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A Civil Engineer's Perspective on the Application of Artificial Intelligence in the Construction Industry

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ABSTRACT

The introduction of artificial intelligence (AI) technologies, the construction industry is on track for a technological revolution. In order to investigate the potential of artificial intelligence (AI) to improve sustainability, safety, and efficiency in the construction industry, this research paper offers a thorough examination of these applications. The study looks at several AI methods, including robots, computer vision, machine learning, and natural language processing, and how they are used in the design, planning, scheduling, monitoring, and maintenance phases of the building lifespan. In order to show the concrete advantages of AI in maximizing resource allocation, cutting project delays, enhancing quality control, and minimizing risks, it also looks at case studies and real-world applications. The study also discusses ethical issues and addresses issues like security of data, workforce upskilling, and interaction with current systems. This report offers useful insights for practitioners, policymakers, and researchers interested in maximizing the revolutionary potential of artificial intelligence (AI) in the construction industry by integrating existing research and industry trends. In the construction industry, any error, miscalculation, or misinterpretation can result in claims, delays in projects, and large cost overruns. The documentation and construction contracting processes are very complex and time-consuming. This research is done to make the process of documentation easy using the AI tools. The respondent's opinion is consistent (Cronbach alpha is greater than 0.80). Educational qualification is influencing application of AI in construction industry by stating that construction industry gets benefitted from AI-powered construction simulation tools helps in accurate 3D modelling for monitoring the progress of the project and also influencing the application of AI in construction industry through Workers are resistant to adopt AI technology due to their lack of skill & awareness in using this technology as a barrier/challenge and also influencing application of AI in construction industry by proving the phenomenal level of acceptance for Collaboration with AI technology developers helps in adopting the AI technologies in construction industry as an enabler to the challenges of application of AI in construction industry.

Keywords: Artificial Intelligence (AI), Efficiency, Workforce upskilling.

Introduction: The construction sector in India is a key driver of economic expansion, making a substantial contribution to both GDP and employment. This industry is broad and includes infrastructural, commercial, residential, and industrial projects. The sector is expanding quickly due to factors including urbanization, government efforts, and increased disposable incomes. The cognitive capacities that enable people to learn, comprehend, reason, and adjust to their surroundings are referred to as human intelligence. It includes a broad variety of abilities, including as creativity, problem-solving, abstract thought, and social and emotional intelligence. Intelligence quotient (IQ) scores obtained from IQ tests are frequently used in psychology to evaluate human intellect and higher IQs are often linked to better life outcomes [8]. "IQ tests are valid measures of the kind of intelligence necessary to do well in academic work," says psychologist Wayne Weiten. However, the validity of IQ testing is called into doubt if the goal is to evaluate intellect more broadly [9]. Gardner [15,16] divides intellect into different parts. He listed the seven different categories of intelligence—logical-

mathematical, linguistic, spatial, musical, kinaesthetic, interpersonal, and intrapersonal—in the first edition of his book Frames of Mind (1983). He included the naturalist and existential intelligences as two more categories of intelligence in a subsequent edition. He contends that only language, logic, and a few facets of spatial intelligence are measured by psychometric (IQ) testing [10]. Psychometric tests measure intelligence, scholastic aptitude, or related constructs. Regardless of method, tests requiring reasoning and question difficulty produce intelligence scores that are generally distributed in the general population. According to psychometric theory, performance on a variety of cognitive tasks is influenced by a single, underlying component known as the general intelligence factor (g). Crystallized intelligence (g_c), which is based on acquired knowledge and experience, is also impacted by g, even though the g-factor is a broad measure of intelligence and is frequently linked to fluid intelligence(g_f), which is the capacity to solve fresh thinking problems. Additional broad intelligence kinds are known as the "g's of intelligence." The following are other g's of intelligence: General memory and learning (g_y), Broad visual perception (g_v), Broad auditory perception (g_u), Broad retrieval ability (g_r), Broad cognitive speediness (g_s), Reaction time (g_t) [12]. Numerous types of IQ tests include a broad range of assessment activities. While some tests only include one kind of task, others use a variety of tasks that ask for various cognitive processes (e.g., reasoning, memory, quick decisions, visual comparisons, spatial imagery, reading, and retrieval of general knowledge) and have varying contents (visual-spatial, verbal, and numerical). The first rigorous factor analysis of correlations between different test tasks was conducted by psychologist Charles Spearman at the beginning of the 20th century. He discovered a pattern known as a positive manifold, in which all of these tests showed positive correlations with one another [11]. According to a 2020 research that was published in the Journal of Applied Psychology, professional success, including salary and job achievement, is significantly influenced by both general intelligence and particular mental skills [13]. As the intricacy of the task rises, the g factor becomes more crucial for job success. A higher general intelligence becomes a larger benefit for vocations that are more complex [14]. The vast field of artificial intelligence (AI) is concerned with building machines that are able to carry out tasks like learning, problem-solving, and language comprehension that normally require human intelligence. In contrast, artificial general intelligence (AGI) is a theoretical idea that describes machines with human-level cognitive abilities that can comprehend and learn any intellectual task that a human can. Conventional AI, also known as rule-based AI, uses algorithms that solve particular problems by adhering to predetermined rules. These systems simply carry out commands within a predetermined operational framework; they don't learn from past experiences. Systems built to learn and adapt from data are included in machine learning, a dynamic subset of artificial intelligence. Supervised and unsupervised learning are further classified into this. When the system learns from a dataset that contains all of the right answers, this is known as supervised learning. Without pre-labeled responses, the system looks for patterns and correlations in data in unsupervised learning. Artificial intelligence (AI) that learns by trial and error and uses feedback from its own experiences and actions to decide on the optimal course of action is called reinforcement learning. In increasingly complicated and dynamic contexts, like as video games where AI characters learn to travel or compete, and in real-world applications like autonomous cars that adjust to shifting traffic circumstances, reinforcement learning has enabled technologies. The capacity of robots to produce material, including realistic pictures, music, and writing, has significantly improved thanks to generative AI. These systems, however, frequently function without a thorough awareness of the output they are producing, which can result in mistakes or "hallucinations," in which the AI fills in knowledge gaps with inaccurate or illogical data. Employees tend to leave the organization. In construction industry the doors are replace with IOT operated doors [36]. Employee turnover in human resources includes recruitment, job changes, and involuntary terminations. It includes voluntary and involuntary turnover. While some motivational constructs remain consistent across organizations, exclusive constructs may differ in service-oriented organizations. Employee turnover can occur due to retrenchment, recession, or sacked out for correctional or rendition-related reasons. Therefore, both voluntary and involuntary

turnover are integral to employee turnover, Hence AI will assist in easing the job of recruitment, retention of talent [37].

Literature Gap: AI implemented in other domains and understood that it is minimizing the human intervention, enhancing the accuracy, documentation and tracking the records. Construction industry is being labour intensive industry, higher level attention requirement towards the safety, critical observation over work execution and progress of the work, it is felt there is a scope of introducing the human cantered AI. It may assist work process automation and minimize documentation process and retrieval the same.

Artificial Intelligence in Construction Industry: Through the introduction of cutting-edge technologies that improve productivity, safety, sustainability, and cost-effectiveness at every stage of the construction lifecycle, artificial intelligence (AI) is completely transforming the construction sector. The following are a few possible applications of AI in the construction sector and they are namely Predictive analytics, Computer Vision, Automation and robotics, Building Information modelling (BIM), Supply Chain Optimization and Generative Design.

Literature Review: The secondary data has been extracted from published research articles. AI is a powerful tool in the AEC industry, but it often lacks consideration for human input and preferences. This is particularly important for decision-makers, who rely on heuristic processes and past experiences. Human-centered AI is needed to understand and utilize human input, enhancing the industry's capabilities and reflecting realistic conceptions. This technology, primarily through natural language processing and machine reading comprehension, can learn from human interests, preferences, languages, and behaviors to create environments that satisfy these interests. Benefits include architectural processing optimization, design and engineering capability enhancement, data-driven project management, collaboration improvement, and safety enhancement. However, personalization and training are major challenges in developing this technology in the AEC industry. Regulation of AEC-specific guidelines and statements is necessary for developing human-centered AI in hazardous areas. Despite these challenges, human-centered AI is expected to provide the highest level of human control in the AEC industry's rapidly growing automation [17]. This mixed research approach used a combination of qualitative and quantitative data collection, analysis, and literature review. It involved an online survey and focus groups with 28 specialists. Four categories were used to classify and prioritize challenges: contractor-side economic issues, client-side economic difficulties, technical and work-culture elements, and weak business case aspects. No relationship was found, providing stakeholders with a better understanding of industry-specific barriers to robot and automated system adoption [18]. Author tries to improves on a previous research method that predicted safety outcomes using machine learning. It uses Natural Language Processing (NLP) to extract attributes from incident reports, and machine learning models are trained to predict safety outcomes. The outcomes are injury severity, injury type, body part impacted, and incident type. However, safety outcomes are not extracted via NLP but provided by human annotations. The study uses a larger dataset, new models, model stacking, a simpler experimental setup, and an analysis of attribute importance scores. The study also improves injury severity prediction, a significant advancement. [19]. Artificial intelligence methods are being applied to the development of construction management systems, allowing for a natural language user interface and unstructured decision tasks. This approach represents the object and its environment as a knowledge base, allowing for deductive and plausible conclusions. The system can work with incomplete or inaccurate information, explain actions, and automatically detect patterns in accumulated facts, thereby enhancing the overall efficiency of the systems [20]. Pareto optimum solutions for green building (GB may now be found utilizing AI techniques instead of more conventional methods thanks to intelligent optimization. The volume of information about current building activities that makes it

possible to monitor and manage GBs in real time. The report identifies new AI algorithms, methods, and technologies and serves as a reference for AI-in-GB. Practitioners and legislators can use it as a guide to determine how prepared they are to adopt AI-in-GB methods and practices. AI-in-GB adoption can improve sustainability and efficiency for both new GB developers and construction stakeholders. Future studies should examine how AI can be integrated with cutting-edge technologies like blockchain, digital twins, AIoT, robotics, and 4D printing. the potential for automation and digitization, it is necessary to look at the moral, ethical, and legal issues surrounding AI technology [21]. It is anticipated that the architecture-engineering construction/facility management (AEC/FM) sector will embrace trends toward automation and information. While artificial intelligence (AI) techniques enable automation, building information modeling (BIM) technology digitizes building information. Using a systematic bibliometric analysis, this study examines BIM-AI integrations in the AEC/FM sector and finds 183 relevant literature items. Three common integrated modes are identified after the findings are compiled from the viewpoints of techniques and applications. The present difficulties and potential paths of BIM-AI integrations are suggested, which aids in the methodical investigation of BIM-AI uses in the AEC/FM sector and offers useful avenues for BIM and AI development [22]. The construction industry, which currently contributes 13% of the world's GDP, is expected to reach $15.5 billion by 2030, with China, the US, and India being the top three countries. The industry faces challenges in maintaining vast amounts of information for subcontractors, contractors, designers, and clients. Information Technology (IT) has been instrumental in integrating disparate information in construction projects. The construction sector is undergoing transformation, with increasing investment in Artificial Intelligence (AI) at an unprecedented rate. This could increase human work productivity by 40% and double annual economic growth rates by 2035. This research discusses various methodologies and reviews the AI used in the construction industry, specifically Construction Project Management [23]. The construction industry, the largest business in India, is facing significant technological and industrial changes due to the rise of IoT, ICT, big data, automation, standardization, disruption, inflection, block chain, and supply chain. The advancement of Cloud Computing, Artificial Intelligence, and Internet of Things offers great potential for a collaborative and integrated environment for construction management. This paper presents an in-depth literature review on the adoption of artificial intelligence in construction management, highlighting the benefits of these emerging technologies in improving productivity in the construction business. As the development of this technology is still in its early stages, this research effort will provide a better understanding of the transformation and pave the way for further research in this area [24]. The Malaysian construction industry is experiencing a skilled labour shortage, project delays, and cost overruns, which are reducing efficiency and production. Artificial intelligence (AI) has been recommended as a transformative solution to address these issues. AI technologies offer novel approaches to improving project management, safety measures, and streamlining operations. This research paper aims to establish potential application areas of AI in the Malaysian construction industry. A questionnaire was used to gather data from industry professionals, and the study found that risk management with project management is the biggest anticipation for AI application in the industry [25]. AI is increasingly being used in the construction industry to enhance efficiency, productivity, accuracy, and safety. It is integrated with digital technologies like BIM, IoT, and Smart Vision. AI is used for estimation, resource management, workplace safety improvement, material selection, and structural analysis. Advancements in digital technology, like 5G connectivity, have further enhanced AI applications. Machine learning and deep learning are crucial for predictive tasks and automated decision-making. However, challenges like data security persist [26]. Artificial intelligence in the construction industry presents challenges such as data privacy, implementation costs, and skills transformation. Stakeholders must collaborate to address these challenges while maximizing technological benefits. A balance between technology application and humanistic care is crucial for AI to drive industry progress. Advancements in machine learning, robotics, and virtual reality will transform traditional practices, reshaping traditional practices and driving innovation [27].

Jobsite is the most significant AI element, followed by technology and human error. Prioritizing AI in safety includes worker disregard, cloud computing, inspection, and training. [28]. AI applications in the infrastructure construction sector, focusing on safety monitoring, control, and process management. Key technologies include machine learning, computer vision, and natural language processing. The review suggests future research should broaden AI applications, explore diverse technologies, and improve AI applications through standardized data sets and generative models. These directions offer potential solutions to infrastructure construction challenges [29]. The findings reveal eight main areas of AI application: cost, time, quality, contract, dispute, risk, safety, and sustainability. The study contributes to theoretical research by mapping current interest in AI studies and identifying gaps for future studies. Practically, it helps construction companies identify crucial areas for investment in AI, enabling them to be early adopters in the industry [30]. The Internet of Things (IoT) is revolutionizing smart city development by enabling real-time data collection, automation, and improved urban management. This study examines the opportunities and challenges of IoT implementation in smart city ecosystems. Results show that IoT integration improves energy efficiency, traffic management, and environmental sustainability, potentially reducing urban carbon emissions by 15% over the next decade. However, security vulnerabilities, interoperability challenges, and scalability constraints remain critical concerns. AI and blockchain can enhance IoT security and decision-making processes. The study emphasizes the need for regulatory guidelines and secure systems in smart city implementation. Future research should include experimental testing and predictive simulations to enhance smart city implementation optimization [31]. Climate change poses challenges to environmental sustainability and community well-being in urban areas due to heat stress, loss of biodiversity, and the impact of urban heat island effects. Green infrastructure (GI) can address these issues by improving ecological stability and promoting social inclusion. GI, such as green roofs, urban parks, and rain gardens, can protect ecological systems, reduce urban heat island effects, and improve community health and social interactions. However, challenges like financial problems, lack of information, bureaucratic issues, and maintenance expenses hinder their implementation. To overcome these, strategic policy frameworks, innovative urban planning approaches, and active community engagement are needed. This study emphasizes the need for GI in urban planning to achieve sustainable and adaptive cities for future environmental and social change [32]. AI technology is transforming the recruitment process by introducing an organization's history, speeding up selection, conducting background checks, assessing onboarding success, providing personalized training, evaluating candidates, filtering resumes, and reducing bias. It also enhances efficiency and diversity in hiring. However, thorough implementation, ongoing monitoring, and ethical considerations are crucial for ensuring fairness and transparency. AI technologies like machine learning, natural language processing, and predictive analytics have the potential to completely change candidate application management. The Cronbach alpha (α) for AI is 0.699, and experienced respondents believe AI is used for candidate evaluation and onboarding success assessment. Therefore, HR professionals must balance AI's potential with its challenges and constraints [33].

Research Aim: To validate the inclination of civil engineers of construction industry/employees towards application of Artificial intelligence (AI) tools in the construction industry in India.
Objectives: The objectives of the study is:
- To identify the role of artificial intelligence in present construction industry.
- To determine how AI is contributing the efficiency, accuracy and productivity in construction projects.
- To analyse the opinions of building construction professionals with various educational qualifications, on the application of AI in construction industry.

Research Methodology: The proposed study/research is depicted in fig.1.Research initiated with the introduction of research topic. The secondary data has been captured by referring to articles published

in electronic form previously published intellectual work. The secondary data is sourced through google search engine as well as google scholar and also Scopus website. The qualitative and quantitative data has been captured from published data. Objectives of the study as well as hypotheses has been constructed. A structured questionnaire has been constructed considering the Likert's scale (1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree) is used in the present study. Nominal Scale classifies the data into distinct categories, hence the nominal scale engaged for the study and analysis. The questionnaire consists of four sections and they are namely a) demographics, b) the benefits of using AI in construction industry, c) barriers / challenges faced during the application of AI in construction industry, d) enablers for encouraging implementation AI in construction industry. A pilot study has been administered and redundant data from the questionnaire has been eliminated. The refined questionnaire has been shared with the known engineers. The responses are collected engaging snow ball technique. The incomplete responses are eliminated. To confirm the data. The secondary data is sourced through google search engine as well as google scholar and also Scopus website. The qualitative and quantitative data has been captured from published data. Objectives of the study as well as hypotheses has been constructed. A structured questionnaire has been constructed considering the Likert's scale (1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree) is used in the present study. Nominal Scale classifies the data into distinct categories, hence the nominal scale engaged for the study and analysis. The questionnaire consists of four sections and they are namely a) demographics, b) the benefits of using AI in construction industry, c) barriers / challenges faced during the application of AI in construction industry, d) enablers for encouraging implementation AI in construction industry. A pilot study has been administered and redundant data from the questionnaire has been eliminated. The refined questionnaire has been shared with the known engineers. The responses are collected engaging snow ball technique. The incomplete responses are eliminated. The secondary data is sourced through google search engine as well as google scholar and also Scopus website. The qualitative and quantitative data has been captured from published data. Objectives of the study as well as hypotheses has been constructed. A structured questionnaire has been constructed considering the Likert's scale (1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree) is used in the present study. Nominal Scale classifies the data into distinct categories, hence the nominal scale engaged for the study and analysis. The questionnaire consists of four sections and they are namely a) demographics, b) the benefits of using AI in construction industry, c) barriers / challenges faced during the application of AI in construction industry, d) enablers for encouraging implementation AI in construction industry. A pilot study has been administered and redundant data from the questionnaire has been eliminated. The refined questionnaire has been shared with the known engineers. The responses are collected engaging snow ball technique. The incomplete responses are eliminated. To confirm the data reliability Cronbach alpha test has been performed. Considering the satisfactory results, the data has been tested using analysis of variance (ANOVA) technique on statistical package for the social sciences (SPSS) platform. The results are compiled under the head of finding/s. From the findings the data has been interpreted and thereafter conclusion/s have been constructed. Cronbach's Alpha coefficient (α) is a widely used method to measure reliability in social, behavioural, and education sciences. It relies on assumptions and assumes data is complete and normally distributed. McDonald's Omega coefficient (ω) relies on fewer and better realistic assumptions. If an item is deleted from Cronbach's Alpha coefficient (α), it doesn't affect population reliability. However, the McDonald's Omega coefficient (ω) reflects true population estimates of reliability by removing a certain scale of item. It is strongly recommended to replace Cronbach's Alpha coefficient (α) with McDonald's Omega coefficient (ω) in research work. This concept is applicable in business management, medical, arts, science, and engineering fields where responses from a sample are needed for analysis and decision-making [35].

Hypothesis Testing: To confirm the relationship between independent variable (Educational qualification) and dependent variable (benefits of application of AI in construction industry; barriers/challenges of implementation of AI in construction industry; enablers for barriers/challenges of application of AI in construction industry) a relationship has been constructed, the same has been tested using hypothesis testing. The actual statement that supports the research objective is defined as alternate hypothesis (H_a), and a null hypothesis (H_o) is a form of hypothesis that is deemed true until proven wrong based on the experimental data.

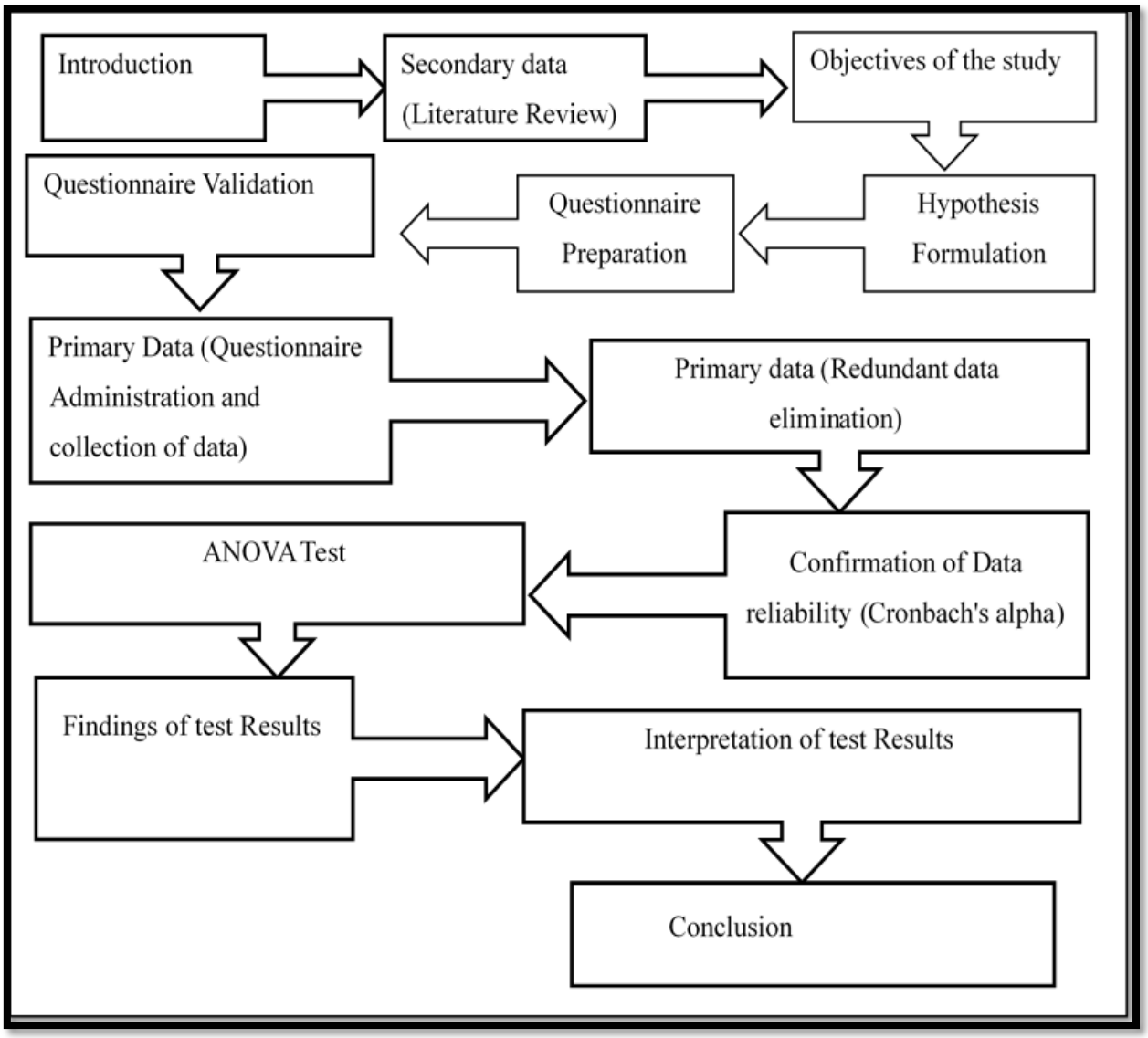

Fig.1: The flow of the research

The hypotheses are formulated and they are as follows:

Educational qualification Vs Benefits of application of AI in construction industry:

- H_{1o}: Certified people with various educational qualifications say that AI-powered construction simulation tools do not helps in accurate 3D modelling for monitoring the progress of the project.
- $H_{1a:}$ Certified people with various educational qualifications say that AI-powered construction simulation tools help in accurate 3D modelling for monitoring the progress of the project.
- $H_{2o:}$ Certified people with various educational qualifications say that AI does not improves the planning process in construction.
- H_{2a}: Certified people with various educational qualifications say that AI improves the planning process in construction.
- $H_{3o:}$ Certified people with various educational qualifications say that AI is a not powerful tool for reducing cost overruns in construction project.
- H_{3a}: Certified people with various educational qualifications say that AI is a powerful tool for reducing cost overruns in construction project.
- $H_{4o:}$ Certified people with various educational qualifications say that AI-powered safety monitoring systems does not enhances the safety of workers on site.
- H_{4a}: Certified people with various educational qualifications say that AI-powered safety monitoring systems enhances the safety of workers on site.
- $H_{5o:}$ Certified people with various educational qualifications say that AI-enabled automation (e.g., robots, drones) does not lead to a reduction in human intervention while performing hazardous tasks.
- H_{5a}: Certified people with various educational qualifications say that AI-enabled automation (e.g., robots, drones) lead to a reduction in human intervention while performing hazardous tasks.
- $H_{6o:}$ Certified people with various educational qualifications say that AI-enabled automation (e.g., robots, drones) does not helps in improving the productivity.
- H_{6a}: Certified people with various educational qualifications say that AI-enabled automation (e.g., robots, drones) helps in improving the productivity.
- H_{7o}: Certified people with various educational qualifications say that AI integrated BIM (building information modelling) cannot visualize complex designs & structures accurately using 3D models.
- H_{7a}: Certified people with various educational qualifications say that AI integrated BIM (building information modelling) can accurately visualize complex designs & structures using 3D models.
- H_{8o}: Certified people with various educational qualifications say that AI-powered computer vision does not enhances construction quality control.
- H_{8a}: Certified people with various educational qualifications say that AI-powered computer vision enhances construction quality control.
- H_{9o}: Certified people with various educational qualifications say that AI does not simplifies the documentation process of the construction project.
- H_{9a}: Certified people with various educational qualifications say that AI simplifies the documentation process of the construction project.
- H_{10o}: Certified people with various educational qualifications say that A data-driven approach (AI technology) does not guides to good decision-making at organizations.
- H_{10a}: Certified people with various educational qualifications say that A data-driven approach (AI technology) guides to good decision-making at organizations.

Educational qualification vs Barriers / Challengers of implementation of AI in construction industry:

- H_{11o} : Certified people with various educational qualifications say that Introducing AI technology into construction industry does not requires high initial investment costs.
- H_{11a}: Certified people with various educational qualifications say that Introducing AI technology into construction industry requires high initial investment costs.

- H_{12o}: Certified people with various educational qualifications say that Managing AI tools does not requires a skilled workforce with knowledge on AI.
- H_{12a}: Certified people with various educational qualifications say that Managing AI tools requires a skilled workforce with knowledge on AI.
- H_{13o}: Certified people with various educational qualifications say that Integrating AI with existing BIM & other relevant construction data will not be challenging.
- H_{13a}: Certified people with various educational qualifications say that Integrating AI with existing BIM & other relevant construction data can be challenging.
- H_{14o}: Certified people with various educational qualifications say that Artificial intelligence does not have any cyber security concerns.
- H_{14a}: Certified people with various educational qualifications say that Artificial intelligence has cyber security concerns.
- H_{15o}: Certified people with various educational qualifications say that Workers are not resistant to adopting AI technology due to their lack of skill & awareness in using this technology.
- H_{15a}: Certified people with various educational qualifications say that Workers are resistant to adopting AI technology due to their lack of skill & awareness in using this technology.
- H_{16o}: Certified people with various educational qualifications say that AI technology does not need any periodic software updates, impacting the overall project cost.
- H_{16a}: Certified people with various educational qualifications say that AI technology needs periodic software updates, impacting the overall project cost.
- H_{17o}: Certified people with various educational qualifications say that Collecting & storing a large amount of data generated by AI is not a concern.
- H_{17a}: Certified people with various educational qualifications say that Collecting & storing a large amount of data generated by AI is a concern.
- H_{18o}: Certified people with various educational qualifications say that It is not difficult to quantify & communicate about AI technologies to stakeholders.
- H_{18a}: Certified people with various educational qualifications say that It is difficult to quantify & communicate about AI technologies to stakeholders.
- H_{19o}: Certified people with various educational qualifications say that Limited availability of AI tools for construction-specific needs is not a challenge.
- H_{19a}: Certified people with various educational qualifications say that Limited availability of AI tools for construction-specific needs is a challenge.
- H_{20o}: Certified people with various educational qualifications say that Data privacy concerns in sharing confidential project data is not into AI.
- H_{20a}: Certified people with various educational qualifications say that Data privacy concerns in sharing confidential project data into AI.

Educational qualification vs Enablers for barriers/challenges of application of AI in construction industry:

- H_{21o}: Certified people with various educational qualifications say that Application of AI technologies are not adaptable for changing project requirements and unforeseen challenges.
- H_{21a}: Certified people with various educational qualifications say that Application of AI technologies are adaptable for changing project requirements and unforeseen challenges.
- H_{22o}: Certified people with various educational qualifications say that Company's management does not acts as a bridge between the workers and AI technologies that enhances the effectiveness for a successful work flow.
- H_{22a}: Certified people with various educational qualifications say that Company's management acts as a bridge between the workers and AI technologies that enhances the effectiveness for a successful work flow.

- H_{23o}: Certified people with various educational qualifications say that Government does not supports and does not gives incentives to implement AI in construction industry.
- H_{23a}: Certified people with various educational qualifications say that Government supports and gives incentives to implement AI in construction industry.
- H_{24o}: Certified people with various educational qualifications say that Active leadership does not supports the implementation & utilization of AI in the construction industry.
- H_{24a}: Certified people with various educational qualifications say that Active leadership supports the implementation & utilization of AI in the construction industry.
- H_{25o}: Certified people with various educational qualifications say that Successful pilot projects does not push the adoption of AI into construction industry.
- H_{25a}: Certified people with various educational qualifications say that Successful pilot projects push the adoption of AI into construction industry.
- H_{26o}: Certified people with various educational qualifications say that Company employees are not encouraged to participate in professional development programs related to the usage of AI in the construction industry.
- H_{26a}: Certified people with various educational qualifications say that Company employees are encouraged to participate in professional development programs related to the usage of AI in the construction industry.
- H_{27o}: Certified people with various educational qualifications say that the company does not recognizes and rewards employees for successful implementation & utilization of AI technologies.
- H_{27a}: Certified people with various educational qualifications say that the company recognizes and rewards employees for successful implementation & utilization of AI technologies.
- H_{28o}: Certified people with various educational qualifications say that Utilization of AI technologies & their effective implementation will not enhance the digital infrastructure of a Company.
- H_{28a}: Certified people with various educational qualifications say that Utilization of AI technologies & their effective implementation enhance the digital infrastructure of a Company.
- H_{29o}: Certified people with various educational qualifications say that Company will not bears the additional costs for training and skill development of employees.
- H_{29a}: Certified people with various educational qualifications say that Company bears the additional costs for training and skill development of employees.
- H_{30o}: Certified people with various educational qualifications say that Collaboration with AI technology developers does not helps in adopting the AI technologies in construction industry.
- H_{30a}: Certified people with various educational qualifications say that Collaboration with AI technology developers helps in adopting the AI technologies in construction industry.

Data Analysis

A 112 responses received through snowball sampling technique. The responses are analysed for data interpretation. The data discloses that 87% of responses are responded by male and remaining 13% of responses are responded by female (Fig.2). A 4.5% of the respondents are holding ITI degree, 5.4% of the respondents are holding diploma degree, 47.3% of the respondents are holding bachelor degree, 41.1% of the respondents are holding post graduate's degree and 1.8% of the respondents are holding PhD degree (Fig 3). A 5.4% of the respondents having more than ten years of experience in construction industry, 4.5% of the respondents having seven to ten years of experience in construction industry, 14.3% of the respondents having four to seven years of experience in construction, 50.9% of the respondent having one to four years of experience in construction industry and remaining 25% of the respondents having one year of experience in construction industry (Fig 4).

The respondent's data has been analysed for reliability, before continuing further study. The responses collected under the head of Benefits of application of AI in construction industry variable, Barriers / Challengers of application of AI in construction industry variable, Enablers of application of AI in

construction industry variable and Benefits of application of AI in construction industry variable, Barriers / Challengers and Enablers are checked for data reliability and the same is summarized under Table.1(Benefits of application of AI in construction industry variable), Table.2 (Barriers / Challengers of application of AI in construction industry variable), Table.3 (Enablers of application of AI in construction industry), Table.4 (Benefits, Barriers / Challengers and Enablers). The Cronbach alpha value is considered for data validity confirmation. The respondent's data has been analysed for reliability, before continuing further study. The responses collected under the head of Benefits of application of AI in construction industry variable, Barriers / Challengers of application of AI in construction industry variable, Enablers of application of AI in construction industry variable and Benefits of application of AI in construction industry variable, Barriers / Challengers and Enablers are checked for data reliability and the same is summarized under Table.1(Benefits of application of AI in construction industry variable), Table.2 (Barriers / Challengers of application of AI in construction industry variable), Table.3 (Enablers of application of AI in construction industry), Table.4 (Benefits, Barriers / Challengers and Enablers). The Cronbach alpha value is considered for data validity confirmation.

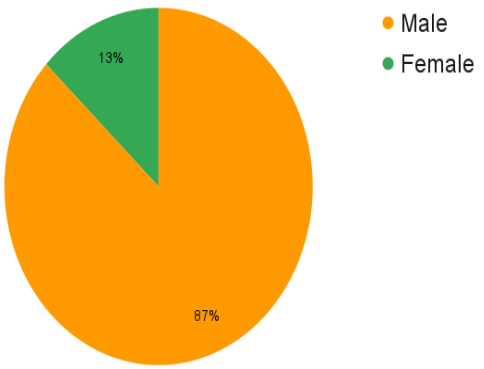

Fig. 2: Classification of gender of respondents

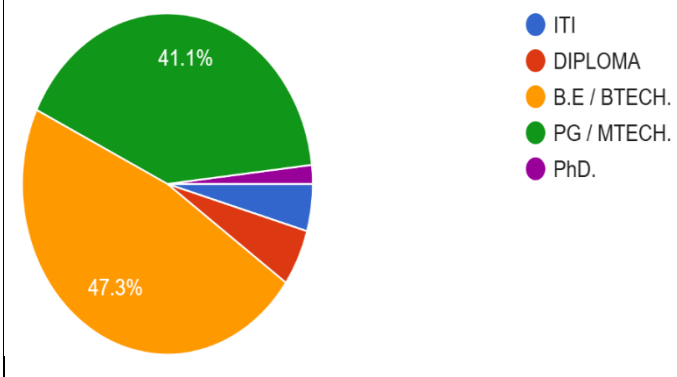

Fig 3: Classification of educational qualification of respondents

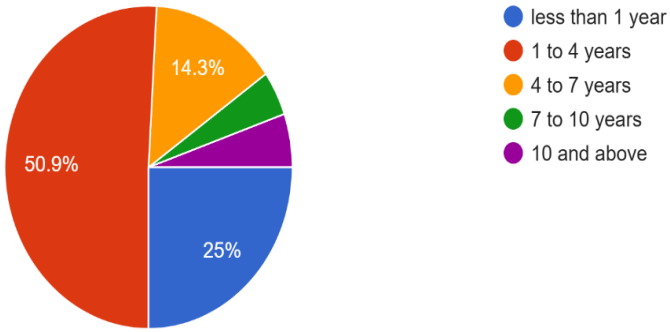

Fig 4: Classification of experience of respondents

For hypotheses testing one way Anova test is administered. The educational qualification is considered as independent variable. The dependent variables are benefits of application of AI in construction industry, barriers/challenges of application of AI in construction industry and enablers for barriers/challenges of application of AI in construction industry. One-way ANOVA test performed with educational qualification as the independent variable and all the 10 statements under benefits of AI in construction industry as the dependent variables. The results obtained from one-way ANOVA

test are tabulated below (Table 5). One-way ANOVA test is performed with educational qualification as the independent variable and all the 10 statements under barriers/challenges of application of AI in construction industry as the dependent variables. The results obtained from one-way ANOVA test are tabulated below (Table-6). One-way ANOVA test is performed with educational qualification as the independent variable and all the 10 statements under enablers for challenges/barriers of application of AI in construction industry as the dependent variables. The results obtained from one-way ANOVA test are tabulated below (Table-7).

Table 1: Results obtained from reliability test of benefits of application of AI in construction industry

Reliability Statistics

Cronbach 's Alpha	N of Items
.912	10

Table 2: Results obtained from reliability test of barriers/challenges of application of AI in construction industry

Reliability Statistics

Cronbach 's Alpha	N of Items
.898	10

Table 3: Results obtained from reliability test of barriers/challenges of application of AI in construction industry

Reliability Statistics

Cronbach 's Alpha	N of Items
.897	10

Table 4: Results obtained from reliability test Benefits, Barriers / Challengers and Enablers of application of AI in construction industry

Reliability Statistics

Cronbach 's Alpha	N of Items
.957	30

Findings: The findings from the analysis is as follows:

✓ The Cronbach's alpha value of the all Benefits, Barriers / Challengers and Enablers of application of AI in construction industry variables together is 0.917.

✓ The Cronbach's alpha values for individual sections- benefits of application of AI in construction industry variables, challenges/barriers of application of AI in construction industry variables and enablers of application of AI in construction industry variables is 0.912, 0.898 and 0.897 respectively.

✓ In the case of educational qualification vs benefits of application of AI in construction industry, the value of significance is obtained as 0.005, found less than P-critical (i.e. <0.05).

✓ In the case of educational qualification vs challenges/barriers of application of AI in construction industry, the value of significance is obtained as 0.040 found less than P-critical (i.e. <0.05).

✓ In the case of educational qualification vs challenges/barriers of application of AI in construction industry, the value of significance is obtained as 0.017 found less than P-critical (i.e. <0.05).

✓ The level of significance of all the other hypothesis is found to be greater than P-critical (0.05).

Interpretation:

- The Cronbach's alpha reliability analysis is being greater than 0.80 the data of responses are internally consistent.
- Educational qualification is influencing application of AI in construction industry by stating that construction industry gets benefitted from AI-powered construction simulation tools helps in accurate 3D modelling for monitoring the progress of the project at 0.005 level of significance, which is lower than 0.05, hence alternate hypotheses is accepted.

- Educational qualification is influencing application of AI in construction industry through Workers are resistant to adopt AI technology due to their lack of skill & awareness in using this technology as a barrier/challenge at 0.04 level of significance, which is lower than 0.05, hence alternate hypotheses is accepted.

Educational qualification is influencing application of AI in construction industry by proving the phenomenal level of acceptance for Collaboration with AI technology developers helps in adopting the AI technologies in construction industry as an enabler to the challenges of application of AI in construction industry at 0.017 level of significance, which is lower than 0.05, hence alternate hypotheses is accepted.

The mentioned objectives have been met through the literature review. The role of the AI has been pressed in this study as well as it is observed the efficiency of the AI in meeting project delivery as well as cost control possibility. Considering construction professionals educational qualification, the study has revealed that a) construction industry gets benefitted from AI-powered construction simulation tools helps in accurate 3D modelling for monitoring the progress of the project, construction industry through Workers are resistant to adopt AI technology due to their lack of skill & awareness in using this technology as a barrier/challenge, construction industry by proving the phenomenal level of acceptance for Collaboration with AI technology developers helps in adopting the AI technologies in construction industry as an enabler.

Conclusion: The construction industry stands at the initial stage of a digital transformation, with Artificial Intelligence (AI) emerging as a critical enabler of innovation, efficiency, and sustainability. This research has comprehensively examined the current applications, benefits, challenges, and enablers of AI integration in construction processes. From design and planning to execution, AI technologies such as machine learning, computer vision, robotics, and natural language processing are redefining conventional workflows, offering substantial improvements in cost control, quality assurance, safety, and productivity. Through quantitative analysis supported by structured questionnaires, the study confirms that AI-powered tools significantly enhance project outcomes, particularly in simulation through 3D models. The findings also reveal that educational qualification plays a pivotal role in influencing the perception of AI's utility and its adoption barriers. Challenges such as high implementation costs, workforce skill gaps, and data security concerns persist but can be mitigated through active leadership, government support, and strategic collaboration with technology developers. As the questionnaire is circulated only to the small-scale construction firms, the results obtained declare their least interest for implementation of AI in their industry. The main reason for this might be higher cost of implementation, that could be very difficult for them to introduce the additional costs into their capital. (limitation: data collected is from a short source and obtained from only few parts of India. And most of the respondents are working in short scale industries). In essence, this research underscores that while the adoption of AI in construction is still evolving, its potential is both vast and transformative. By embracing a human-centered approach and investing in upskilling and innovation, the construction industry can leverage AI not just as a tool, but as a catalyst for a smarter, safer, and more sustainable future.

Table 5: Output from one-way ANOVA test of educational qualification Vs benefits of application of AI in construction industry

Benefits- Statements	F	Sig.
AI powered construction simulation tools helps in accurate 3D modelling	3.980	0.005
AI improves the planning process in construction	1.301	0.275
AI is a powerful tool for reducing cost over runs in construction	1.219	0.307
AI powered safety monitoring systems enhances the safety of work	0.706	0.590
AI enabled automation eg. Robots, drones lead to a reduction	0.130	0.971
AI enabled automation eg. Robots, drones help in improving	1.100	0.360
AI integrated BIM building information modelling can accurately	0.951	0.438
AI powered computer vision enhances construction quality control	0.641	0.634
AI simplifies the documentation process of the construction process of the	0.100	0.982
AI data driven approach AI technology guides to good decision- making at organizations	0.677	0.609

Table 6: Output from one-way ANOVA test of educational qualification Vs barriers / challenges of application of AI in construction industry

Barriers -Statements	F	Sig.
Introducing AI technology in to construction industry requires high initial	0.798	0.529
Managing AI tools requires a skilled work force with knowledge on AI	1.722	0.151
Integrating AI with existing BIM & other relevant construction data can be	0.737	0.569
Artificial intelligence has cyber security concerns	0.911	0.461
Workers are resistant to adopting AI technology due to their lack of skill &	2.603	0.040
AI technology needs periodic software updates impacting the overall	1.763	0.142
Collecting & storing a large amount of data generated by AI is a concern	1.075	0.372
It is difficult to quantify & communicate about AI technologies to	1.254	0.293
Limited availability of AI tools for construction-specific needs is a	1.973	0.104
Data privacy concerns in sharing confidential project data into AI	0.924	0.453

Table 7: Results obtained from one-way ANOVA test of educational qualification Vs enablers of application of AI in construction industry

Enablers - Statements	F	Sig.
Application of AI technologies are adaptable for changing project requirements and unforeseen challenges	1.859	0.123
Company's management acts as a bridge between the workers and AI technologies that enhances the effectiveness for a successful work flow.	0.549	0.700
Government supports and gives incentives to implement AI in construction industry	2.449	0.051
Active leadership supports the implementation & utilization of AI in the construction industry	1.364	0.251
Successful pilot projects push the adoption of AI in to construction industry	2.081	0.088
Company employees are encouraged to participate in professional development programs related to the usage of AI in the construction industry	1.349	0.257
The company recognizes and rewards employees for successful implementation & utilization of AI technologies	0.809	0.522
Utilization of AI technologies & their effective implementation enhance the digital infrastructure of a Company	0.854	0.494

Company bears the additional costs for training and skill development of employees	0.882	0.477
Collaboration with AI technology developers helps in adopting the AI technologies in construction industry	3.158	0.017

References:

1. Ertas¸, H., Erdogan, A.S., (2017). An analysis of occupational accidents in demolition work. Civil engineering and architecture 5, 37–51.
2. S. W. Doebling, C. R. Farrar, M. B. Prime, and D. W. Shevitz,(1996). "Damage identification and health monitoring of structural and mechanical systems from changes in their vibration characteristics: a literature review," 1996, doi: 10.2172/249299.
3. Abioye, S. O., Oyedele, L. O., Akanbi, L., Ajayi, A., Davila Delgado, J. M., Bilal, M. Akinade, O. O., & Ahmed, A. (2021). Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. Journal of Building Engineering, 44, Article 103299. https://doi.org/10.1016/j. jobe.2021.103299
4. M.J. Ballesteros, M.D. Fernandez, ´ S. Quintana, J.A. Ballesteros, I. Gonz´alez, (2010). Noise emission evolution on construction sites. Measurement for controlling and assessing its impact on the people and on the environment, Build. Environ. 45 (2010) 711–717, https://doi.org/10.1016/j.buildenv.2009.08.011.
5. Agostinelli, S., Cumo, F., Guidi, G., Tomazzoli, C., (2021). Cyber-physical systemsimproving building energy management: digital twin and artificial intelligence.Energies 14 (8), 2338. https://doi.org/10.3390/en14082338.
6. Y. Hu, A. P. C. Chan, and Y. Le, (2012). "Conceptual frame work of program organisation for managing construction megaprojects-Chinese clients' perspective," 2012.
7. Roozbeh Kangari and Yasuyoshi Miyatake,(2010). "Developing and Managing Innovative Construction Technologies in Japan," Journal of Construction Engineering and Management, vol. 123, no. May 2010, pp. 72–78, 1997.
8. Brown, M.I.; Wai, J. (2021). "Can You Ever Be Too Smart for Your Own Good? Comparing Linear and Nonlinear Effects of Cognitive Ability on Life Outcomes". Perspectives on Psychological Science. 16 (6): 1337–1359. doi:10.1177/1745691620964122. PMID 33682520. S2CID 232142799.
9. Weiten W (2016). Psychology: Themes and Variations. Cengage Learning. p. 281. ISBN 978-1305856127.
10. Neisser, U.; Boodoo, G.; Bouchard, T. J., J.; Boykin, A. W.; Brody, N.; Ceci, S. J.; Halpern, D. F.; Loehlin, J. C.; Perloff, R.; Sternberg, R. J.; Urbina, S. (1996). "Intelligence: Knowns and unknowns". American Psychologist. 51 (2): 77–101. doi:10.1037/0003-066X.51.2.77. S2CID 20957095.
11. Delen, E.; Kaya, F.; Ritter, N. (2012). "Test review: Test of Comprehensive Nonverbal Intelligence-2 (CTONI-2)". Journal of Psychoeducational Assessment. 30 (2): 209–213. doi:10.1177/ 0734282911415614. S2CID 144773295.
12. Glanagan DP, Dixon SG. (2014). The Cattell-Horn-Carroll theory of cognitive abilities. Encyclopedia Spec Educ. 2014. doi:10.1002/9781118660584.ese0431.
13. Lang JWB, Kell HJ. (2020). General mental ability and specific abilities: Their relative importance for extrinsic career success. Journal of Applied Psychology. 2020;105(9):1047-1061. doi: 10. 1037 /ap l0000472.
14. Gottfredson LS. (1997). Why g matters: The complexity of everyday life. Intelligence. 1997; 24(1) :79-132. doi:10.1016/S0160-2896(97)90014-3.
15. Gardner, Howard (1999). Intelligence Reframed: Multiple Intelligences for the 21st Century, Basic Books, ISBN 978-0-465-02611-1

16. Gardner, H. (2004). Changing Minds: The art and science of changing our own and other people's minds, Harvard Business School Press, ISBN 978-1422103296
17. Rafsanjani, H. N., & Nabizadeh, A. H. (2023). Towards human-centered artificial intelligence (AI) in architecture, engineering, and construction (AEC) industry. *Computers in Human Behavior Reports*, *11*, 100319. https://doi.org/10.1016/j.chbr.2023.100319
18. Delgado, J. M. D., Oyedele, L., Ajayi, A., Akanbi, L., Akinade, O., Bilal, M., & Owolabi, H. (2019). Robotics and automated systems in construction: Understanding industry-specific challenges for adoption. Journal of Building Engineering, 26, 100868. https://doi.org/10.1016/j.jobe.2019.100868
19. Baker, H., Hallowell, M. R., & Tixier, A. J. (2020). AI-based prediction of independent construction safety outcomes from universal attributes. Automation in Construction, 118, 103146. https://doi.org/10.1016/j.autcon.2020.103146
20. Fedor Klashanov (2016). Artificial intelligence and organizing decision in construction, Procedia Engineering 165, (2016,) 1016 – 1020. www.sciencedirect.com
21. Debrah, C., Chan, A. P., & Darko, A. (2022). Artificial intelligence in green building. Automation in Construction, 137, 104192. https://doi.org/10.1016/j.autcon.2022.104192
22. Zhang, F., Chan, A. P., Darko, A., Chen, Z., & Li, D. (2022). Integrated applications of building information modeling and artificial intelligence techniques in the AEC/FM industry. Automation in Construction, 139, 104289. https://doi.org/10.1016/j.autcon.2022.104289
23. Korke, P., Gobinath, R., Shewale, M., & Khartode, B. (2023). Role of artificial intelligence in construction project management. E3S Web of Conferences, 405, 04012. https://doi.org/10.1051/e3sconf/202340504012
24. Ar. Gayatri Patil (2019). Applications of Artificial Intelligence in Construction Management, International Journal of Research in Engineering, IT and Social Sciences, 9, 21-28, ISSN 2250-0588.
25. Nasir, S. R. M., Sahidi, N. a. M., & Hasim, S. (2024). Digital transformation barriers in the Malaysian construction industry: staff competency, and company initiatives. In Advances in computer science research (pp. 109–118). https://doi.org/10.2991/978-94-6463-589-8_12
26. Silitonga, D. M., & Jin, O. F. (2024). Application of Artificial Intelligence (AI) in Construction Management: A Systematic Literature review. INVOTEK Jurnal Inovasi Vokasional Dan Teknologi, 23(3), 155–166. https://doi.org/10.24036/invotek.v23i3.1153.
27. Lyu, Y. (2024). Application of artificial intelligence in construction. Applied and Computational Engineering, 90(1), 26–34. https://doi.org/10.54254/2755-2721/90/20241707.
28. Razi, P., Sulaiman, S., Ali, M., Ramli, N., Saad, M., Jamaludin, O., & Doh, S. (2023). How artificial intelligence changed the construction industry in safety issues. IOP Conference Series Earth and Environmental Science, 1140(1), 012004. https://doi.org/10.1088/1755-1315/1140/1/012004.
29. Chen, K., Zhou, X., Bao, Z., Skibniewski, M. J., & Fang, W. (2024). Artificial intelligence in infrastructure construction: A critical review. *Frontiers of Engineering Management*. https://doi.org/10.1007/s42524-024-3128-5.
30. Aladağ, H., Güven, İ., & Balli, O. (2024). Contribution of artificial intelligence (AI) to construction project management processes: State of the art with scoping review method. Sigma Journal of Engineering and Natural Sciences – Sigma Mühendislik Ve Fen Bilimleri Dergisi, 1654–1669. https://doi.org/10.14744/sigma.2024.00125.
31. Shamim Ahmad Khan, H. Arivazhagan, Sudipto Kumar Sahu, B Ravinder, Varun Goel (2025). Internet of Things (IOT) In Smart Cities: Challenges and Opportunities. EPH - International Journal of Science and Engineering. ISSN): 2454-2016 https://doi.org/10.53555/ephijse.v11i1.305.

32. Sethi, D., N, M., Upadhyay, M., Islam, A., Bansode, G. S., Ravinder, B., & Band, G. (2025). Integration of Green Infrastructure in Urban Design: Enhancing Ecological And Social Resilience. Journal of Applied Bioanalysis, 11(02). https://doi.org/10.53555/jab.v11i2.210.
33. B Ravinder, N. (2025). AI Assistance in Human Resource Application Processing: Revolutionizing Recruitment and hiring – Applicants perspective. Journal of Informatics Education and Research, 5(2). https://doi.org/10.52783/jier.v5i2.2503
34. B. Ravinder, Dr. A.B. Saraswathi (2020). Literature Review of Cronbach alpha coefficient (A) And Mcdonald's Omega Coefficient (Ω), European Journal of Molecular & Clinical Medicine, 7(06), 2943-2949pp, ISSN 2515-8260. https://ssrn.com/abstract=4443362
35. B. Ravinder, Dr. A.B. Saraswathi (2020). Talent Turn Out with Special Reference to Civil Engineers Perspective - Reliability of the Instrument Using Principal Component Analysis Cronbach's Alpha and Omega, European Journal of Molecular & Clinical Medicine, 7(4), 943-951. https://ssrn.com/abstract=4442908
36. B. Ravinder, Fire Door Awareness Among the Stake Holders of Construction Industry (2020). International Journal of Application or Innovation in Engineering & Management (IJAIEM), 9(6), 63-68, June 2020, https://ssrn.com/abstract=3648824
37. B. Ravinder, Dr. A.B. Saraswathi (2020). Talent Turn Out with Special Reference to Civil Engineers Perspective - A Literature Review, International Journal of Management, 11(5), 416-4332, DOI: 10.34218/IJM.11.5.2020.0