

Strategic Framework for Digital Transformation in Architecture, Engineering, and Construction Organizations

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Abstract: Digital transformation has become a pivotal focus in the Architecture, Engineering, and Construction (AEC) industry, driven by an urgent need to enhance productivity and optimize resource management. This transformation plays an essential role throughout the entire project lifecycle, from the early stages of conception to the final phases of completion. The paper underscores the critical importance of aligning digital transformation initiatives with the broader business strategies of AEC organizations. This alignment is key to gaining a competitive edge and fostering sustainable growth within the industry. The paper introduces a comprehensive and adaptable strategic framework for digital transformation. This framework is designed to be flexible, allowing AEC organizations to tailor digital transformation strategies to meet their specific needs and objectives. The framework not only addresses the technological aspects but also considers the cultural and operational shifts required for successful implementation. Moreover, the paper delves into various aspects of digital transformation, such as data management, workflow automation, and the integration of emerging technologies like AI and IoT in AEC processes. It discusses the potential barriers to digital adoption and offers strategies to overcome these challenges. This paper serves as an in-depth guide for AEC organizations looking to seamlessly integrate digital technologies into their business models. It provides valuable insights and methodologies that are crucial for any entity in the AEC industry striving to thrive in an increasingly digitalized world, making it a must-read for leaders and decision-makers within the industry.

Key words: digital transformation, digitization, digitalization

1. INTRODUCTION

Digital transformation has recently emerged as a critical agenda in the Architecture, Engineering, and Construction (AEC) industry, driven primarily by the desire to enhance organizational competitiveness and ensure successful development [1, 2]. This transformation encompasses the integration and exploitation of digital technologies and innovative business models across all organizational facets, leading to profound changes in operations and the delivery of value to stakeholders [1, 3]. Consequently, digital transformation presents a multifaceted challenge, intersecting with various business activities within an organization [1]. The complexity of this transformation requires the development and implementation of tailored digital transformation strategies to achieve optimal outcomes.

This study broadens the perspective from focusing on a specific organization to encompassing the AEC industry as a whole. In this sector, digital transformation is crucial for maintaining and enhancing operational efficiency and effectiveness. This importance is particularly evident in the significant role digital strategies play in design, construction, and overall project management processes.

The study provides an overview of the digital transformation journey in the AEC industry, aiming to harness the benefits of digital technologies, such as improved productivity, efficiency, and resource optimization. The paper is structured as follows: It starts with a background and review of related studies to offer a comprehensive understanding of the digital transformation landscape in the AEC industry.

This is followed by a detailed explanation of the strategic framework for digital transformation, customized to meet the specific needs and objectives of AEC organizations. The study concludes with observations and conclusions, drawing on the broader implications of digital transformation in the AEC industry.

2. BACKGROUND AND REVIEW OF RELATED STUDIES

2.1. Digital Transformation

Research by Ismail et al. [4] categorizes thousands of studies on “digital transformation” into six perspectives as illustrated in Figure 1: era, social/economic, industry/ecosystem, network, company/institutional, and individual.

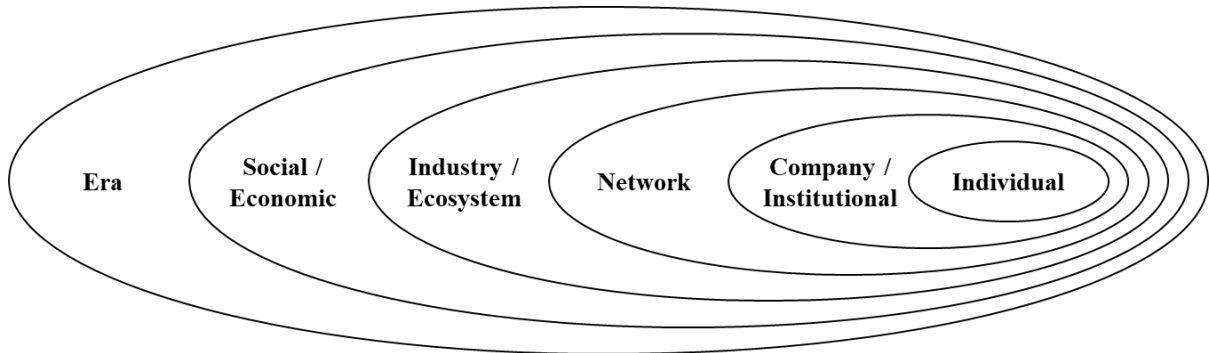


Figure 1. Digital Transformation Perspectives in Previous Studies

Within these, the perspective relevant to AEC organizations falls under “company/institutional.” Matt et al. [5] emphasize that digital transformation strategies for companies and institutions should align with the organization’s broader business strategies (see Figure 2), typically divided into operational strategy (covering products, markets, processes, etc.) and functional strategy (including finance, human resources, information technologies, etc.).

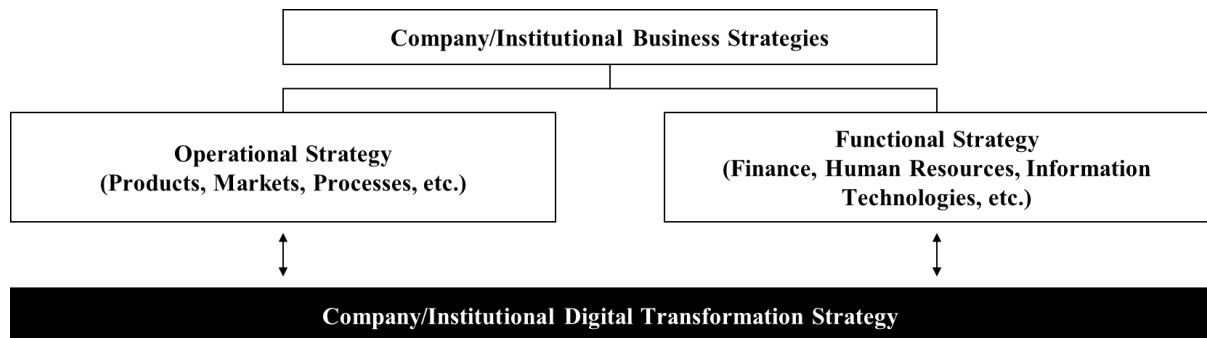


Figure 2. Relation between Digital Transformation Strategy and Other Business Strategies

Furthermore, company/institutional digital transformation necessitates significant organizational changes [6]. Bloomberg [7] distinguishes between the organization’s digital transformation and its digitization or digitalization, referencing the Organisation for Economic Co-operation and Development (OECD) definition. The OECD [8] describes digital transformation as the economic and societal impacts of digitization and digitalization, where digitization converts analog data and processes into machine-readable formats, and digitalization applies digital technologies and data to change or create new activities. The OECD [8] underscores the importance of considering the individual in digital transformation initiatives, arguing that without the engagement and benefit of all individuals, transformation cannot be positive and inclusive. This sentiment is echoed by Del Rowe [9] and Ismail et al. [4], who note the paramount importance of the human factor over technology in the successful digital transformation of an organization.

2.2. Digital Transformation in the AEC Industry

The AEC industry's digital transformation literature highlights a pivotal shift from traditional operational practices to digitally advanced, collaborative management approaches [10, 11]. This evolution is marked by significant innovations in organizational management, operations, and innovation strategies, notably through the adoption of digital twins, Building Information Modeling (BIM) technology, and big data platforms. These technologies are crucial for improving the management of construction projects across their lifecycle and fostering a comprehensive construction ecosystem connecting all stakeholders [12].

Historically, the construction industry has been criticized for its slow technological adoption rate compared to other sectors, contributing to its traditionally modest productivity gains [13]. However, this perception is undergoing change, propelled by the digital revolution in broader industries and the disruptive effects of the COVID-19 pandemic. These factors have encouraged the adoption of various technological tools in the construction domain, such as Radio-frequency identification, robotics, blockchain, and the Internet of Things, marking a significant increase in the uptake of innovative technologies [14].

Despite these advancements and the clear movement towards digitalization, a gap in holistic and comprehensive studies on digital transformation within the AEC industry over the past decade persists. This gap presents an opportunity for further research, especially to understand the comprehensive impact of digital transformation on industry productivity, stakeholder engagement, and project delivery methods.

3. STRATEGIC FRAMEWORK FOR DIGITAL TRANSFORMATION

Informed by a thorough understanding of digital transformation and a review of pertinent literature, this study proposes a digital transformation strategy specifically tailored for AEC organizations. This strategy, rooted in the organizations' existing business strategies, advocates for the digitization and digitalization of their practices.

3.1. Key Objectives and Goals

The digital transformation of AEC organizations is driven by specific objectives and goals aimed at enhancing overall operational effectiveness and innovation:

- Objectives:
 - 1) To integrate multiple disciplines into a cohesive system.
 - 2) To reduce operational inefficiencies.
 - 3) To foster improved engagement and collaboration across disciplines.
 - 4) To modernize and upgrade technological systems, fostering innovation and introducing new products or services.
- Goals:
 - 1) To digitize and automate project delivery using appropriate procedures and technologies.
 - 2) To mitigate project delivery risks through enhanced controls, governance, and reporting.
 - 3) To cultivate a culture of innovation, facilitating the development of new products, solutions, and services.

3.2. Key Challenges associated with the Digital Transformation

In the process of digital transformation, AEC organizations face several key challenges that must be identified and understood for successful implementation. These challenges, as detailed in Table 1, stem from various organizational and technological complexities.

Firstly, the inherent complexity of AEC organizations presents a significant challenge. These organizations are composed of multiple disciplines, each with its own tasks, processes, and characteristics. This multiplicity requires a nuanced approach to digital transformation, as each discipline may have unique needs and may prioritize different benefits from technological advances.

Another challenge is the competition among technology priorities. Within an AEC organization, various disciplines may see the same technology differently, leading to potential conflicts in

prioritization. What might be crucial for one discipline could be of less immediate benefit to another, making it challenging to decide where to allocate resources and attention.

Change management and the complications associated with implementation form another hurdle. Each department's transformation necessitates changes in current processes and technologies. Managing these changes can be difficult due to the varying roles and responsibilities of stakeholders involved. The complexity of change management processes is often amplified in larger, more established organizations, where there are more layers of bureaucracy and existing systems are deeply entrenched.

Budgetary restrictions also pose a significant barrier. While substantial investment is often required for thorough digital transformation, the available funds may be limited, particularly in the context of an organization's broader financial commitments and constraints.

Lastly, the lack of relevant knowledge among stakeholders can impede the adoption of new technologies. Effective digital transformation is not just about the technology itself but also about stakeholders' understanding of these technologies. Without adequate knowledge and understanding, the potential of new technologies cannot be fully realized, hampering the transformation efforts of the organization.

Table 1. Challenges in Digital Transformation

Challenges	Description
Complexity of the AEC organizations	The organization consists of multiple disciplines, and the disciplines have their own tasks, processes, and characteristics.
Competing technology priorities	In accordance with each discipline's task, process, and characteristic, technologies that have the same benefits could be prioritized differently by each discipline.
Change management and implementation complications	The digital transformation of the department requires changes in each discipline's current processes and technologies. The change management of each discipline could be challenging to corresponded stakeholders' roles and responsibilities, and it is a complex and difficult initiative for large and established organizations.
Restriction of dedicated budget	A substantial investment is required to the digital transformation of the organizations. However, the available budget for the journey could be limited considering the organizations' characteristics.
Lack of relevant knowledge	Introducing new technologies needs corresponded stakeholders' relevant knowledge and understanding. Without the knowledge and understanding, technology itself is not enough to the transformation of the organizations.

3.3. Key Digital Transformation Strategies and Recommendations for Challenge Resolutions

This section offers strategic recommendations to tackle the digital transformation challenges in AEC organizations, aligning with the OECD's framework [8]. The strategies in Table 2 provide a comprehensive method to navigate these challenges, emphasizing an integrated approach across technology, data, processes, and people.

At the core of these strategies is the development of an Enterprise Common Data Environment (ECDE) to align legacy systems with current industry standards, effectively managing crucial project data. This is a fundamental integration of technology and data management. Additionally, the creation of a central database utilizing historical data for cost rates aims to refine estimations and reduce reliance on external sources, underscoring the value of data precision and availability.

From a procedural standpoint, the paper suggests standardizing measurement methods to enhance cost estimation and deploying a secure, centralized reporting platform, merging advanced technology with personalized data insights for better decision-making.

On the process side, it advocates for a tiered reporting structure to promote transparency in organizational performance, alongside a consistent reporting cycle to ensure stakeholder engagement and information dissemination.

For the human aspect, it is recommended to introduce a Data Governance Lead to strengthen data management and uphold accountability, ensuring data architecture aligns with the organizational goals.

A discipline-specific approach is advised to establish a central project controls discipline, which monitors and manages project baselines within a robust change management framework, reflecting the organization’s strategic objectives.

The paper also emphasizes the need to initiate performance indicators and implement a quality management system compliant with ISO standards, crucial for maintaining governance and assuring process quality.

Collectively, these strategic recommendations propose a unified strategy to address the diverse challenges of digital transformation, illustrating an integrated approach that encompasses technology, data, processes, and people.

Table 2. Strategies for Mitigating Digital Transformation Challenges

Recommendation	Strategies
Establish an ECDE to integrate legacy systems with industry-standard systems to manage scope, cost, schedule, risk, and change data. Over time the ECDE will incorporate all disciplines’ datasets and be synchronized with project-level project management information systems.	Technology, Data
Develop a central database of costs rates, labor rates, and sustainability rates based on historical data to enable the development of estimates and schedules. Reduce the reliance on third-party estimation.	Data
Create a standard method of measurement to support quantification to improve cost estimating in addition to sustainability and whole life costing.	Procedure
Create a central reporting platform with secure access and personalized insights. Utilize off-the-shelf products (e.g., Microsoft Power BI) and use cloud services (e.g., Microsoft Azure). Develop a hierarchical reporting structure from contract/project level through to discipline leads. Instigate an organization wide data date and date exchange date.	People, Technology, Process, Data
Mandate a monthly reporting cycle from projects, workstreams, programs, portfolio, and enterprise to provide a clear line of sight of organization performance.	Procedure
Improve data specification, collection, management, storage, and availability. Establish a data management capability (i.e., Data Governance Lead) within an organization to retain accountability for data governance including data architecture.	People, Process, Data
Create a central project controls discipline. Monitor projects against baselines (i.e., scope, schedule, and cost) with a robust change management process (i.e., incorporating impacts to cost, schedule, scope, and risk) managed by the project controls discipline.	People, Process
Initiate a series of discipline, project, portfolio, and enterprise-level key performance indicators aligned with the data dictionaries and built-in accordance with an organization of the works standard operating procedure comprising of all breakdown structures, file naming, and classification.	Process, Data
Establish a quality management system aligned to ISO 9001 and managed by Quality Assurance Discipline Manager. Establish a quality manager for process and governance quality assurance.	People, Process

3.4. Strategic Framework for Digital Transformation of the AEC Organizations

Drawing on the identified challenges and mitigation strategies, a comprehensive strategic framework for AEC organizations has been developed, as depicted in Figure 3. This framework consists of two

primary workstreams: Transformation and Initiatives and Productization, each aligning with the AEC organizations' business strategies.

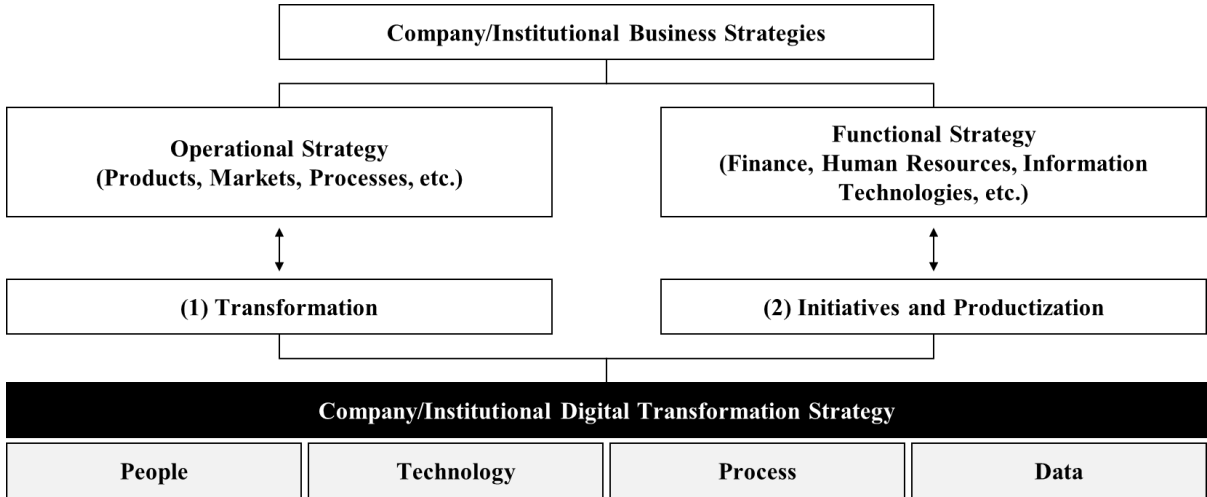


Figure 3. Strategic Framework for Digital Transformation in AEC Organizations

The Transformation workstream focuses on the digital transformation of the operational strategy aspect of AEC organizations. Its aim is to synergize the various disciplines and personnel within an AEC organization, establishing a unified working system that leverages shared data, processes, and technology. This is achieved through a meticulous discipline-by-discipline review to identify:

- The services provided by each discipline and their interactions with others.
- The data produced, collected, or utilized by each discipline.
- The technology or systems employed by the disciplines.
- The procedures and processes in use, and their integration with other disciplines along the value chain.
- The existing skills, competencies, and knowledge within each discipline, and methods for their capture, retention, and dissemination.

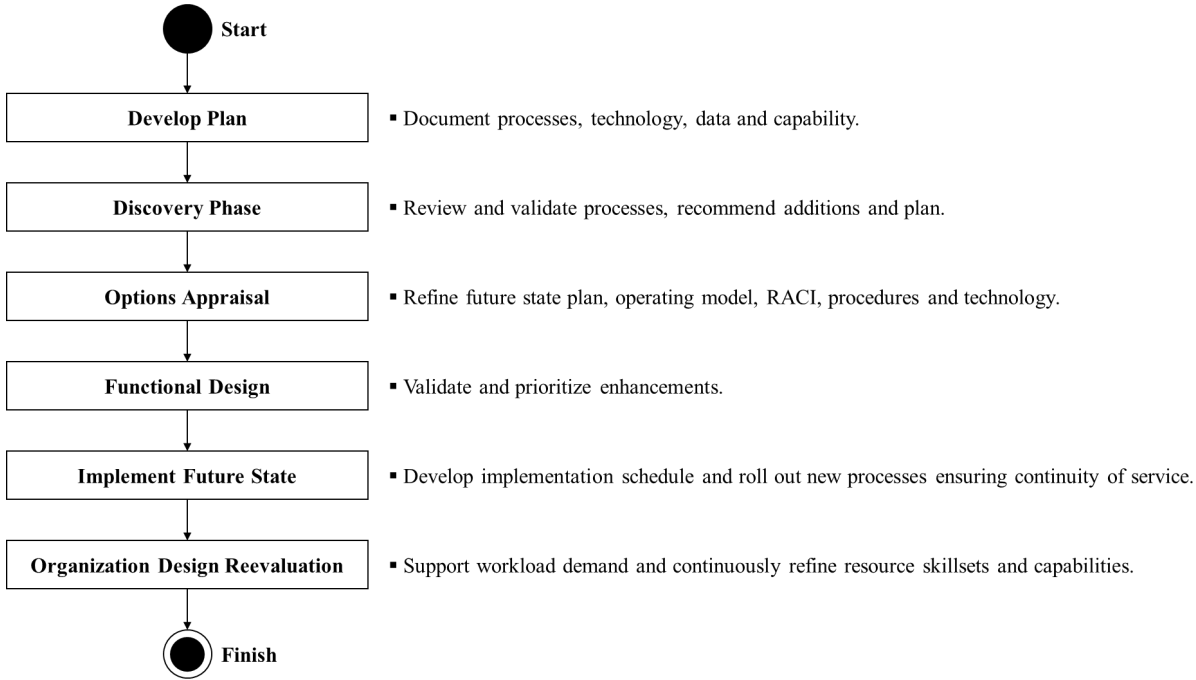


Figure 4. Overview of the Transform Workstream Change Management Roadmap

Management of the Transformation workstream is executed via a change management roadmap, outlined in Figure 4, encompassing:

- A discovery phase to investigate, validate, and verify the current operational state.
- An options appraisal phase to determine the optimal operational state based on global best practices, tailored to meet the strategic and tactical goals of the AEC organizations.
- The implementation phase of the future state, ensuring a unified operational approach across all disciplines and team members, optimized to fulfill the targeted operating model of the AEC organizations.

The Initiatives and Productization workstream addresses the digital transformation of the functional strategy aspect of AEC organizations. Its objective is to swiftly develop new products, such as tools, processes, workflows, and templates, to address challenges pinpointed during the Transformation workstream. This workstream is structured into seven phases, with each initiative being meticulously executed as depicted in Figure 5.

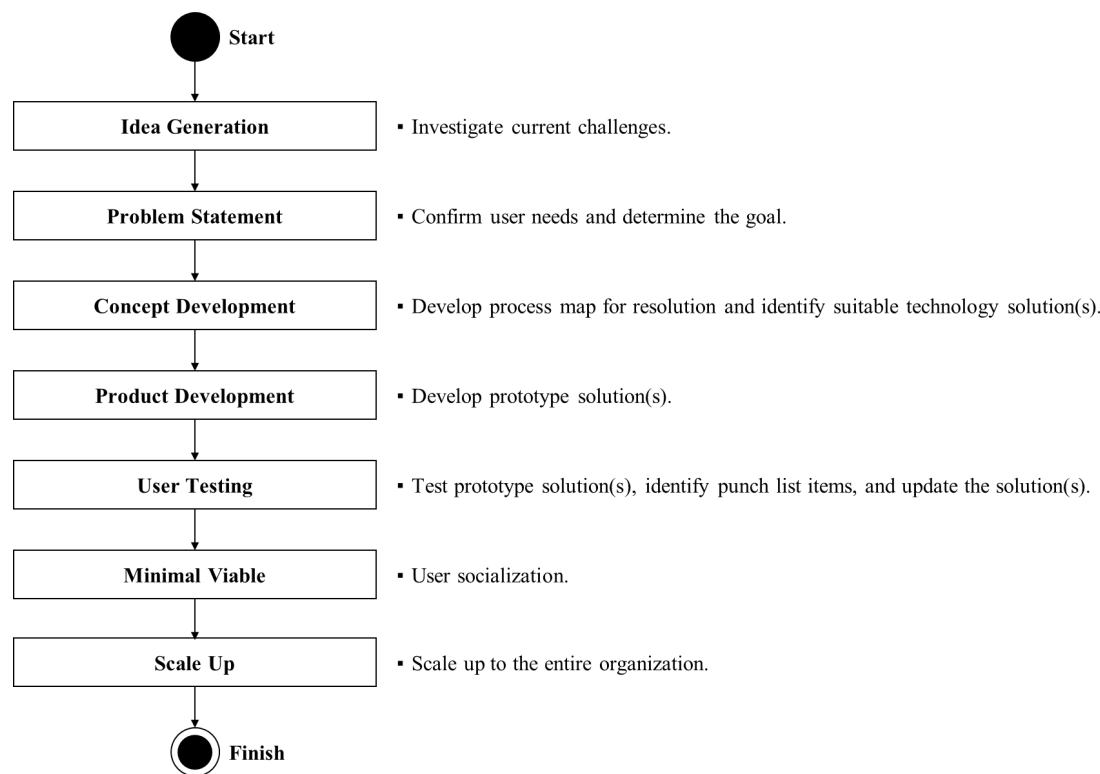


Figure 5. Overview of the Initiatives and Productization Workstream Roadmap

4. SUMMARY AND CONCLUSIONS

This paper delved into the significance of digital transformation within the Architecture, Engineering, and Construction (AEC) industry, driven by the imperative to boost organizational competitiveness and spearhead successful development. By reviewing existing literature and crafting a tailored digital transformation strategy for AEC organizations, the study highlighted the complex, multifaceted nature of this transformation, which includes both digitization and digitalization of organizational practices in alignment with overarching business strategies.

The research outlined a strategic framework centered on enhancing operational and functional strategies within AEC organizations. This framework is designed to foster integration across various disciplines, aiming for a cohesive system that leverages shared data, processes, and technology to improve project management, stakeholder engagement, and project delivery.

Key findings underscore the shift towards digitally enhanced, collaborative management practices facilitated by digital twins, BIM technology, and big data platforms. However, the journey is fraught

with challenges, notably the need for fundamental organizational changes and the integration of new technologies. Addressing these challenges requires a disciplined approach, focusing on people, technology, process, and data to achieve the desired transformation.

In conclusion, digital transformation in the AEC industry is an extensive, ongoing process that demands a strategic, holistic approach. The strategic framework proposed in this study provides a structured method for AEC organizations to navigate digital transformation complexities, emphasizing the necessity of adapting to technological advancements and industry evolution. Successful implementation of these strategies is pivotal for enhancing productivity, efficiency, and ultimately revolutionizing AEC organizational operations in the digital era.

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