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Technological innovation and the environmentally friendly building material supply chain: Implications for sustainable environment

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This study aims to analyze the relationship between technological innovation and the supply chain of environmentally friendly building materials in the context of a sustainable environment. With the increasing need for more environmentally conscious construction practices, technological innovation plays a pivotal role in enhancing sustainability within the construction industry. Through an extensive literature review, it is found that the adoption of technological innovation in the supply chain of environmentally friendly building materials can have a positive impact on the sustainable environment. Technological innovation enables improved resource efficiency, reduced construction waste, and promotes the utilization of eco-friendly building materials. Moreover, this research highlights the crucial role of the supply chain in mediating the relationship between technological innovation and a sustainable environment. The supply chain plays a vital part in integrating technological innovation into construction practices, ensuring compliance with environmental standards, and fostering wider adoption of sustainable solutions. This study employs a quantitative analysis method, gathering data from various primary and secondary sources. The analysis results demonstrate a positive correlation between technological innovation and the supply chain of environmentally friendly building materials with regard to a sustainable environment. The implications of this research lie in providing a better understanding of the significance of technological innovation and the supply chain in achieving sustainability within the construction industry.

1. Introduction

The construction industry has a significant impact on the environment, making it crucial to address the sustainability of building materials in the supply chain (Arıoğlu Akan et al., 2017; Badi & Murtagh, 2019). Traditional construction practices often involve the use of materials that are harmful to the environment, such as concrete with high carbon emissions and non-renewable resources like timber (Abed et al., 2022; Tian & Spatari, 2022). These practices contribute to deforestation, habitat destruction, and increased greenhouse gas emissions (Zhang et al., 2022). As the demand for construction materials continues to rise, it becomes imperative to explore innovative solutions that promote environmentally friendly alternatives (Hansen, 2016). Technological innovation has emerged as a key driver in transforming the supply chain of building materials towards environmental sustainability (Kamble et al., 2020; Manavalan & Jayakrishna, 2019; Y. Yu et al., 2021). Innovations such as digital technologies, automation, and renewable energy solutions offer opportunities to revolutionize the construction industry (Ahmad et al., 2021; Ghobakhloo, 2020). Digital platforms enable better inventory management, tracking of material sources, and efficient logistics, reducing waste and improving traceability (Centobelli et al., 2022; Nandi et al., 2021; Park & Li, 2021). Automation streamlines processes, resulting in higher precision and decreased resource consumption (Rejeb et al., 2019). Renewable energy technologies contribute to reducing the carbon footprint by powering manufacturing processes with clean energy sources (Chen et al., 2021; Jahanger et al., 2023; Obaideen et al., 2021).

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The adoption of innovative technologies in the supply chain of environmentally friendly building materials brings multiple benefits (Agrawal et al., 2022; Ferreira et al., 2023; Soufi et al., 2023). First, it allows for the production of sustainable materials with reduced carbon emissions, recycled content, and low embodied energy. For example, the use of recycled aggregates, eco-friendly binders, and advanced insulation materials can significantly decrease the environmental impact of construction projects. Second, technological innovations improve resource efficiency and waste management. Digital monitoring systems and smart sensors enable real-time tracking of material usage, reducing overordering and minimizing waste generation. Third, these innovations enhance the overall sustainability performance of the construction sector. By integrating renewable energy systems into the manufacturing process and employing energy-efficient machinery, the industry can reduce its carbon footprint and reliance on fossil fuels. However, the implementation of technological innovations in the supply chain of environmentally friendly building materials faces several challenges. One significant challenge is the initial investment required to adopt new technologies and upgrade existing infrastructure. Small and medium-sized contractors might face financial constraints in adopting these innovations, highlighting the need for financial support and incentives from governments and financial institutions (Feng et al., 2022). Additionally, there may be a lack of awareness and technical expertise within the industry regarding the benefits and implementation of these technologies (Mathivathanan et al., 2021). Proper training, education, and knowledge-sharing initiatives are essential to overcome these barriers (Nadason et al., 2017).

To address these challenges and promote the widespread adoption of environmentally friendly building materials in the construction industry, collaboration among stakeholders is crucial (Manzoor et al., 2021). Governments, industry associations, research institutions, and material suppliers need to work together to develop supportive policies, standards, and guidelines (Rissman et al., 2020). Financial incentives, such as tax breaks or grants, can encourage construction companies to invest in sustainable technologies and practices (Rana et al., 2021; Yuan et al., 2023). Research and development initiatives should focus on exploring innovative materials and technologies, while also considering their life cycle impacts and compatibility with existing construction practices.

The existing literature on the impact of technological innovation on the supply chain of environmentally friendly building materials is relatively limited, indicating a research gap in this area. While there are studies that discuss the adoption of individual technologies or specific sustainable practices in the construction industry, there is a need for comprehensive research that examines the broader implications of technological innovation on the supply chain of environmentally friendly building materials. Furthermore, limited research has been conducted on the specific implications of these technological innovations on the environment. While there is recognition that technological advancements can contribute to sustainability, there is a lack of empirical studies that quantitatively analyze the environmental benefits and trade-offs associated with the adoption of these technologies. Understanding the extent to which technological innovations in the supply chain of building materials can mitigate environmental impacts is essential for policymakers and industry stakeholders seeking to develop effective sustainability strategies.

Additionally, the research gap lies in the exploration of challenges and barriers faced by construction companies in implementing these technological innovations. The literature does not sufficiently address the financial, operational, and organizational challenges that construction firms encounter when adopting environmentally friendly technologies in their supply chain. Investigating these challenges can provide valuable insights into the barriers that hinder wider adoption and help identify strategies to overcome them. Moreover, there is a lack of research that examines the social and economic implications of implementing technological innovations in the supply chain of environmentally friendly building materials. Understanding the broader socio-economic impacts, such as job creation, cost-effectiveness, and stakeholder engagement, is crucial for assessing the feasibility and sustainability of these innovations in the construction industry.

This research aims to contribute to the existing body of knowledge by addressing several key novelties in the field of technological innovation and the supply chain of environmentally friendly building materials. Firstly, unlike previous studies that focused on isolated technologies or practices, this research takes a comprehensive approach by exploring the integration of multiple technological innovations throughout the supply chain. By considering the synergistic effects and interdependencies among these innovations, a more holistic understanding of their impact on sustainability can be achieved. Secondly, while previous research has acknowledged the potential environmental benefits of technological innovations, this study seeks to provide a novel contribution by conducting a quantitative analysis of their environmental impacts. By quantifying parameters such as carbon emissions, energy consumption, and resource utilization, this research aims to provide concrete data on the extent to which these innovations contribute to reducing the environmental footprint of the construction industry. Furthermore, a distinctive aspect of this study is its focus on the challenges and barriers faced by construction companies during the implementation of technological innovations in the supply chain of environmentally friendly building materials. By identifying and analyzing these challenges, such as financial constraints and lack of technical expertise, this research aims to provide valuable insights that can help stakeholders overcome implementation barriers and facilitate the adoption of these innovations.

In addition, this research seeks to address the gap in the literature regarding the socio-economic implications of adopting technological innovations in the supply chain of environmentally friendly building materials. By examining factors such as job creation, cost-effectiveness, and stakeholder engagement, this study aims to provide a comprehensive understanding of the broader impacts associated with these innovations. Understanding the socio-economic implications is crucial for assessing the feasibility, sustainability, and overall value proposition of these technologies. Lastly, this research aims to provide practical recommendations that can guide policymakers, industry practitioners, and other stakeholders. By synthesizing the findings from the analysis of technological innovations, environmental impacts, implementation challenges, and socio-economic implications, this study will offer actionable insights and guidelines for promoting the adoption of environmentally friendly building materials in the construction industry. Overall, through its comprehensive approach, quantitative analysis of environmental impacts, examination of implementation challenges, exploration of socio-economic implications, and provision of practical recommendations, this research aims to contribute significantly to the field by advancing our understanding of the role of technological innovation in promoting sustainability in the supply chain of building materials.

2. Literature review and hypothesis development

2.1 Technological innovation

Buermans and den Dunnen (2014) assert that technological innovation refers to the process of introducing new or improved technologies, methods, or systems that bring about significant advancements, improvements, or breakthroughs in various fields. It involves the development and application of novel ideas, techniques, or tools to create innovative solutions to existing problems or to enhance existing processes, products, or services. The concept of technological innovation encompasses a wide range of activities, including research and development, design, prototyping, testing, implementation, and commercialization of new technologies (Ruff, 2015). It can involve the creation of entirely new technologies or the adaptation and improvement of existing ones. Technological innovation plays a vital role in driving economic growth, improving productivity, and enhancing competitiveness across industries and sectors (Xu et al., 2023). It enables organizations to create value, differentiate themselves from competitors, and meet the evolving needs and demands of customers and society (Kuo et al., 2022). By harnessing the potential of new technologies, organizations can achieve higher efficiency, effectiveness, and sustainability in their operations. Innovation can occur in various forms, such as product innovation, process innovation, business model innovation, or organizational innovation. Parida et al. (2019) explain that product innovation involves the development of new or improved products or services, often incorporating novel features, functionalities, or designs. Process innovation focuses on enhancing operational efficiency, streamlining workflows, or optimizing production processes through the adoption of new technologies or methodologies. Business model innovation involves rethinking and restructuring the way organizations create, deliver, and capture value, often driven by technological advancements. Organizational innovation pertains to the implementation of new management practices, structures, or cultures that facilitate and support innovation within an organization. Technological innovation is closely linked to societal progress and sustainable development (Dantas et al., 2021; Goi, 2017; Palomares et al., 2021). It enables the creation of environmentally friendly technologies, solutions, and practices that promote resource efficiency, reduce environmental impact, and address pressing global challenges, such as climate change, pollution, and resource scarcity. By fostering innovation, societies can address complex problems and create more sustainable and resilient systems (Hu et al., 2022; Khan et al., 2022; Z. Yu et al., 2022). Overall, technological innovation is a dynamic and transformative process that drives progress, fosters creativity, and propels societies forward. It enables organizations to adapt, evolve, and thrive in an ever-changing and increasingly interconnected world.

2.2 Environmentally Friendly Building Material Supply Chain

According to Manco et al. (2023), the concept of an Environmentally Friendly Building Material Supply Chain refers to the series of processes and activities associated with the acquisition, production, distribution, and utilization of building materials that have low environmental impact. This concept aims to minimize the use of natural resources, reduce greenhouse gas emissions, limit waste generation, and promote sustainable lifecycle practices for building materials. The approach to an environmentally friendly building material supply chain involves the selection of eco-friendly raw materials, such as recycled materials, renewable resources, or materials with low carbon footprints. Additionally, the production processes of these building materials should consider energy efficiency, wise water usage, and proper waste management. During the distribution stage, smart logistics choices can reduce transportation emissions and ensure efficient delivery. Furthermore, in the utilization stage, environmentally friendly maintenance practices and efficient use of building materials can help mitigate negative environmental impacts (Hegab et al., 2023). One of the goals of an environmentally friendly building material supply chain is to create a sustainable lifecycle for building materials (Khan et al., 2022). This involves considering reuse, recycling, and the recovery of materials that are no longer in use or damaged. By considering this lifecycle perspective, benefits can be derived in terms of reducing construction waste and achieving more resource-efficient practices (Manco et al., 2023). Moreover, the concept also involves collaboration among various stakeholders involved in the building material supply chain, such as manufacturers, suppliers, contractors, architects, and project owners. Effective communication and coordination among all parties are necessary to identify and adopt best practices in the selection, use, and processing of environmentally friendly building materials. This entails information exchange, standardization, and the adoption of certification systems that promote sustainability. By implementing the concept of an environmentally friendly building material supply chain, the aim is to achieve environmental sustainability in the construction industry. In addition to environmental benefits, this approach can also provide economic advantages, such as operational efficiency, improved company reputation, and meeting the increasing market demand for environmentally friendly buildings (Soufi et al., 2023).

2.3 Sustainable Environment

The concept of a sustainable environment is significantly influenced by advancements in technology and environmentally friendly building material supply chains (Costantini et al., 2017; Li et al., 2020; Nureen et al., 2023). Technology plays a crucial role in developing innovative solutions to address environmental challenges and improve resource efficiency. Goi (2017) reveals that technological innovation plays a crucial role in driving advancements and improvements in the supply chain processes and practices for environmentally friendly building materials, thereby contributing to the overall sustainability of the environment. Feng et al. (2022) declare that technological innovation enables the development and implementation of new and improved manufacturing techniques, material sourcing methods, and distribution systems that prioritize environmental sustainability. For example, innovative technologies can facilitate the use of recycled or renewable materials, reduce energy consumption during production, and optimize transportation routes to minimize carbon emissions. Furthermore, technological innovations can enhance the efficiency and effectiveness of the supply chain, leading to reduced waste generation, improved resource management, and increased recycling and reusing of building materials (Parida et al., 2019). Automation and digitalization can streamline processes, enhance communication and collaboration among stakeholders, and enable real-time monitoring and data analysis for better decision-making regarding sustainability practices (Hu et al., 2022). By integrating technological innovations into the environmentally friendly building material supply chain, it becomes possible to achieve significant environmental benefits (Z. Yu et al., 2022). These innovations contribute to the reduction of greenhouse gas emissions, conservation of natural resources, and minimization of environmental pollution associated with traditional construction practices (Hu et al., 2022). Moreover, advancements in technology can lead to the development of high-performance and energy-efficient building materials that promote sustainable building designs and operations. The relationship between technological innovation, the environmentally friendly building material supply chain, and a sustainable environment is symbiotic (Costantini et al., 2017; Li et al., 2020; Nureen et al., 2023). Technological advancements drive improvements in the supply chain, enabling the adoption of more sustainable practices, while a sustainable environment creates opportunities for further technological innovation. This reciprocal relationship fosters a positive feedback loop, where each aspect reinforces and supports the other in the pursuit of environmental sustainability. Ultimately, the combination of technological innovation and an environmentally friendly building material supply chain contributes to the creation of a sustainable environment by reducing the ecological footprint of the construction industry, promoting resource efficiency, and supporting the transition towards more sustainable and resilient built environments (Khan et al., 2022).

Based on the available information, the study generated hypotheses and constructed a conceptual framework that serves as a foundation for the research. The conceptual framework, presented in Figure 1, illustrates the relationships and interdependencies between technological innovation, the environmentally friendly building material supply chain, and their impact on achieving a sustainable environment. The framework provides a visual representation of the key variables and their hypothesized connections, guiding the investigation and analysis conducted in the study. By establishing this conceptual framework, the research aims to contribute to the understanding of how technological innovation can influence the supply chain of environmentally friendly building materials and, subsequently, contribute to the promotion of a sustainable environment.

H1: *Technological Innovation relates to the Environmentally Friendly Building Material Supply Chain.*
H2: *Technological Innovation relates to the Sustainable Environment.*
H3: *The Environmentally Friendly Building Material Supply Chain relates to Sustainable Environment.*
H4: *The Environmentally Friendly Building Material Supply Chain meditate on Technological Innovation related and Sustainable Environment.*

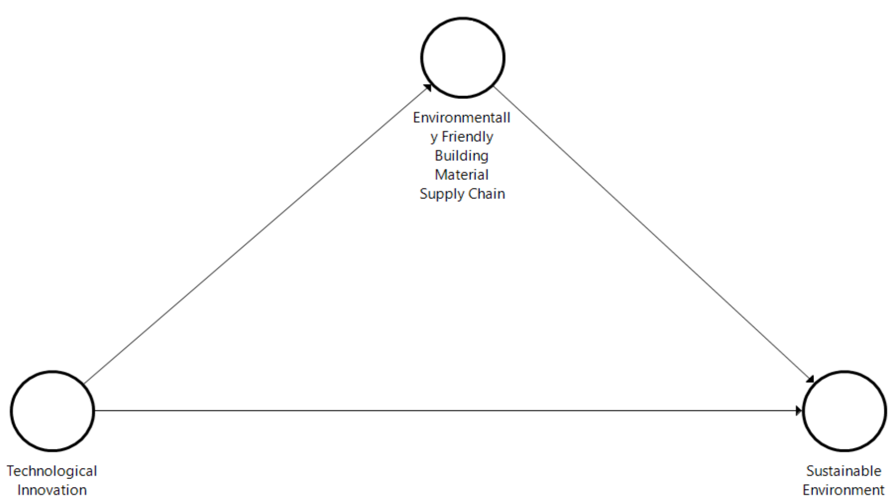

Fig. 1. Framework model

3. Research method

This study employs a quantitative research design to analyze the relationship between technological innovation and the supply chain of environmentally friendly building materials in the context of a sustainable environment. The sample population consists of 150 construction companies in Banten Province, Indonesia, that have adopted technological innovations in their supply chain practices (Marwanto et al., 2020). Data is collected through structured questionnaires or interviews, and statistical analysis is used to examine the relationship between technological innovation, the environmentally friendly building material supply chain, and the achievement of a sustainable environment (Soenyono & Basrowi, 2020). In this study, data will be collected using structured questionnaires as the primary data collection instrument (Suwarno et al., 2020). The questionnaires will be designed based on established constructs and variables related to technological innovation, the supply chain of environmentally friendly building materials, and the sustainable environment (Basrowi & Maunnah, 2019). Closed-ended questions with predefined response options will be used to ensure consistency and facilitate data analysis (Basrowi & Utami, 2020). The questionnaire will include items that measure the level of technological innovation adoption, the integration of environmentally friendly practices in the supply chain, and the perceived impact on the sustainable environment. Variables will be measured using Likert scales or ordinal scales, where respondents will indicate their level of agreement or disagreement with specific statements (Basrowi & Utami, 2020). The Likert scale will typically range from 1 to 5, with 1 indicating strongly disagree and 5 indicating strongly agreeing. To ensure the reliability and validity of the measurement instruments, a pilot test will be conducted with a small sample of participants before the main data collection phase. This will help identify any ambiguities or issues with the questionnaire items and refine them accordingly. The pilot test results will be analyzed using techniques such as Cronbach's alpha to assess the internal consistency and reliability of the measurement scales. Measurement of these variables will be performed using designed measurement instruments, such as structured questionnaires. These measurement instruments consist of a series of questions or statements designed to gather data about the variables of interest. The measurement components of this study include: Technological Innovation were modified using 7 indicators from Nureen et al. (2023). Environmentally Friendly Building Material Supply Chain measurements were adopted using 8 indicators from Ferreira et al. (2023). Finally, 10 indicators for a sustainable environment by Agrawal et al. (2022). The measurement process has been modified for the writer's purposes and involves administering relevant measurement tools or questionnaires to selected respondents, which may include construction company executives. The collected data is then analyzed using appropriate statistical techniques to obtain meaningful insights and draw conclusions.

4. Result and discussion

4.1 Validity and reliability

We assessed the validity of the indicator by employing the convergent method, which yielded the external loading factor. The acceptable range for the loading factor in exploratory studies, which are the initial stages of developing a measurement scale, is 0.50 to 0.70. In our specific investigation, all indicators exhibited an outer loading value greater than 0.70, meeting the criteria for convergent validity (refer to Table 1).

Table 1
Confirmatory factor analysis

Construct	Items	Outer Loading	Cronbach's Alpha	rho_A	CR	AVE
Technological Innovation	TINN1 = Research and Development (R&D) Investment	0.717	0.932	0.935	0.946	0.714
	TINN2 = Patents and Intellectual Property	0.889				
	TINN3 = Adoption of Clean Technologies	0.880				
	TINN4 = Efficiency Improvements	0.885				
	TINN5 = Digital Solutions	0.884				
	TINN6 = Collaborative Initiatives	0.825				
	TINN7 = Market Growth	0.818				
Environmentally Friendly Building Material Supply Chain	EFBM1 = Certification and Labeling Systems	0.833	0.967	0.97	0.973	0.817
	EFBM2 = Material Traceability	0.952				
	EFBM3 = Life Cycle Assessment	0.964				
	EFBM4 = Carbon Footprint	0.878				
	EFBM5 = Waste Reduction and Recycling	0.895				
	EFBM6 = Supplier Engagement	0.794				
	EFBM7 = Transparency and Reporting	0.939				
	EFBM8 = Stakeholder Engagement	0.963				
Sustainable Environment	SENV1 = Carbon Footprint	0.851	0.969	0.972	0.973	0.781
	SENV2 = Biodiversity and Ecosystem Health	0.875				
	SENV3 = Renewable Energy Adoption	0.919				
	SENV4 = Water Management	0.901				
	SENV5 = Waste Management	0.929				
	SENV6 = Land Use and Conservation	0.898				
	SENV7 = Air Quality	0.816				
	SENV8 = Sustainable Transportation	0.895				
	SENV9 = Education and Awareness	0.817				
	SENV10 = Policy and Governance	0.929				

In the next phase, we compared the square root coefficient of variance (AVE) extracted from each latent factor to the correlation coefficient between the other factors in the model. This analysis aimed to determine if the variables demonstrated discriminant validity, indicating their ability to differentiate between distinct groups. The AVE values significantly exceeded 0.5, as indicated in Table 1. Consequently, all constructs examined in this study exhibited discriminant validity higher than 0.50, as per Fornell & Larcker (1981). In the final step of the process, we employed composite reliability to assess the value of the variable indicators. Both the composite reliability and Cronbach's alpha exceeded 0.70, affirming the trustworthiness of the results (Chin, 2010).

The calculation of composite reliability for the variables in this study resulted in values ranging from 0.946 to 0.973, which exceeded the threshold of 0.70. These findings indicate that the indicators used to measure the variables were reliable and consistent. Additionally, Cronbach's alpha values ranging from 0.932 to 0.969 were obtained, further confirming the dependability of the indicators and indicating that they were free from measurement error (MacKenzie et al., 2011).

4.2 Testing research hypothesis

The results of the hypothesis testing demonstrated that Technological Innovation had significant and positive influence on the Environmentally Friendly Building Material Supply Chain (t=11.117>1.96) and Sustainable Environment (t=2.284>1.96). Furthermore, the Environmentally Friendly Building Material Supply Chain had significant and positive influence on the Sustainable Environment (t=2.688>1.96). Furthermore, the study examines the pathway coefficients to investigate whether Environmentally Friendly Building Material Supply Chain can mediate the relationship between Technological Innovation and Sustainable Environment. Environmentally Friendly Building Material Supply Chain has a favorable effect on Technological Innovation and Sustainable Environment positively (t=2.347>1.96). Consequently, it is possible to argue that an Environmentally Friendly Building Material Supply Chain can mediate the association between Technological Innovation and Environmentally Friendly Building Material Supply Chain. Therefore, all hypotheses from H1 to H4 are accepted (see Table 2).

Table 2
Path Coefficient

Hypothesis	Construct *)	Original Sample	Standard Deviation	T Statistics	P Values	Remark
H1	TINN → EFBM	0.706	0.063	11.117	0.000	Accepted
H2	TINN → SENV	0.308	0.135	2.284	0.023	Accepted
H3	EFBM → SENV	0.337	0.125	2.688	0.007	Accepted
H4	TINN → EFBM → SENV	0.238	0.101	2.347	0.019	Accepted

*): TINN=Technological Innovation; EFBM= Environmentally Friendly Building Material Supply Chain; SENV=Sustainable Environment

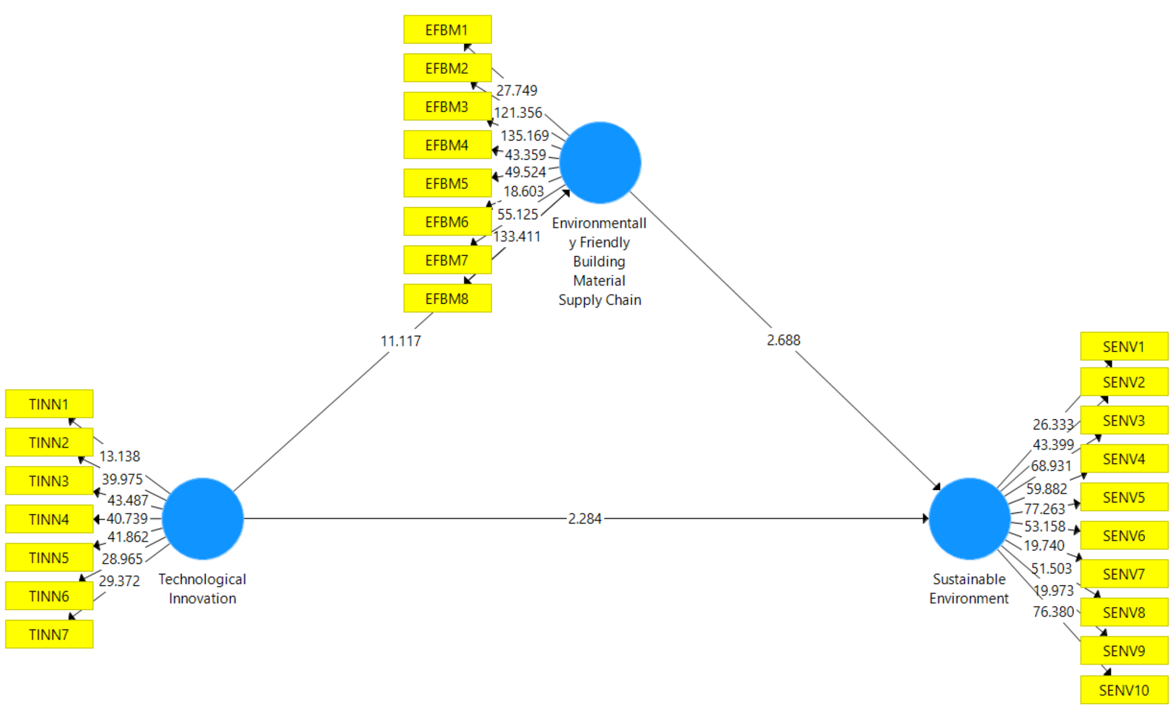

Fig. 2. Analysis result

The relation between technological innovation and the environmentally friendly building material supply chain is a crucial aspect that significantly influences the overall sustainability of the built environment. Technological innovation plays a pivotal role in driving advancements and improvements in the supply chain processes and practices for environmentally friendly building materials. Firstly, technological innovation enables the development and implementation of new and improved manufacturing techniques, material sourcing methods, and distribution systems that prioritize environmental sustainability. Innovations such as advanced material production processes, automation, and digitization can contribute to resource efficiency, waste reduction, and lower carbon emissions throughout the supply chain. These innovations promote the use of renewable or recycled materials, enhance energy efficiency, and optimize transportation logistics, resulting in a reduced environmental impact. Secondly, technological innovation fosters the creation of high-performance and energy-efficient building materials. Innovations in material composition, design, and production techniques can lead to the development of sustainable alternatives to conventional construction materials. For example, the use of eco-friendly materials like bamboo, recycled plastics, or low-carbon concrete can significantly reduce the environmental footprint of buildings. Technological advancements also contribute to the improvement of material performance, durability, and insulation properties, enhancing the overall energy efficiency and environmental sustainability of buildings. Furthermore, technological innovation facilitates the adoption of sustainable practices and certifications throughout the supply chain. Tools such as Building Information Modeling (BIM), Internet of Things (IoT) sensors, and real-time monitoring systems enable better tracking and management of materials, energy usage, and waste generation. These innovations enhance transparency, traceability, and accountability, ensuring compliance with environmental regulations and sustainability standards. Overall, the relationship between technological innovation and the environmentally friendly building material supply chain is mutually reinforcing. Technological advancements drive improvements in the supply chain, enabling the adoption of more sustainable practices. Simultaneously, the demand for environmentally friendly materials and sustainable construction practices stimulates further technological innovation. This symbiotic relationship supports the transition towards a more sustainable built environment, where resource efficiency, reduced environmental impact, and improved occupant well-being are prioritized.

Technological innovation has a close relationship with a sustainable environment. Technological innovations play a significant role in addressing environmental challenges, promoting sustainable development, and creating a positive impact on the environment. Here are some key interpretations of this relationship: Firstly, technological innovation helps to reduce environmental impact. Innovations in renewable energy, waste management, water conservation, and pollution control contribute to mitigating environmental degradation. These advancements help to reduce greenhouse gas emissions, preserve natural resources, and protect ecosystems, thus fostering a sustainable environment. Secondly, technological innovation promotes resource efficiency. Innovations in energy-saving technologies, such as smart grids, energy-efficient appliances, and LED lighting systems, reduce energy consumption and carbon emissions. Advanced manufacturing processes and recycling technologies enhance material efficiency, reduce waste generation, and preserve valuable resources. These innovations contribute to sustainable resource management and support the transition to a circular economy. Thirdly, technological innovation enables effective environmental monitoring and management. Tools such as remote sensing, satellite imagery, and data analytics provide real-time information on environmental conditions, ecosystem health, and climate patterns. This enables informed decision-making and proactive environmental planning. Enhanced monitoring capabilities help policymakers and stakeholders assess environmental impacts, detect environmental risks, and implement targeted interventions to safeguard the environment. Fourthly, technological innovation supports sustainable mobility and transportation. Innovations in electric vehicles, shared mobility platforms, and intelligent transportation systems help reduce carbon emissions, improve air quality, and alleviate traffic congestion. Additionally, advancements in logistics and supply chain management optimize transportation routes, reducing fuel consumption and promoting overall sustainability in the transportation sector. Lastly, technological innovation fosters environmental awareness and education. Digital platforms, mobile applications, and online resources provide accessible and interactive means to disseminate information about sustainable practices, climate change, and environmental conservation. These innovations empower individuals and communities to make informed choices and actively participate in sustainable behaviors, fostering a culture of environmental stewardship. In summary, technological innovation is closely intertwined with a sustainable environment. It enables the development and implementation of solutions that address environmental challenges, enhance resource efficiency, facilitate environmental monitoring and management, promote sustainable mobility, and raise environmental awareness. By harnessing the potential of technological innovation, societies can strive towards a sustainable future where environmental preservation and human well-being are prioritized.

The relationship between the Environmentally Friendly Building Material Supply Chain and a Sustainable Environment is crucial for achieving long-term environmental sustainability in the construction industry. The supply chain plays a pivotal role in promoting sustainable practices and materials, minimizing environmental impacts, and fostering a more sustainable built environment. The Environmentally Friendly Building Material Supply Chain aims to reduce the environmental footprint of the construction industry by implementing sustainable sourcing practices. This involves sourcing materials from suppliers who prioritize environmentally responsible practices, such as using renewable resources, minimizing energy consumption, and reducing emissions during the production process. Additionally, the supply chain focuses on energy efficiency and resource conservation. By adopting energy-efficient technologies and optimizing transportation logistics, the supply chain reduces energy consumption and minimizes carbon emissions. This contributes to a more sustainable and low-carbon construction industry. Another aspect of the relationship is the promotion of sustainable material selection. The supply chain prioritizes the use of building materials with lower embodied carbon, reduced toxicity levels, and high levels of recycled content. By encouraging the adoption of these sustainable materials, the supply chain supports the shift towards environmentally friendly construction practices and reduces the environmental impact associated with traditional materials. Furthermore, the supply chain plays a crucial role in waste reduction and recycling. By implementing waste management strategies, such as minimizing construction waste, promoting material reuse, and establishing recycling programs, the supply chain helps divert waste from landfills and contributes to a more circular economy. This reduces the depletion of natural resources and minimizes the environmental impact of waste disposal. Moreover, the supply chain embraces life cycle assessment (LCA) and environmental certification processes. Conducting LCAs allows for a comprehensive evaluation of the environmental impact of building materials throughout their entire life cycle. Environmental certifications, such as LEED certification, ensure that materials meet specific sustainability criteria. By integrating LCA and certification practices into the supply chain, the industry can make more informed decisions and prioritize materials with lower environmental impacts. In summary, the relationship between the Environmentally Friendly Building Material Supply Chain and a Sustainable Environment is characterized by sustainable sourcing, energy efficiency, sustainable material selection, waste reduction and recycling, and the integration of life cycle assessment and environmental certification. By adopting these practices, the supply chain contributes to the creation of a more sustainable construction industry, minimizing environmental impacts and promoting a greener built environment.

The Environmentally Friendly Building Material Supply Chain plays a mediating role in the relationship between Technological Innovation and a Sustainable Environment. This supply chain serves as a crucial bridge, facilitating the integration of innovative and sustainable technologies into construction practices. By enabling the adoption and implementation of these technologies, it ensures that environmentally friendly building materials and sustainable practices are incorporated throughout the construction process. The supply chain also plays a pivotal role in driving market demand for sustainable solutions by promoting and prioritizing the use of eco-friendly materials. Moreover, it ensures compliance with environmental standards and certifications, guaranteeing that only sustainable innovations are embraced. The supply chain fosters collaboration and knowledge exchange among stakeholders, thereby facilitating the development and dissemination of sustainable technologies. Additionally, it drives continuous improvement by encouraging the integration of new and more sustainable technologies into construction practices. Overall, the Environmentally Friendly Building Material Supply Chain significantly mediates the relationship between Technological Innovation and the achievement of a Sustainable Environment. By serving as a conduit for innovation, the Environmentally Friendly Building Material Supply Chain plays a critical role in advancing sustainable practices and mitigating environmental impacts. This supply chain acts as a catalyst for the adoption of technological advancements that contribute to a sustainable environment. It facilitates the efficient sourcing, production, distribution, and disposal of environmentally friendly building materials, ensuring that they are seamlessly integrated into the construction process. Through collaboration with suppliers, manufacturers, and construction firms, the supply chain promotes the use of eco-friendly materials and encourages the implementation of sustainable practices, such as energy-efficient construction methods and waste reduction strategies. Furthermore, the supply chain enables traceability and transparency in the sourcing of materials, ensuring their compliance with environmental standards and certifications. By optimizing the flow of materials and minimizing waste, it helps to reduce the carbon footprint and ecological impact of the construction industry. The Environmentally Friendly Building Material Supply Chain acts as a transformative force, driving the adoption of sustainable technologies and practices, and ultimately contributing to the creation of a more sustainable environment.

6. Conclusion

In conclusion, this study has demonstrated a significant relationship between technological innovation, the environmentally friendly building material supply chain, and sustainable environment in the construction industry. The findings have indicated that technological innovation has the potential to transform and enhance environmental sustainability through its influence on the building material supply chain. By adopting innovative technologies in the environmentally friendly building material supply chain, the use of sustainable building materials can be significantly increased. This includes the utilization of recycled materials, waste reduction, energy efficiency, and the implementation of other green technologies. The supply chain plays a crucial role in ensuring that these innovative technologies are effectively adopted in construction practices, thereby promoting the creation of a more sustainable environment. Furthermore, the study has revealed that the building material supply chain acts as a mediator between technological innovation and sustainable environment. The supply chain facilitates the integration of innovative technologies into construction practices, ensures compliance with environmental standards, and encourages broader adoption of sustainable solutions. The conclusion of this study indicates that the adoption of technological innovation in the environmentally friendly building material supply chain has a positive impact on the sustainable environment in the construction industry. It drives a shift towards more environmentally friendly construction practices and contributes to reducing negative environmental impacts. However, to achieve a sustainable environment, it is important to consider the challenges and limitations in implementing technological innovations and managing the supply chain. Collaboration among stakeholders, including the government, construction industry, manufacturers, and contractors, is needed to address these constraints and achieve greater success in realizing a sustainable environment in the construction industry.

The implications of this study are to provide a better understanding of the relationship between Technological Innovation, the Environmentally Friendly Building Material Supply Chain, and Sustainable Environment in the construction industry context. The findings can serve as a basis for developing more effective strategies and policies to encourage the adoption of sustainable and innovative technologies in the sector. Additionally, the study sheds light on the importance of the supply chain's role in mediating the impact of technology on environmental sustainability. However, this study has some limitations that need to be considered. Firstly, it may be limited to specific geographical or sectoral contexts, thus limiting the generalizability of the findings. Moreover, data collection and analysis in this study may rely on secondary sources, which could affect the accuracy and comprehensiveness of the information used. Furthermore, the study may be influenced by external factors that are difficult to control, such as regulatory changes or market conditions. Furthermore, this study assumes that the adoption of technological innovations in the environmentally friendly building material supply chain directly contributes to achieving a sustainable environment. However, the complexity of the relationships among these factors may involve other unexplored variables. Therefore, further research could incorporate additional factors that influence the relationship between technological innovation, supply chain, and sustainable environment. Despite these limitations, the obtained results and findings still make a valuable contribution to understanding the relationship between technological innovation, the environmentally friendly building material supply chain, and sustainable environment. The implications of this research can be used as a foundation for further development efforts in promoting sustainability in the construction sector and informing decision-making in designing sustainable policies and strategies.

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