



Green Productivity Analysis in The Construction Industry

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Abstract. The objective of this study is to apply the Analytic Network Process (ANP) to prioritize strategies for enhancing green productivity in housing development. The identification process yielded five ways that can support green productivity in residential construction: Environmentally Friendly Building Materials, Energy Efficiency, Waste Management, Efficient Water Usage, and Smart Technology. These methods served as criteria in the ANP model, with interconnections among some criteria to better represent green productivity goals. The results indicate that Environmentally Friendly Building Materials holds the highest priority with a weight of 0.59, marking it as the primary focus for companies aiming to achieve green productivity. Following this, Energy Efficiency ranked second with a weight of 0.21, Waste Management third at 0.11, Efficient Water Usage at 0.05, and Smart Technology last at 0.03. The consistency index value of 0.08, below the threshold of 0.10, confirms the adequacy and reliability of the pairwise comparison assessment.

Keywords: Analytic Network Process, Friendly Building Materials, Green Productivity, Housing Development

1 Introduction

Green productivity is increasingly acknowledged as crucial for advancing sustainable development and boosting corporate performance across diverse sectors. Integrating eco-friendly practices into business processes not only addresses environmental issues but also promotes economic efficiency by optimizing resources and reducing waste. For example, adopting green supply chain management practices can significantly enhance sustainability performance, especially in industries that depend heavily on natural resources [1]. Green productivity plays a key role in fostering sustainable development and improving operational efficiency in various sectors. By embracing environmentally conscious practices, businesses can greatly reduce waste and pollution while maximizing resource efficiency, leading to enhanced operational performance [2]. Companies that prioritize green productivity are more likely to meet regulatory standards and societal expectations, ultimately supporting a more sustainable economy [3].

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Moreover, developing green products and innovations is crucial for meeting the increasing consumer demand for eco-friendly options, thus supporting both market expansion and environmental sustainability [4, 5].

Construction companies must prioritize green productivity, as this practice not only supports environmental sustainability but also enhances operational efficiency and market competitiveness. By adopting sustainable construction principles, companies can reduce waste and carbon emissions, addressing critical environmental issues in an industry known as a significant contributor to ecological degradation [6]. Additionally, implementing green productivity practices can lead to long-term cost savings through efficient resource and energy use, while also strengthening the company's image among consumers and stakeholders [7].

In the pursuit of green productivity, construction companies can employ an effective multi-criteria approach to prioritize sustainability-focused efforts. The Multi-Criteria Decision-Making (MCDM) method can be used to weight multiple criteria to find the priority criteria that should be focused on [8]. Multi-Criteria Decision-Making (MCDM) can be applied to select green suppliers in mega construction projects, where green supplier evaluation identifies and prioritizes improvement opportunities to minimize environmental impact [9]. One applicable method is the Analytic Network Process (ANP), which allows companies to assess interrelated factors within the decision-making process. ANP can be utilized to select appropriate green supply chain management (GSCM) strategies, helping identify relevant GSCM practices within Indonesia's construction industry [10].

Furthermore, ANP can be combined with DEMATEL to evaluate drivers and barriers in implementing integrated waste management systems within the construction industry, helping identify key factors critical to achieving green productivity [11]. Additionally, ANP can be integrated with the MARCOS method for green supplier selection, demonstrating that this combined approach offers a more comprehensive decision-making solution [12]. Based on this background, the objective of this study is to apply ANP to prioritize ways to increase green productivity in housing development.

2 Materials and Methods

This study used Analytic Network Process to see the priority of ways to achieve green productivity in housing development. The following is an explanation of the steps in Analytic Network Process (ANP)

- Define the Problem and Objective

Clearly state the decision-making problem and clarify the analysis objective.

- Identify Criteria and Options

Establish the criteria that will guide decision-making, including primary criteria, sub-criteria, and the alternatives under consideration.

- Create the Network Structure

Arrange the criteria, sub-criteria, and alternatives in a network diagram to illustrate their relationships and dependencies. Unlike AHP's hierarchical structure, ANP accommodates complex interconnections.

- **Develop Pairwise Comparison Matrices**

Perform pairwise comparisons between criteria and alternatives. Experts or stakeholders evaluate the relative importance of each criterion using a scale (e.g., 1 to 9), creating matrices that capture the preferences between criteria, sub-criteria, and alternatives.

- **Calculate Priority Weights**

Apply eigenvector methods or other mathematical techniques to derive priority weights from the pairwise matrices, quantifying the relative importance of each network element.

- **Construct the Supermatrix**

Formulate a supermatrix, a block matrix representing relationships among criteria and alternatives, capturing both direct and indirect influences among elements.

- **Normalize the Supermatrix**

Normalize the supermatrix by adjusting the columns to sum to one, creating a stochastic matrix where values represent probabilities or contributions.

- **Calculate the Limit Supermatrix**

Elevate the normalized supermatrix to successive powers (until convergence) to form the limit supermatrix, reflecting the overall priority weights for criteria and alternatives and accounting for feedback and interdependencies.

- **Interpret Results**

Analyze the limit supermatrix results to make well-informed decisions, assessing the priority weights for each alternative and understanding the criteria's influence on the final decision.

- **Conduct Sensitivity Analysis**

Perform sensitivity analysis to evaluate how variations in input values (e.g., pairwise comparisons) impact the results, assessing the robustness of outcomes and identifying key criteria.

- **Select the Best Alternative**

Choose the alternative that best aligns with the defined goal and prioritizations based on the analysis.

3 Results

In this study, the identification results reveal five methods that can be utilized to achieve green productivity in house construction, namely: Environmentally Friendly Building Materials, Energy Efficiency, Waste Management, Efficient Water Usage, Smart Technology. This is then used in the ANP as a criterion, several of which are interrelated to achieve green productivity, as seen in Fig. 1.

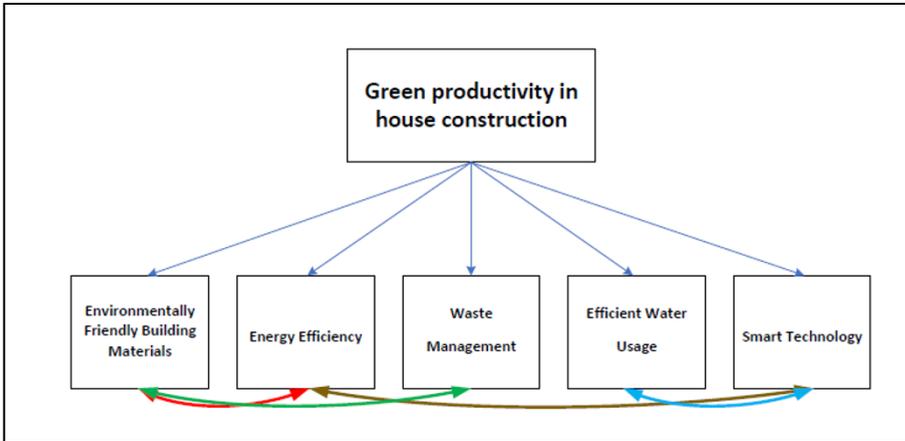


Fig. 1. Results of the passenger model at the bus station

In the Analytical Network Process (ANP) method, several of these criteria can be interrelated because ANP recognizes the interrelationship or dependency between various elements in the system. In this study, several of these criteria can be interrelated in the context of ANP:

- Environmentally Friendly Building Materials and Energy Efficiency:

The use of environmentally friendly materials is often associated with increased energy efficiency. For example, materials that have good insulation can reduce the energy needs for heating and cooling.

- Energy Efficiency and Smart Technology:

Smart technology can help in managing energy use more efficiently, such as automatically adjusting lighting or temperature based on actual needs.

- Waste Management and Environmentally Friendly Building Materials:

Environmentally friendly building materials tend to produce less waste during construction and management, and are easier to recycle, supporting better waste management systems.

- **Efficient Water Usage and Smart Technology:**

Smart technology can be used to manage water use efficiently, such as sensors that detect leaks or automatic irrigation systems that regulate water use based on weather conditions.

Using ANP, the relationship between these criteria can be modeled and their mutual influence on each other can be measured. The interplay of criteria can provide better insight into the decision-making process related to green buildings.

Once the criteria and the relationships between them were identified to align with the study's objective, pairwise comparisons were performed for each criterion. This approach allowed for an in-depth assessment of the relative importance of each criterion, based on expert evaluations and structured comparisons. Following these comparisons, calculations were carried out to determine the specific weight of each criterion, as described in detail within the methodology section. These calculated weights reflect the priority levels assigned to each criterion and provide a basis for further analysis. Additionally, the consistency index was computed to ensure the reliability and coherence of the pairwise comparisons. The final results, detailing both the criteria weights and the consistency index, are summarized in Table 1, offering a clear overview of the priority structure established in the study.

Table 1. Criteria and Inconsistency

Criteria	Weight
Environmentally Friendly Building Materials	0.59
Energy Efficiency	0.21
Waste Management	0.11
Efficient Water Usage	0.05
Smart Technology	0.03
Index of consistency	0.08

4 Discussion

The analysis results provide a detailed prioritization of green productivity criteria based on ANP (Analytic Network Process) weights, highlighting key areas for companies aiming to enhance sustainable practices. Among the identified criteria, Environmentally Friendly Building Materials emerged with the highest priority weight at 0.59, indicating its critical importance in the construction industry's transition toward green productivity. This result underscores the value of sustainable materials as a foundation for reducing environmental impact, conserving resources, and meeting sustainability goals, making it a primary focus for industry players committed to ecological responsibility.

The second most significant criterion is Energy Efficiency, holding a weight of 0.21. This factor plays a vital role in reducing operational costs and minimizing carbon footprints, which are essential aspects of sustainable housing development. Following Energy Efficiency is Waste Management, with a weight of 0.11. This criterion emphasizes

the importance of minimizing and managing construction waste effectively to reduce environmental degradation. The remaining criteria include Efficient Water Usage (0.05) and Smart Technology (0.03), which rank fourth and fifth, respectively. While these criteria have relatively lower weights, their integration still contributes to a holistic green productivity strategy, especially as technology and efficient water practices continue to evolve.

Additionally, the consistency index value of 0.08, below the standard threshold of 0.10, affirms that the pairwise comparison assessment is reliable and meets consistency requirements. This validation is crucial for the robustness of the study's findings, ensuring that the results are dependable for further analyses. Future research can build on these established criteria to create refined measurement tools for green productivity, facilitating the continued advancement of sustainable practices in housing construction and supporting a broader industry shift towards greener, more resilient development models.

5 Conclusions

In this study, ANP can be applied to prioritize efforts to increase green productivity in home construction. In this study, ANP can be applied to prioritize efforts to improve green productivity in home construction. The results show that Green Building Materials play an important role as the main priority for companies seeking to achieve green productivity. The second rank is Energy Efficiency, followed by Waste Management, Efficient Water Use and the last is Smart Technology. In further research, green productivity can be assessed using the established criteria, which provide a comprehensive framework for evaluating sustainable practices in construction. By focusing on factors such as Environmentally Friendly Building Materials, Energy Efficiency, Waste Management, Efficient Water Usage, and Smart Technology, researchers can gain deeper insights into areas of improvement that significantly impact environmental performance

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