Unveiling the Potential of AI Assistants: A Review of AI in Building Materials Selection

Andi Prasetiyo Wibowo[1]
[1] Centre for Manufacturing and Materials, Coventry University, Priory Street, Coventry, CV1 5FB, United Kingdom

Article Info

Article history:

Received June 2nd, 2024
Revised June 24th, 2024
Accepted July 18th, 2024

Keywords:

Artificial intelligence (AI),
Building materials,
Construction materials,
Efficiency,
Estimation,

ABSTRACT

Fast-advancing Artificial Intelligence (AI) has transformed many industries, including construction. AI offers innovative solutions to increase efficiency and effectiveness in various aspects of construction, one of which is selecting building materials. By reading relevant literature, this study aims to determine how much AI can help choose building materials so that projects go more easily and quickly. Using SCOPUS as its principal database, this study conducted a literature review. The method of this study begins with the process of filtering articles using the key string: ("artificial intelligence" OR AI) AND ("building materials" OR "construction materials") AND ("efficiency" OR "time" OR "cost") to find relevant articles. The research results show that AI can help improve time and cost efficiency in selecting building materials through various means, such as data analysis, material recommendations, cost optimisation, and performance estimation. In conclusion, this study shows that AI has much potential to make choosing building materials more efficient and effective, thus reducing building time, costs, and environmental damage. Still, it also dramatically impacts building monitoring and maintenance and task automation.

This is an open-access article under the [Creative Commons Attribution 4.0](#) International License.

Corresponding Author:

Andi Prasetiyo Wibowo,
Centre for Manufacturing and Materials, Coventry University,
Priory Street, Coventry, CV1 5FB, United Kingdom
Email: wibowoa@coventry.ac.uk, Phone No.: +44 790 3027797

1. INTRODUCTION

Modern developments in building materials technology have greatly influenced the improvement of construction. The discovery of innovative materials, such as ultra-lightweight concrete [1], corrosion-resistant steel for concrete reinforcement, and reinforced polymers [2], offers many benefits. The relationship between humans and humanoid robots will inevitably strengthen in the coming years, potentially leading to widespread adoption and serving as a form of social engagement [3], robotic technology and 3D printing in the construction field accelerate the construction process and enhance its accuracy [4], Thus allowing the development of complex and revolutionary structures. Therefore, it is essential for architects, engineers, and contractors to consistently stay updated on advancements in technology and make thoughtful choices regarding selecting appropriate materials for every construction project.

The successful completion of construction projects depends on the careful and efficient choice of building materials. The selection process is essential for determining the quality, duration, and result of the work to be done. The right resources could also reduce construction's environmental effects while improving a structure's strength, longevity, and service life. This intricate procedure for material selection must consider numerous factors, such as the structure's purpose, environmental conditions, material availability, and sustainability. Energy-efficient and long-lasting materials have the potential to result in considerable cost savings over time in energy usage and building maintenance [5]. Alternative materials such as lightweight brick, eco-friendly concrete, composite wood, and laminated bamboo may be viable options. Therefore, safe, long-lasting, and ecologically conscious buildings can be constructed with careful consideration of various issues and the careful selection of appropriate materials.

Determining the most suitable construction materials generates a complicated challenge. Despite the wide variety of materials, since each material has specific features and limitations, the process of selecting the most ideal one requires finding a balance between cost-effectiveness, sustainability (e.g. low carbon footprint), safety factors (e.g., due to seismic activity, or strong wind), and functionality (e.g., healthcare hygiene). Navigating through these complex factors can be a daunting task.

With the advancements in technology, particularly in the field of Artificial Intelligence (AI), the process of selecting building materials could also be revolutionised. Traditional methods of selecting building materials often rely on manual processes, which are time-consuming and might lead to errors. AI, on the other hand, can process large datasets quickly and efficiently, considering numerous factors such as cost, availability, sustainability, and performance characteristics of materials. Using AI algorithms, construction professionals can access real-time data on various building materials. [6], compare their properties and identify the most suitable options for specific project requirements. This approach ensures that decisions are based on evidence-backed analysis rather than subjective judgment, leading to more accurate selections of building materials that align with project goals and specifications. The advancement of AI in construction creates new prospects for improving efficiency, safety, and sustainability [7]. This paper will address and investigate these changes, focusing on the scope in which artificial intelligence is used and implemented in the building and construction sector, especially to explore how far the AI's ability to assist in the analysis and decision-making process while selecting suitable building materials.

This study adapts some part of a systematic literature review method to examine existing research and present a complete overview. Several literature review studies on artificial intelligence have been published, but they mainly focus on using AI in building materials selection. However, this paper will also discuss other areas like damage detection/monitoring systems, energy efficiency, predicting mechanical properties, i.e. compressive strength, and structural performance assessment. To the best of the authors' knowledge, there needs to be a more dedicated discussion on the relationship of artificial intelligence to the effectiveness of building materials selection. Therefore, to improve the ability of artificial intelligence to assist in the effective selection of building materials, a literature review is first necessary to ensure understanding. The findings of this study are likely to give valuable insights to stakeholders in the construction sector, paving the path for more widespread use of AI to build a safer, more sustainable, and efficient future.

2. RESEARCH METHOD

This article employs systematic review techniques even though it only partially satisfies the guidelines and references outlined in the implementation protocol for Systematic Literature Review reporting developed by M. J. Page et al. [8]. Consequently, the author must assert that the article's title is a systematic literature review. The process of composing this review article commences with a research question that aims to determine the extent of AI's advancements in the field of construction and building materials, particularly in its application and utilisation to enhance the efficiency of the selection of building materials and the efficiency of construction stages, including time and cost. The subsequent phase involves the search for articles from reputable and trusted databases, such as SCOPUS. Keywords guarantee consistency and prevent bias when conducting an article search. Following acquiring these articles, a selection process is implemented to identify pertinent articles that can address research inquiries. The results of selecting these articles are subsequently reviewed, traced, and presented in this article's results and discussion portions. To enhance the legibility and comprehension of this article, processed graphic forms, including images and graphs, will be included.

The process of gathering articles starts by creating research questions or determining the goal of the literature review. The primary objectives of this study are to assess the influence of AI on the construction industry and the development of building materials technology. Specifically, we aim to investigate how AI influences the selection of effective and efficient building materials. A compilation of essential keywords/strings was generated and structured to get the answer to this question in the following way: ("artificial intelligence" OR AI) AND ("building materials" OR "construction materials") AND ("efficiency" OR "time" OR "cost"). Subsequently, the key string is employed to retrieve articles from the SCOPUS database. The use of the Scopus database relies on the author's prior experience, which demonstrates that the Scopus database is a dependable repository of research articles. Figure 1 displays the outcomes of the article compilation. After searching and gathering articles, the metadata obtained from the search is incorporated into a reference manager program or software like Mendeley or Zotero. This software helps organise the articles and prevents any duplication. Adding article data to this reference manager programme significantly simplifies the screening/selection process. The screening or selection process is conducted through multiple steps, as depicted in Figure 3. This article will address articles that do not match the requirements, including those that will be discussed in detail. The purpose is to provide a comprehensive overview of the writing process and to demonstrate each stage leading up to the final display of an article that aligns with the objectives and research questions.

The author utilised AI-based software, specifically Gemini and claude.ai, to compile and match the selection results for this paper. Applications such as Grammarly and Quillbot were employed to enhance and verify grammar, facilitating readers' comprehension. The selected articles were examined more thoroughly using the typset.io and elicit.com applications. Additionally, the author utilised map-this.com software to generate a mind map of the article's contents, aiming for better understanding. The utilisation of AI-driven software is restricted solely to aiding in the compilation of articles. At the same time, the generation of ideas and the determination of the writing direction remain within the author's control. The author takes complete responsibility for the content of the writing.

3. RESULTS AND DISCUSSION

This section will give the findings of the search and data analysis conducted on previously gathered publications, which will then be synthesised into a review article. A search was conducted in the SCOPUS database using predetermined keywords/keywords, which yielded 168 publications (Figure 1). The SCOPUS Ai feature is included here as part of the first mapping of 168 articles that fulfil the search parameters (Figure 2). Based on the mapping, it is evident that among the 168 articles, there are three prominent topics: AI in building materials selection, Building materials, and Material Management. Hence, the primary objective of this review is to assess the level of advancement and use of artificial intelligence (AI) in automating the process of selecting building materials. A thorough selection and screening procedure must be conducted. Subsequently, the results/selection process effectively determined four articles that aligned with the intended goal of authoring this post. Figure 3 displays each of the stages of the complete selection outcomes.

While this paper primarily focuses on four selected articles, it also incorporates other documents as a starting point and introduction to the primary issue. The rationale for analysing the records that were not chosen is twofold: firstly, to present a comprehensive overview of the process involved in preparing a literature review, and secondly, to give readers further insights into the role of AI in construction and building materials. The content of this chapter is organised according to the stages of selection. It begins with papers that discuss AI but are unrelated to construction and building materials. Then, it includes articles that mention AI as suggestions for future research. Next, it focuses on the application of AI in construction and building materials. Finally, the discussion delves into a detailed analysis of the four selected articles.

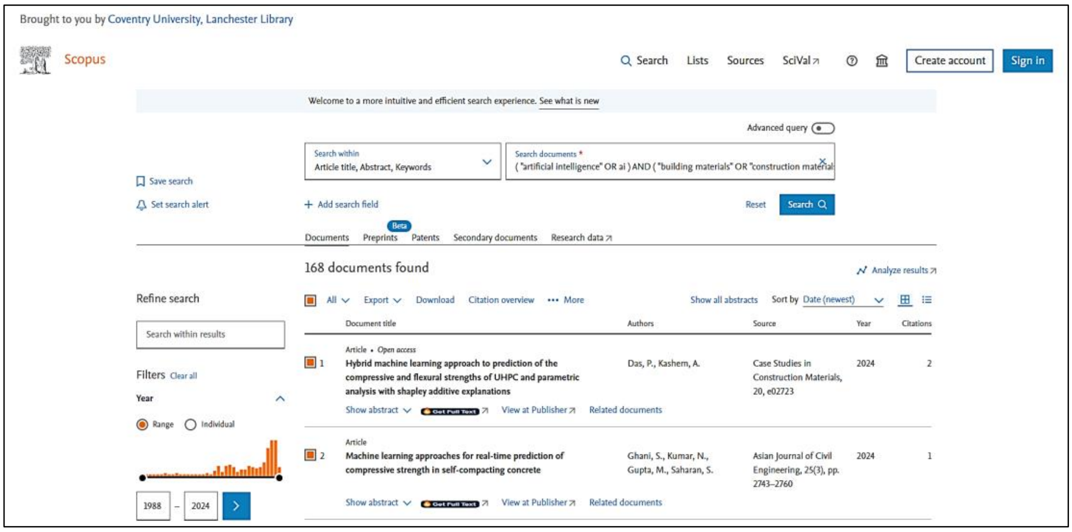

Figure 1. Search results in SCOPUS' database

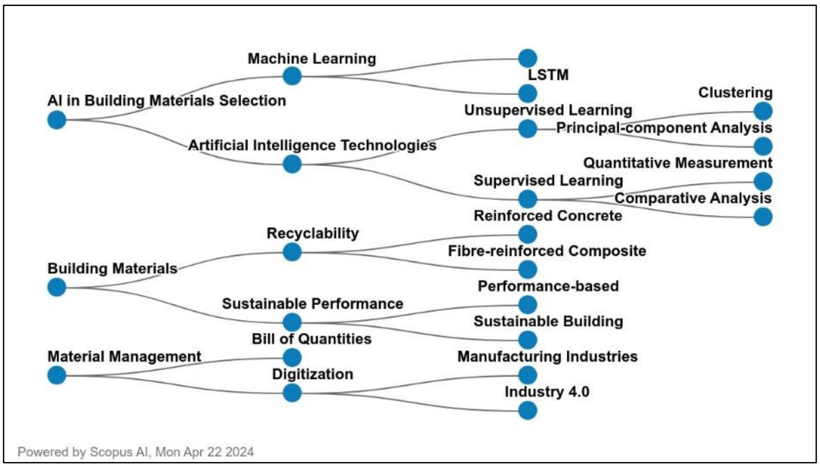

Figure 2. Mind Map generated from SCOPUS AI

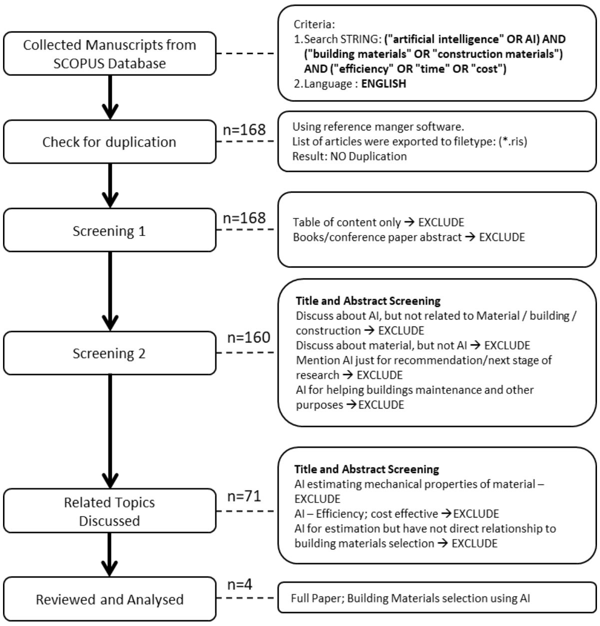

Figure 3. Flowchart of Selection Process

While conducting the literature review on using artificial intelligence (AI) in building material selection, several articles mentioned AI but were unrelated to building materials selection. One of those articles talks about the concept of applying AI to this domain as early as the late 1980s and early 1990s [9]. Another study proposed a routing algorithm leveraging AI to reduce travel and order-picking time in warehouse management [10]. The article demonstrated the potential of AI to improve efficiency in logistics and supply chain operations, but it also fell outside the scope of the current literature review. While we focus on AI's role in building materials, our review uncovered other interesting advancements in materials science. One study demonstrates the creation of highly robust and conductive carbonized bamboo aerogels (CBA) through a simple three-step process [11]. This innovative material has potential applications beyond construction, such as wearable strain sensors for human motion recognition when combined with silicone composites. Similarly, another study explores the use of advanced characterization techniques like X-ray diffraction (XRD) and electron microscopy (SEM) to analyze the structural changes occurring during the synthesis of geo-polymers [12]. The last two mentioned studies, though not directly related to AI, showcase the ongoing development of novel materials with unique properties that could benefit the construction industry in the future.

The filtering procedure of this literature review article also yields numerous articles that match the critical string criteria but do not necessarily meet the purpose of the literature study. Those studies, as the abstract mentioned, only provide insightful information and point up exciting directions for future research, especially in machine learning (ML) and artificial intelligence (AI). One study underscores the potential of AI for various applications within the construction industry, inviting further exploration in this area [13]. Another highlights the limitations of a current method for asbestos detection and suggests investigating machine learning as a more practical approach in the next phase [14]. Similarly, a separate study emphasizes the need for extensive knowledge of existing buildings, which could be facilitated by utilizing AI and machine learning alongside established technologies like BIM and GIS [15]. Meanwhile, research into concrete mixture properties suggests incorporating new learning techniques to improve them in future studies [16]. These references collectively point towards a future where AI and machine learning significantly advance construction processes and materials science.

3.1. The Rise of AI in Monitoring: From Bridges to Buildings

The future of monitoring across various infrastructure and construction projects is increasingly intertwined with Artificial Intelligence (AI). This section explores the diverse applications of AI in monitoring, showcasing its potential to revolutionize how we assess and manage the health of our built environment.

Firstly, AI is employed in bridges and buildings' structural health monitoring (SHM) systems. An integrated system for the Zhejiang Bridge utilizes AI for data management and decision-making, enabling proactive maintenance strategies [17]. Firstly, AI is employed in bridges and buildings' structural health monitoring (SHM) systems. An integrated system for the Zhejiang Bridge utilizes AI for data management and decision-making, enabling proactive maintenance strategies [18]. This technology extends beyond bridges, with research exploring the use of AI for monitoring street and road networks and the condition of power transformers [19] [20].

Beyond traditional monitoring techniques, AI offers innovative approaches to analyzing data. For instance, researchers have utilized convolutional neural networks (CNNs) to analyze images and classify road conditions based on surface quality [21]. Similarly, AI is being explored for analysing acoustic emission signals, potentially leading to improved methods for structural health monitoring [22].

The impact of AI extends beyond existing structures to the design and development of new materials. Studies are investigating AI algorithms to optimize the design of Cemented Hydraulic Backfill (CHB) used in underground construction, aiming to achieve desired strength levels more efficiently. [23]. Furthermore, AI has the potential to play a crucial role in corrosion control and protection strategies for existing infrastructure [24].

Looking beyond traditional infrastructure, AI is finding applications in building inspections. Research explores using AI alongside non-destructive inspection techniques like microwave technology to detect issues like tile separation [25]. Even in cultural heritage preservation, AI-based tools are being developed to assess the vulnerability of monuments, aiding in proactive conservation efforts [26].

In conclusion, these references paint a clear picture: AI is rapidly transforming the monitoring landscape across various aspects of construction and infrastructure. From bridges and roads to buildings and cultural heritage sites, AI offers a powerful toolkit for proactive monitoring, improved decision-making, and, ultimately, a more resilient built environment.

3.2. The Role of AI in Boosting Operational Efficiency and Reducing Costs

Artificial intelligence (AI) is revolutionizing various industries by enhancing efficiency and cost-effectiveness through innovative applications. For instance, adopting intelligent automatic detection, classification, and optimization in sawing production lines has led to a remarkable improvement in the wood processing sector. The comprehensive utilization value of optimized sawing timber using AI is 14.13% higher than that of manually marked sawing timber, highlighting significant resource use and operational efficiency gains [52].

In the construction industry, AI has developed advanced methods for materials design and supply chain management. An AI-based method for cement-slag concrete design balances economic and mechanical properties, ensuring cost-effective and high-performance materials [53]. Furthermore, AI tools facilitate the efficient analysis and management of building materials and technical resources and the automated recording of used and damaged resources on construction sites [54]. This capability optimizes resource allocation, minimizes wastage, and reduces overall project costs.

AI's role in selecting outsourcing suppliers is another area where its impact is profoundly felt. A new model incorporating the Analytic Hierarchy Process (AHP) with a Particle Swarm Optimization (PSO) algorithm offers a superior method for choosing suppliers based on quality, price, and delivery. This hybrid approach outperforms traditional methods like genetic algorithms and ant colony optimization, leading to more effective and cost-efficient supplier selection [55].

Moreover, AI aids in environmental sustainability within the construction sector. A method combining construction cost and carbon emission considerations mimics the traditional A+B (price-time bi-parameter) procurement method, effectively reducing greenhouse gas emissions [56]. Additionally, a web-based Decision Support System (DSS) accurately estimates construction and demolition waste (CDW) quantities for various building types. It proposes optimal end-of-life management alternatives considering economic and environmental criteria [57]. This system underscores the economic benefits of recycling concrete from building demolitions through a closed-loop material cycle, supported by a bi-objective mixed-integer linear optimization model that optimizes the location and number of sorting screens and defines material flows within a regional recycling network [58].

Lastly, AI accelerates the development of greener alternatives to traditional building materials. For instance, alkali-activated binders, which reduce CO2 emissions compared to conventional cement, benefit from AI's ability to swiftly determine optimal material formulations. Contribution AI expedites development and enhances environmental sustainability through user-friendly interfaces and efficient experimentation. [59]. By integrating AI into these processes, industries can achieve significant cost savings and operational efficiencies while contributing to environmental conservation.

3.3. AI-Driven Estimation for Enhanced Efficiency and Cost-Effectiveness in Construction

Artificial intelligence (AI) is becoming a cornerstone in enhancing efficiency and cost-effectiveness across various construction and building maintenance aspects. One notable application is in predicting the properties of construction materials. For instance, AI models such as multilayer perceptron neural networks and supervised machine learning methods like Bagging, AdaBoost, and Random Forest have been utilized to predict the ultrasonic pulse velocity of waste marble dust concrete, which is closely related to its density and compressive strength [60]. Additionally, the thermal conductivity coefficient of rubberized concrete can be accurately estimated using AI, contributing to better energy efficiency in buildings [61].

AI also plays a crucial role in predicting the durability of building materials. Methods like the Adaptive Neuro-Fuzzy Inference System (ANFIS), Genetic Programming (GP), and Multi-expression Programming (MEP) have been implemented to predict the biological corrosion of structures [62] , such as cement concrete (CC) and sulfur concrete (SC) in sewer systems, ensuring long-term durability and reducing maintenance costs [63]. Furthermore, the relationship between cost and building energy consumption has been thoroughly investigated using AI models like Extreme Learning Machine (ELM) and Teaching Learning Based Optimization (TLBO), revealing a strong positive correlation that helps optimise both economic and energy aspects of building management [64].

Energy efficiency is another critical area in which AI makes significant contributions. A hybrid simulation strategy that integrates AI techniques with the EnergyPlus™ building energy simulation tool has been proposed to predict the annual cooling energy consumption of residential buildings, particularly in regions like Hong Kong, enhancing the overall energy management of buildings [65]. Moreover, the performance analysis of wall insulation for energy efficiency has been improved using thermal conductivity predictors based on the Harmony Search (HS) algorithm [66].

AI's role extends to non-destructive testing and maintenance of buildings. A non-destructive system based on electrical tomography and machine learning analyses the moisture content in building materials like bricks and cement, utilizing special electrodes to ensure good contact with surfaces [67]. Similarly, thermal imaging integrated with AI, such as a convolutional neural network (CNN), allows for automated inspection and problem identification in high-temperature floor blocks, preserving the building structure while providing detailed analysis [68].

Regarding conservation and preservation, AI-driven expert systems have been created to identify the most effective repair methods for specific building materials and propose appropriate conservation techniques. This approach ensures systematic problem-solving, saving time and providing efficient conservation methods for heritage buildings [69].

Through these various applications, AI not only enhances the efficiency and cost-effectiveness of building construction and maintenance but also ensures the sustainability and longevity of the structures, making it an indispensable tool in modern construction practices.

3.4. Predicting the Strength Properties of Concrete Using AI

In recent years, artificial intelligence (AI) and machine learning (ML) techniques have gained significant traction in predicting the strength properties of concrete mixtures. Several studies have explored applying these advanced computational methods to estimate concrete's compressive strength, flexural strength, and other mechanical properties incorporating various materials and additives.

One area of focus is predicting compressive strength for concrete mixtures incorporating silica fumes and steel fibres [39], as well as the assessment of steel-fibre-reinforced concrete (SFRC) in terms of flexural strength (FS) prediction [40]. Additionally, researchers have applied multiple AI methods to find the most accurate input-output relationships within concrete mixtures [41], We are aiming to develop reliable predictive models. Furthermore, data-driven techniques like artificial neural networks (ANNs), genetic programming, and fuzzy logic have been employed to efficiently predict the 28-day strength of concrete [42]. While fuzzy logic algorithms have shown promising results, efforts have been made to streamline the rule-defining process by leveraging model tree approaches.

Extending the application of AI to novel materials, a study developed an AI model using machine learning algorithms to predict the compressive strength of Nano silica-concrete mixtures [43]. This model was trained on experimental data and incorporated information on Nano silica particle properties, demonstrating the potential of AI in optimizing the use of emerging nanomaterials in concrete. Moreover, researchers have conducted comprehensive reviews of successful ML and deep learning (DL) model applications for predicting concrete mechanical properties [44]. These reviews provide valuable insights and pave the way for further advancements in this field.

3.5. Concrete Additives and Waste Materials

In addition to traditional concrete mixtures, AI and ML techniques have been explored for predicting the properties of concrete incorporating waste materials and industrial by-products. One study [45] aimed to predict the compressive strength of concrete containing waste foundry sand (CCWFS) using a hybrid approach combining biogeography-based optimization (BBO) and artificial neural networks (ANNs), minimizing reliance on experimental activities. Similarly, supervised ML techniques, such as decision trees (DT) with XGBoost and Gradient Boosting, and support vector machines (SVM) with Bagging and AdaBoost, have been employed to predict the compressive strength of recycled coarse aggregate concrete (RCAC) [46]. Techniques like Shapley additive explanations (SHAP) analysis have also been used to understand the influence of input parameters and their interactions on RCAC's compressive strength. Furthermore, researchers have used AI to estimate the splitting-tensile strength of concrete containing recycled coarse aggregate (RCA) [47]. The performance of ANNs has also been evaluated for predicting the strength parameters of concrete containing waste foundry sand (CCWFS) [48], exploring sustainable alternatives to traditional concrete mixtures.

3.6. A.I for Other Applications in Building Materials and Construction

Beyond predicting strength properties, AI and ML techniques have also been employed in other areas related to concrete and building materials. For instance, a study [49] utilized AI and ML to predict steel's time-temperature-transformation (TTT) curve, a crucial parameter in material design and processing, using limited experimental data. When exposed to abrupt thermal loads, soft computational approaches have been applied to analyze the thermoelastic reaction of advanced building materials, such as concrete sandwich beams with transversely graded composite face sheets [50]. These investigations demonstrate the versatility of AI and ML techniques in addressing various challenges in structural engineering and building materials.

Overall, the presented references highlight the growing adoption of AI and ML techniques in predicting the strength properties of concrete mixtures, optimizing the use of sustainable materials and waste products, and addressing various challenges in the construction and materials science domains [51]. As these techniques evolve, their applications in building materials are expected to expand, leading to more efficient and sustainable practices.

The role of AI in construction material selection will be the primary emphasis of this review; nevertheless, the impact of AI goes much beyond this sector. Design, planning, execution, and maintenance are just a few areas of the construction workflows that AI is transforming.

One exciting application lies in automated construction processes. Research explores using AI robotics for tasks like wooden residential construction, paving the way for greater efficiency and potentially lower costs [27]. This technology can automate repetitive tasks currently performed by human workers, such as framing, panelling, and installation. By reducing reliance on manual labour, AI robots could significantly shorten construction times, leading to faster project completion and lower costs for homeowners and developers. Furthermore, AI also influences the design and construction of intelligent interiors. Studies delve into the development of AI-based materials that enhance the indoor environment and living experiences through advanced technology integration [28]

Beyond the physical structure, AI plays a role in project management and optimization. For instance, research explores using AI models to support contractors in price negotiations [29] and manage sustainable supply chains within the construction materials industry [30]. AI can even predict greenhouse gas emissions during construction, allowing for more environmentally friendly practices [31].

For the construction phase, AI-powered 3D printing offers exciting possibilities. Researchers are actively exploring how machine learning can improve this technology for efficient and precise construction [32]. Additionally, AI is being harnessed for robot-assisted object detection during building inspections [33] and even autonomous building maintenance with the help of nanotechnology [34].

AI further enhances data management and optimization. Semantic web technologies are being investigated to support building performance assessment, allowing continuous improvement [35]. Similarly, AI platforms can improve the quality, efficiency, and standardization of visual inspections [36]. AI can even optimize construction scheduling, with research demonstrating solutions for minimizing crane working time through algorithms like ant colony optimization [37].

Finally, AI is being used to support sustainable design decisions. By integrating life cycle assessment (LCA) with AI, researchers are developing models to help project owners and architects select building structures and materials that minimize environmental impact and total costs throughout the building's lifespan [38].

In conclusion, these diverse applications highlight the immense potential of AI to transform the construction industry, making it more efficient, sustainable, and intelligent from conception to completion.

3.7. MAIN FINDINGS: Integrating Artificial Intelligence in Construction Material Evaluation and Decision Support.

Integrating artificial intelligence (AI) and advanced optimization techniques is transforming the construction industry by enhancing the efficiency and accuracy of material selection processes. The main findings of this research revolve around four key references. First of all, a framework that integrates system dynamics (SD) and ant colony optimization (ACO) modules to promote sustainable and environmentally friendly practices in the selection of building materials based on LEED credits and costs is proposed in References [70] and [71], which the author determined to be the same study. This approach demonstrates the potential of integrating AI techniques with sustainability goals in the construction industry.

Then, Reference [72] presents a hybrid approach that combines artificial intelligence methods, such as case-based reasoning and neural networks, with traditional techniques like regression analysis. This combination aims to develop accurate estimates of resource requirements, including construction material quantities, in project planning and execution.

Next, Reference [73] introduces a theoretical evaluation model based on decision support methods for selecting residential construction materials and elements. This model provides a structured approach to material selection, considering various factors relevant to residential construction projects.

Lastly, reference [74] highlights the potential of AI-based approaches to improve material selection in the construction industry. By leveraging AI techniques, this study suggests that the time, costs, and errors associated with manual material selection methods can be reduced, leading to more efficient and accurate decision-making processes.

Despite not being selected as the primary references, other references can be considered because of their relevance to the research objectives. Reference [75] explores the application of AI and image processing techniques to reuse steel in the construction industry, contributing to sustainable practices and material conservation. Reference [76] evaluates the performance of different machine learning techniques, such as Multilayer Perceptron (MLP), Radial Basis Function (RBF), and Support Vector Machine (SVM), for the detection and classification of common building materials like concrete, red brick, and Oriented Strand Board (OSB) boards.

By encompassing these references, the main findings chapter offers a comprehensive overview of the research outcomes, including AI-based frameworks for sustainable material selection, hybrid approaches combining AI and traditional techniques for resource estimation, theoretical models for residential construction material selection, and the potential of AI-based approaches to improve material selection efficiency. Additionally, the chapter acknowledges the relevance of AI and image processing techniques in steel reuse and building material detection, highlighting the broader applications of these technologies in the construction industry. For comparison, Table 1 shows the selected paper's method, research objectives, and practical implications.

Table 1. Method, Research Objectives, and Practical Implications of Selected Paper

PAPER CODE Title/references	**PAPER-1** Selecting Sustainable Building Materials Using System Dynamics And Ant Colony Optimization (Marzouk et al. – 2012) [71]	**PAPER-2** Preliminary Resource-based Estimates Combining Artificial Intelligence Approaches and Traditional Techniques (DeSoto and Adey – 2016) [72]	**PAPER-3** Model For Residential House Element And Material Selection By Neutrosophic MULTIMOORA Method (Zavadskas et al. – 2017) [73]	**PAPER-4** Revolutionizing Material Selection in Construction 4.0: A Comparative Analysis of Artificial Intelligence Technologies (Kaulage et al. – 2023) [74]
Methods Used	- System Dynamics module for material selection based on Leadership in Energy and Environmental Design (LEED) credits. - Ant Colony Optimization module for green building material selection.	- Regression analysis, neural networks, and case-based reasoning were utilized. - Backward elimination technique was employed to evaluate the variables. - Historical data was used to estimate Construction Material Quantities (CMQs) of target structures.	- Step-Wise Weights Assessment Ratio Analysis (SWARA) method for criteria weighting evaluation. - Single-valued neutrosophic set for decision-making model.	- Supervised and Unsupervised Learning. - Decision trees, Neural networks, K-means clustering, Principal component analysis.
Research Objectives (RO)	- Develop framework for sustainable material selection in residential buildings. - Optimize material selection based on LEED credits and costs.	- Combine AI with traditional techniques for accurate resource-based cost estimates. - Improve decision support for project managers and decision makers.	- Develop a theoretical model for residential house construction materials selection. - Implement the Multi-Objective Optimization on the basis of a Ratio Analysis plus the full Multiplicative form (MULTIMOORA) method for single-family residential building projects. - Assess building elements and materials	- Analyse AI technologies for material selection in Construction 4.0. - Compare supervised and unsupervised learning, neural networks, and clustering algorithms.

			for sustainability in single-family houses.	
Practical Implications	- Framework aids in selecting green building materials with LEED credits. - Integrates environmental and economic constraints for sustainable material selection.	- Combining AI and traditional techniques for accurate resource-based cost estimates. - Improved decision support for project managers and better tracking mechanisms. - Potential for use in various infrastructure projects and other structures. - Integration of learning, adjusting, and estimating concepts for better estimates.	- Offers decision support for single-family house materials and elements selection. - Enhances sustainability in building design through material selection criteria. - Provides a theoretical model for creating a decision support system.	- AI enhances material selection in Construction 4.0 for high-performance buildings. - Reduces time, costs, and errors in manual selection methods.

It is apparent from the four selected papers that three of them (PAPER 1, 3, and 4) concentrate on the weight of the criteria for selecting building materials. In contrast, PAPER-2 concentrates on cost efficiency in selecting building materials. For additional information, refer to figures 4, 5, 6, and 7, which illustrate the mapping of papers 1, 2, 3, and 4, respectively.

Figure 4. Mind Map of Paper-1 [71]

Figure 5. Mind Map of Paper-2 [72]

Figure 6. Mind Map of Paper-3 [73]

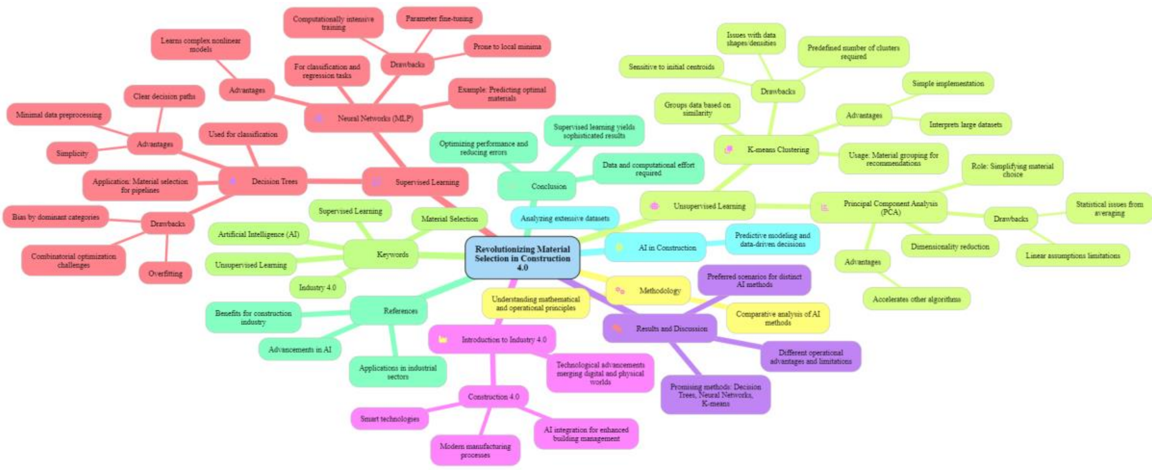

Figure 7. Mind Map of Paper-4 [74]

The construction and industrial sectors are increasingly recognizing the significance of sustainable practices and minimizing environmental impact, driven by growing concerns about the ecological consequences of their activities and the need for responsible development. Several articles emphasize the importance of selecting environmentally friendly materials and incorporating green rating systems like LEED to promote sustainability in building design and construction.

Concurrently, advancements in artificial intelligence (AI) and machine learning (ML) techniques are transforming various processes within these domains. Multiple articles highlight the application of these technologies for material selection, cost estimation, predictive analytics, and handling large datasets. By identifying patterns and making informed decisions, AI and ML are improving the efficiency and accuracy of estimations, ultimately enhancing decision-making processes in these sectors.

Another notable area of emphasis is integrating advanced computational methods, such as neural networks, regression analysis, and case-based reasoning. These techniques enhance the accuracy and efficiency of estimations and decision-making processes in construction and industrial settings. By leveraging sophisticated computational methods, stakeholders can make more informed decisions and optimize their operations.

Multi-criteria decision-making approaches are also commonly utilized to evaluate and select optimal alternatives based on various criteria, such as cost, environmental impact, and material properties. Techniques like the SWARA method and neutrosophic MULTIMOORA are employed to rank and select the best options, considering multiple factors simultaneously. This approach ensures that decisions are made holistically, considering all relevant aspects rather than focusing on a single criterion.

Despite advancements in technology and computational methods, the articles highlight data availability's challenges and limitations. The accuracy and reliability of estimations and predictions are often hindered by a lack of comprehensive data or the unavailability of similar cases or detailed project documentation. Addressing these data limitations is crucial for enhancing the effectiveness of the employed techniques and methods.

While the primary application areas discussed in the articles are the construction and industrial sectors, the principles and methodologies can be extended to other domains. AI, advanced computational methods, and multi-criteria decision-making approaches can be adapted to improve processes, optimize resources, and make informed decisions across various industries.

The articles emphasize the importance of expert input and feedback throughout these decision-making processes. Experts play a vital role in determining criteria weights, validating models, and providing practical insights to enhance the reliability of the outcomes. Their domain knowledge and experience ensure that the techniques and methods align with real-world practices and considerations.

4. CONCLUSION

In conclusion, a growing body of research underscores the transformative potential of Artificial Intelligence (AI) in construction material selection. This review has examined various studies demonstrating how AI empowers construction professionals to make informed decisions throughout the building process. By leveraging AI's analytical capabilities, the selection of materials can transcend traditional considerations like cost and strength, leading to a more holistic approach to those factors in long-term performance, sustainability, and project-specific needs.

The keyword mapping in this research can be used to lead and as a foundation for searching related papers for future research. For example, the study found that Ant Colony Optimization or Step-Wise Weights Assessment Ratio Analysis (SWARA) could be explored using A.I. to help decide the optimum and efficient selection of building materials. From this point, future works could utilize the same method to be improved or to find different approaches. Meanwhile, other findings that can be observed from the study on how A.I. can revolutionize material selection:

- Data analysis: AI can process large amounts of material data to help identify optimal materials.
- Cost optimization: AI can help with accurate cost estimation and identify cost-effective material alternatives.
- Performance forecasting: AI can predict long-term material performance, helping to select durable, low-maintenance materials.
- Task automation: AI can automate repetitive tasks, such as data collection and analysis, freeing professionals' time to focus on more strategic aspects.

- Material recommendations: AI can provide material recommendations that match project needs and budget.

By harnessing the power of AI, construction professionals can leverage data-driven insights, streamline decision-making processes, and unlock new avenues for innovation. The ability to process vast amounts of material data empowers AI systems to identify optimal materials that meet project specifications while considering cost, durability, and environmental impact. Furthermore, AI-driven material recommendations can seamlessly align with project needs and budgetary constraints, ensuring optimal resource allocation and cost optimization.

Moreover, AI's forecasting capabilities extend beyond material selection, enabling professionals to predict long-term material performance and make informed choices prioritising durability and low-maintenance requirements. This proactive approach enhances the longevity of structures and contributes to cost savings over the building's lifespan.

Equally significant is AI's potential to automate repetitive tasks, such as data collection and analysis, thereby freeing up valuable time and resources for construction professionals to focus on more strategic and value-adding aspects of their work. Combining human expertise and AI-driven automation creates a harmonious ecosystem where efficiency and productivity thrive.

The next step derived from this research is developing and perfecting the algorithm regarding the effectiveness of building materials selection. Other studies may be conducted, but not limited to exploration development and creating software that can be used to calculate and extract information about the best options/choices regarding building materials selection. Studies in specific regions are also attractive to discuss since different structure types, building architecture, and other factors like the availability of materials, regulation, and standardization could become a concern and influence factor.

REFERENCES

[1] Q. L. Yu, P. Spiesz, and H. J. H. Brouwers, “Ultra-lightweight concrete: Conceptual design and performance evaluation,” *Cem. Concr. Compos.*, vol. 61, pp. 18–28, Aug. 2015, doi: 10.1016/j.cemconcomp.2015.04.012.

[2] L. Mohammed, M. N. M. Ansari, G. Pua, M. Jawaid, and M. S. Islam, “A Review on Natural Fiber Reinforced Polymer Composite and Its Applications,” *Int. J. Polym. Sci.*, vol. 2015, pp. 1–15, 2015, doi: 10.1155/2015/243947.

[3] T. Mahendarto, “From Artificial Intelligence to Artificial Consciousness: An Interior Design Implication,” *J. Artif. Intell. Archit.*, vol. 2, no. 1, pp. 41–52, Feb. 2023, doi: 10.24002/jarina.v2i1.6627.

[4] Z. Xu, T. Song, S. Guo, J. Peng, L. Zeng, and M. Zhu, “Robotics technologies aided for 3D printing in construction: a review,” *Int. J. Adv. Manuf. Technol.*, vol. 118, no. 11–12, pp. 3559–3574, Feb. 2022, doi: 10.1007/s00170-021-08067-2.

[5] Z. Wu, “Performance analysis of new energy-saving and environment-friendly materials for building decoration based on the whole life cycle,” *J. Exp. Nanosci.*, vol. 18, no. 1, p. 2170358, Dec. 2023, doi: 10.1080/17458080.2023.2170358.

[6] S. O. Abioye *et al.*, “Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges,” *J. Build. Eng.*, vol. 44, p. 103299, Dec. 2021, doi: 10.1016/j.jobe.2021.103299.

[7] Y. Pan and L. Zhang, “Roles of artificial intelligence in construction engineering and management: A critical review and future trends,” *Autom. Constr.*, vol. 122, p. 103517, Feb. 2021, doi: 10.1016/j.autcon.2020.103517.

[8] M. J. Page *et al.*, “The PRISMA 2020 statement: An updated guideline for reporting systematic reviews,” *Int. J. Surg.*, vol. 88, p. 105906, Apr. 2021, doi: 10.1016/j.ijsu.2021.105906.

[9] J. C. Perkowski, “Technical trends in the E and C business: The next 10 years,” *J. Constr. Eng. Manag.*, vol. 114, no. 4, pp. 565–576, 1988, doi: 10.1061/(ASCE)0733-9364(1988)114:4(565).

[10] K. Srivilas and P. Cherntanomwong, “Routing algorithm in warehouse with congestion consideration using an ACO with VLC support,” presented at the 2017 International Electrical Engineering Congress, iEECON 2017, 2017. doi: 10.1109/IEECON.2017.8075830.

[11] W.-B. Zhu *et al.*, “High-Performance Fiber-Film Hybrid-Structured Wearable Strain Sensor from a Highly Robust and Conductive Carbonized Bamboo Aerogel,” *ACS Appl. Bio Mater.*, vol. 3, no. 12, pp. 8748–8756, 2020, doi: 10.1021/acsabm.0c01128.

[12] M. Taxiarchou, D. Panias, C. Panagiotopoulou, A. Karalis, and C. Dedelousdis, “Study on the suitability of volcanic amorphous aluminosilicate rocks (perlite) for the synthesis of geopolymer-based concrete,” presented at the ASTM Special Technical Publication, 2013, pp. 34–53. doi: 10.1520/STP156620120077.
[13] D. Kumar, M. Kamran, C. Zhang, L. Wang, H. Zhai, and S. Demirkesen, “Evaluating the Impact of Contracting and Procurement Methods on Energy and Carbon Emissions Reduction in the Public Construction Sector,” presented at the ASCE Inspire 2023: Infrastructure Innovation and Adaptation for a Sustainable and Resilient World - Selected Papers from ASCE Inspire 2023, 2023, pp. 886–894. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85179855022&partnerID=40&md5=ebc1cedf0fd7d0a1e15af26e53c2df1b
[14] V. Arnold, M. Ashkerov, and S. B. Globa, “Methods for Automatic Detection of Asbestos in Construction Materials,” presented at the Lecture Notes in Networks and Systems, 2021, pp. 1355–1361. doi: 10.1007/978-3-030-69415-9_149.
[15] F. Aldebei and M. Dombi, “Mining the built environment: Telling the story of urban mining,” *Buildings*, vol. 11, no. 9, 2021, doi: 10.3390/buildings11090388.
[16] J. A. Becerra-Duitama and D. Rojas-Avellaneda, “Pozzolans: A review,” *Eng. Appl. Sci. Res.*, vol. 49, no. 4, pp. 495–504, 2022, doi: 10.14456/easr.2022.49.
[17] B. Chen, X. Wang, D. Sun, and X. Xie, “Integrated system of structural health monitoring and intelligent management for a cable-stayed bridge,” *Sci. World J.*, vol. 2014, 2014, doi: 10.1155/2014/689471.
[18] G. Hong, X.-P. Wang, J. Lee, Y.-C. Loo, and M. Blumenstein, “Modelling long-term bridge deterioration at structural member level using Artificial Intelligence techniques,” presented at the Applied Mechanics and Materials, 2011, pp. 444–453. doi: 10.4028/www.scientific.net/AMM.99-100.444.
[19] Y. E. Vasiliev, M. A. Fineeva, E. V. Kotlyarskiy, and I. Y. Sarichev, “Intellectualization of the Monitoring Process of Street and Road Network Objects,” presented at the 2021 Intelligent Technologies and Electronic Devices in Vehicle and Road Transport Complex, TIRVED 2021 - Conference Proceedings, 2021. doi: 10.1109/TIRVED53476.2021.9639133.
[20] J.-L. Wei, G.-J. Zhang, M. Dong, H.-B. Mu, and Z. Yan, “Research progress on insulation condition estimation for oil-immersed power transformer,” presented at the Proceedings of the International Symposium on Electrical Insulating Materials, 2008, pp. 32–35. doi: 10.1109/ISEIM.2008.4664436.
[21] T. Ishtiak, S. Ahmed, M. H. Anila, S. Islam, R. Shelim, and T. Farah, “Road state classification of Bangladesh with convolutional neural network approach,” presented at the WMSCI 2019 - 23rd World Multi-Conference on Systemics, Cybernetics and Informatics, Proceedings, 2019, pp. 129–134. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85074160745&partnerID=40&md5=6168be04b3232bbf06462de9f909f14e
[22] C. Scuro, R. S. Olivito, F. Lamonaca, and D. L. Carnì, “Structural Health Monitoring Based on Artificial Intelligence Algorithm and Acoustic Emission Analysis,” presented at the Lecture Notes in Civil Engineering, 2021, pp. 258–266. doi: 10.1007/978-3-030-64908-1_24.
[23] E. Sadrossadat, H. Basarir, A. Karrech, R. Durham, A. Fourie, and H. Bin, “The optimization of cemented hydraulic backfill mixture design parameters for different strength conditions using artificial intelligence algorithms,” presented at the Springer Series in Geomechanics and Geoengineering, 2020, pp. 219–227. doi: 10.1007/978-3-030-33954-8_28.
[24] P. R. Roberge, “Tools for corrosion intelligence,” presented at the Applications of Artificial Intelligence in Engineering, 1994, pp. 407–414. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-0028553388&partnerID=40&md5=197294974b74b552ce0aeffe221cb741
[25] T. Honda, T. Tanaka, S. Doi, S. Uchida, and M. Q. Feng, “Visualization of voids between tile and concrete by multi-layered scanning method with electromagnetic waves,” *J. Robot. Mechatron.*, vol. 31, no. 6, pp. 863–870, 2019, doi: 10.20965/jrm.2019.p0863.
[26] R. Ortiz and P. Ortiz, “Vulnerability Index: A New Approach for Preventive Conservation of Monuments,” *Int. J. Archit. Herit.*, vol. 10, no. 8, pp. 1078–1100, 2016, doi: 10.1080/15583058.2016.1186758.
[27] H. Abaza, A. Clark, A. Schwartz, H. J. Ducre, and D. A. Guerra-Zubiaga, “INDUSTRIALIZING RESIDENTIAL CONSTRUCTION USING ARTIFICIAL INTELLIGENT (AI) ROBOTICS,” presented at the ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE), 2022. doi: 10.1115/IMECE2022-96675.

[28] Z. Shaikh, T. Naaz, and B. Rajput, “Intelligent Flooring Systems in Interiors-Exploring the Impact on Well-Being,” presented at the Lecture Notes in Mechanical Engineering, 2022, pp. 361–375. doi: 10.1007/978-981-19-0296-3_33.
[29] S.-S. Leu, P. V. Hong Son, and P. T. Hong Nhung, “Optimize negotiation price in construction procurement using Bayesian Fuzzy Game Model,” *KSCE J. Civ. Eng.*, vol. 19, no. 6, pp. 1566–1572, 2015, doi: 10.1007/s12205-014-0522-2.
[30] K.-S. Liu and M.-H. Lin, “Performance assessment on the application of artificial intelligence to sustainable supply chain management in the construction material industry,” *Sustain. Switz.*, vol. 13, no. 22, 2021, doi: 10.3390/su132212767.
[31] T. Li, E. Zhu, Z. Bai, W. Cai, H. Jian, and H. Liu, “Predicting and assessing greenhouse gas emissions during the construction of monorail systems using artificial intelligence,” *Environ. Sci. Pollut. Res.*, vol. 31, no. 8, pp. 12229–12244, 2024, doi: 10.1007/s11356-023-31783-z.
[32] S. Geng, Q. Luo, K. Liu, Y. Li, Y. Hou, and W. Long, “Research status and prospect of machine learning in construction 3D printing,” *Case Stud. Constr. Mater.*, vol. 18, 2023, doi: 10.1016/j.cscm.2023.e01952.
[33] I. Muhammad, K. Ying, M. Nithish, J. Xin, Z. Xinge, and C. C. Cheah, “Robot-Assisted Object Detection for Construction Automation: Data and Information-Driven Approach,” *IEEEASME Trans. Mechatron.*, vol. 26, no. 6, pp. 2845–2856, 2021, doi: 10.1109/TMECH.2021.3100306.
[34] N. D. Cortiços, “Self-learning and self-repairing technologies to establish autonomous building maintenance,” presented at the MATEC Web of Conferences, 2019. doi: 10.1051/matecconf/201927804004.
[35] U. J. Pont, N. Ghiassi, S. Fenz, J. Heurix, and A. Mahdavi, “SEMERGY: Application of semantic web technologies in performance-guided building design optimization,” *J. Inf. Technol. Constr.*, vol. 20, pp. 107–120, 2015.
[36] D. Blom, I. Berchenko, F. Samie, and D. Frajberg, “Shell Autonomous Integrity Recognition - Machine Vision Application for Inspections,” presented at the Society of Petroleum Engineers - ADIPEC 2022, 2022. doi: 10.2118/211838-MS.
[37] P. Hirsch, A. Palfi, and M. Gronalt, “Solving a time constrained two-crane routing problem for material handling with an ant colony optimisation approach: An application in the roof-tile industry,” *Int. J. Prod. Res.*, vol. 50, no. 20, pp. 6005–6021, 2012, doi: 10.1080/00207543.2011.640957.
[38] C.-C. Wei, C.-C. Hsiang, and T.-C. Shan, “Decision support model with life cycle assessment for building in design phase,” presented at the 31st International Symposium on Automation and Robotics in Construction and Mining, ISARC 2014 - Proceedings, 2014, pp. 966–971. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84912564129&partnerID=40&md5=57061366d79d5545d922ed1484d0e0b2
[39] S. S. Sahota, H. C. Arora, A. Kumar, K. Kumar, and H. S. Rai, “ML-Based Computational Model to Estimate the Compressive Strength of Sustainable Concrete Integrating Silica Fume and Steel Fibers,” presented at the Lecture Notes in Networks and Systems, 2023, pp. 231–244. doi: 10.1007/978-3-031-31153-6_20.
[40] M. Anjum, K. Khan, W. Ahmad, A. Ahmad, M. N. Amin, and A. Nafees, “New SHapley Additive ExPlanations (SHAP) Approach to Evaluate the Raw Materials Interactions of Steel-Fiber-Reinforced Concrete,” *Materials*, vol. 15, no. 18, 2022, doi: 10.3390/ma15186261.
[41] H. N. Muliauwan, D. Prayogo, G. Gaby, and K. Harsono, “Prediction of Concrete Compressive Strength Using Artificial Intelligence Methods,” presented at the Journal of Physics: Conference Series, 2020. doi: 10.1088/1742-6596/1625/1/012018.
[42] V. Nagarkar, P. Kulkarni, and S. Londhe, “Prediction of Concrete Compressive Strength Using Fuzzy Logic and Model Tree,” in *Lecture Notes in Civil Engineering*, vol. 74, 2020, pp. 231–240. doi: 10.1007/978-981-15-4079-0_20.
[43] V. K. Bhadke, “Prediction of Concrete Strength with Artificial Neural Networks Enhanced by Nano-Silica,” presented at the 2023 10th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering, UPCON 2023, 2023, pp. 959–963. doi: 10.1109/UPCON59197.2023.10434809.
[44] M. Mohtasham Moein *et al.*, “Predictive models for concrete properties using machine learning and deep learning approaches: A review,” *J. Build. Eng.*, vol. 63, 2023, doi: 10.1016/j.jobe.2022.105444.
[45] R. Kazemi and M. Z. Naser, “Towards sustainable use of foundry by-products: Evaluating the compressive strength of green concrete containing waste foundry sand using hybrid biogeography-

based optimization with artificial neural networks," *J. Build. Eng.*, vol. 76, 2023, doi: 10.1016/j.jobe.2023.107252.

[46] M. N. Amin, W. Ahmad, K. Khan, A. Ahmad, S. Nazar, and A. A. Alabdullah, "Use of Artificial Intelligence for Predicting Parameters of Sustainable Concrete and Raw Ingredient Effects and Interactions," *Materials*, vol. 15, no. 15, 2022, doi: 10.3390/ma15155207.

[47] X. Pan *et al.*, "Use of Artificial Intelligence Methods for Predicting the Strength of Recycled Aggregate Concrete and the Influence of Raw Ingredients," *Materials*, vol. 15, no. 12, 2022, doi: 10.3390/ma15124194.

[48] A. Tavana Amlashi, P. Alidoust, M. Pazhouhi, K. Pourrostami Niavol, S. Khabiri, and A. R. Ghanizadeh, "AI-based formulation for mechanical and workability properties of eco-friendly concrete made by waste foundry sand," *J. Mater. Civ. Eng.*, vol. 33, no. 4, 2021, doi: 10.1061/(ASCE)MT.1943-5533.0003645.

[49] Z. Gao, X. Fan, T. Xia, W. Xue, and S. Gao, "Research on TTT Curve of Alloy structural Steel based on Machine Learning," presented at the Journal of Physics: Conference Series, 2023. doi: 10.1088/1742-6596/2459/1/012139.

[50] D. Li, P. Wang, N. Sarhan, and M. Sharaf, "Soft computational approach on the thermoelastic assessment of the sandwich beams with transversely functionally graded composite concrete face-sheets as an advanced building material," *Mech. Adv. Mater. Struct.*, 2023, doi: 10.1080/15376494.2023.2227413.

[51] D. A. Joshi and M. Shewale, "Structural Engineering: Trends, Applications, and Advances," in *Data Science for Civil Engineering: A Beginner's Guide*, 2023, pp. 89–123. doi: 10.1201/9781003316671-4.

[52] M. Ji, W. Zhang, X. Diao, G. Wang, and H. Miao, "Intelligent Automation Manufacturing for Betula Solid Timber Based on Machine Vision Detection and Optimization Grading System Applied to Building Materials," *Forests*, vol. 14, no. 7, 2023, doi: 10.3390/f14071510.

[53] F. Zhu, X. Wu, M. Zhou, M. M. S. Sabri, and J. Huang, "Intelligent Design of Building Materials: Development of an AI-Based Method for Cement-Slag Concrete Design," *Materials*, vol. 15, no. 11, 2022, doi: 10.3390/ma15113833.

[54] A. Ginzburg, O. Kuzina, and A. Ryzhkova, "Unified resources marking system as a way to develop artificial intelligence in construction," presented at the IOP Conference Series: Materials Science and Engineering, 2018. doi: 10.1088/1757-899X/365/6/062021.

[55] Y. Li, K. Ding, L. Wang, W. Zheng, Z. Peng, and S. Guo, "An optimizing model for solving outsourcing supplier selecting problem based on particle swarm algorithm," *J. Ind. Prod. Eng.*, vol. 35, no. 8, pp. 526–534, 2018, doi: 10.1080/21681015.2018.1533893.

[56] T.-H. Fu and W.-D. Yu, "A pilot study of A+C method for reducing GHG emissions in construction industry," presented at the 2011 2nd International Conference on Artificial Intelligence, Management Science and Electronic Commerce, AIMSEC 2011 - Proceedings, 2011, pp. 6928–6931. doi: 10.1109/AIMSEC.2011.6010909.

[57] G. Banias, C. Achillas, C. Vlachokostas, N. Moussiopoulos, and I. Papaioannou, "A web-based Decision Support System for the optimal management of construction and demolition waste," *Waste Manag.*, vol. 31, no. 12, pp. 2497–2502, 2011, doi: 10.1016/j.wasman.2011.07.018.

[58] N. Tsydenova, T. Becker, and G. Walther, "Optimised design of concrete recycling networks: The case of North Rhine-Westphalia," *Waste Manag.*, vol. 135, pp. 309–317, 2021, doi: 10.1016/j.wasman.2021.09.013.

[59] C. Völker, S. Kruschwitz, B. M. Torres, R. Firdous, G. A. Zia, and D. Stephan, "ACCELERATING THE SEARCH FOR ALKALI-ACTIVATED CEMENTS WITH SEQUENTIAL LEARNING," presented at the fib Symposium, 2022, pp. 153–161. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85143896280&partnerID=40&md5=142862124eecec3f2a96bef49b4a7176

[60] D. Yang *et al.*, "Investigating the Ultrasonic Pulse Velocity of Concrete Containing Waste Marble Dust and Its Estimation Using Artificial Intelligence," *Materials*, vol. 15, no. 12, 2022, doi: 10.3390/ma15124311.

[61] S. İpek, G. Özer Yaman, and C. Kılınç, "Investigation of thermal conductivity of rubberized concrete as an energy-efficient building material and modeling by artificial intelligence," *Arch. Civ. Mech. Eng.*, vol. 23, no. 3, 2023, doi: 10.1007/s43452-023-00701-y.

[62] D. Bajno, A. Grzybowska, and Ł. Bednarz, "Old and modern wooden buildings in the context of sustainable development," *Energies*, vol. 14, no. 18, 2021, doi: 10.3390/en14185975.
[63] M. R. Sabour, G. A. Dezvareh, and K. P. Niavol, "Application of Artificial Intelligence Methods in Modeling Corrosion of Cement and Sulfur Concrete in Sewer Systems," *Environ. Process.*, vol. 8, no. 4, pp. 1601–1618, 2021, doi: 10.1007/s40710-021-00542-y.
[64] Z. Wei, Y. Zandi, M. Gholizadeh, A. Selmi, A. Roco-Videla, and U. Konbr, "On the optimization of building energy, material, and economic management using soft computing," *Adv. Concr. Constr.*, vol. 11, no. 6, pp. 455–468, 2021, doi: 10.12989/acc.2021.11.6.455.
[65] K. W. Mui, L. T. Wong, M. K. Satheesan, and A. Balachandran, "A hybrid simulation model to predict the cooling energy consumption for residential housing in Hong Kong," *Energies*, vol. 14, no. 16, 2021, doi: 10.3390/en14164850.
[66] X. Wang, X. Lü, L. Vähä-Savo, and K. Haneda, "A Novel AI-Based Thermal Conductivity Predictor in the Insulation Performance Analysis of Signal-Transmissive Wall," *Energies*, vol. 16, no. 10, 2023, doi: 10.3390/en16104211.
[67] T. Rymarczyk, G. Kłosowski, and E. Kozłowski, "A non-destructive system based on electrical tomography and machine learning to analyze the moisture of buildings," *Sens. Switz.*, vol. 18, no. 7, 2018, doi: 10.3390/s18072285.
[68] C.-X. Yu *et al.*, "Application of Deep Learning Techniques for Thermal Imagery Analysis in Abnormal Identification of Floor Tiles in Heritage Environments," presented at the 2023 Asia Pacific Signal and Information Processing Association Annual Summit and Conference, APSIPA ASC 2023, 2023, pp. 1878–1884. doi: 10.1109/APSIPAASC58517.2023.10317400.
[69] M. Marzouk, M. ElSharkawy, P. Elsayed, and A. Eissa, "Resolving deterioration of heritage building elements using an expert system," *Int. J. Build. Pathol. Adapt.*, vol. 38, no. 5, pp. 721–735, 2020, doi: 10.1108/IJBPA-12-2019-0106.
[70] M. M. Marzouk, M. S. Abdelhamid, and M. T. Elsheikh, "Selecting building materials using system dynamics and ant colony optimization," presented at the ICSDC 2011: Integrating Sustainability Practices in the Construction Industry - Proceedings of the International Conference on Sustainable Design and Construction 2011, 2012, pp. 577–584. doi: 10.1061/41204(426)71.
[71] M. Marzouk, M. Abdelhamid, and M. Elsheikh, "Selecting sustainable building materials using system dynamics and ant colony optimization," *J. Environ. Eng. Landsc. Manag.*, vol. 21, no. 4, pp. 237–247, 2013, doi: 10.3846/16486897.2013.788506.
[72] B. G. D. DeSoto and B. T. Adey, "Preliminary Resource-based Estimates Combining Artificial Intelligence Approaches and Traditional Techniques," presented at the Procedia Engineering, 2016, pp. 261–268. doi: 10.1016/j.proeng.2016.11.618.
[73] E. K. Zavadskas, R. Bausys, B. Juodagalviene, and I. Garnyte-Sapranaviciene, "Model for residential house element and material selection by neutrosophic MULTIMOORA method," *Eng. Appl. Artif. Intell.*, vol. 64, pp. 315–324, 2017, doi: 10.1016/j.engappai.2017.06.020.
[74] A. N. Kaulage, P. K. Tomar, R. Pant, L. Debnath, R. K. Ibrahim, and M. B. Alazzam, "Revolutionizing Material Selection in Construction 4.0: A Comparative Analysis of Artificial Intelligence Technologies," presented at the 2023 3rd International Conference on Advance Computing and Innovative Technologies in Engineering, ICACITE 2023, 2023, pp. 2707–2712. doi: 10.1109/ICACITE57410.2023.10182419.
[75] A. Kanyilmaz, M. Birhane, R. Fishwick, and C. del Castillo, "Reuse of Steel in the Construction Industry: Challenges and Opportunities," *Int. J. Steel Struct.*, vol. 23, no. 5, pp. 1399–1416, 2023, doi: 10.1007/s13296-023-00778-4.
[76] A. Rashidi, M. H. Sigari, M. Maghiar, and D. Citrin, "An analogy between various machine-learning techniques for detecting construction materials in digital images," *KSCE J. Civ. Eng.*, vol. 20, no. 4, pp. 1178–1188, 2016, doi: 10.1007/s12205-015-0726-0.

BIOGRAPHIES OF AUTHOR

Andi Prasetiyo Wibowo	Mr. Wibowo enlisted as a Doctoral Student at Centre for Manufacturing and Materials, Coventry University, United Kingdom. His research interest are Building Structure and Construction, Building Materials Technology, Building Maintenance, Green Technology, and Engineering Software. His profile can be found in https://pureportal.coventry.ac.uk/en/persons/andi-prasetiyo-wibowo/publications/