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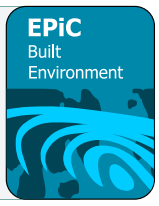

Perception Analysis of A-Class Construction Companies of Nepal Regarding Construction Automation

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Nepal's construction industry holds immense potential, demanding an urgent and active transition to automated technology to address challenges facing economic growth, urbanization, and escalating infrastructure needs. This paper explores the current state of construction automation in Nepal, emphasizing challenges, benefits, and the industry's knowledge levels. An IRB-approved Survey-based analysis was conducted with A-Class construction companies which reveals that while the sector incorporates automation, the primary emphasis remains on using construction equipment. Major hurdles identified include financial constraints and a shortage of skilled manpower. Recommendations include governmental support, curriculum enhancements in engineering programs, and intensified research initiatives to bridge knowledge gaps. The study urges an integrated education approach and calls for heightened awareness, policy advocacy, and curriculum reforms to drive innovation and sustainability in Nepal's construction sector. Positioned as a foundational exploration, The study aims to deepen comprehension and facilitate the real-world implementation of construction automation technologies in Nepal's evolving construction landscape. This includes practical applications such as optimizing project timelines, improving safety measures, and enhancing overall construction efficiency.

Key Words: Construction Automation, Challenges, Benefits, Automation Technology.

Introduction

In the rapidly evolving landscape of the construction industry, Construction Automation and Robotics has emerged as a transformative technology with the potential to bring the construction sector on par with other industries globally. The construction automation technology has garnered significant attention from academia and industry researchers, reflecting the growing recognition of its pivotal role (Pan et al., 2018). Construction automation, a multifaceted concept, has been defined by various scholars, each contributing nuanced perspectives. Skibiniewski (1992) characterizes construction automation as engineering construction works using mathematically driven equipment operated remotely, either partially or fully automatic. Hewitt & Gambatese (2003) view it as applying

mechanical and electronic means to mechanize construction tasks, emphasizing cost and time savings, improved work quality, enhanced safety, and increased productivity. Vähä et al. (2013) delve into real-time sensing and numerically controlled automatic assembly, while Bock (2015) simplifies it as technological and procedural innovations revolutionizing construction. Willmann et al. (2016) redefine construction automation as "digital fabrication" in customized building construction. This paper defines construction automation as high-tech solutions addressing real-world construction challenges to maximize workforce efficiency and profitability across all construction engineering sectors.

The global significance of the construction industry is underscored by its contribution to the GDP of developing countries, constituting 10%, with more than one-fourth of the GDP in some cases (Kim et al., 2015). Research and Markets (2023) report predicts substantial growth in the global construction automation market, from $12.5 billion in 2022 to $35.6 billion by 2029, at a Compound Annual Growth Rate of 18.2%. Developed nations are at the forefront of adopting construction automation technologies, as indicated by McGraw Hill Construction (2014) reports highlighting high returns on investment in countries such as the United States and those in the European Union.

While the United States and Japan have a legacy of employing automation technologies since the early 1990s (Skibiniewski, 1992; Rohana, 2012), the European Union actively funds projects aiming at cost reduction through eco-friendly, energy-efficient components and buildings (BERTIM, 2016). Malaysia promotes innovative technologies through the Industrialized Building System (IBS) approach (Rohana, 2012), and China, a technological powerhouse, is marked by groundbreaking developments in construction technologies, albeit with a need for better documentation (Shiyao et al., 2020). Conversely, developing nations need help in implementing automation techniques, as highlighted by Bhattarai & Kisi (2022) and Ismail et al. (2017), citing a lack of awareness and low implementation rates in South-Asian countries.

In the context of Nepal, where construction digitalization has made significant strides (Paneru et al., 2023), there exists a need for concerted efforts from all stakeholders to harness the full potential of digital tools and technologies. This research addresses a literature gap by examining the current state of A-class construction companies in Nepal regarding their adoption and perception of construction automation, thereby shedding light on the benefits and challenges associated with automation techniques in the Nepalese AEC industry. The Nepal Law Commission, Construction Business Rules (2000), mentions four different grades of construction companies where A-class construction companies must have a running capital of NPR ten million (approx. USD 77,000) with a work experience of four projects completed worth a minimum of NPR ten million five thousand (approx. USD 80,000) each or various projects valued at a total of NPR sixty million (approx. USD 462,000). This study focused on the A-class construction companies strive to integrate automation and underscores the importance of authorities' supportive policies, funding, subsidies, and awareness initiatives to propel the industry toward widespread mechanization.

Challenges and Benefits of Automation in Construction

Embracing new technology, particularly automation in construction, presents a formidable yet rewarding challenge. The potential benefits span all project phases, from design to decommissioning (Dakhil et al., 2021). However, this adoption has hurdles. Key challenges in the construction domain include high initial investment, a shortage of skilled manpower, insufficient strategic planning, time constraints, limited reusability, absence of national-level policies influencing the use of automation, and market availability issues (Chen et al., 2018; Dakhil et al., 2021; Kamaruddin et al., 2016). Despite these obstacles, the advantages offered by construction automation are substantial. The technology is anticipated to enhance safety, increase productivity, improve workability, reduce

construction time, boost knowledge acquisition, and elevate the reputation of companies involved in the industry (Dadhich et al., 2016; Faghihi et al., 2015; Shiyao et al., 2020). These challenges and benefits can be attributed to various stakeholders, including clients, contractors, or consultants. For this study, the selected challenges and benefits have been curated from a broad spectrum of options, providing a focused exploration of the complexities and advantages of integrating automation in construction in Nepal.

Methodology

This study assesses the comprehension level of A-class construction companies in Nepal regarding construction automation. To achieve this comprehensive assessment, an IRB-approved survey methodology was employed to analyze the perceptions of these companies. An online questionnaire containing 19 questions was crafted using Google Forms and disseminated to 75 relevant and accessible A-class construction companies through electronic media channels. The collected responses were analyzed using Excel and SPSS.

The questionnaire comprises two sections. The first section focuses on gathering demographic information about the company's representative, while the second section addresses questions related to the perception of employing construction automation including challenges, benefits, and uses. The questionnaire selection related to challenges, benefits, application, and adaptation is based on references from prior literature concerning analogous studies conducted in other developing nations. This structured approach allows for an inclusive exploration of the subject, combining demographic insights with specific perceptions to better understand the construction companies' perspectives on construction automation in Nepal.

Results and Discussion

The researcher received 46 responses from the 75 survey forms sent to the executive members of the A-class construction companies, of which 45 were completed and used in this study for analysis. This section has been subdivided into several other parts to analyze data.

Demography

Within the valid responses received, 64.44% of participants (29 individuals) held technical degrees, while 35.56% (16 individuals) were professionals in the construction industry without technical degrees. Notably, respondents specializing in building construction constituted the majority at 44.44%, surpassing those focused on road construction (22.22%) and hydropower projects. A minority (11.11%) engaged in various other construction sectors, such as bridge construction, irrigation, and water supply projects.

Participants were then queried about their experience in the construction industry. Approximately 65% of respondents (29 out of 45) boasted over 10 years of experience, providing valuable insights into how the construction industry has navigated automation techniques over a substantial period. On the other hand, about 35% (16 out of 45) had less than or equal to 10 years of experience, potentially offering perspectives rooted in awareness of new technologies and methodologies within the construction industry. This diversity in experience levels among participants enhances the study's richness by incorporating a broad spectrum of insights.

Understanding Construction Automation

This section delves into participants' overall perceptions of construction automation, capturing their initial thoughts. Approximately 50% of respondents view construction automation through the lens of advanced construction management tools, while 36% associate it with the automation of construction equipment. Some participants consider alternative technological aspects within construction automation, as illustrated in Figure 1. This diversity in viewpoints underscores the varied interpretations and understandings of construction automation among the surveyed participants.

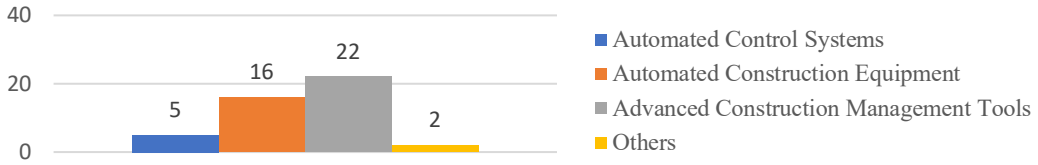

Figure 1. Perception about Construction Automation

Following this, participants were asked which construction phase they perceived as the most automated. Through cross-tabulation analysis, it was found that approximately 60% of respondents specializing in hydropower and building construction believe that automation is predominantly utilized during the construction phase. Conversely, professionals engaged in road construction believe that both designing, and construction phases equally leverage automation techniques, as depicted in Figure 2. Across all sectors of construction, there is a consensus among respondents that Operation and Maintenance represent the least automated phase in construction.

Challenges for Construction Automation

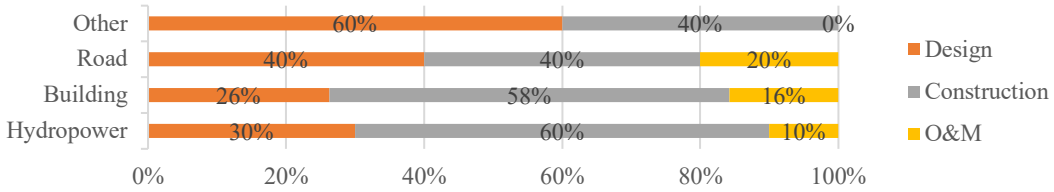

Figure 2 Use of Automation in Different Phases of Construction in Different Sectors

Despite the potential benefits, applying construction automation techniques poses substantial challenges for companies. Out of 45 respondents, 41 believed their companies would gain from adopting construction automation. Employing the Relative Index of Inequality (RII) method, researchers analyzed the perceived challenges among different respondent categories in applying construction automation.

Table 1 provides a comprehensive overview of the major challenges of applying construction automation. Based on the professionals' experience, the analysis of challenge rankings revealed a consensus across both groups. The primary challenge identified was the high initial investment required to procure construction automation technology, followed closely by a shortage of skilled manpower needed to implement these techniques in the Nepalese construction industry.

However, a nuanced difference emerged when comparing professionals with technical degrees to those without. The former group considered the lack of skilled manpower a more significant issue, while the latter deemed the initial investment the major hurdle. Interestingly, all groups agreed that

lack of reusability and time-frame boundaries are minor challenges compared to others. Nevertheless, experts from the road and other construction sectors identified a shortage of skilled manpower as the foremost challenge to overcome. The dynamics shifted when respondents ranked their second most significant challenge, with experts in hydropower and building sectors citing a lack of skilled manpower. In contrast, experts in road and other sectors prioritized high initial investment as the second most challenging factor in implementing automation in the construction industry in Nepal. The collective ranking of challenges indicates that Nepal's primary obstacles to implementing construction automation are high initial investment and a shortage of skilled manpower. This alignment is consistent across various professional categories. However, professionals without technical degrees deviate from this overall trend, identifying high initial investment and a lack of strategic planning as the major challenges in implementing construction automation.

Table 1

Relative Index of Inequality (RII) of challenges based on experience and degree

Challenges	Based on Experience				Based on Degree				Overall	
	< 10 years	Rank	> 10 years	Rank	Non-Technical	Rank	Technical	Rank	Overall	Rank
High Initial Investment	16.15	1	16.14	1	16.02	1	16.21	2	16.76	1
Lack of Skilled Manpower	15.79	2	15.59	2	14.18	5	16.54	1	15.71	2
Lack of Strategic Planning	14.52	3	13.61	5	14.92	2	13.38	5	13.53	5
Time-Frame Boundaries	12.52	7	12.62	6	13.63	6	11.97	7	12.06	7
Lack of Reusability	13.07	6	12.40	7	11.97	7	13.06	6	12.20	6
Lack of National Level Policy to influence its use	13.97	4	14.49	4	14.92	2	13.93	4	14.31	4
Not Abundantly Available in the local market	13.97	4	15.15	3	14.36	4	14.91	3	15.29	3

The data paints a clear picture, emphasizing that the high initial investment required for construction automation techniques and the scarcity of skilled manpower stand out as the two primary challenges in applying construction automation in Nepal. Intriguingly, factors such as market availability and strategic planning are perceived as insignificant hindrances, suggesting that the construction industry is receptive to adopting automation techniques. Notably, respondents with technical degrees highlight the shortage of skilled manpower as the primary challenge in implementing construction automation. It is noteworthy that despite this acknowledgment, two of Nepal's prominent universities, Tribhuvan University (2012) and Pokhara University (2013), need more subjects or topics related to construction automation in their graduate-level study curricula. This observation raises concerns about the course curriculum's alignment with the latest technological advancements in the construction industry.

Benefits of Construction Automation

The benefits of automation in the Nepalese construction industry were assessed using the Likert scale. Respondents overwhelmingly perceived time savings as a significant benefit, scoring an average of 3.98 out of 5. However, the responses indicated that safety and knowledge enhancement are areas where construction automation is considered to have comparatively fewer benefits. The insights from

Table 2 reveal that professionals with more experience are more inclined to believe in the benefits of construction automation, particularly in workability, productivity, knowledge enhancement, company reputation, and time savings, compared to their less-experienced counterparts.
The results in Table 2 illustrate a correlation between the perceived benefits of construction automation and professional experience. Individuals with more than 10 years of experience consistently rated every benefit, except safety, higher than professionals with less than or equal to 10 years of experience. The data underscores the belief among construction companies in Nepal that automation techniques hold the potential to save time, enhance productivity, and bolster the company's reputation.

Table 2

Benefits of Construction Automation (1: Least Useful; 5: Highly Useful)

Benefits	Less than or equal 10 years	More than 10 years
Increase Safety	4.00	3.88
Increase Workability	3.81	4.08
Increase Productivity	3.94	4.19
Enhance of Knowledge	3.88	3.96
Build Company's Reputation	4.06	4.08
Save Time	4.13	4.19

Use of Automation Techniques

Participants were queried about the primary field in which their companies predominantly employed automation techniques. Approximately 50% (22 out of 45) of the respondents indicated that their companies mainly utilized construction equipment for construction automation, as outlined in Table 3. Around 18% of the responders reported that their companies primarily relied on computer software and programs as automation tools. Manpower management and construction planning techniques were favored by only a few companies, while a minority of respondents provided feedback on the use of Information Modeling, construction site visualization, and resource management. The responses reflect diverse approaches among companies in adopting automation techniques across various aspects of the construction process.

Table 3
Application of Construction Automation

Application areas	Frequency	Percentage
Construction Equipment	22	48.89%
Computer Programs and Software	8	17.78%
Manpower Management	5	11.11%
Construction Planning Techniques	5	11.11%
Others	5	11.11%

The participants were asked how their respective companies embraced construction automation, given that they were adopting it. Respondents could select multiple methods if their company utilized various approaches. As depicted in Table 4, most construction companies in Nepal embraced

construction automation predominantly through advanced construction equipment (21 responses), followed closely by providing training to their workforce on automation techniques (19 responses). In contrast, only five companies engaged in research on automation techniques, and merely four utilized construction automation for safety purposes.

The responses paint a picture of the strategies construction companies employed in Nepal to integrate construction automation into their operations. The prevalent use of construction equipment stands out as the most popular application, overshadowing other avenues of construction automation. These companies are actively adapting to construction automation techniques by leveraging advanced equipment and imparting training to their workforce. However, a notable gap is observed in the research sector, with only a minority of these companies involved in research endeavors that could furnish them with comprehensive knowledge about the application of new technologies in the construction industry.

Table 4

Adaptation of Construction Automation

Adaptation Method	Number of Responses
Training the Manpower	19
Using Advanced Equipment	21
Research	5
Using Modern Computer Software	10
Using Advanced Safety Techniques	4
Using Modern Construction Management Techniques	16

Conclusion and Recommendations

In summary, this study delved into the current landscape of construction automation technology perception within Nepalese A-class construction companies, shedding light on crucial facets of industry development. The survey responses illuminate a notable trend: while the Nepalese construction sector has initiated integrating automation techniques, the primary focus remains on using construction equipment. Key takeaways from the study lead to several insightful conclusions and recommendations:

Challenges Hindering Implementation: Construction companies in Nepal exhibit an understanding of the potential benefits of construction automation. However, the implementation faces substantial challenges primarily rooted in financial constraints and a shortage of skilled manpower (as shown in Table 1). These findings highlight the necessity for targeted interventions to surmount these barriers and facilitate a more widespread adoption of automation technologies within the industry.

Experience, Education, and Curriculum Enhancement: The study emphasizes the positive correlation between industry experience and the perceived benefits of construction automation (Table 2). Professionals with technical backgrounds express concerns about the shortage of skilled manpower, underscoring the need for hands-on experience. Furthermore, the incorporation of construction automation courses into the curriculum of engineering programs is recommended, aligning educational offerings with the evolving needs of the industry.

Prioritizing Research Initiatives: The study reveals a concerning trend - a low prioritization of research on construction automation (Table 4). Addressing this gap necessitates collaboration between the construction industry and academic institutions in Nepal. By fostering research initiatives, industry can stay abreast of emerging technologies, fostering innovation and sustainability.
Limited Criteria for Adoption and Untapped Knowledge Enhancement: While most participants expressed a positive stance on construction automation, the limited selection of criteria for adaptation indicates a degree of hesitancy or unpreparedness within the industry (Table 4). Additionally, the potential benefit of construction automation as a knowledge enhancer still needs to be utilized, reflecting the need for increased incorporation of these technologies in educational settings.
Awareness Building and Policy Advocacy: To propel the construction industry into a new era, the study underscores the critical need for heightened awareness about construction automation techniques among professionals in Nepal. Achieving this necessitates multifaceted efforts, including government-level policy initiatives, increased research endeavors, and integration of construction automation topics into engineering and construction course curricula.
In conclusion, the Nepalese construction industry stands at a crucial juncture where embracing construction automation is imperative for sustainable growth. This research aims to catalyze industry efforts, instigating a shift towards innovation and positioning Nepal's construction sector on par with global advancements. While the study provides a foundational exploration, future research opportunities lie in niche investigations into specific construction sectors, paving the way for a more comprehensive understanding and application of construction automation technologies in Nepal.

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