are flushed by pushing chemical compounds through the pipeline or mechanically using pigging machines. Swabbing is a crucial first step in pigging as it aids in assessing the amount of debris in the pipeline. The swabbing technique is performed with a foam or polymer instrument known as a pig. The pig is inserted at the inlet of the pipeline to undergo drying and propulsion over the entire length of the pipeline channel until it reaches the outlet. This activity is conducted between two consecutive sections, having facilities for pig launching and receiving, like the Dispatch Station to an IP station, between two successive IP stations. The initial swabbing pig is a flexible foam pig with a soft and sponge-like texture. The pig's malleability is advantageous as it navigates through the pipeline. The pipeline is vacuum-dried to eliminate water droplets and purged with pure nitrogen to make it oxygen-free. After that, "Gas-In" is done in the pipeline. The gas pressure is monitored at different SV/IP stations till it reaches the operating level. Leakages are checked at different above-ground piping sections at dispatch/receipt stations and the SV/IP stations to ensure safe operations. Gauge pigging is also done during pipeline commissioning. Gauge pigging is a pipeline inspection technique using an aluminum gauge plate to measure the pipeline's interior diameter, detecting wear and obstructions as it passes through the pipeline [40].

5.8 Closeout (W_8)

The NGPL project's closeout phase is crucial. This phase might take 6 months to a year to complete; therefore, it must be given reasonable weightage. The following are the major activities:

1. Capitalization of projects
2. Closure of all purchase and work orders
3. Vendor and contractor performance evaluation
4. Release of retention funds as per the order conditions
5. Closeout meetings with vendors and contractors

6. Compilation of lessons learned during project execution

7. Preparation of the project closeout report

8. Document actual results, success factors, failures, innovative steps, etc.

9. Acknowledgment of outstanding performers

10. Revisions in procedure guidelines, if required

11. Sharing of experiences with major stakeholders, including the project team.

4. *Step 4*: The fourth step is to determine each WBS element's scheduled physical progress and calculate each month's overall scheduled percentage progress, as shown in **Table 6**. Based on this, the physical progress for any given month is calculated as follows:

$$\text{OSIP} = \sum W_j * SP_j, where\, j = 1\, to\, 8 \tag{12}$$

$$\text{OSCP} = \sum W_j * CP_j, where\, j = 1\, to\, 8 \tag{13}$$

Where,

- OSIP is the overall schedule incremental physical progress (%)
- OSCP is the overall schedule cumulative physical progress (%)

The month-wise OSIP and OSCP for the NGPL project with a scheduled duration of S_D months from its start till project closeout is in **Table 7**.

For the first month, the OSCP is the same as the OSIP. However, from the second month onwards, the OSCP is the sum of the incremental scheduled physical progress

Sl.	WBS element (WBS_i)	Weight (W_j)	Incremental schedule % physical progress for the month	Cumulative schedule % physical progress up to the month
i.	WBS_1	W_1	SP_1	CP_1
ii.	WBS_2	W_2	SP_2	CP_2
iii.	WBS_3	W_3	SP_3	CP_3
iv.	WBS_4	W_4	SP_4	CP_4
v.	WBS_5	W_5	SP_5	CP_5
vi.	WBS_6	W_6	SP_6	CP_6
vii.	WBS_7	W_7	SP_7	CP_7
viii.	WBS_8	W_8	SP_8	CP_8

Source: Authors analysis.

Table 6.
Scheduled physical progress.

Month no.	Month (MM)-Year (YY)	$OSIP_i$ (%)	$OSCP_i$ (%)
1	MM1-YY	$OSIP_1$	$OSCP_1$
2	MM2-YY	$OSIP_2$	$OSCP_2$
3	MM3-YY	$OSIP_3$	$OSCP_3$
4	MM4-YY	$OSIP_4$	$OSCP_4$
5	MM5-YY	$OSIP_5$	$OSCP_5$
6	MM6-YY	$OSIP_6$	$OSCP_6$
S_D	MMS_D-YY	$OSIPS_D$	$OSCPS_D$
Source: Authors analysis.			

Table 7.
Month-wise incremental and cumulative Scheduled physical progress %.

of all the previous months up to the review month, denoted by n. Mathematically, for n^{th} month, OSCP is $OSCP_n$

$$\text{OSCPn} = \sum OSIP_n, where\ n = 1\ to\ S_D \tag{14}$$

When n = S_D; $OSCP_n$ = 100%

5. *Step 5*: The fifth step is to calculate each WBS element's actual incremental and overall physical progress, as shown in **Table 8**, and then calculate each month's actual overall and cumulative percentage progress mathematically as Eqs. (15) and (16), respectively. The NGPLs project's actual cumulative progress is in **Table 9**.

Based on this, the actual overall and cumulative physical progress is calculated as follows:

$$\text{AOP}_\text{j} = \sum AIP_{ji}, where\ j = 1\ to\ 8; i = 1\ to\ S_D \tag{15}$$

$$\text{ACP}_\text{i} = \sum W_j * AIP_{ji}, where\ j = 1\ to\ 8; i = 1\ to\ S_D \tag{16}$$

WBS element: WBS_j; *where j = 1 to 8*			
Month no.	**Month (MM)-Year (YY)**	**AIP_{ji} (%)**	**AOP_{ji} (%)**
1	MM1-YY	AIP_{j1}	AOP_{j1}
2	MM2-YY	AIP_{j2}	AOP_{j2}
3	MM3-YY	AIP_{j3}	AOP_{j3}
4	MM4-YY	AIP_{j4}	AOP_{j4}
S_D	MMS_D-YY	AIP_jS_D	AOP_jS_D
Source: Authors analysis.			

Table 8.
WBS_j element's actual incremental and overall physical progress.

		Month no.				
WBS element	**WBS weight**	***1***	***2***	***3***	***i***	S_D
WBS_1	W_1	AOP_{11}	AOP_{12}	AOP_{13}	AOP_{1i}	AOP_1S_D
WBS_2	W_2	AOP_{21}	AOP_{22}	AOP_{23}	AOP_{2i}	AOP_2S_D
WBS_3	W_3	AOP_{31}	AOP_{32}	AOP_{33}	AOP_{3i}	AOP_3S_D
WBS_4	W_4	AOP_{41}	AOP_{42}	AOP_{43}	AOP_{4i}	AOP_4S_D
WBS_5	W_5	AOP_{51}	AOP_{52}	AOP_{53}	AOP_{5i}	AOP_5S_D
WBS_6	W_6	AOP_{61}	AOP_{62}	AOP_{63}	AOP_{6i}	AOP_6S_D
WBS_7	W_7	AOP_{71}	AOP_{72}	AOP_{73}	AOP_{7i}	AOP_7S_D
WBS_8	W_8	AOP_{81}	AOP_{82}	AOP_{83}	AOP_{8i}	AOP_8S_D
NGPL cumulative physical progress		ACP_1	ACP_2	ACP_3	$ACPi$	$ACPS_D$

Source: Authors analysis.

Table 9.
WBS element's actual overall and NGPL cumulative physical progress.

Where,

- AIP is the actual incremental physical progress (%) for j^{th} WBS element in the i^{th} month.
- AOP is the actual overall physical progress (%) for j^{th} WBS element in the i^{th} month.
- ACP is the NGPL project's actual cumulative physical progress (%) in the i^{th} month.

6. *Step 6*: The sixth step compares the project's cumulative actual progress against the cumulative schedule for the review month. This is depicted in **Table 10** and Eq. (17). The reasons for deviation are also ascertained WBS element-wise by comparing the cumulative actual overall percent progress with the schedule progress. Three scenarios emerge for this, as depicted in **Table 11**.

$$CV_i = ACP_i - CP_i \tag{17}$$

Where,
CV_i = Cumulative variation for the i^{th} month
ACP_i is as per Eq. (16)

$$CP_i = \sum W_j * SP_{ji}, where\ j = 1\ to\ 8; i = 1\ to\ S_D \tag{18}$$

Scenarios 1 and 3 are not significant, but Scenario 2 is concerning due to project delay. A contingency plan [29] should be developed for WBS elements falling behind schedule, executed, and monitored in real time. Limited resources can lead to delays and cost overruns, especially in NGPL infrastructure projects. Decision tree analysis can help mitigate this issue.

WBS element	WBS weight	Incremental schedule % physical progress for the month	Cumulative schedule % physical progress up to the month	Actual incremental % progress for the month	Cumulative actual overall % progress up to the month	Cumulative variation = (Actual – Schedule)
WBS_1	W_1	SP_1	CP_1	AOP_1	ACP_1	ACP_1-CP_1
WBS_2	W_2	SP_2	CP_2	AOP_2	ACP_2	ACP_2-CP_2
WBS_3	W_3	SP_3	CP_3	AOP_3	ACP_3	ACP_3-CP_3
WBS_4	W_4	SP_4	CP_4	AOP_4	ACP_4	ACP_4-CP_4
WBS_5	W_5	SP_5	CP_5	AOP_5	ACP_5	ACP_5-CP_5
WBS_6	W_6	SP_6	CP_6	AOP_6	ACP_6	ACP_6-CP_6
WBS_7	W_7	SP_7	CP_7	AOP_7	ACP_7	ACP_7-CP_7
WBS_8	W_8	SP_8	CP_8	AOP_8	ACP_8	ACP_8-CP_8

Source: Authors analysis.

Table 10.
Cumulative actual progress vs. schedule.

Scenario	Value of CV	Implication on project schedule
1	0	On schedule
2	<0	Behind schedule
3	>0	Ahead of schedule

Source: Authors analysis.

Table 11.
Implication of project schedule.

7. *Step 7*: The seventh step involves drawing the "S" curve [41]. An S-curve is a mathematical graph employed in project management to monitor the advancement of a project over time, detect potential issues, and compare the actual progression with the projected progress [42]. The S-curve is a visual representation of the cumulative percentage of progress or other quantities plotted against time. The term "S-curve" is derived from the curve shape that resembles the letter "S," with a flatter slope at the beginning and finish and a steeper slope in the middle [29]. The "S-curve" follows the 50/70 rule, meaning that at the halfway point, precisely 50% of the project schedule duration ($S_D/2$), it is expected that 70% of the cumulative physical progress should have been completed. The remaining 30% of the cumulative physical progress must be completed within 50% of the balance allotted time [43]. A typical "S-curve" is given in **Figure 5**.

Using the "S-Curve", project managers utilize performance analysis to gain insights, identify critical issues, and guarantee adherence to the project's timeline and budgetary limitations. It is helpful to forecast the project's progress, help in risk

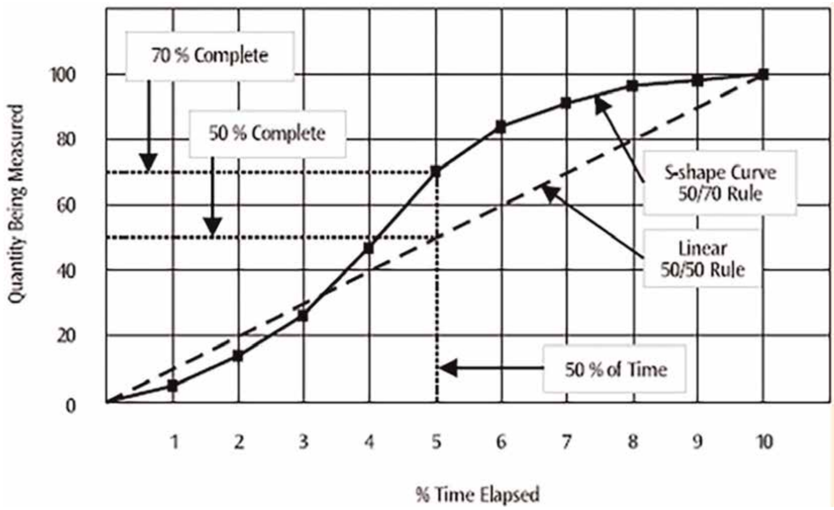

Figure 5.
Physical progress "S-curve" [43].

management, and ascertain the construction maturity in NGPL infrastructure projects.

An Excel sheet can create a mathematical model for physical progress monitoring. The typical weights for the different WBS elements in **Tables 2** and **3** are WBS_1 3%, WBS_2 8%, WBS_3 15%, WBS_4 25%, WBS_5 20%, WBS_6 25%, WBS_7 2%, WBS_8 2%.

6. Mathematical model for financial progress monitoring

Financial monitoring is essential in large infrastructure projects like the NGPL project since it involves huge capital expenditure, comprising equity and debt available at cost. Therefore, efficient capital expenditure management is required to optimize debt and equity funds. This involves estimating costs, predicting cash outflow timings, securing funds, monitoring cash outflow, identifying deviations, and modifying the baseline plan periodically. This process requires knowledge of schedules, progress, commercial purchase conditions, and bill processing time. The financial progress monitoring is done through cash flow management. Cash flow management should adapt quickly to changing environments and ensure sufficient funds are available for payments without affecting delivery while managing risk. It is a systematic process synchronizing with the scheduled physical progress plan, with lag. The steps followed for financial monitoring through cash flow management are detailed herein.

Step 1: Identification of cost heads and cost estimation

NGPL projects involve various cost heads, including direct, indirect, hard, and soft costs, estimated in the Detailed Feasibility Report (DFR). Project investment approval allocates costs, including taxes and duties, based on experience, market estimates, and cost databases. Considering changing market conditions, a 20%deviation from DFR is reasonable for estimation purposes. Costs of some items may be in a foreign currency

Sl.	Cost head	Cost head variable: CHV_i	DFR cost estimate: TC_i
1.	Land, survey, and statutory permissions	CHV_1	TC_1
2.	Procurent packages ($PO1, PO2 \ldots .PO_p$)	CHV_2	TC_2
3.	Work packages ($WO1, WO2 \ldots .WO_w$)	CHV_3	TC_3
4.	Owners management expenses	CHV_4	TC_4
5.	Contingency reserve	CHV_5	TC_5
6.	inflation, interest on debt, margin money for working capital	CHV_6	TC_6
Total approved DFR cost (The project investment approval is the baseline at Time T_0)			$\mathbf{TACB_0}$
Source: Authors conceptualization.			

Table 12.
NGPL project cost heads.

for which the published exchange rates are considered. The NGPL project's major cost head items (**Table 12**) are as follows:

i. Land, survey, and statutory permissions.

ii. Purchase order (PO) against various procurement packages such as equipment, line materials like valves and fitting flanges, and machinery.

iii. Work order (PO) against various work packages for different types of specialized contract work like pipeline construction.

iv. Project management consultancy (PMC) and services of a third-party inspection agency (TPIA).

v. Owners' management expenses (OME) include workers' wages, salary, lodging and boarding expenses, and expenditures incurred toward setting up offices.

vi. Contingency or management reserve for managing known and unknown risks [44].

vii. Inflation, interest, margin money for working capital, foreign exchange variation, etc.

$$\mathrm{TACB}_0 = \sum TC_h, where\ h = number\ of\ cost\ heads \tag{19}$$

Step 2: Calculation of monthly cash outflows

Large NGPL projects typically take 3–5 years to complete. Upon investment approval, a physical progress schedule (Section 5) is prepared based on a forecast of monthly progress. The project manager forecasts expenditures, including DFR estimates, vendor/contractor bills, and anticipated bill amounts, to determine monthly planned expenditures and cumulative cash flow (**Table 13**).

			Monthly projected cash outflow			
Sl	**Cost head variable**	**DFR Cost: TC_i**	**Month-1**	**Month-2**	**Month-3**	**Month-N**
1	CHV_1	TC_1	TC_{11}	TC_{12}	TC_{13}	TC_{1N}
2	CHV_2	TC_2	TC_{21}	TC_{22}	TC_{23}	TC_{2N}
3	CHV_3	TC_3	TC_{31}	TC_{32}	TC_{33}	TC_{3N}
4	CHV_4	TC_4	TC_{41}	TC_{42}	TC_{43}	TC_{4N}
5	CHV_5	TC_5	TC_{51}	TC_{52}	TC_{53}	TC_{5N}
6	CHV_6	TC_6	TC_{61}	TC_{62}	TC_{63}	TC_{6N}
Total approved DFR cost (The project investment approval is the baseline at Time T_0)		**$TACB_0$**	**TC_{M1}**	**TC_{M2}**	**TC_{M3}**	**TC_{MN}**
Cumulative monthly baseline projected expenditure			**TC_{M1}**	**$TC_{M1+}TC_{M2}$**	**$TC_{M1+}TC_{M2}$ $_+TC_{M3}$**	**$TC_{M1+}TC_{M2+}TC_{M3} + \ldots.$ $_+TC_{MN}$**
% Cumulative monthly estimated projected cash outflow baseline			**TC_{M1}/ $TACB_0$**	**$(TC_{M1} + TC_{M2})$/ $TACB_0$**	**$(TC_{M1+}TC_{M2}$ $_+TC_{M3})/TACB_0$**	**$(TC_{M1+}TC_{M2}$ $_+TC_{M3} + \ldots. + TC_{MN})$/ $TACB_0$**

Source: Authors analysis.

Table 13.
Monthly planned cash outflow based on estimated DFR Cost.

Step 3: Calculation of the cash outflow for each item based on actual ordered value and planned incremental scheduled progress

DFR estimates differ from actual order values due to the time gap between estimate preparation and financial commitment, which is the actual order date. Cash flow is calculated by recording actual order value against purchase and work orders, and computing planned expenditure. The cash flow statement for each PO is based on the actual delivery schedule and payment milestone dates. After placing WOs, the Scope of work, completion schedule, payment terms and conditions, and running account (RA) bill schedule are used to prepare the anticipated cash flow statement for each WO. The sum of the monthly planned cash flow against all POs and WOs gives the cumulative planned expenditure for the month. At time horizon "T1," the new financial monitoring baseline is the expected cash flow statement after all POs and WOs are placed. When NGPL begins commercial operations, contingency (CHV_5), inflation, interest, margin money, and foreign exchange variation (CHV_6) costs are booked as actuals and reported during project capitalization. The T1 cash flow statement will exclude cost components CHV_5 and CHV_6 for simplified financial monitoring.

The cost subheads under land, survey, and Statutory Permissions (CHV1) correspond to the WBS sub-element shown in earlier **Table 4**. Likewise, the cost subheads under PO (CHV_2), WO (CHV_3), OMEs (CHV_4) relate to the WBS level 3 under

			Monthly projected cash outflow			
Sl.	**Cost head variable**	**Order value: TOC_i**	**Month-1**	**Month-2**	**Month-3**	**Month-N**
1	CHV_1	TOC_1	TOC_{11}	TOC_{12}	TOC_{13}	TOC_{1N}
2	CHV_2	TOC_2	TOC_{21}	TOC_{22}	TOC_{23}	TOC_{2N}
3	CHV_3	TOC_3	TOC_{31}	TOC_{32}	TOC_{33}	TOC_{3N}
4	CHV_4	TOC_4	TOC_{41}	TOC_{42}	TOC_{43}	TOC_{4N}
Total Ordered Value (Baseline at Time T_1)		**$TOCB_1$**	**TOC_{M1}**	**TOC_{M2}**	**TOC_{M3}**	**TOC_{MN}**
Cumulative monthly baseline projected expenditure			TOC_{M1}	TOC_{M1} + TOC_{M2}	TOC_{M1} + TOC_{M2} + TOC_{M3}	TOC_{M1} + TOC_{M2} + TOC_{M3} + ……+ TOC_{MN}
% Cumulative monthly estimated projected cash outflow Baseline at T1			**TOC_{M1}/ $TOCB_1$**	**(TOC_{M1} + TOC_{M2})/ $TCOB_1$**	**(TOC_{M1} + TOC_{M2} + TOC_{M3})/ $TOCB_1$**	**(TOC_{M1} + TOC_{M2} + TOC_{M3} + ……+ TOC_{MN})/$TOCB_1$**

Source: Authors analysis.

Table 14.
Monthly planned cash outflow based on actual order value.

corresponding heads. The details are given in **Table 14** and the following equations represent this.

$$C_{PO} = \sum CPO_q \text{ where } q = 1 \text{ to } N_{PO} \tag{20}$$

$$C_{WO} = \sum CWO_r \text{ where } r = 1 \text{ to } N_{WO} \tag{21}$$

$$C_{OME} = \sum COME_s \text{ where } s = 1 \text{ to } N_{OME} \tag{22}$$

Where,

- C_{PO} is the cumulative order value of all purchase orders
- C_{WO} is the cumulative order value of all work orders
- C_{OME} is the cumulative order value of all expenditures under owners management expenses
- N_{PO} is the total number of purchase orders
- N_{WO} is the total number of work orders
- $N_{OME}$is the total number of cost heads under owners management expenses

Step 4: Recalculate the project's cash outflow based on actual physical progress and balance expenditures

Sl.	Cost head variable	Order value: TOC_i	Cumulative expenditure till previous month (TCi)	Balance expenditure ($Zi = TOC_i$-TCE_i)
1	CHV_1	TOC_1	TCE_1	$Z_1 = TOC_1 - TCE_1$
2	CHV_2	TOC_2	TCE_2	$Z_2 = TOC_2 - TCE_2$
3	CHV_3	TOC_3	TCE_3	$Z_3 = TOC_3 - TCE_3$
4	CHV_4	TOC_4	TCE_4	$Z_4 = TOC_4 - TCE_4$
	Total	**$TOCB_1$**	**TCE_n**	**Z_n**
% Expenditure			**$TCE_n/TOCB_1$**	**$Z_n/TOCB_1$**

Source: Authors analysis.

Table 15.
Calculation of balance expenditure.

There are obstacles to infrastructure projects because of political, economic, social, technical, legal, and environmental factors. As a result, there is a difference between the actual and scheduled percentage progress, which impacts the actual cash outflow. Delayed projects at any moment will cost less in real terms than estimated. Calculating the projected cash outflow for the upcoming months involves determining the aggregate expenditure after the present month. This balance expenditure is the difference between the actual order value and the total of all the payments made for the items up to the previous month. The remaining expenses are allocated in the upcoming months per the condition of the commercial order and the current progress (**Table 15**). The anticipated cash outflow is computed in this manner. This approach yields a realistic cash outflow for every item for the following months.

This is the baseline-2 cash outflow based on balance spending. The balance of spending and updated cash flow are estimated monthly as the project progresses. This continual process enhances prediction accuracy for future expenditures. Nonetheless, the project will experience cost overruns if the actual spending exceeds the DFR anticipated cost.

Step 5: Prepare a contingency plan to minimize deviations

Cross-country NGPL infrastructure project's physical progress often falls behind schedules, necessitating contingency plans [31] for Work Breakdown Structure elements. However, scarce resources may prevent contingency plan execution, leading to cost overruns. Therefore, a decision tree analysis [31] is necessary to assess the financial impact of not implementing contingency plans. Nevertheless, the financial model provides a Contingency Reserve (CHV_5) [44] to manage delays caused by risks [26] by implementing contingency plans.

Step 6: Monitoring the actual cash outflow

Maintaining a constant track of cash outflow is crucial for effective financial monitoring. Due to the dynamic nature of this process, it is imperative to incorporate electronic monitoring tools to effectively monitor progress and furnish the project manager with timely updates on critical areas.

The factors encompassed in this analysis consist of the accessibility of financial resources for capital investment, the expenses linked to these resources, the outstanding payment for each item identified under the cost category, the anticipated cash flow strategy for forthcoming months, the percentage of financial progress attained within each cost category, and the overall percentage financial progress. The

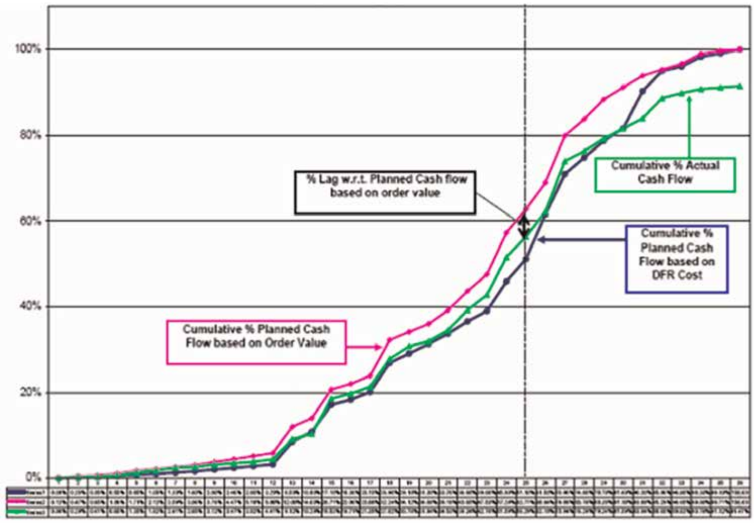

Figure 6.
Cash flow "S-Curve". Source: Authors analysis.

proposed financial model aims to give the project manager a complete overview of the probable incidence of cost overruns experienced within the NGPL project (**Figure 6**). The model can be created in an Excel sheet and quickly adopted.

7. Findings and discussions

The research provides answers to the two research questions. The author developed simple mathematical Excel models synthesizing the fundamental concepts for progress monitoring that help project managers make quick decisions in complex situations during project execution for delivering projects within schedule and budget. The Excel models can be accessed on mobile phones anywhere, anytime, through cloud applications, providing speed, flexibility, and real-time collaboration on the project. If appropriately applied, the models will ensure precise physical and financial progress monitoring during the NGPL project execution. Due to its generic nature, the models are applicable for any linear infrastructure projects. The salient features are:

i. Rolling progress: The physical and financial progress can be monitored continuously using the models. So, it is a rolling process.

ii. Forecast values: The cash outflows are adjusted according to the variance between scheduled and actual physical progress. So it is flexible.

iii. Forecasting process: The physical progress and cash flow begins from the ground up, considering the previous month's cumulative actual values as the baseline. So, it is zero-based.

iv. Setting goals: The inclusion of all individuals accountable for attaining the specific objectives is ensured. So, it is a participatory process.

8. Implications and conclusions

Over time, the project management research domain has evolved, matured, and diversified to dovetail multiple interdisciplinary theories like supply chain management to promote global carbon neutrality with affordable NG access [45]. Nevertheless, a systematic approach to enhancing project performance is essential to attaining project objectives and attracting stakeholders' delight [25]. Nine schools of project management research were reported in the literature [46] that applied different theories and perspectives for managing complex projects. However, applying project management tools, practices, and support alongside individual and project team performance is significant in delivering successful projects [27]. The instant research has practical implications for linear projects, providing easy implementation models to schedule and monitor the project's physical and financial progress. Adopting these models helps identify task and activity level delays. Therefore, it aids in preventing time and cost overruns. Project sponsors and contractors will find this model handy and easy to implement using Excel spreadsheets. This has broad societal ramifications since the cost of service remains uninflated. The study is revolutionary as it introduces a novel model that today does not exist. Adopting the models by project sponsors and contracts will help them keep their organizational reputation intact, which would otherwise be impacted if projects are delayed. The reseach expands the project management domain knowledge by providing the methodology to precisely quantify delay. Nevertheless, further research can be carried out to develop mathematical models for non-linear projects. Alternatively, it could be researched, to what extent components of non-linear projects can be linearnized to adopt this model.

Project managers must use previous months' understanding to make proactive strategies adhering to standard project management practices [47]. Senior management should manage risks and allocate resources based on progress. Physical progress monitoring helps adapt plans. Accurately estimating monthly cash outlays is crucial for infrastructure projects funded through borrowing. However, tracking project progress requires creativity and expertise.

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References

[1] United Nations. Climate Change. United Nations; 2024. Available from: https://www.un.org/en/global-issues/climate-change

[2] UNFCC. The Paris Agreement. UNFCC; 2016. Available from: https://unfccc.int/process-and-meetings/the-paris-agreement

[3] United Nations. Sustainable Development. Department of Economic and Social Affairs Sustainable Development; 2016. Available from: https://sdgs.un.org/goals

[4] United Nations. Nationally Determined Contributions (NDCs). United Nations Climate Change; 2016. Available from: https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs

[5] Energy Institute. Statistical Review of World Energy 2023. 2024

[6] IEA. Net Zero by 2050: A Roadmap for the Global Energy Sector [Online]. IEA; 2021. Available from: https://www.iea.org/reports/net-zero-by-2050

[7] Kamal WA. Global warming and the emerging importance of natural gas. SPE Gas Technology Symposium. Jun 1993;**1**:361-370. DOI: 10.2118/26175-MS

[8] Demirbas A. The importance of natural gas as a world fuel. Energy Sources, Part B: Economics, Planning, and Policy. Dec 2006;**1**(4):413-420. DOI: 10.1080/15567240500402586

[9] Worldometer. World Natural Gas Statistics. World Natural Gas Statistics; 2024. Available from: https://www.worldometers.info/gas/

[10] ASME. ASME B31.8 Gas Transmission and Distribution Piping Systems Code. ASME; 2022. Available from: https://www.asme.org/codes-standards/find-codes-standards/b31-8-gas-transmission-distribution-piping-systems

[11] Orangi A, Palaneeswaran E, Wilson J. Exploring delays in Victoria-based Astralian pipeline projects. Procedia Engineering. 2011;**14**:874-881. DOI: 10.1016/j.proeng.2011.07.111

[12] Kvalnes Ø. Living with the unknown unknown: Uncertainty in projects. Project Management Journal. 2016;**47**(3):101-108. DOI: 10.1177/875697281604700309

[13] Prasad A. Risk and challenges in speedy commencement of natural gas supplies for last mile consumer connectivity projects. In: ASME 2013 India Oil and Gas Pipeline Conference, IOGPC 2013. 2013. DOI: 10.1115/IOGPC2013-9843

[14] Mohammed RMM, Suliman SMA. Delay in pipeline construction projects in the oil and gas industry: Part 1 (risk mapping of delay factors). International Journal of Construction Engineering and Management. 2019;**8**:24-35. [Online]. Available from: https://api.semanticscholar.org/CorpusID:170027502

[15] Stephenson A. With Pipeline Facing New Delay, Trans Mountain Ponders How to Remove 'Obstruction'. Canadian Press; 2024. Available from: https://calgaryherald.com/business/energy/trans-mountain-ponders-obstruction-removal-construction-delay

[16] Sharafabadi HM, Movafaghpour M. Investigating causes of delay in natural gas distribution pipeline projects: A correlation analysis (case study:

Khuzestan Province of Iran). Journal of Applied Research on Industrial Engineering. 2022;**9**(1):68-77

[17] Onyango D. GAIL delays completion of Urja ganga gas pipeline to march 2025. Pipeline Technology Journal. 2024. Available from: https://www.pipeline-journal.net/news/gail-delays-completion-urja-ganga-gas-pipeline-march-2025

[18] Selliabreint Y, Silvianita DR, Citrosiswoyo W, Ng C. Risk analysis on offshore pipeline installation delay: A case study for Mahakam block, Indonesia. In: Proceedings of the 7th International Seminar on Ocean and Coastal Engineering, Environmental and Natural Disaster Management, no. Isoceen 2019. 2019. pp. 106-112. DOI: 10.5220/0010057601060112

[19] Strupp J. Mountain Valley Pipeline delayed; cost rises to $7.2B, Construction Dive. 2023. Available from: https://www.constructiondive.com/news/mountain-valley-pipeline-delay-cost-increase/697596/

[20] Fallahnejad MH. Delay causes in Iran gas pipeline projects. International Journal of Project Management. 2013;**31**(1):136-146. DOI: 10.1016/j.ijproman.2012.06.003

[21] Alshibani A, Julaih M, Adress A, Alshamrani O, Almaziad F. Identifying and ranking the root causes of schedule delays in oil and gas pipeline construction projects. Energies. 2023;**16**(1):1-22. DOI: 10.3390/en16010283

[22] Gamma R. Risk mitigation delay design of natural gas pipeline project. International Journal of Applied Engineering Research. 2015;**10**(17):37619-37623

[23] GlobalData. India's Major Project Pipeline Continues to Delay in December 2023. World Construction Network; 2024. Available from: https://www.worldconstructionnetwork.com/analyst-comment/india-major-project-pipeline-delays/

[24] Müller R, Drouin N, Sankaran S. Modeling organizational project management. Project Management Journal. 2019;**50**(4):499-513. DOI: 10.1177/8756972819847876

[25] Anantatmula V, Thomas M. Managing global projects: A structured approach for better performance. Project Management Journal. 2008;**39**(April):28-42. DOI: 10.1002/pmj

[26] Kwon H, Kang CW. Improving project budget estimation accuracy and precision by analyzing reserves for both identified and unidentified risks. Project Management Journal. 2019;**50**(1):86-100. DOI: 10.1177/8756972818810963

[27] Jitpaiboon T, Smith SM, Gu Q. Critical success factors affecting project performance: An analysis of tools, practices, and managerial support. Project Management Journal. 2019;**50**(3):271-287. DOI: 10.1177/8756972819833545

[28] Ordoñez REC, Vanhoucke M, Coelho J, Anholon R, Novaski O. A study of the critical chain project management method applied to a multiproject system. Project Management Journal. 2019;**50**(3):322-334. DOI: 10.1177/8756972819832203

[29] PMI. PMBOK Guide. 6th ed. New York, USA: Project Management Institute; 2017

[30] Frame JD. Philosophy of project management: Lessons from the philosophy of science. Project Management Journal. 2016;**47**(3):35-47. DOI: 10.1177/875697281604700304

[31] PMI. PMI Lexicon of Project Management Terms Version 3.2. New York, USA: PMI; 2017

[32] Prasad A, Tripathi BC. Execution of the Dahej – Vijaipur pipeline project. Petromin Pipeliner. Aug 2006:55-63

[33] Alabintei-Ignis EI, Anthony IT. Critics of open system theory. Bushwealth Academic Journal. 2022; **10**(3):58-63. Available from: https://www.bwjournal.org/index.php/bsjournal/issue/view/7

[34] Bastedo M. Open systems theory. In: The SAGE Encyclopedia of Educational Leadership and Administration. 2004. pp. 1-2

[35] Takahashi M, Indulska M, Steen J. Collaborative research project networks: Knowledge transfer at the fuzzy front end of innovation. Project Management Journal. 2018;**49**(4):36-52. DOI: 10.1177/8756972818781630

[36] Prasad A. Risks and challenges in the speedy execution of pipeline projects. Premier Pipeline International Digest. Oct 2011:5-9

[37] Zhang S, Xie S, Li Y, Yuan M, Qian X. Detection of gas pipeline leakage using distributed optical fiber sensors: Multi-physics analysis of leakage-fiber coupling mechanism in soil environment. Sensors. Jun 2023;**23**(12): 5430. DOI: 10.3390/s23125430

[38] Ren L, Ni Y, Liu Q, Chen J. Experimental and numerical prediction model for the dangerous radius of natural gas leakage in soil. ACS Omega. 2022;**7**(35):30879-30893

[39] Chandra S. Pre-commissioning and commissioning of pipelines. In: Chanda S, editor. Petroleum Pipelines: A Handbook for Onshore Oil and Gas Pipelines. Foundation Books; 2013. pp. 127-139

[40] De Freitas VCG, De Araujo VG, De Crisóstomo DCC, De Lima GF, Neto ADD, Salazar AO. Velocity prediction of a pipeline inspection gauge (PIG) with machine learning. Sensors. 2022;**22**(23):1-34. DOI: 10.3390/s22239162

[41] Cristóbal JRS. The S-curve envelope as a tool for monitoring and control of projects. Procedia Computer Science. 2017;**121**:756-761. [Online]. Available from: https://core.ac.uk/reader/158328960

[42] Irawan JD, Munasih MCE, Prasetya RP, Auliansyah CR. Construction project management monitoring system using s-curve. World Journal of Advanced Research and Reviews. 2023;**17**(2):296-305. DOI: 10.30574/wjarr.2023.17.2.0231

[43] Whitten N. Neal, The s-shape curve. PM Network. 1999;**13**(10):19

[44] Ortiz JI, Pellicer E, Molenaar KR. Determining contingencies in the management of construction projects. Project Management Journal. 2019; **50**(2):226-242. DOI: 10.1177/8756972819827389

[45] Prasad A, Kumar A, Chatnani NN. Carbon neutrality with sustainable supply chain project management framework for affordable access to natural gas in India. Pacific Business Review International. 2023;**15**(12):1-17

[46] Bredillet CN. Blowing hot and cold on project management. Project Management Journal. 2008;**39**(3):28-42. DOI: 10.1002/pmj

[47] Tereso A, Ribeiro P, Fernandes G, Loureiro I, Ferreira M. Project management practices in private organizations. Project Management Journal. 2019;**50**(1):6-22. DOI: 10.1177/8756972818810966

Chapter 9

Leadership in Digital Project Management World

Alex Lapshun

Abstract

Discussion on leadership and leadership styles is not new for the business and academic worlds. However, with the development of Industry 4.0 and the digitalization of the world, this discussion entered a new phase to answer whether leadership principles are different in a digital world and whether the traits of a successful leader differ from those we knew 20 years ago. Three years of the COVID-19 pandemic accelerated the digitalization of businesses and business processes, shaping the definition of leadership. This chapter aims to verify the validity of blended mini-ethnography and case study research in the wake of the pandemic and answer the question about a leadership style in a hybrid environment that fosters a high-performance organizational culture. This chapter validates the outcomes of this research in the post-pandemic world by analyzing it with 76 peer-reviewed papers published during and after the pandemic on digital leadership. The future of leadership will demand a continuous commitment to learning, adaptability, and a focus on driving innovation and human connection. Successful leaders will embrace the complexities of a digitally driven world while remaining grounded in trust, respect, and empathy. These leaders will shape the future of work and the future of organizations in an increasingly digital, yet undeniably human, world.

Keywords: E leadership, leadership in digital world, digital leader, digital leadership, leadership style

1. Introduction

The history of leadership is as long as the history of humanity. Since the very first days of the homo sapiens, somebody had to lead the tribe. Somebody had to assume responsibility for others' well-being. Over time, the evolution of leadership theories and models reflects changes in societal values, organizational structures, and our understanding of human behavior. The digital era has ushered in unprecedented changes across all industries, transforming how we work, communicate, and lead. Nowhere has this shift been more evident than in the rapid adoption of hybrid work environments—a trend accelerated by the COVID-19 pandemic. As organizations scrambled to adapt to remote work during global lockdowns, digital technologies became the backbone of daily operations, enabling businesses to continue functioning while reshaping the traditional office structure.

This chapter summarizes two pieces of research. The first research was conducted at the beginning of the pandemic and aimed to identify the new leadership style for the new digital world. The research question of this research was: what are the characteristics of the leader in a digital environment that contribute to a team's high performance? In 2020, this research aimed to fill a gap in the literature on this topic. In the last few years, however, plenty of literature has been on digital leadership in a digital world. Hence, the second research aims to check the validity of the four-year-old outcomes in light of the new knowledge collected during and after the pandemic.

2. Literature review

The twenty-first century has fundamentally altered the role of leadership. Leaders in the digital age must navigate complex challenges, managing both in-person and remote teams, fostering collaboration across digital platforms, and maintaining organizational culture without the benefit of face-to-face interactions. In this hybrid environment, leadership is no longer just about managing processes; it is about embracing agility, harnessing digital tools, and building resilient, adaptable teams that thrive in a constantly evolving landscape. Leaders might need special skills to develop strategies fostering the dynamic capabilities of teams [1]. As companies embrace hybrid work models, leaders must balance technological fluency with emotional intelligence, ensuring that remote and on-site employees feel engaged, supported, and connected.

Lapshun and Fusch [2, 3] argued that leaders who lead teams for high performance invest in an environment of trust and safety; they also develop a strong culture of getting and giving feedback within the team. These arguments are supported by the works of Fusch and Gillespie [4], Cravens et al. [5], and many others. Cuhadar [6] argued that COVID-19 contributed to creating a new leadership style. The author argued that moving from in-person interactions to digital communication urged leaders to change their leadership style. This argument, however, did not find broad support in the literature. To many authors, the definition of a successful or digital leader is the same. Having a compelling and attractive vision and demonstrating values of trust, transparency, and respect have never disappeared from the portfolio of a great leader [7, 8].

However, within the domain of digital leadership, there is a particular misconception or unclarity in the definition of E leadership and digital leadership. This misconception requires a brief clarification. The definition of E leadership started appearing in the literature at the beginning of this century. The E leadership is a social response to evolving dependency on Information Technology (IT) [7]. Later, Jameson [9], Carreno [10], and Ottestad [11] mentioned that E leadership is effective in virtual teams, especially if a swift-minded and technology-savvy leader creates an atmosphere of trust among geographically distributed team members. The essential qualities of the E Leader are a fast mind and technology savvy.

Digital leadership is a dynamic and agile process with less hierarchy [12]. The emerging concept of digital leadership is presented in **Figure 1**. The dyadic relationship between followers and leaders exists in data and digital processes, while the ultimate objective of this relationship is to drive innovation [8, 13–15]. The key qualities of the digital leader are in using data and digital processes to drive continuous innovation.

When discussing E leadership, we emphasize using technology for agile and effective communication. When we talk about digital leadership, the emphasis is on

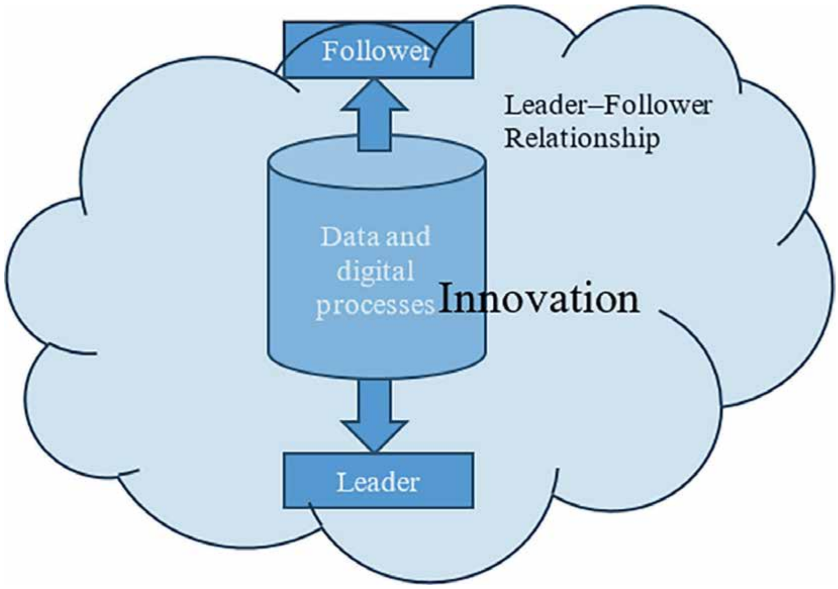

Figure 1.
Leader-followers' relationship in the digital world.

innovation. Although, until today, there has been no absolute consensus about the definitions of these two types of leadership, there is an agreement on differences between the two.

Klein [13] and Eberl and Drews [16] suggested that digital leadership includes leading digital transformation, which provides for using IT tools and the organizational transition to a new process and technologies that will innovate data processes. Miharjo et al. [17] described digital leadership as combining digital culture and competence, which agrees with De Waal et al.'s [18] definition. Digital leadership is about innovation, digital and information technology adoption, employees' and customers' centricity, and problem-solving [13, 16]. Additionally, an excellent digital leader has the quality of a business optimizer [19]. Büyükbeşe et al. [20] created a two-dimensional digital leadership scale. These two dimensions are innovation and supportiveness. Digital leaders should encourage and motivate their followers, help reduce stress, promote innovative behavior, and encourage and support followers' adaptation to the dynamic requirements of a digital world. Digital leaders must have a clear vision, growth mindset, and emotional intelligence. This conclusion might not look too different from the traits or qualities of a transformational leader [7, 18, 21].

3. The research

3.1 Part one: Research methodology

In the wake of the pandemic, with my doctoral chair, we conducted mini-ethnographic research in a Fortune 500 IT company, investigating leadership qualities that contribute to the team's high performance in the digital world. The sample consisted of six mid-level managers with at least three years of management experience.

Purposeful sampling is a deliberate process where the researcher picks participants for their specific qualities [22]. In support of using purposeful sampling for qualitative ethnographic research, Benoot et al. [23] claimed that purposeful sampling could provide a similar level of information richness as exhaustive sampling. Among ten managers who met the criteria, we chose six who represented different functional departments of the same business unit. The six mid-level manager participants represented varying company functions, including Sales, Operations, Supply Chain, Services, Human Resources, and Manufacturing. The Regional Head of the Business approved this study, giving access to internal documents. It confirmed that participants were high performers, determined based on their financial performance, customer satisfaction, and employee satisfaction results achieved over the last two years.

Since the beginning, we have focused on understanding people's actions and intentions. Merriam and Tisdell [24] and then Gerring [25] suggested a qualitative method for exploring phenomena and implications. The choice of blended mini-ethnography and the case study drove our desire to preserve the depth and contain our effort within a reasonable time. A complete ethnographic study might take years. A case study may not discover certain cultural aspects.

3.2 Part one: Data collection

The combination of mini-ethnography and the case study appeared to us as the most suitable design. The data collection included six semi-structured interviews, member checking, 50 hours of observations, and company document review. Limitations of the COVID-19 made this process completely digital. After three weeks of data collection, I was immersed in the operational unit's daily activities and rigorous data analysis, and the following themes emerged. See **Table 1**.

Lapshun and Fusch [2], Lapshun and Ng [26], and Lapshun and Fusch [3] discussed the first four themes in detail. This chapter shows the relevance of embracing leadership styles in the digital world. Before presenting the significance of embracing leadership styles, I would like to briefly present this research's relevant findings.

Theme	Subtheme	Appearances
The way of doing things matters.	Culture, norms, teamwork, proactiveness, professionalism, transparency.	49
Creating an environment of safety and trust.	Clarity, feeling of belonging, honesty, integrity, norms, transparency.	65
Embracing leadership style.	Empowerment, healthy competition, ethics, fairness, investing in yourself, protecting your team, understanding and respecting individuals.	42
Enforcing a culture of work-related, immediate, specific, and educative feedback.	Rewards and incentives, appraisal, improvement, recognition.	39
Alignment on purpose.	Alignment with corporate objectives, customer focus.	17

Table 1
Emerged themes.

3.3 Part one: Findings

3.3.1 Embracing leadership style

The employee satisfaction survey is a document that gives employees views and feedback on leadership and provides a firsthand understanding of how things work in the company. It also contains some specific questions designed to allow an employee to evaluate a manager's performance in equitability. Discussing with participants their leadership style, I asked, "What method did you use to assess the effectiveness of your strategies to affect a high-performance organizational culture?" and the follow-up questions, "How did you know that your team trusted you?" and, "what did you do to build this trust?" All participants declared the importance of treating staff equally without prejudice or prejudgment. William (participant's pseudonym) said he received the highest score in Asia on equitability. Five out of six participants scored higher than the company's average in this area.

All participants unanimously and independently mentioned that the goal is the equal successful treatment of each team member. They added how it was necessary to filter out disruptive messages to preserve a productive environment for their teams. They saw no benefit in pushing blame to build trust with their teams. Instead, it was invaluable to own up to mistakes or shortcomings and demonstrate an effort to improve. In answering the authors' question, "What do you do when something goes wrong at the higher level?" Sam (another participant's pseudonym[1]) said,

> *I can't be responsible for what the big boss says or does. However, I am responsible for what I do and my team's results and well-being. So, I explain and, when needed, protect them from the storms from above.*

It was common for all participants—they did not withhold information. They merely filtered it for relevance and shared it with sufficient context to yield the result of performance improvement. Where it was justified and necessary, they did speak up to higher management on behalf of the staff. Sam purposefully protected his team "from the storms from above," creating a safe and constructive environment for staff and avoiding mediocrity. Luis noted,

> *My strategy is to be a buffer, to hold all transactions that might be counterproductive for the team. I am trying to ensure that the team is united in day-to-day work. We do things because we know what we do and why, not because the big boss asks for it.*

None of the participants were new to the digital world. They have been living in the digital world forever. They were aware of its advantages and flaws of impersonality. To compensate, they were willing to extend their business trips and take long drives to meet up with their team members, whom they occasionally met. A pattern of giving equal attention to team members and establishing an emotional connection with them was identified in the observation of interviews and one-on-one meetings—the culture of respect for an individual, open-door policy, support, and empathy was evident. The diligent attention of the participants yielded great results during the restrictive times of the pandemic. Many participants have team members

[1] All names below are participant's pseudonyms.

located across the Asia Pacific region. Darren, the Singapore-based participant, has employees located in Thailand. When he travels there, he ensures that each of them is allotted one and a half hours of his time, dedicating it to their one-on-one meetings even if it requires the extra effort of commuting. He listened to their concerns and fears about the impact of restrictions, giving them as much reassurance as possible to navigate through the turbulent times of a global pandemic. During a staff meeting, Darren presented a genuine business challenge to the team—how to deliver hands-on training under COVID-19 restrictions. The customer would not allow external staff to visit the premises, and the company would not allow employees to travel. He started the meeting with the following:

> *I can't do this alone. I need you all to focus on the challenge that we have here. I know you are the best group of people in the company to address this challenge. You see the product, the process, and the customer. Please think. I trust you.*

The encouraged and empowered team devised an out-of-the-box solution for delivering training using Google Glass and iPad. Another emphasis in leadership style when encouraging individuals to execute on their full potential is to consistently ensure that competition within the team remains cordial and healthy. We asked participating managers: "What strategies have you used to motivate your employees to improve their performance?" One participant, Jim, mentioned that he found internal competition helpful in solving a few challenging problems with the local distributor. "How do you feel about internal competition in your team?" was the follow-up question. William, another participant, answered,

> *When the rules are clear, transparent, and fixed, and the entire context of the organization and the direction are clear, the competition within the team is healthy. I keep my team on purpose. It helps to avoid hidden agendas and maintain clarity.*

3.4 Part one: Takeaways

This study revealed the emergence of a new leadership style. This style is not based on intense personal communication in presence but exists mainly in the virtual or digital realm. Managers are responsible and accountable for the organization's performance in any business environment, including the digital world [27]. Participants of this study demonstrated highly dynamic capabilities—they rose to challenges and led their teams through change and uncertainties in the digital realm for years. Leaders might pay more attention to embracing differences. Leaders also have to innovate and encourage innovation. These actions will drive excellence. While attention to differences and details is always necessary, the required attention reaches a new high in a digital and less personal world. Building an environment of trust and safety in a digital space becomes a crucial quality for leaders in years to come [2, 28].

3.5 Part two: The need for validation

Bernard Bass, one of the most reputable and eminent scholars investigating leadership, said, "Leadership is not a mystical or ethereal concept, but a set of observable and learnable practices." Research on leadership has grown rapidly in recent decades. Leadership is also a widely taught subject at different levels. It is unsurprising—every time we see a challenge, we look for a leader to guide us. An "authentic," "charismatic," "servant," or "transformational" leader is someone we trust to lead us, organizations, and societies to better times [29].

The last few years of an unprecedented modern business pandemic have accelerated the digital transformation of the world that started at the beginning of this century. Digitalization is more than translating or transforming the existing data collection processes into digital (i.e., "digitization"). It involves organizing new socio-technical structures and communication channels with digital elements, including creating or changing them [21]. Communication channels via new socio-technological structure—this is a concise description of our digital milieu. What leadership qualities are required in this new milieu?

3.5.1 Part two—Research question

In the last three years, dozens of papers have been written describing the traits of a successful digital leader. The primary role of digital leadership is promoting an innovation plan and guiding a business innovation plan to success [30]. By this definition, our six mid-level managers are very successful leaders, prompting and supporting innovation almost daily. One way to do so is to empower the team to innovate.

However, in the current literature, there is no consensus on the definition of the digital leader. Six categories where a good leader in a digital world must excel are (1) digital knowledge and literacy, (2) vision, (3) customer focus, (4) agility and change management, (5) creating an environment of risk-taking, and (6) collaboration [21], considering different locations and often time zones of the followers. Digital leadership combines the quality of transformational leadership and digital technology [18]. Is it really that simple? Are findings from **Table 1**, namely empowerment, healthy competition, ethics, fairness, investing in yourself, protecting your team, understanding and respecting individuals, still valid in today's digital world?

3.5.2 Part two: Methodology

To validate four-year-old findings, I reviewed peer-reviewed papers published in the last four years on digital leadership to answer this question. Around 76 papers from the Web of Science website were reviewed. The cross-appearance of keywords such as digital leadership, E leadership, new leadership style, and leadership style in the digital era narrowed my research to 36 papers. Those articles are under four years old and have 100 citations at least. ATLAS software was used for data organization and analysis. **Figure 2** represents the results of the cross-appearance analysis.

		digital leaders... 31	E-leadership 26	E-leadership... 4	New leadershi 16
Leader teleworker	33	4	3	0	5
Leadership	40	10	9	0	3
Leadership in digital era	20	3	8	0	4
Leadership style in digi...	12	2	4	0	2

Figure 2.
Keywords cross-appearance analysis. Source: ATLAS 23.3.0.

4. Findings and discussion

The digital world relies heavily on digital technologies for processes and information management. For the last 20 years, people and businesses have been continuously transitioning into this world. Digital transformation can be achieved only through people who can both ensure the organization's sustainability and drive it [20]. There is a distinguishing line between digital and classical leadership. Digital leaders drive organizational success and digital transformation, while classical leaders focus only on organizational success [13].

However, the distinguishing difference between a traditional leader and a digital leader is in the innovative character of the leadership process, developing the team through driving the transformation of communication and processes. In today's world, it is difficult to imagine many business processes secluded in a closed office environment and do not involve people in different locations, often in various countries and time zones. There are fewer and fewer teams that operate under the same roof. In such an environment, the meaning of charisma gets a twist from the physical appearance to the digital appearance, from the physical to a virtual presence. Here is where we feel and see the difference between classical and digital leadership.

The six managers, participants in the research I introduced in the first part of this chapter, demonstrated charisma and a strong presence in the digital space. They also showed strong support for their team members. The literature analysis revealed a few capabilities that correlate with the research outcomes. Strong leaders excel in building an environment of trust and safety, building this environment on principles of respect, transparency, and information sharing [2, 31, 32].

5. Summary and conclusions

The digital era has revolutionized how we lead, work, and interact, creating challenges and unprecedented opportunities for industry leaders. As we transition into an age defined by hybrid work environments, virtual collaboration, and rapid technological advancement, the role of leadership has undergone a profound transformation [33]. No longer confined to the traditional office setting, leadership in the digital age requires a delicate balance between leveraging technology and maintaining human-centered values that foster trust, empathy, and connection. Our research into leadership within a Fortune 500 IT company offers valuable insights into this evolving landscape. Leaders today must navigate the complexities of managing geographically dispersed teams, often without the benefit of face-to-face interaction. This shift has introduced new demands on leadership—particularly the need to be technologically adept, agile in decision-making, and innovative in problem-solving. However, as demonstrated by the six managers we studied, the foundation of effective leadership in the digital era remains deeply rooted in timeless qualities: trust, transparency, fairness, and a commitment to the team's well-being.

Leadership in the digital era is not simply about overseeing remote teams or managing digital tools. It is about creating environments where employees feel safe, valued, and empowered to contribute their best work. The managers we observed and participants prioritized equitability, open communication, and emotional intelligence, ensuring that each team member felt supported and connected, even without regular physical interactions. Klein [13] and Büyükbeşe et al. [20] underscored that successful digital leadership is defined by a leader's ability to drive continuous innovation. The digital world is fast-paced and constantly changing, and leaders must adapt to these changes and encourage their teams to do the same.

6. Implications

6.1 Implication for business

As businesses increasingly digitalized, leadership will become more critical [34]. Leaders manage technological transitions and ensure their teams remain cohesive, motivated, and aligned with organizational goals. The research and literature highlight that leaders must embrace their roles as facilitators of trust and innovation. Implementing digital tools or managing remote workers is not enough; the real challenge lies in maintaining the human connection that drives team performance, collaboration, and morale. Looking ahead, the demands on leadership will continue to grow as digital transformation accelerates. The most successful leaders will be those who can blend the agility and innovation required in a digital world with the empathy and emotional intelligence that have always been at the heart of outstanding leadership. They must cultivate environments where teams are empowered to innovate, adapt to new challenges, and find creative solutions to complex problems.

At the same time, leaders must recognize the unique needs of their teams in a digital-first world. Ensuring remote and on-site employees feel equally engaged and valued will be critical in maintaining high performance and organizational culture. Leadership in the digital era is about much more than technology; it is about creating an inclusive, supportive environment where every team member feels connected to a shared purpose, regardless of location. As the digital landscape continues to evolve, so too must leadership. The future of leadership will demand a continuous commitment to learning, adaptability, and a focus on driving innovation and human connection. Leaders who can navigate this balance, embracing the complexities of a digitally driven world while remaining anchored in the core principles of trust, respect, and empathy, will succeed and thrive in leading teams to new heights of performance and creativity. Ultimately, these leaders will shape the future of work and the future of organizations in an increasingly digital, yet undeniably human, world.

6.2 Theoretical contribution

This study adds to the immense literature written by De Waal et al. [18], Ottestad [11], Klein [13], Erbel and Drews [16], Classen et al. [12], Gierlich-Joas et al. [14], Karakose et al. [8], Weisbock and Hess [15], McCarthy et al. [19], Purwanto [32], and Bussel and Weidner [33] that discussed new emerging leadership style—digital leadership. At the same time, this chapter argues that the above papers show that digital leadership is more than just technology and the desire for transformation. Along with Cuhadar [6], Lapshun and Fusch [2], and Lapshun and Fusch [3], this study emphasizes the importance of a deep level of trust between leader and followers, embracement of the culture of feedback, and the ability to motivate for high performance in personal and impersonal communication. This study helps to close the necessary gaps in the definition of digital leadership.

6.3 Contribution to policymakers and Society in Large

It is difficult to underestimate the role of leadership in policymaking and society. Leaders have power over society and can use it for or against society. This study should help policymakers understand the needs of businesses in the current digital realm and drive policies that support businesses and broader communities. It might also be a tool for making leadership communication more effective in a world where physical and personal communication given way to virtual impersonal channels of contact. Community and society leaders could use this paper similarly, learning to influence and motivate people without physical presence.

6.4 Limitations and future research

This study is limited to the outcomes of one multinational company in Asia after the pandemic. It might be interesting to repeat a similar immersive study in the post-pandemic reality of a similar company in another region. The results could help clarify more about digital leadership traits and qualities. Another way to enhance this research would be to delve into followers' motivation in the digital era.

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References

[1] Cuhadar S. Link between leadership style of managers and employee's performance in organizations during COVID–19 crisis. Cross–Cultural Management Journal. 2022;**24**(1):65-74. Available from: https://seaopenresearch.eu/Journals/articles/

[2] Lapshun AL, Fusch GE. Trust and safety as fundamental conditions for a high-performance team. Performance Improvement. 2021;**60**(3):15-19. DOI: 10.1002/pfi.21964

[3] Lapshun A, Fusch GE. Times of uncertainties require embracing leadership and feedback. The Qualitative Report. 2023;**28**(3):828-847. DOI: 10.46743/2160-3715/2023.5609

[4] Fusch GE, Gillespie RC. A Practical Approach to Performance Interventions and Analysis: 50 Models for Building a High-Performance Culture. NJ: FT Press; 2012

[5] Cravens KS, Oliver EG, Oishi S, Stewart JS. Workplace culture mediates performance appraisal effectiveness and employee outcomes: A study in a retail setting. Journal of Management Accounting Research. 2015;**27**(2):1-34

[6] Schoemaker PJ, Heaton S, Teece D. Innovation, dynamic capabilities, and leadership. California Management Review. 2018;**61**(1):15-42. DOI: 10.1177/0008125618790246

[7] Avolio BJ, Kahai SS. Adding the "e" to e-leadership: How it may impact your leadership. Organizational Dynamics. 2003;**31**(4):325-338

[8] Karakose T, Kocabas I, Yirci R, Papadakis S, Ozdemir TY, Demirkol M. The development and evolution of digital leadership: A bibliometric mapping approach-based study. Sustainability. 2022;**14**(23):16171

[9] Jameson J. Distributed e-leadership and trust: The visibility/invisibility paradox in the ecology of online school communities. In: International Congress for School Effectiveness and Improvement. Yogyakarta: ICSEI; 2014

[10] Carreño IDVG. Emergent leadership: E-leadership implications for virtual education. Revista de Estudios Para El Desarrollo Social de La Comunicación. 2014;**10**:308-324. DOI: 10.15213/redes.n10.p309

[11] Ottestad G. School leadership for ICT and teachers' use of digital tools. Nordic Journal of Digital Literacy. 2013;**8**(1-2):107-125

[12] Claassen K, Dos Anjos DR, Kettschau J, Broding HC. How to evaluate digital leadership: A cross-sectional study. Journal of Occupational Medicine and Toxicology. 2021;**16**:1-8

[13] Klein M. Leadership characteristics in the era of digital transformation. Business and management studies: An. International Journal. 2020;**8**(1):883-902. DOI: 10.15295/bmij.v8i1.1441

[14] Gierlich-Joas M, Hess T, Neuburger R. More self-organization, more control –or even both? Inverse transparency as a digital leadership concept. Business Research. 2020;**13**(3):921-947

[15] Wiesbock F, Hess T. Digital innovations – Embedding in organizations. Electronic Markets. 2020;**30**:75-86

[16] Erbel JK, Drews P. Digital leadership – Mountain or molehill? A literature review. In: International Conference on Wirtschaftsinformatik. Switzerland: Springer; 2021. pp. 223-237

[17] Mihardjo L, Sasmoko S, Alamsjah F, Elidjen E. Digital leadership role in developing business model innovation and customer experience orientation in industry 4.0. Management Science Letters. 2019;**9**(11):1749-1762

[18] De Waal B, Van Outvorst F, Ravesteyn P. Digital leadership: The objective-subjective dichotomy of technology revisited. In: 12 th European Conference on Management, Leadership and Governance ECMLG. UK: Academic Conferences and Publishing International Limited; 2016. p. 52

[19] McCarthy P, Sammon D, Alhassan I. Digital transformation leadership characteristics: A literature analysis. Journal of Decision Systems. 2021;**32**(1):1-31

[20] Büyükbeşe T, Dikbaş T, Klein M, Ünlü SB. A study on digital leadership scale (DLS) development. Kahramanmaraş Sütçü İmam Üniversitesi Sosyal Bilimler Dergisi. 2022;**19**(2):740-760

[21] Yoo Y, Lyytinen K, Boland R, Berente N, Gaskin J, Schutz D, et al. The next wave of digital innovation-opportunities and challenges. Digital Challenges in Innovation Research. 2010:1-37. DOI: 10.2139/ssrn.1622170

[22] Etikan I, Musa SA, Alkassim RS. Comparison of convenience sampling and purposive sampling. American Journal of Theoretical and Applied Statistics. 2016;**5**(1):1-4. DOI: 10.11648/j.ajtas.20160501.11

[23] Benoot C, Hannes K, Bilsen J. The use of purposeful sampling in a qualitative evidence synthesis: A worked example on sexual adjustment to a cancer trajectory. BMC Medical Research Methodology. 2016;**16**(21):1-12. DOI: 10.1186/s12874-016-0114-6

[24] Merriam SB, Tisdell EJ. Qualitative Research: A Guide to Design and Implementation. NJ: John Wiley and Sons; 2015

[25] Gerring J. Qualitative methods. Annual Review of Political Science. 2017;**20**(1):15-36. DOI: 10.1146/annurev-polisci-092415-024158

[26] Lapshun A, Ng AWK. Internal competition in a high-performance team. Performance Improvement Journal. 2022;**61**(2):1-8. DOI: 10.56811/PFI-22-0008

[27] Gilbert T. Human Competence: Engineering Worthy Performance. Tribute ed. CA: Pfeiffer; 2007

[28] Al-Habsi N, Luo M, Zighan SM. A systematic literature review explores digitalization's impact on leadership towards a new leadership style. International Journal of Business Innovation and Research. 2022;**29**(2):169-193

[29] Wilson S. Thinking Differently about Leadership: A Critical History of Leadership Studies. Edward Elgar Publishing; 2016

[30] Antonopoulou H, Halkiopoulos C, Barlou O, Beligiannis GN. Associations between traditional and digital leadership in academic environment: During the COVID-19 pandemic. Emerging Science Journal. 2021;**5**(4):405-428

[31] Promsri C. The developing model of digital leadership for a successful digital transformation. GPH-International Journal of Business Management. 2019;**2**(08):01-08

[32] Purwanto A. The role of digital leadership, e-loyalty, e-service quality and e-satisfaction of Indonesian E-commerce online shop. International Journal of Social and Management Studies. 2022;**3**(5):51-57

[33] Busse R, Weidner G. A qualitative investigation on combined effects of distant leadership, organizational agility, and digital collaboration on perceived employee engagement. Leadership and Organization Development Journal. 2020;**41**(4):535-550

[34] Behie SW, Pasman HJ, Khan FI, Shell K, Alarfaj A, El-Kady AH, et al. Leadership 4.0: The changing landscape of industry management in the smart digital era. Process Safety and Environmental Protection. 2023;**172**:317-328

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In *Digital Project Management – Strategic Theory and Practice*, the authors emphasize the importance of maintaining rigor and depth while leveraging digital tools to address traditional challenges such as cost overruns and time constraints. This book is written for a wide-ranging audience with varying expertise in project management. Undergraduate and postgraduate students and practitioners in social sciences, science, technology, business, healthcare, and education will benefit from foundational and advanced concepts. Experienced project management researchers seeking to incorporate digital tools into their methodologies will find practical and theoretical insights. Additional audiences include industry practitioners in project management research, strategic consulting, and policy analysis, who can use the book to enhance the strategic application of digital project management in real-world scenarios. Non-traditional project managers are also addressed as individuals exploring project management practice in a digital age for creative, government-funded projects, NGOs, and advocacy projects. This book is a foundational resource for courses on digital project management methods, offering step-by-step guidance and real-world examples. It provides actionable insights into implementing digital tools in project management studies, from data collection to visualization. The book also highlights the role of strategic theory and practice in project management strategic decision-making across project planning, execution, monitoring and control management.

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