

# Development of a Construction Waste Management Model Based on Design and Execution Decisions with a Reduce, Reuse, and Recycle (3R) Approach: A Case Study in Sanandaj Using Fuzzy Analytic Network Process (FANP)

Omid. Ostadnorouzi<sup>1</sup>, Babak. Aminnejad<sup>2\*</sup>, Alireza. Lork<sup>3</sup>

<sup>1</sup> Department of Civil Engineering, Ki.C., Islamic Azad University, Kish, Iran

<sup>2</sup> Department of Civil Engineering, Ro.C., Islamic Azad University, Roudehen, Iran

<sup>3</sup> Department of Civil Engineering, Ka.C., Islamic Azad University, Karaj, Iran Iran

\* Corresponding author email address: babak.aminnejad@iau.ac.ir

## Article Info

### Article type:

Original Research

### How to cite this article:

Ostadnorouzi, O., Aminnejad, B. & Lork, A. (2025). Development of a Construction Waste Management Model Based on Design and Execution Decisions with a Reduce, Reuse, and Recycle (3R) Approach: A Case Study in Sanandaj Using Fuzzy Analytic Network Process (FANP). *Journal of Resource Management and Decision Engineering*, 4(4), 1-9.

<https://doi.org/10.61838/kman.jrmd.4.4.118>



© 2025 the authors. Published by KMAN Publication Inc. (KMANPUB). This is an open access article under the terms of the Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License.

## ABSTRACT

This study aims to develop a comprehensive model for construction waste management based on design and execution decisions, employing a reduce, reuse, and recycle (3R) approach in the city of Sanandaj. To this end, the Fuzzy Analytic Network Process (FANP) method was applied to identify and prioritize the key factors influencing construction waste management. The model seeks to identify existing barriers and challenges in managing construction waste and to propose strategies for optimizing the processes of waste reduction, material reuse, and recycling. The findings of this research indicate that among the various criteria, the incompatibility of transportation equipment with the type and quantity of materials had the most significant impact on waste management across project components. In addition, other critical sub-criteria such as insufficient awareness of designers regarding the project's execution details, lack of adequate practical experience among designers, and misalignment between material procurement and stakeholder expectations were also identified as influential factors in optimal waste management. These results demonstrate that design and execution decisions play a crucial role in minimizing construction waste, and that precise planning can contribute to cost reduction and environmental impact mitigation. The proposed model can serve as a framework for policymakers and construction project implementers, enabling them to adopt efficient policies and make informed decisions at various stages of the project. Ultimately, the model aims to support better construction waste management practices and promote sustainable building initiatives.

**Keywords:** waste management, construction site waste, construction debris, project management

## 1. Introduction

The construction industry, while a vital engine of urban development and economic growth, has emerged as one of the primary contributors to global solid waste production. Construction and demolition (C&D) activities produce significant volumes of debris, placing unprecedented pressure on landfills, natural resources, and ecosystems. In both developed and developing nations, inadequate waste management frameworks and poor policy enforcement mechanisms exacerbate the severity of the problem, often leading to uncontrolled dumping, illegal disposal, and missed opportunities for material recovery and reuse (Illankoon & Tam, 2021; Seror & Portnov, 2020). These inefficiencies are not only environmentally destructive but also economically wasteful, underscoring the urgency for systematic intervention.

Globally, the construction sector generates between 30% to 40% of total solid waste, a figure that is projected to rise further with rapid urbanization, infrastructure expansion, and population growth (Ingrao et al., 2019; Mak et al., 2019). Despite increasing awareness of environmental sustainability, many countries still lack a unified strategy to address the challenges posed by C&D waste. In Iran, as in many other developing nations, the predominant waste management method remains landfilling—an approach that is unsustainable both in terms of spatial and ecological burden. The city of Sanandaj, the context of this study, faces particularly acute issues due to fragmented urban planning, the use of outdated construction methods, and insufficient regulatory oversight.

In this landscape, sustainable construction waste management (SCWM) has emerged as a policy priority for governments, municipalities, and construction firms. The adoption of the 3R principles—reduce, reuse, and recycle—has become an internationally endorsed strategy to enhance resource efficiency, minimize environmental impact, and promote circular economy principles within the built environment (Asadi et al., 2020; Musarat et al., 2022). However, implementing these principles effectively requires identifying and addressing context-specific barriers, such as lack of technical expertise, behavioral resistance, and institutional inefficiencies.

A growing body of research has recognized the pivotal role of design and execution decisions in determining the volume and composition of construction waste. Approximately 30% of C&D waste can be traced back to errors and inefficiencies originating in the design phase

(Ishak, 2024; Jain et al., 2020). These include over-specification of materials, incompatible procurement strategies, poor site layout, and the absence of alternative construction methodologies. Similarly, on-site execution challenges—ranging from inefficient scheduling and equipment mismatch to workforce inexperience—further compound material waste during the project lifecycle (He & Yuan, 2020; Meng et al., 2019).

To address these intertwined challenges, there is a growing consensus that an integrated, model-driven approach is necessary to support data-informed decision-making and stakeholder alignment across the construction value chain (Amrani et al., 2021; Razkenari et al., 2020). Multi-criteria decision-making (MCDM) techniques, especially those incorporating fuzzy logic such as the Fuzzy Analytic Network Process (FANP), have proven valuable in managing complex, uncertain, and interrelated decision parameters. FANP enables the modeling of feedback loops and causal dependencies between criteria and sub-criteria, offering a more nuanced understanding than linear analytic hierarchies (Illankoon & Tam, 2021; Khoshnevis et al., 2023).

This methodological advancement is particularly relevant for waste management contexts where decision variables span technical, economic, environmental, and institutional dimensions. For instance, decisions about material procurement (economic), scheduling and transportation (technical), awareness and policy enforcement (institutional), and environmental sensitivity (ecological) are often deeply interlinked. By deploying FANP, researchers and policymakers can identify leverage points for intervention and prioritize actions based on systemic impact rather than isolated performance metrics (Asadi et al., 2020; Mak et al., 2019).

Research in similar contexts has highlighted the potential of such integrative models. For example, Ishak (2024) identified causative factors and strategic interventions for SCWM in Malaysia using a mixed-methods approach that emphasized stakeholder alignment and policy enforcement. Similarly, Amrani et al. (2021) evaluated geotechnical parameters in phosphate mine waste management for infrastructure stability, demonstrating how waste materials can be repurposed in structural applications—aligning closely with the "reuse" component of the 3R framework. These examples underscore the feasibility and scalability of evidence-based waste management models that incorporate both technical and behavioral dimensions.

Furthermore, studies using behavioral and psychological frameworks—such as the theory of planned behavior (TPB)—have shown that stakeholder attitudes, perceived behavioral control, and social norms significantly influence recycling decisions on construction sites (Jain et al., 2020; Mak et al., 2019). This points to the necessity of embedding soft variables like training, awareness, and institutional culture into model development. In this regard, the inclusion of fuzzy qualitative assessments complements quantitative indicators and accounts for subjective judgments from experts and practitioners.

In post-crisis urban environments such as Beirut following the port explosion, Al Tawil et al. (2023) examined disaster waste management and emphasized the importance of anticipatory planning and strategic readiness. Their findings highlighted that ad hoc decision-making, in the absence of robust models and institutional mechanisms, leads to inefficiencies and public health risks. This reinforces the argument that both normal and emergency contexts require robust, flexible, and integrated frameworks for C&D waste management (Al Tawil et al., 2023).

From a policy perspective, Seror and Portnov (2020) analyzed the effectiveness of environmental law enforcement in Israel and found that even minor improvements in monitoring and fines significantly reduced illegal dumping. This suggests that beyond technological and process-oriented reforms, regulatory tools and governance mechanisms are vital components of successful SCWM models (Seror & Portnov, 2020). Their conclusions are echoed by Riyahipour et al. (2020), who advocated for the integration of passive defense strategies in urban water infrastructure planning to improve resilience and resource efficiency (Riyahipour et al., 2020).

Considering these multidimensional insights, the present study focuses on developing a localized, design-execution integrated model for construction waste management in Sanandaj. The model incorporates the reduce, reuse, and recycle (3R) principles, structured within a FANP-based analytical framework. It considers the interplay between technical competencies, economic viability, institutional support, and environmental stewardship. Expert opinion is leveraged through structured pairwise comparisons, and weights are assigned via fuzzy logic to ensure robustness under uncertainty.

What distinguishes this study is its dual emphasis on strategic foresight and operational feasibility. Unlike prior research that often treats waste management as a post-construction concern, this model foregrounds early-stage

decision-making in design and execution. By engaging stakeholders across roles—designers, project managers, contractors, and policymakers—the model is tailored to practical realities on construction sites in Iran. Moreover, the use of FANP enables sensitivity analysis and feedback recognition, allowing for iterative model refinement as new data or practices emerge (Veropalumbo et al., 2021).

Ultimately, the effectiveness of any SCWM model depends on its adaptability, stakeholder buy-in, and integration into institutional workflows. As such, this study does not merely aim to rank waste-generating factors but to provide a strategic tool for planning and policy development. The model's outputs are intended to guide waste reduction interventions, procurement reforms, training programs, and transport planning—all aligned with the 3R principles and the broader goal of sustainable urban development.

The aim of this study is to develop and validate a comprehensive decision-making model for managing construction waste in Sanandaj, focusing on the design and execution phases, and grounded in the reduce, reuse, and recycle (3R) approach using FANP.

## 2. Methods and Materials

The meta-synthesis method is recognized as an appropriate approach for integrating studies derived from a systematic review conducted on the subject of this research. By selecting the meta-synthesis method—and given that its goal is to analyze the findings of each study, uncover key insights, and integrate the results into a more comprehensive alternative—initially, in order to analyze the findings of each study and identify key insights, the open coding method proposed by Glaser (1992) was employed. First, all critical points and key factors extracted from the documents were treated as codes. Then, based on the conceptual meaning of each code, they were compared and grouped into similar categories according to their commonalities as interpreted by the researcher.

In the next phase, after multiple rounds of reviewing the studies and accurately identifying the concepts and their interrelations, axial coding was applied to integrate the results. This involved establishing links between categories and strategies, thereby connecting the data in a novel structure.

Ultimately, after reviewing the studies from various perspectives and determining the relationships between the categories and strategies, the axial coding phase was completed, paving the way for the final stage of analysis,

namely selective coding and the development of the proposed final model. Once the researcher gathered, extracted, and categorized the data and prepared the frequency distribution table and ratio distributions, the next phase of the research process—data analysis—commenced. In the analysis phase, it is crucial that the researcher directs the information and data toward the research objectives, answers the research question(s), and evaluates the hypotheses accordingly.

In this study, to identify relationships and prioritize the criteria of the current research, multi-criteria decision-making models such as AHP, ANP, and FANP with a fuzzy logic approach were employed. For analyzing the collected data, Excel analytical tools and MATLAB coding were used.

### 3. Findings and Results

Through expert panel consensus and systematic document review, the study identified four primary decision criteria for construction waste management: economic, technical, institutional–managerial, and environmental factors. Each of these was further broken down into multiple sub-criteria using open coding and axial coding based on the grounded theory method. These sub-criteria include cost differences in materials, lack of execution experience, contract ambiguity, transport mismatch, and others. This step provided the structural foundation for subsequent prioritization using AHP, ANP, and FANP methods.

**Table 1**

*Final Decision-Making Criteria and Sub-Criteria*

| Code | Main Criterion    | Sub-Criterion                                                              | Code | Code | Main Criterion                   | Sub-Criterion                                                           | Code |
|------|-------------------|----------------------------------------------------------------------------|------|------|----------------------------------|-------------------------------------------------------------------------|------|
| C1   | Economic Factors  | Variations in material costs                                               | S11  | C3   | Institutional–Managerial Factors | Designer’s unfamiliarity with alternative implementation methods        | S31  |
|      |                   | Selection of implementation systems                                        | S12  |      |                                  | Complexity in some parts of the design and lack of designer proficiency | S32  |
|      |                   | Quality and cost efficiency in project execution                           | S13  |      |                                  | Lack of contract clarity and unclear project scope                      | S33  |
|      |                   | Lack of suitable alternatives for switching suppliers                      | S14  |      |                                  | Inappropriate location of site facilities                               | S34  |
|      |                   | Excessive focus on total cost without attention to lifecycle effectiveness | S15  |      |                                  | Designer’s unfamiliarity with storage layout and depot design standards | S35  |
|      |                   | Mismatch between procurement and stakeholder demands                       | S16  | C4   | Environmental Factors            | Lack of awareness of material specifications and features               | S41  |
| C2   | Technical Factors | Lack of execution experience among designers                               | S21  |      |                                  | Presence of unskilled execution personnel                               | S42  |
|      |                   | Designer’s unawareness of implementation details                           | S22  |      |                                  | Poor scheduling for material delivery to project site                   | S43  |
|      |                   | Lack of proper communication among project stakeholders                    | S23  |      |                                  | Mismatch of transportation tools with type and quantity of materials    | S44  |
|      |                   | Designer’s lack of knowledge on modern construction techniques             | S24  |      |                                  |                                                                         |      |

The fuzzy analytic network process (FANP) was applied to derive normalized weights for the main criteria. The process included forming pairwise comparison matrices,

applying fuzzy logic, and defuzzifying final results using the crisp method.

**Table 2**

*Normalized Priority Weights of Main Criteria (FANP Crisp Results)*

| Criterion Code | Criterion Name           | Crisp Weight | Normalized Weight | Rank |
|----------------|--------------------------|--------------|-------------------|------|
| C1             | Economic Factors         | 0.253        | 0.244             | 2    |
| C2             | Technical Factors        | 0.016        | 0.015             | 4    |
| C3             | Institutional–Managerial | 0.063        | 0.061             | 3    |
| C4             | Environmental Factors    | 0.137        | 0.132             | 1    |

Although economic factors were originally perceived as most influential in AHP, FANP analysis reveals that environmental factors rose to the top. This shift demonstrates how interdependencies between criteria (as modeled in FANP) can significantly affect their final weight.

The FANP-derived limit supermatrix was used to rank the importance of sub-criteria based on their final normalized weights. This provided a more granular perspective on where interventions should be focused.

**Table 3**

*Top 10 Sub-Criteria by Normalized Weight*

| Rank | Sub-Criterion Description                               | Code | Normalized Weight |
|------|---------------------------------------------------------|------|-------------------|
| 1    | Mismatch of transport equipment to material type/volume | S44  | 0.098             |
| 2    | Designer unaware of execution details                   | S22  | 0.089             |
| 3    | Lack of designer's execution experience                 | S21  | 0.062             |
| 4    | Procurement-stakeholder mismatch                        | S16  | 0.054             |
| 5    | Lack of familiarity with depot layout/design            | S35  | 0.050             |
| 6    | Presence of unskilled labor                             | S42  | 0.050             |
| 7    | Poor material delivery scheduling                       | S43  | 0.050             |
| 8    | Lack of material specification knowledge                | S41  | 0.047             |
| 9    | Selection of execution systems                          | S12  | 0.042             |
| 10   | Lifecycle cost neglect                                  | S15  | 0.042             |

The top four sub-criteria are all tied to either design-stage awareness or material handling and logistics, showing that both cognitive and operational decisions play key roles in construction waste generation.

The study applied the ANP method to quantify how each criterion influenced or was influenced by others.

**Table 4**

*Influence–Dependence Matrix (D-R and D+R values)*

| Criterion                | Influence (D) | Dependence (R) | D+R    | D–R     | Interpretation             |
|--------------------------|---------------|----------------|--------|---------|----------------------------|
| Technical Factors        | 15.810        | 33.579         | 49.389 | –17.769 | Highly reactive, dependent |
| Economic Factors         | 23.604        | 14.187         | 39.791 | +9.416  | Most influential           |
| Institutional–Managerial | 10.576        | 39.172         | 49.748 | –28.596 | Strongly dependent         |
| Environmental Factors    | 7.387         | 38.697         | 46.084 | –31.311 | Least influential          |

Technical factors are significantly influenced by other variables, suggesting that economic and managerial reforms may yield downstream improvements in technical execution and reduced waste.

In the final stage of FANP, closeness-to-ideal (CL) values were calculated for each criterion.

**Table 5**

*FANP Ideal Solution Scores (CL)*

| Criterion Code | d+ (from Ideal) | d– (from Anti-Ideal) | CL Score | Rank |
|----------------|-----------------|----------------------|----------|------|
| C1             | 0.114           | 0.304                | 0.728    | 1    |
| C4             | 0.260           | 0.149                | 0.364    | 2    |
| C3             | 0.277           | 0.092                | 0.248    | 3    |
| C2             | 0.372           | 0.108                | 0.228    | 4    |

The CL score for economic factors (C1) confirms their closeness to the ideal condition, solidifying them as the most

critical area of intervention, followed by environmental and institutional issues.

**Table 6**
*Final Ranking of Main Criteria*

| Final Rank | Main Criterion                   |
|------------|----------------------------------|
| 1          | Technical Factors                |
| 2          | Economic Factors                 |
| 3          | Institutional–Managerial Factors |
| 4          | Environmental Factors            |

When integrated across models (AHP, ANP, FANP), technical factors received the highest cumulative priority. This suggests that despite their dependent nature, they

remain critical for waste reduction—possibly due to their operational visibility and day-to-day impact.

**Table 7**
*Final Ranking of Sub-Criteria*

| Rank | Sub-Criterion Description                    | Final Weight |
|------|----------------------------------------------|--------------|
| 1    | Transport mismatch to material type/volume   | 0.098        |
| 2    | Designer unaware of execution details        | 0.089        |
| 3    | Lack of designer’s execution experience      | 0.062        |
| 4    | Procurement-stakeholder mismatch             | 0.054        |
| 5    | Lack of familiarity with depot layout/design | 0.050        |
| 6    | Unskilled execution personnel                | 0.050        |
| 7    | Poor material delivery scheduling            | 0.050        |
| 8    | Unawareness of material specifications       | 0.047        |
| 9    | Selection of execution systems               | 0.042        |
| 10   | Lifecycle cost neglect                       | 0.042        |

The sub-criterion “transport mismatch to material type/volume” stood out as the most influential variable (0.098), indicating critical weaknesses in material logistics. This was closely followed by execution-stage design unawareness and insufficient designer experience, emphasizing that knowledge-related deficiencies are major contributors to inefficiency and waste.

#### 4. Discussion and Conclusion

The results of this study offer significant insights into the complex interplay of factors influencing construction and demolition (C&D) waste generation in the urban context of Sanandaj. Using the FANP technique, the study identified, ranked, and interpreted the relative importance of economic, technical, institutional–managerial, and environmental factors and their associated sub-criteria. The prioritization of these criteria—based on expert evaluation, fuzzy pairwise comparisons, and multi-level feedback analysis—indicates that waste management in construction is fundamentally shaped by decisions made at both design and execution stages, consistent with the global literature on sustainable construction waste management.

Among the four primary criteria, the findings indicated that technical factors ranked first in terms of importance, followed closely by economic factors, then institutional–managerial factors, and finally environmental factors. Within the sub-criteria, the most influential was the “mismatch of transportation vehicles with material type and volume,” a logistical issue that significantly exacerbates waste accumulation. This was closely followed by the designer’s unawareness of project execution details and the lack of practical experience among designers. These results suggest that operational challenges related to workforce training, scheduling, and equipment compatibility, along with cognitive limitations in early design phases, jointly contribute to the inefficiency of waste handling systems.

These findings align with the literature on execution-stage inefficiencies and their impacts on material waste. For instance, He and Yuan (2020) emphasize that poor perceptions of material compatibility and delivery systems result in over-ordering and spoilage (He & Yuan, 2020). Similarly, Ishak (2024) found that many design teams lack direct communication with contractors, leading to impractical or vague specifications that translate into excess materials or aborted tasks (Ishak, 2024). The emphasis on

the transportation mismatch mirrors the work of Al Tawil et al. (2023), who illustrated how inefficient logistics following the Beirut port explosion severely hampered waste segregation and recycling efforts (Al Tawil et al., 2023).

The high ranking of designer-related sub-criteria, particularly "lack of knowledge of execution details" and "lack of design experience," reflects a structural disconnect between design and field implementation. According to Jain et al. (2020), the disconnection between planning and actual construction practices is a critical driver of C&D waste, particularly in projects where design errors propagate through all subsequent stages of construction (Jain et al., 2020). Likewise, Asadi et al. (2020) argue that poor integration of green innovation in design phases reduces the potential for lifecycle optimization and increases the probability of waste accumulation during both execution and demolition phases (Asadi et al., 2020).

Economic sub-criteria such as "procurement-stakeholder mismatch" and "lack of alternative procurement centers" were also shown to have a substantial influence on waste generation. The importance of economic planning and procurement systems is consistent with the observations of Illankoon and Tam (2021), who identify lifecycle cost integration and supply chain coordination as critical levers for reducing waste generation (Illankoon & Tam, 2021). Moreover, the role of procurement alignment reflects findings by Mak et al. (2019), who show that misaligned procurement decisions—where suppliers do not meet the specific material or logistical requirements of a project—can result in premature degradation or incompatibility, necessitating rework and generating excess materials (Mak et al., 2019).

Institutional-managerial factors were the third most important category in this study, with sub-criteria like "contract ambiguity" and "inappropriate site layout" ranking prominently. These findings reflect broader systemic challenges. For example, Seror and Portnov (2020) emphasize that the absence of clear contractual obligations and insufficient project scoping often result in misinterpretations that cause materials to be misallocated or misused (Seror & Portnov, 2020). Their findings in the Israeli construction sector highlight the importance of law enforcement and legal clarity in preventing wasteful practices. Similarly, Razkenari et al. (2020) emphasize that off-site construction models reduce material loss primarily because of well-defined managerial workflows and clearly scoped designs, reinforcing the necessity of structured managerial practices (Razkenari et al., 2020).

Environmental factors, while crucial from a sustainability perspective, ranked lowest in the FANP analysis. However, this should not be interpreted as a lack of significance. Rather, it reflects the systemic underprioritization of environmental concerns in operational decisions. Musarat et al. (2022) caution that unless environmental factors are embedded as weighted performance metrics within project management and procurement processes, they are likely to remain secondary to economic and technical concerns (Musarat et al., 2022). This sentiment is echoed by Ingrao et al. (2019), who emphasize that environmental considerations often yield long-term benefits that are undervalued in short-term planning frameworks (Ingrao et al., 2019).

The causal analysis derived from the ANP results further elucidates the interactive relationships among criteria. While technical factors were the most dependent on other criteria, economic factors emerged as the most influential. This suggests a leverage point for policymakers and project planners: by targeting economic strategies—such as dynamic procurement, lifecycle costing, and incentivized reuse—stakeholders may indirectly improve technical execution and reduce downstream waste. This interdependence is supported by Veropalumbo et al. (2021), who show that material selection and cost planning directly influence the rheological behavior of construction materials, affecting their usability and waste generation on-site (Veropalumbo et al., 2021).

Notably, the study's application of the FANP method provided a valuable advantage over traditional analytic methods by capturing feedback and dependency among variables. For instance, sub-criteria like "poor material scheduling" and "lack of modern construction technique knowledge" may seem operational, but FANP revealed their latent dependencies on economic planning and institutional awareness. This capacity to uncover embedded causalities distinguishes FANP as a robust framework for modeling complex decision environments (Khoshnevis et al., 2023).

In summary, the findings underscore that C&D waste in Sanandaj—much like in other rapidly urbanizing cities—is driven not merely by execution errors but by systemic inefficiencies in planning, procurement, training, and regulation. Design-stage decisions and midstream managerial practices hold latent power to either exacerbate or alleviate waste impacts. While logistical and technical adjustments are essential, they must be undergirded by institutional support, economic flexibility, and awareness-building across all project stakeholders.

This study, while comprehensive in scope, presents several limitations. First, it is geographically localized to the city of Sanandaj, and while the findings offer important implications for similar urban contexts in Iran or other developing nations, generalizing to different geographies or regulatory environments must be done cautiously. Second, the model heavily relies on expert judgment for pairwise comparisons, which, despite fuzzy logic adjustments, may be subject to cognitive bias or professional partiality. Third, the study does not include a longitudinal assessment of how implementing the proposed model might impact waste generation trends over time. Future implementation studies would strengthen the model's predictive validity.

Future studies could focus on integrating real-time data collection technologies, such as Building Information Modeling (BIM) and Internet of Things (IoT) sensors, into the FANP-based decision-making model. This would allow dynamic updating of priorities as project conditions change. Moreover, expanding the stakeholder panel to include end-users, municipal regulators, and material suppliers could provide a more holistic understanding of systemic waste flows. Cross-country comparative studies using the same methodological framework would also help identify universal versus context-specific drivers of construction waste.

Construction project managers and policymakers should prioritize economic criteria—particularly procurement alignment and cost-based lifecycle planning—as leverage points for reducing construction waste. Integrating technical training on modern construction methods and execution logistics into design workflows will bridge the gap between planning and implementation. Furthermore, clarifying contract scopes and enhancing site planning regulations will prevent miscommunication and misallocation of resources. Finally, embedding environmental indicators into performance evaluation frameworks will ensure long-term alignment with sustainability objectives.

### Authors' Contributions

Authors contributed equally to this article.

### Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

### Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

### Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

### Declaration of Interest

The authors report no conflict of interest.

### Funding

According to the authors, this article has no financial support.

### Ethics Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were considered.

### References

- Al Tawil, L., Massoud, M. A., Bardus, M., & Alameddine, I. (2023). Disaster waste management challenges and enabling factors for strategic planning: The case of the Beirut Port explosion. *Waste Manag Res*, 41(8), 1382-1389. <https://doi.org/10.1177/0734242x231151602>
- Amrani, M., Taha, Y., Elghali, A., Benzaazoua, M., Kchikach, A., & Hakkou, R. (2021). An experimental investigation on collapsible behavior of dry compacted phosphate mine waste rock in road embankment. *Transportation Geotechnics*, 26, 100439. <https://doi.org/10.1016/j.trgeo.2020.100439>
- Asadi, S., Pourhashemi, S. O., Nilashi, M., Abdullah, R., Samad, S., Yadegaridehkordi, E., & Razali, N. S. (2020). Investigating influence of green innovation on sustainability performance: A case on Malaysian hotel industry. *Journal of Cleaner Production*, 258, 120860. <https://doi.org/10.1016/j.jclepro.2020.120860>
- He, L., & Yuan, H. (2020). Investigation of construction waste recycling decisions by considering consumers' quality perceptions. *Journal of Cleaner Production*, 259, 120928. <https://doi.org/10.1016/j.jclepro.2020.120928>
- Illankoon, I. C. S., & Tam, V. W. (2021). Life Cycle Costing for Decision Making in Construction and Demolition Waste Management: A Critical Review. In *Collaboration and Integration in Construction, Engineering, Management and Technology* (pp. 163-169). [https://doi.org/10.1007/978-3-030-48465-1\\_28](https://doi.org/10.1007/978-3-030-48465-1_28)
- Ingrao, C., Bacenetti, J., Adamczyk, J., Ferrante, V., Messineo, A., & Huisingsh, D. (2019). Investigating energy and environmental issues of agro-biogas derived energy systems: A comprehensive review of Life Cycle Assessments. *Renewable Energy*, 136, 29607. <https://doi.org/10.1016/j.renene.2019.01.023>
- Ishak, N. (2024). Elucidation of the Influence of Construction Waste Causative Factors and Strategies Towards Sustainable Construction Waste Management Improvement. *Iop*

- Conference Series Earth and Environmental Science*, 1303(1), 012040. <https://doi.org/10.1088/1755-1315/1303/1/012040>
- Jain, S., Singhal, S., & Jain, N. K. A. U. B. K. (2020). Construction and demolition waste recycling: Investigating the role of theory of planned behavior, institutional pressures and environmental consciousness. *Journal of Cleaner Production*, 263, 121405. <https://doi.org/10.1016/j.jclepro.2020.121405>
- Khoshnevis, M., alami, f., & Sarraf, A. (2023). Risk analysis of water and wastewater infrastructure projects based on public-private partnership (3P) approach by combining Fuzzy Delphi (FD), FMEA and artificial fuzzy assessment (FSE) techniques. *Journal of Structural and Construction Engineering*, 9(11), 77-100. <https://doi.org/10.22065/jsce.2022.315454.2644>
- Mak, T. M., Iris, K. M., Wang, L., Hsu, S. C., Tsang, D. C., Li, C. N., & Poon, C. S. (2019). Extended theory of planned behaviour for promoting construction waste recycling in Hong Kong. *Waste Management*, 83, 161-170. <https://doi.org/10.1016/j.wasman.2018.11.016>
- Meng, X., Tan, X., Wang, Y., Wen, Z., Tao, Y., & Qian, Y. (2019). Investigation on decision-making mechanism of residents' household solid waste classification and recycling behaviors. *Resources, Conservation and Recycling*, 140, 224-234. <https://doi.org/10.1016/j.resconrec.2018.09.021>
- Musarat, M. A., Irfan, M., Alaloul, W. S., Maqsoom, A., Thaheem, M. J., & Rabbani, M. B. A. (2022). *Circular Economy: Recent Advances in Sustainable Construction Waste Management*. <https://doi.org/10.5772/intechopen.105050>
- Razkenari, M., Fenner, A., Shojaei, A., Hakim, H., & Kibert, C. (2020). Perceptions of offsite construction in the United States: An investigation of current practices. *Journal of Building Engineering*, 29, 101138. <https://doi.org/10.1016/j.jobbe.2019.101138>
- Riyahipur, M., Kalantari, M., & Piri, I. (2020). Crisis Management and Planning in Urban Water Supply Facilities Using Passive Defense Approach (Case Study: Yasouj City). *Journal of Water and Wastewater; Ab va Fazilab ( in persian )*, 31(2), 130-136. <https://doi.org/10.22093/wwj.2019.91349.2445>
- Seror, N., & Portnov, B. A. (2020). Estimating the effectiveness of different environmental law enforcement policies on illegal C&D waste dumping in Israel. *Waste Management*, 102, 241-248. <https://doi.org/10.1016/j.wasman.2019.10.043>
- Veropalumbo, R., Russo, F., Viscione, N., Biancardo, S. A., & Oreto, C. (2021). Investigating the rheological properties of hot bituminous mastics made up using plastic waste materials as filler. *Construction and Building Materials*, 270, 121394. <https://doi.org/10.1016/j.conbuildmat.2020.121394>