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NAVIGATING THE IMPACTS OF DIGITALIZATION ON CONSTRUCTION PROJECT MANAGEMENT AND FIELD OPERATIONS

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Abstract

This study investigates the impact of technology adoption on project management and field crew competencies in construction firms. A survey of 96 U.S. construction firms identified four clusters based on technology adoption patterns: Traditional Low-Tech, Selective Adopters, High-Tech Innovators, and Medium-Sized High-Tech firms. Firms with higher technology adoption performed better in project management areas like stakeholder relations, planning, and product acceptance, while field crew competencies remained consistent across clusters. These findings show the advantages of strategic digital integration and emphasize areas for addressing adoption barriers, providing practical guidance for firms navigating digital transformation.

Introduction

The construction industry is experiencing a transformative shift as it increasingly embraces advanced digital and automation technologies. Innovations such as 3D printing, Geographic Information Systems (GIS), drones, augmented and virtual reality (AR/VR), and robotics are redefining how construction projects are managed and executed while enhancing efficiency, precision, and safety (Faheem et al., 2024; Olanipekun & Sutrisna, 2021). As construction projects grow in complexity, the strategic integration of these tools enables firms to better manage stakeholder expectations, streamline project transitions, and meet quality standards in highly competitive environments (Ghansah & Edwards, 2024; Brozovsky et al., 2024). The adoption of these technologies is critical in addressing labor shortages and improving productivity, as explored by Sadeh et al. (2024). Despite the promising impacts of these tools, the level and method of technology adoption vary significantly across firms, depending on factors such as operational capacity, firm size, and sector focus (Sepasgozar et al., 2016; Sadeh et al., 2021a; Sadeh et al., 2021b; Sadeh et al., 2024). Furthermore, the strategic adoption of advanced technologies in construction affects productivity and efficiency and shapes organizational competencies in distinct ways. Firms categorized as high-tech innovators excel in managing complex project phases, stakeholder relationships, and quality standards. Additionally, firms within the construction industry that adopt high-tech solutions are increasingly leveraging AI-driven data insights to enhance project planning and stakeholder engagement, providing them with a distinct competitive edge. This mirrors the impact of AI in enhancing software development practices (Daniel Ajiga et al., 2024; Chen et al., 2022). Understanding these distinctions is crucial for firms aiming to improve their performance by navigating digital transformation effectively.

While existing research has largely focused on the general benefits of technology adoption, a critical gap remains in understanding how specific technology adoption profiles influence the development of organizational competencies, such as project management skills and field crew capabilities. This gap is particularly relevant as firms with varying levels of digital integration may gain distinct advantages in project management, handle complex workflows differently, or exhibit varying proficiency in optimizing field crew performance (Kissi et al., 2024; Cassandro et al., 2024; Yang et al., 2022). Furthermore, there is a lack of research on the effect of new technologies on the construction workforce and the required skills needed for their application (De Souza & Debs, 2023). The technologies selected in this study—GIS, Drones, AR/VR, Robotics, 3D Printing, Wearables, and Modular Construction—were chosen due to their demonstrated, practical applications in project management and field operations. Drones enhance spatial data accuracy, real-time progress tracking, and deployment logistics, significantly improving site productivity and safety (Rachmawati & Kim, 2022). Robotics automate high-risk or repetitive tasks, reducing labor dependency and improving safety (Bogue, 2025). 3D printing shortens construction timelines and reduces manual labor, addressing workforce shortages while increasing efficiency (Hossain et al., 2020; De Souza & Debs, 2023). Wearable devices monitor physiological signals and health risks on-site, enhancing worker safety (Al-Sahar et al., 2021). Modular construction offers a reduced physical site footprint and lower labor demands, contributing to a safer, more controlled work environment (Chatzimichailidou & Ma, 2022). These tools fall under established categories of advanced manufacturing and smart tools in Construction 4.0 literature (De Souza & Debs, 2023). In contrast, AI and machine learning were excluded from this study because they require extensive data preprocessing and infrastructure, making them less applicable to day-to-day field operations in many firms (Baduge et al., 2022). The study intentionally focuses on technologies with observable and measurable impact in construction project delivery and field operations. Additionally, his study aims to address this gap by examining how specific profiles of technology adoption influence competencies within construction firms, particularly in project management and field operations. By investigating this relationship, we aim to contribute to a more tangible understanding of how the depth and breadth of technology adoption can enhance organizational capabilities. The findings of this study will help construction firms make informed decisions regarding digital investments and workforce training, thereby providing a practical roadmap for navigating digital transformation. To explore and develop such correlations, the following research questions need to be addressed:

RQ1: What are the competency levels of the project management team and craftsmen in key operational areas as perceived by industry stakeholders?

RQ2: How do patterns of advanced technology adoption and organizational characteristics differentiate construction contractors into distinct groups?

RQ3: Are there significant differences in project management and field crew competencies among the construction firms based on their technology adoption profiles?

H1: There are significant differences in project management competencies among construction firms categorized by different levels of technology adoption.

H2: There are significant differences in field crew competencies among construction firms categorized by different levels of technology adoption.

Research Methodology

The goal of this study is to systematically identify and analyze the profiles of construction firms based on their adoption of advanced technologies and to evaluate the impact of these technological integrations on project management and field crew competencies. Accordingly, a survey design was developed based on a structured questionnaire, which was distributed among construction firms at three job fairs across different U.S. university campuses. Many local, regional, and national construction firms attended these job fairs. The questionnaire was distributed to around 140 companies by construction management students using an iPad. In addition, some were printed and handed out. In total, 102 responses were collected, with 96 being deemed complete and suitable for the analysis. Prior to the distribution of the survey, a pilot study was conducted among the research team to gauge the duration of the survey, as well as to remove and revise any questions that were vague or did not match the aims of the study. The questionnaire consisted of two parts: demographic questions related to the firm's operational capacities such as size, revenue, and type of construction, and questions directly related to the research goals of this study. The latter included yes/no questions on the types of advanced technologies utilized by firms, such as 3D Printing, Geographic Information Systems (GIS), Drones, Modular Construction, Wearable Technologies, Augmented and Virtual Reality (AR/VR), and Robotics, along with rating questions on competency levels of project management and field crews. Respondents were asked to evaluate their competencies in project management and field crew skills using a Likert scale from 1 to 5 across various areas. For project management, firms rated competencies in: (1) effectively managing stakeholder relationships; (2) developing and structuring project plans; (3) monitoring project progress; (4) managing product delivery to meet quality standards; (5) transitioning projects between stages; and (6) using performance data to evaluate and improve project outcomes. Similarly, field crew competencies assessed included: (1) the ability to sustain physical effort in demanding environments; (2) performing tasks requiring precision and coordination; (3) understanding and executing standard construction processes; (4) effectively using modern construction technologies; and (5) demonstrating proficiency in specific trades such as electrical, plumbing, masonry, or carpentry. These questions were developed based on an extensive literature review of project management and construction competencies within firms. Inferential and exploratory statistical analyses—including cluster analysis, Kruskal-Wallis test, and Bonferroni correction—were applied to analyze the data using SPSS 29.

Demographic: The profiles of participating construction firms—covering firm size, annual revenue, firm type, and the educational and professional experience of respondents—are presented in Tables 1 through 4 and Figure 1. In addition to these characteristics, we provide below a narrative summary of respondents' job roles and the types of construction projects their firms primarily undertake.

Table 1: Firm Size

Firm Size	N	%
1 - 49	8	8.3%
1000+	19	19.8%
250 - 499	19	19.8%
50 - 249	31	32.3%
500 - 999	19	19.8%

Table 2: Firms' Revenue

Revenue	N	%
$10 million or less	6	6.3%
$10.1 million - $50 million	12	12.5%
$100.1 million - $500 million	27	28.1%
$50.1 million - $100 million	18	18.8%
$500 million+	33	34.4%

Table 3: Respondents' Education

Education	N	%
Bachelor's degree	68	70.8%
High School or less	2	2.1%
Master's degree	14	14.6%
Some college	9	9.4%
Trade/technical/vocational training	3	3.1%

Table 4: Firm Type

Firm Type	N	%
General Contractor	67	69.8%
Trade Contractor	18	18.8%
Owner/Owner's rep	5	5.2%
Other	6	6.3%

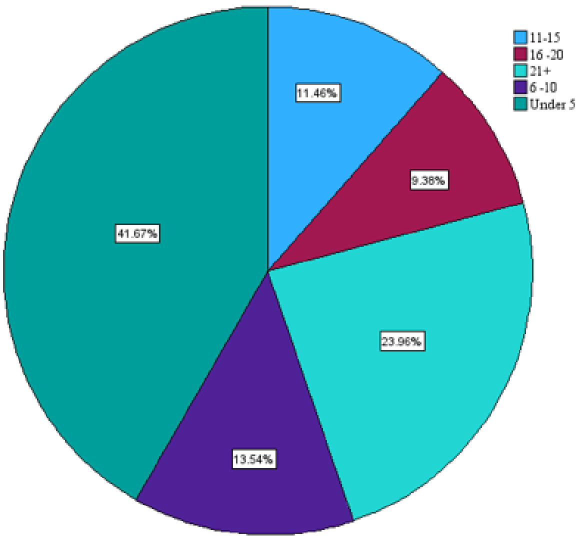

Figure 1: Respondents' Experience

Additionally, the participants in this study represented a broad range of professional roles within their respective construction firms, offering insight from both operational and executive perspectives. Nearly one-third of respondents (29.2%) held executive leadership positions, indicating strong participation from individuals involved in strategic planning and organizational decision-making. Project managers made up 20.8% of the sample, followed by project engineers (15.6%) and HR professionals (14.6%). Other roles included superintendents (6.3%), field engineers (4.2%), BIM specialists, estimators, and schedulers, as well as a small group classified as other. This distribution reflects input from diverse job functions across the construction lifecycle, from field operations to administrative and technical support. Regarding the types of projects undertaken by the firms, the majority (57.3%) specialized in commercial construction. A substantial portion (19.8%) operated in the heavy civil sector, while smaller percentages worked on residential (7.3%), institutional (6.3%), and mixed-use (6.3%) projects. A few firms also reported involvement in environmental, industrial/process, and utility/energy projects (1.0% each). This distribution supports the study's applicability across a range of construction project types and operational scales.

Results and Discussion

Project Management & Field Crew Competencies (RQ1)

Figure 2 presents a detailed breakdown of performance ratings across various project management competencies, focusing on the strengths and areas for improvement within the construction industry. The data shows a strong performance in Stakeholder Relations and Project Planning, with 49.0% and 47.9% of firms rating their performance as Very Good**,** respectively, and a quarter of the firms in each category achieving an Outstanding level. Project Progress and Product Acceptance also show high proficiency, with 30.2% and 25.0% of firms, respectively, rating their capabilities as Outstanding. In contrast, Project Transitions and Project Performance exhibit more variability, with 22.9% and 24.0% of firms rating their performance as Outstanding, respectively, yet a noticeable percentage of firms feel there is room for improvement, particularly in Project Performance where 7.3% rate their performance as only Fair and 2.1% as Needs Improvement. The interpretation of these results could mean that while many firms excel in managing stakeholder relations, project planning, and quality control, there are opportunities to strengthen efficiency in project transitions and overall performance evaluation, areas that could drastically benefit from targeted improvements and technological integration.

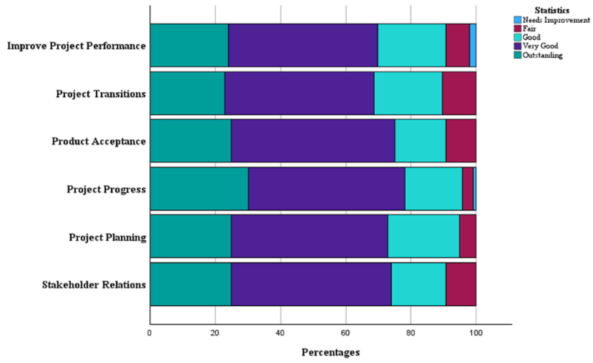

Figure 2: Project Management Competencies

Figure 3 below outlines the distribution of performance ratings across several key competencies relevant to field crew skills in the construction industry. The analysis reveals strong performance in Physical Endurance and Hand-Eye Coordination, with 40.6% and 43.8% of firms respectively rating their performance as "Very Good," and about 19% in each category deeming it "Outstanding." Conversely, Construction Methods and Modern

Technology Proficiency display more mixed results. A notable 9.4% and 16.7% of firms rate their proficiency as merely "Fair" in these areas, which indicates a significant portion of the workforce that sees room for substantial improvement in adopting modern tools and methods effectively. Despite these challenges, Skills Related to Specific Trades are well regarded, with nearly 46% of firms rating their expertise as "Very Good" and 24% as "Outstanding." This contrast stresses a gap in the integration and application of newer technologies versus traditional skills, pointing to opportunities for strategic enhancements to training and development programs.

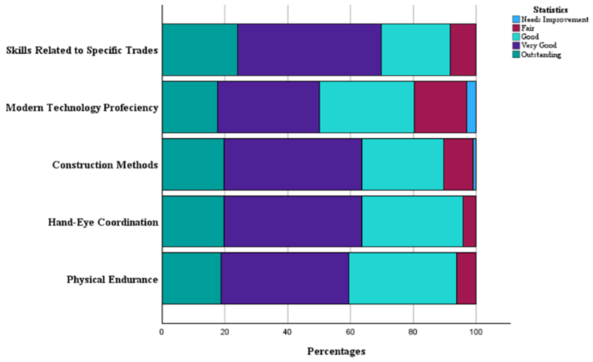

Figure 3: Field Crew Competencies

Cluster Analysis of Technology Adoption in Construction Contractors (RQ2)

The Two-Step Cluster analysis identified four distinct groups of construction contractors differentiated by their patterns of technology adoption and organizational characteristics. These clusters are defined by the specific technologies utilized by the firms, alongside variables such as revenue, project type, and firm size. The delineation of these clusters is detailed in Figure 4, which illustrates the composition and profiles of the firms within each group. Additionally, the importance of various predictors in defining these clusters is marked by their impact on the grouping process, ordered from the most to least influential: 3D Printing, GIS, Modular Construction, Drones, AR/VR, Wearable Technologies, and Robotics.

Cluster 1: Traditional Low-Tech Contractors

This cluster represents 29.2% of the sample, encompassing 28 firms characterized by minimal adoption of new technologies. None of the firms in this cluster reported using 3D Printing, GIS, Modular Construction, AR/VR, or Wearable Technologies, and only a small fraction (7.1%) has incorporated Robotics. These firms predominantly rely on traditional construction methods and have been slow to embrace the potential benefits of emerging technologies.

In terms of operational characteristics, these firms primarily engage in the commercial construction sector, accounting for 53.6% of this cluster. They generally report revenues ranging from $50.1 million to $100 million. A significant proportion of these firms are medium-sized, with employee counts between 50 and 249, making up 28.6% of the cluster.

The findings indicate that these firms are lagging in technological innovation, potentially impacting their competitiveness in a rapidly evolving industry. Their conservative approach to technology adoption may reflect a strategic choice or a hesitance to invest in unproven technologies, but it places them at a potential disadvantage as the construction sector increasingly moves towards digital integration.

Cluster 2: Selective Adopters with High Revenue

This cluster represents the largest group in our analysis, comprising 38.5% of the sample with 37 firms. These firms have adopted a selective approach to technology integration, as they primarily focus on technologies that align with their specific operational needs. Notably, Modular Construction technology has seen considerable uptake, with 78.4% of firms in this cluster adopting it. Wearable Technologies are also popular, used by 48.6% of the firms. In contrast, the adoption rates for other technologies like GIS (8.1%), Drones (32.4%), and AR/VR (37.8%) are relatively modest. Advanced tools such as 3D Printing and Robotics are even less prevalent, with only 2.7% and 18.9% adoption rates, respectively.

In terms of financial metrics, these firms are typically high earners, with 35.1% reporting revenues exceeding $500 million. This indicates that while the firms are financially robust, they prefer a cautious approach to adopting new technologies unless they directly contribute to their core business objectives. Operationally, the majority of these firms (64.9%) are involved in the commercial construction sector, and a substantial portion (37.8%) employs a workforce of 50-249 people, which classifies them as medium-sized businesses. Despite their conservative approach to technology integration, the adoption patterns within this cluster suggest there is room for further technological engagement, potentially driving even greater efficiencies and innovation in their projects. This nuanced adoption strategy shows a pragmatic yet progressive approach to technology, where selective integration is likely influenced by both perceived value and the readiness to embrace new solutions that promise tangible benefits.

Cluster 3: High-Tech Innovators

Comprising 14.6% of the sample, this cluster includes 14 firms that represent the vanguard of technology adoption in the construction industry. These firms are distinguished by their comprehensive embrace of advanced technologies, with every firm utilizing 3D Printing. Significant numbers also employ GIS (64.3%), Modular Construction (57.1%), Drones (78.6%), AR/VR (71.4%), Wearable Technologies (57.1%), and Robotics (64.3%). Further, in terms of economic impact, the majority of these firms, 71.4%, generate over $500 million annually, which is an indication of their substantial financial

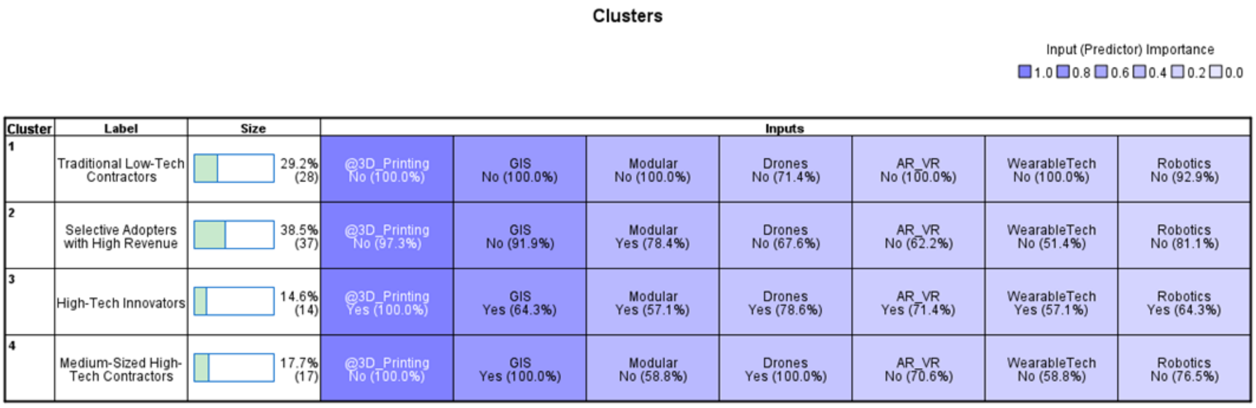

Figure 4: Firm Clusters

prowess. Additionally, they are predominantly large-scale operators, with 42.9% of them employing more than 1,000 people, which aligns with their capability to support significant technological investments. Operational activities within this cluster are primarily focused on commercial projects, which constitute 64.3% of their ventures. This focus likely reflects the demand for innovative solutions to enhance efficiency and productivity in complex, high-value projects. The extensive adoption of new technologies by these firms not only sets them apart as industry leaders but also shows the profound competitive advantages that can be leveraged through strategic technological advancements.

Cluster 4: Medium-Sized High-Tech Contractors

Cluster 4 comprises 17.7% of the sample, including 17 firms characterized as medium-sized entities that adopt high-tech solutions selectively. These firms universally utilize GIS and Drones. This reflects a strong commitment to technologies that enhance site management and aerial surveying capabilities. However, their adoption of other technologies is more measured; only 41.2% have integrated Modular Construction and Wearable Technology, and a smaller fraction, 23.5%, have implemented Robotics. Notably, none of these firms have adopted 3D Printing, and AR/VR usage is limited to 29.4%. The financial profiles of these firms typically show annual revenues ranging from $100.1 million to $500 million, representing 47.1% of the cluster. This revenue bracket supports their ability to invest in certain technologies while maintaining a cautious approach to capital-intensive innovations. A significant focus of these firms is on heavy civil projects, also making up 47.1% of their activities, which require specific technologies that enhance operational efficiency and project management in challenging construction environments. Furthermore, these firms generally maintain a workforce of 50-249 employees, encompassing 41.2% of the cluster. This size supports a flexible, yet robust operational capacity, ideal for medium-sized firms looking to leverage technology for competitive advantage without the extensive resource commitments required by larger firms. Overall, Cluster 4's selective technology adoption strategy illustrates a pragmatic approach to integrating innovations that provide clear, immediate benefits to their specialized needs, particularly in heavy civil construction.

Competency of Project Management and Field Crew by Cluster (RQ3)

The Kruskal-Wallis Test was conducted to determine whether there are significant differences between the four clusters of construction firms with regard to the competency of their project management teams and field crews. The responses were evaluated across the four clusters to assess whether competency levels vary depending on the firm's technology adoption pattern.

Hypothesis Test Summary

Stakeholder Relations: The Kruskal-Wallis test indicated a significant difference in the distribution of stakeholder relationship management across the four digital adoption clusters ($p = 0.002$). The null hypothesis was rejected, implying that digital adoption affects firms' ability to manage stakeholder relations differently across the clusters.

Project Planning: Significant differences were also observed in project planning competencies across the clusters ($p = 0.004$), leading to the rejection of the null hypothesis. Firms within the clusters exhibit different levels of effectiveness in planning project activities.

Project Progress Management: The results revealed a significant difference in managing project progress ($p = 0.009$), with the null hypothesis rejected. This finding suggests that the level of digital adoption influences how effectively firms manage project timelines and overall progress.

Product Acceptance: The competency in managing product acceptance across clusters showed significant differences ($p = 0.008$). The null hypothesis was rejected, indicating that digital adoption plays a role in how well firms handle the acceptance and quality control of deliverables.

Project Transition: A significant difference was found in managing project transitions across clusters ($p = 0.002$), leading to the rejection of the null hypothesis. Firms with varying digital technology adoption differ in how smoothly they manage transitions between project phases.

Project Performance Evaluation: The Kruskal-Wallis test revealed significant differences in the ability to evaluate and improve project performance across clusters (p = 0.020), leading to the rejection of the null hypothesis. Digital adoption appears to influence how firms assess and enhance project outcomes.

Field Crew Endurance: There were no significant differences in physical endurance across the clusters (p = 0.218). The null hypothesis was retained, suggesting that digital adoption does not significantly affect the physical endurance of field crews.

Hand-Eye Coordination of Field Crew: No significant differences were found in hand-eye coordination across clusters (p = 0.366), leading to the retention of the null hypothesis. This skill is relatively consistent across firms, regardless of digital adoption.

Knowledge of Construction Methods: The Kruskal-Wallis test indicated no significant differences in knowledge of construction methods across clusters (p = 0.199). The null hypothesis was retained, showing that digital adoption does not significantly impact this competency.

Proficiency with Modern Technologies: No significant differences were found in proficiency with modern technologies across clusters (p = 0.552). The null hypothesis was retained, indicating that digital adoption does not significantly influence this skill.

Skills Related to Specific Trades: The results showed no significant differences in skills related to specific trades across the clusters (p = 0.148), leading to the retention of the null hypothesis. This suggests that trade-specific skills are consistent across firms regardless of their digital adoption levels.

A post hoc analysis was conducted following a Kruskal-Wallis test to evaluate differences among clusters on various aspects of project management, as field competencies results were not found to be significant as stated previously. The results identify significant disparities in performance between clusters, with a particular focus on the role of adoption of digital technology in enhancing project management capabilities. Below are the detailed findings:

Managing Stakeholder Relations: The comparison between Clusters 1 (Traditional Low-Tech Firms) and 4 (Medium-Sized High-Tech Firms) showed the most substantial differences, with a test statistic of -29.387 (p < .001, adjusted p = .001). Medium-Sized High-Tech Firms demonstrated superior abilities in managing stakeholder relations, likely due to their advanced digital tools enhancing communication and engagement strategies. Similarly, a significant disparity was found between Clusters 2 (Selective Adopters with High Revenue) and 4, with a test statistic of -23.029 (p = .002, adjusted p = .014), stressing the benefits of comprehensive digital integration in stakeholder management.

Managing Project Planning: There was a notable difference between Clusters 1 and 4, with Cluster 4 showing considerably better project planning capabilities (test statistic of -28.417, p < .001, adjusted p = .002). The use of advanced digital tools in planning and resource management is likely a contributing factor to this discrepancy.

Managing Project Progress: A significant difference was observed between Clusters 1 and 4 in managing project progress, with a test statistic of -26.317 (p < .001, adjusted p = .005). Medium-Sized High-Tech Firms outperformed Traditional Low-Tech Firms, likely due to their utilization of advanced project management software and real-time data tracking tools.

Managing Product Acceptance: A marked difference was noted between Clusters 1 and 4, with Cluster 4 significantly outperforming Cluster 1 in product acceptance (test statistic of -25.021, p = .002, adjusted p = .009). This superior performance can be attributed to the use of sophisticated quality control systems and digital tracking tools.

Managing Project Transitions: There was a significant difference in managing project transitions between Clusters 1 and 4, with a test statistic of -30.195 (p < .001, adjusted p = .001), indicating that Medium-Sized High-Tech Firms manage transitions more effectively. Another notable difference was observed between Clusters 2 and 4 (test statistic of -22.183, p = .004, adjusted p = .023), further highlighting the advantages of digital integration in managing complex project dynamics.

Evaluating and Improving Project Performance: A significant difference was found between Clusters 2 and 4, with Cluster 4 outperforming Selective Adopters with High Revenue in monitoring and enhancing project performance (test statistic of -20.439, p = .008, adjusted p = .046).

These findings suggest that the depth of digital technology adoption is crucial in enhancing various aspects of project management, with firms in higher technology adoption clusters (Clusters 3 and 4) generally performing better across all competencies. The results emphasize the need for clusters with lower technology adoption (Clusters 1 and 2) to consider enhancing their digital capabilities to improve their competitiveness and efficacy in project management.

Detailed Technology Adoption Patterns and Analysis

The analysis of technology adoption among construction firms revealed specific usage patterns for each technology rather than uniform trends. The utilization varied considerably by technology type, displaying distinct strategic choices within the industry. Firms showed a strong preference for certain technologies aligned closely with their operational objectives and resource capabilities, as evidenced by varying adoption levels across clusters. Technology adoption varied distinctly across construction firms. 3D Printing was fully adopted by High-Tech Innovators (100%) but minimally by Selective Adopters (2.7%), and not at all by Medium-Sized High-Tech or Traditional Low-Tech firms. GIS saw universal adoption by Medium-Sized High-Tech firms (100%) and significant use among High-Tech Innovators (64.3%) but was minimally adopted by Selective Adopters (8.1%) and avoided entirely by Traditional firms. Modular Construction was favored by Selective Adopters (78.4%), moderately adopted by High-Tech Innovators (57.1%) and Medium-Sized firms (41.2%), but unused by Traditional firms. Drones were highly popular among Medium-Sized High-Tech (100%) and High-Tech Innovators (78.6%), moderately adopted by Selective Adopters (32.4%), and entirely absent among Traditional firms. AR/VR was primarily adopted by High-Tech Innovators (71.4%), modestly by Selective (37.8%) and Medium-Sized High-Tech firms (29.4%), and not at all by Traditional firms. Wearable Technologies saw moderate adoption among High-Tech Innovators (57.1%) and Selective Adopters (48.6%), slightly less in Medium-Sized High-Tech firms (41.2%), and none in Traditional firms. Lastly, Robotics was predominantly adopted by High-Tech Innovators (64.3%), with limited use among Medium-Sized High-Tech firms (23.5%), Selective Adopters (18.9%), and minimal adoption among Traditional firms (7.1%). These specific adoption patterns highlight targeted technology strategies tied closely to firm operations and resources. Firms extensively adopting these technologies exhibited notably stronger competencies in stakeholder management, project planning, and overall project performance, whereas traditional field skills remained consistent across all adoption levels, suggesting opportunities to enhance technology integration at the field level.

Conclusion

This study provides critical perspective into how technology adoption influences the competency levels of construction firms, particularly in project management and field crew capabilities. Through a cluster analysis of construction contractors, four distinct profiles emerged based on their technology adoption patterns: Traditional Low-Tech Contractors, Selective Adopters with High Revenue, High-Tech Innovators, and Medium-Sized High-Tech Contractors. Each cluster displayed varying degrees of adoption of advanced technologies such as GIS, Drones, AR/VR, and Robotics, which directly impacted their project management and, to a lesser extent, field crew competencies. However, the analysis also revealed distinct adoption rates for each specific technology, indicating that firms strategically choose technologies aligned with their operational needs rather than uniformly adopting advanced tools. For example, GIS (100%) and Drones (100%) were fully adopted by Medium-Sized High-Tech Contractors, while High-Tech Innovators universally adopted 3D Printing (100%) and strongly favored AR/VR (71.4%). Selective Adopters significantly utilized Modular Construction (78.4%), whereas Traditional Low-Tech firms minimally engaged with these technologies, demonstrating clear disparities in technology adoption across firm types. The results confirm that firms in higher technology adoption clusters, specifically the High-Tech Innovators and Medium-Sized High-Tech Contractors, significantly outperformed other clusters in managing key project management competencies. These include stakeholder relationship management, project planning, progress monitoring, and product acceptance. The ability of these firms to transition between project phases and improve performance was also notably stronger, which suggests that advanced technologies are critical in enhancing project efficiency and outcome quality. On the other hand, while field crew competencies were consistent across clusters, the adoption of modern construction technologies showed no direct impact on these elements. This could point out that traditional skills remain vital to construction success, but there is potential for improvement in areas like proficiency with modern tools and construction methods. Specifically, the moderate to low adoption rates of technologies like Wearables (41.2%-57.1%) and Robotics (7.1%-64.3%) indicate substantial room for growth in integrating modern tools into daily field operations.

The findings imply that firms lagging in technological adoption may face competitive disadvantages as the construction industry continues to embrace digital transformation. For these firms, investing in more advanced technologies could significantly enhance project management outcomes and overall efficiency. Furthermore, selective adopters can benefit from targeted digital integration, by focusing on technologies that provide the most direct benefits to their operational needs. While the contributions of this study are twofold, it has several limitations. First, the sample size of 96 firms, while adequate for analysis, limits generalizability, particularly as the data was collected from specific U.S. regions. Additionally, the competency ratings were self-reported, which may introduce bias. The focus on specific technologies excludes other emerging tools like generative AI, potentially limiting the breadth of technological impact assessed. This was because they require extensive data infrastructure and are more commonly applied in backend analytics rather than direct field operations. Furthermore, most respondents represented office-based roles, with less input from field crew members, potentially skewing the competency assessment towards project management rather than field operations. Future studies could expand this research by incorporating a longitudinal design to track the evolution of technology adoption and its long-term effects on competencies over time. Additionally, exploring the barriers to adopting these technologies, such as cost, training, or firm culture, would provide valuable information for firms hesitant to invest in digital transformation. Finally, investigating the specific role of digital tools in field crew training and upskilling could further bridge the gap between traditional construction methods and modern technology integration.

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