Evaluation of the Role of Circular Economy Readiness as a Mediator of the Relationship between Environmentally Friendly Product Innovation and Urban Sustainability.

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ABSTRACT

There is an increasing need for environmentally friendly product innovations that contribute to urban sustainability in the city of Urban. However, the implementation of a circular economy, based on the readiness of various parties, remains a challenge in achieving this sustainability. This study aims to evaluate how circular economy readiness mediates the relationship between environmentally friendly product innovation and urban sustainability in the city of Urban, to measure the influence of product innovation on urban sustainability through circular economy readiness, and to provide empirical evidence using quantitative methods with bootstrapping mediation analysis. This study uses a quantitative method with a bootstrapping-based mediation analysis approach. Data were collected through a survey of 188 respondents representing industry players and stakeholders in the urban area. The research instrument is in the form of a structured questionnaire that measures environmentally friendly product innovation, circular economy readiness, and urban sustainability indicators in the city of Urban. Data analysis was carried out using bootstrap mediation techniques to test the role of circular economy readiness as a mediator. The results of the study show that environmentally friendly product innovation has a significant effect on urban sustainability in the city of Urban. Circular economy readiness has proven to act as a mediator that strengthens the positive relationship between environmentally friendly product innovation and urban sustainability. These findings indicate that increasing circular economy readiness is very important to realize sustainability through product innovation. In conclusion, circular economy readiness is a key factor linking environmentally friendly product innovation to urban sustainability in the city of Urban. The implications of this study emphasize the need for strategies to increase circular economy readiness to support sustainable innovation and policies in the development of greener and more environmentally friendly cities.

I. INTRODUCTION

The implementation of the circular economy in Indonesia faces various complex obstacles, especially in the urban context in the city of Urban, which requires the integration of environmentally friendly product innovation and urban sustainability. A study conducted by Akbar (2024) shows that public awareness of the concept of circular economy is still very limited, with a low and inconsistent search volume for the keyword "circular economy" compared to the concept of "waste recycling," which is better known to the public. This indicates that although people understand recycling practices, information about a more comprehensive circular economy system still needs to be significantly improved.

Infrastructure supporting the circular economy in urban environments in the city of Urban, Indonesia, is also still limited. OECD research (2020) identified that 73% of surveyed cities and regions experienced constraints related to insufficient funding, while 69% faced financial risks in the implementation of the circular economy. This condition is exacerbated by the lack of adequate investment scale and the lack of involvement of the private sector, which reached 43% of the survey respondents. This limited infrastructure has a direct impact on the city's ability to integrate eco-friendly product innovations in a sustainable circular economy system.

However, some studies show results that contradict the above conditions. The study found that the circular economy can play an effective role as a mediator between green advertising and sustainable purchasing behavior, with a significance value of $\beta = 0.164$, t-value = 2.491, $p < 0.05$. These findings are in contrast to the field conditions that show low public awareness, indicating that there is great potential that has not been optimally utilized in the implementation of the circular economy as a link between product innovation and sustainability.

Stakeholder collaboration in implementing the circular economy faces numerous obstacles. Mossakowska & Napierski (2024) identify that while proactive stakeholder engagement, technological advancements, and supporting policies are essential to drive collaboration and sustainability, coordination between sectors remains a major barrier in the transition to circular economy practices(Kazancoglu et al., 2023). This is reinforced by the findings of Senaratne (2023), which show that stakeholder collaboration for the circular economy still faces significant research gaps, especially in connecting various stakeholders for CE implementation.

Some important aspects that are not yet known in depth are how the readiness of the circular economy can function as an effective mediation factor between environmentally friendly product innovation and urban sustainability in the city of Urban(Liu, 2025). Previous studies have focused more on partial aspects such as consumer behavior or technological infrastructure, but have not comprehensively explored the mediating role of circular economy readiness in the urban context of the city of Urban. In addition, there is still uncertainty about the specific mechanism by which the readiness of various stakeholders can strengthen the relationship between sustainable product innovation and measurable urban sustainability outcomes.

Evaluation of the role of circular economy readiness as a mediator of the relationship between environmentally friendly product innovation and urban

sustainability in the city of Urban has several important functions in the context of sustainable development(Ghisellini et al., 2018). First, the readiness of the circular economy plays a role in bridging the relationship between environmentally friendly product innovation and urban sustainability in the city of Urban, so that these innovations can be applied effectively and have a real impact on the preservation of the city's environment(Agrawal et al., 2024). This readiness includes technical readiness, knowledge, and awareness of various stakeholders, which are important parameters in encouraging economic transformation based on circular principles. In addition, the evaluation of the role of circular economy readiness helps identify inhibiting and supporting factors in the process of implementing environmentally friendly product innovations, so that a more targeted strategy can be formulated to improve urban sustainability in the city of Urban.

The role of circular economy readiness is also very strategic in strengthening collaboration between various actors, including the government, the private sector, and the community, in supporting the achievement of a more sustainable urban development model(Tița et al., 2024). With high readiness, the process of adaptation and adoption of environmentally friendly product innovations is not only an individual initiative but also part of an integrated ecosystem. This contributes to resource optimization, waste reduction, and increased efficiency in the urban product and service cycle in the city of Urban. In addition, the evaluation of the role of circular economy readiness also functions as an indicator of successful adaptation to changes in environmental regulations and digital technology trends that are increasingly developing in the urban green sector in the city of Urban. Thus, the readiness of the circular economy not only accelerates the achievement of sustainability goals but also strengthens the overall economic competitiveness of the city(Ciorobea et al., 2025).

The ideal condition that is expected but has not yet been realized is the creation of an integrated circular economy ecosystem in the city of Urban, where environmentally friendly product innovations can contribute optimally to the sustainability of the city through the readiness of a mature circular economy system. This vision includes harmonious coordination among stakeholders, adequate infrastructure, and high public awareness of circular economy practices(Razminiene, 2019). However, based on existing empirical evidence, the achievement of these ideal conditions still requires systematic and coordinated efforts from various parties.

This study's novelty lies in employing bootstrapping mediation analysis to assess circular economy readiness as an intermediary between environmentally friendly product innovation and urban sustainability in the city of Urban(Hojnik et al., 2024). In contrast to previous studies that examined these aspects separately, this study integrates all three constructs in one comprehensive mediation model for the urban context of the Indonesian city of Urban.

The indicator of this research can be seen from the fact that although Indonesia has great potential for the implementation of a circular economy with a GDP that can increase by 593-638 trillion rupiah through the adoption of CE practices in five priority sectors, its implementation is still hampered by the

factors mentioned earlier(Kosta & Ramadani, 2025). This paradoxical condition shows the need for a better understanding of how circular economy readiness can mediate the relationship between eco-friendly product innovation and urban sustainability in the city of Urban. The purpose of this study is to evaluate the extent to which circular economy readiness can play a mediator in the relationship between environmentally friendly product innovation and urban sustainability in Urban city, measure the influence of environmentally friendly product innovation on urban sustainability in Urban city through circular economy readiness as an intermediate factor, and provide an empirical picture using quantitative methods with bootstrapping mediation analysis on the role of readiness circular economy in encouraging urban sustainability based on environmentally friendly product innovation(Kumar & Chhabra, 2022).

Gaps in previous research can be identified from several important studies. First, Cuevas-Pichardo et al.'s (2025) research entitled "The Mediating Role of Circular Economy in Manufacturing Firms" only focuses on the manufacturing context and does not explore the relationship with urban sustainability. Second, the study by Tetteh et al. (2024) on the effect of partial mediation of circular economy implementation on business analytics capabilities and sustainable performance is still limited to the business context and has not touched on specific aspects of environmentally friendly product innovation. Third, the Personal research (2025) entitled "Developing Circular Cities in Emerging Economies," which examines circular economy initiatives in the urban food system in the city of Semarang and other cities in Indonesia, has not integrated the mediation aspect of circular economy readiness for product innovation and sustainability holistically. One relevant theory is the Theory of Planned Behavior (TPB), which explains how the intentions of individuals or organizations in adopting innovations, such as eco-friendly products and digital technologies, are influenced by attitudes, subjective norms, and perceptions of control. In this context, circular economy readiness can be seen as a perception of control that mediates the relationship between environmentally friendly product innovation and the achievement of urban sustainability in the city of Urban. TPB also supports understanding how digital technology in green supply chains can motivate behavioral changes in business operations towards efficiency and sustainability.

In addition, the Resource-Based View (RBV) is a very important theory in this analysis. RBV emphasizes that the company's competitive advantage comes from its internal resources and unique and non-replicable organizational capabilities, such as digital technologies in the supply chain and eco-friendly product innovation(Corrao et al., 2025). In this study, circular economy readiness can be considered as an organizational capability that allows companies to optimize the use of digital technology and green innovation in improving sustainable business performance. RBV helps link how digital technologies are applied in green supply chains to improve operational efficiency and strengthen relationships with suppliers and customers through ongoing collaboration. The Resource-Based View (RBV) perspective provides an in-depth theoretical explanation of the research findings that circular economy readiness functions as a unique and difficult-to-replicate organizational capability(Giusti et al., 2025).

The research data showed significant variations in readiness between industrial sectors, with manufacturing (4.20) and technology (4.15) showing higher readiness than the service sector (3.65) and MSMEs (3.50). This indicates that circular economy readiness is an internal resource and strategic capability that enables organizations to optimize environmentally friendly product innovations to improve urban sustainability(Han et al., 2025). Mehmood's research (2025) supports this finding by explaining that eco-product and eco-process innovation play a role in increasing circular economy readiness through digital solutions, which is in line with RBV that technology and innovation capabilities become sustainable competitive advantages. The variation in readiness between sectors reflects differences in the accumulation of resources and capabilities that each industry has in integrating circular economy principles.

In addition, supported by Systems Theory is also an important framework in understanding how various elements, such as product innovation, circular economy readiness, digital technology, green supply chains, and urban sustainability in the city of Urban, interact dynamically(Khan et al., 2023). This theory views an organization as a system made up of interconnected parts that function together to achieve complex goals, such as sustainability. With a systems approach, research can examine how the integration of digital technology facilitates the flow of green information among stakeholders in the supply chain and its contribution to the achievement of holistic sustainability goals(Hang et al., 2025).

Also supported by Rogers' Diffusion of Innovation (DOI) theory explains the process by which innovations, including eco-friendly products and digital technologies, are disseminated and adopted by organizations and society. DOIs help explain the variables that affect the speed and success of digital technology adoption in the green supply chain, such as relative superiority, compatibility, complexity, trialability, and observability. In the context of the circular economy, DOI can highlight how an organization's readiness to implement a circular economy plays a role as a factor influencing the adoption of sustainable digital technology innovations.

Furthermore, strengthened by theory, Stakeholder Theory emphasizes the importance of collaboration and involvement from all interested parties in the successful implementation of the circular economy and digital technology within the green supply chain. This theory emphasizes that an organization's performance depends not only on internal factors but also on the relationships and influence of various stakeholders, including suppliers, customers, governments, and society. Based on this theory, this research evaluates how circular economy readiness enhances synergy and stakeholder interaction to promote business sustainability through digital technology and environmentally friendly product innovation. The integration of these theories provides a solid foundation for analyzing the complex relationships in this study.

II. METHODOLOGY

The research method used in this study is a method. This design is suitable for analyzing the relationship between green innovation variables, circular economy readiness, and sustainability in areas with high ecological stress through mediation analysis using bootstrapping techniques. Bootstrapping allows testing the significance of mediating effects by reinforcing the validity of statistical results without assuming data normality, making it especially relevant in social research with sample data.

The population of this study is entrepreneurial actors in areas with high ecological challenges who are actively engaged in green innovation. The sample used was 188 respondents, who were selected using purposive sampling techniques to ensure that the respondents were individuals or business people who have experience and direct involvement in green innovation and entrepreneurial practices in the region. The specific research subjects are entrepreneurs or business actors who actively apply the principles of environmentally friendly innovation and are related to the readiness to implement the circular economy in areas with high ecological pressure. The research instrument consisted of a structured questionnaire with measurement scales for green innovation, circular economy readiness, and regional sustainability variables. The instrument was developed through adaptation and modification of previous research instruments that had been proven to be valid and reliable, and then an initial validity and reliability test was carried out using a trial on a small number of similar respondents. Furthermore, a confirmatory factor analysis was carried out to ensure the construct and validity of the instrument, as well as reliability testing with Cronbach's alpha. The instrument was developed through a literature review and expert consultation to compile indicators relevant to high-ecological-pressure areas and green entrepreneurship models. Data analysis used the statistical method of Structural Equation Modeling (SEM) with a partial least squares (PLS-SEM) approach equipped with a bootstrapping technique to test the hypothesis of direct and indirect influence (mediation) between variables. This technique allows the detection of the strength of the relationship between constructs and path significance in a comprehensive research model.

The steps of the research procedure began with the collection of primary data through the distribution of questionnaires to 188 selected respondents in a purposive manner, adjusted to the criteria of entrepreneurship and the level of ecological challenges of the region. If using the mixed-method method, the research is then followed by in-depth interviews or focus group discussion forums (FGDs) to deepen understanding of the local context and validate quantitative findings. Qualitative data are analyzed thematically to reinforce quantitative findings and provide more contextual policy recommendations. The combination of these methods provides a holistic picture of the implementation of green innovation and the role of the circular economy in supporting the sustainability of high ecological areas.

III. RESULTS AND DISCUSSION.

The results of this study state that the readiness of the circular economy has a central role as a mediator in connecting environmentally friendly product innovation with urban sustainability in the city of Urban. Based on data analysis from 188 respondents of industry players and stakeholders in the Urban area with high ecological pressure, it was found that the implementation of environmentally friendly innovations in urban areas in the city of Urban is not optimal if it is not supported by the readiness of a mature circular economy system. In this case, the readiness of the circular economy is not just a complementary component but functions as a catalyst that strengthens the positive impact of product innovation on the achievement of urban sustainability goals(Razminiene, 2019).

The circular economy mediation process is reflected in its ability to provide relevant technical foundations, knowledge, and cross-sector collaboration to encourage the adoption of environmentally friendly products in an integrated manner. Using ex-post facto quantitative methods and bootstrapping analysis, the mediating effects identified are significant and reinforce the position of the circular economy as a strategic link between innovation and urban socio-ecological outcomes in the city of Urban. This shows that increasing circular economy readiness among industry players and urban communities directly contributes to improving resource efficiency, reducing waste, and building an inclusive and adaptive urban policy ecosystem. Statistically, the circular economy has been proven to be able to strengthen the relationship between product innovation and sustainability with an increase in significance value, which empirically indicates the need for policies and strategies to strengthen the circular economy in the urban agenda in the city of Urban to be sustainable.

In its implementation, the readiness of the circular economy is multidimensional, including infrastructure readiness, technological knowledge, and coordination of stakeholders from various sectors(Tsakalova et al., 2024). This study found that collaboration between the government, the private sector, and the community greatly determines the level of readiness of the circular economy. The main obstacles that arise are limited investment, a lack of socialization of circular economy principles, and a lack of technical assistance in adopting environment-based product innovations. However, this weak point can be overcome gradually through education, training, and harmonization of regulations at the local and national levels to encourage the integration of the circular economy into urban development policies. Thus, this research is important in the role of the circular economy as a learning and collaboration platform for all elements of urban society. The circular economy expands opportunities for participation in environmentally friendly product innovation across production, distribution, and consumption processes(Fernandes & Rozenfeld, 2024). Every effort by industry players to adopt sustainable products and technologies is part of an economic cycle that not only prioritizes economic added value but also brings measurable positive environmental impacts. The adoption of digital technology in green supply chains, for example, helps

facilitate information exchange and build connectivity between various actors, so that the decision-making process becomes more data-based, efficient, and responsive to ecological challenges.

The findings of this study also show that there are quite prominent readiness variants between sectors. The technology and manufacturing sectors tend to be more prepared and proactive in integrating the circular economy, while the service sector and MSMEs still face challenges related to access to financing and limited human resources who understand circular principles. However, a pattern of inclusion and gradual adoption can be designed so that all levels of urban society get equal opportunities to participate in the innovation ecosystem and circular economy. An important discourse emerging from the research is the need to shift the paradigm of urban innovation in the city of Urban from individual, sporadic efforts toward a systemic, holistic approach grounded in the circular economy. The circular economy strengthens incentives and motivation for business actors to innovate greenly, driven by regulations, collaborative ecosystems, and clear market incentives(Cappelletti et al., 2024). The theoretical implications of this research result are supported by the concepts of the Theory of Planned Behavior and the Resource-Based View, where circular economy readiness is positioned as a form of organizational control and strategic capability in achieving better environmental and economic outcomes. The circular economy serves as a mechanism aligning innovation with sustainability goals in urban areas, encompassing economic, social, cultural, and ecological dimensions(Berkemeier et al., 2024).

Empirically, adopting a circular economy in urban areas of the city of Urban involves two main streams: infrastructure adaptation and behavioral change among actors. These two currents complement each other, where infrastructure adaptation becomes the technical foundation that allows business actors to develop environmentally friendly product innovations effectively. Meanwhile, changes in the behavior of actors, such as business actors and urban consumers, are driven by circular economy literacy and policy incentives developed by local governments. The relationship between circular economy readiness, product innovation, and city sustainability is considered to be dynamic and requires promotive, educational, and policy harmonization efforts across sectors.

This research also confirms that sustainable urban economic growth can only be achieved if environmentally friendly product innovation is supported by strong circular economy readiness and active stakeholder involvement(Liu, 2025). In this case, the circular economy not only functions as a link but also as a driver for the transformation of business systems and urban governance. Collaboration between sectors is the main strength that allows the circular economy model to develop inclusively and sustainably. The evaluation of the role of circular economy mediators shows that increased readiness is achieved through technology investment, human resource training, and strengthening networks between business actors and policy makers, among others. The empirical practice of the research results shows that in large cities facing high ecological pressure, the circular economy mediation model is able to increase the effectiveness of environmentally friendly product innovations in supporting

waste management, energy efficiency, and environmental protection(Wenger et al., 2024). The ideal conditions for a sustainable city will be achieved through the integration of the circular economy in spatial planning, transportation management, green industry development, and environmentally friendly digital supply chain systems. The series of innovations adopted along with the readiness of the circular economy has been proven to produce better social, economic, and environmental outcomes, with indicators of urban GDP in the city of Urban and the rapidly increasing quality of life of the community(Krummeck et al., 2022).

Table 1. Descriptive Statistics

Variable	Average (Mean)	Standard Deviation	Minimum	Maximum	Number of Respondents (N)
Eco-Friendly Product Innovation	4.25	0.56	2.50	5.00	188
Circular Economy Readiness	3.98	0.62	2.00	5.00	188
Urban Sustainability	4.10	0.59	2.75	5.00	188

Table 1 shows a summary of basic data from the three main variables in the study, namely environmentally friendly product innovation, circular economy readiness, and urban sustainability. The mean value shows that in general, respondents give a positive assessment with a score above 4 for product innovation and urban sustainability, and almost close to 4 for circular economy readiness. The standard deviation, ranging from 0.56 to 0.62, indicates a variation in respondents' opinions, although the difference is not too large. The minimum and maximum data showed that respondents gave a variety of answers ranging from low to maximum scores, reflecting a wide spectrum of perceptions of the three variables.

Table 2. Mediation Analysis

Line	Types of Hypotheses	Beta Value (β)	T-Value	P-Value	Significant
Urban Sustainability Product Innovation	Immediately	0.38	3.95	0.000	Yes
Circular Economy Readiness Product Innovation	Immediately	0.45	5.10	0.000	Yes
Urban Sustainability Circular Economy Readiness	Immediately	0.52	5.75	0.000	Yes
Product Innovation Circular Economy Readiness → Urban Sustainability	Mediation	0.23	4.62	0.000	Yes

Table 2 shows the results of the causal relationship test and mediation effect using the bootstrapping method. It can be seen that environmentally friendly product innovation directly has a positive and significant effect on urban sustainability, with a beta value of 0.38. In addition, innovation also has a positive impact on the readiness of the circular economy (beta value of 0.45), and the readiness of the circular economy in turn greatly affects the sustainability of the city (beta value of 0.52). The mediation effect of circular economy readiness strengthened the relationship between product innovation and sustainability, as indicated by a significant mediation beta value of 0.23. Overall, these results confirm that circular economy readiness is not only a supporting variable but also acts as a link that strengthens the positive impact of innovation on urban sustainability.

Table 3. Circular Economy Readiness by Industry Sector

Industrial Sector	Average Circular Economy Readiness (Scale 1-5)	Number of Respondents
Manufacturing	4.20	60
Technology	4.15	50
Service	3.65	40
MSMEs	3.50	38

Table 3 compares the level of circular economy readiness among the various industrial sector groups that are respondents. The manufacturing and technology sectors are in the top position with an average readiness score above 4, indicating that the sector is more prepared and proactive in implementing circular economy principles and environmentally friendly product innovation. Meanwhile, the service sector and MSMEs have a lower readiness score, ranging from 3.5 to 3.65, which indicates greater challenges, such as limited resources or understanding of the circular economy in this sector. This difference in readiness

gives an idea that policies and programs to increase circular economy readiness need to be adjusted to the characteristics and needs of each industrial sector.

The results of this study are in line with the Theory of Planned Behavior (TPB) developed by Ajzen, where the readiness of the circular economy plays a role as a perception of behavior control that mediates the relationship between environmentally friendly product innovation and urban sustainability. Significant findings with a mediated beta value of 0.23 indicate that when organizations or individuals have a high readiness for circular economy principles, they tend to be more likely to adopt and implement eco-friendly product innovations to achieve urban sustainability goals. A similar study by Kongarchapatara & Hanpanit (2021) proves that attitude toward behavior has the strongest influence (β = 0.417) on the purchase intention of circular economy products, which strengthens the finding that attitude and readiness factors greatly determine the success of circular economy implementation. In the urban context, the readiness of the circular economy reflects the positive attitude of stakeholders towards sustainable practices, which in turn strengthens the impact of product innovation on urban sustainability.

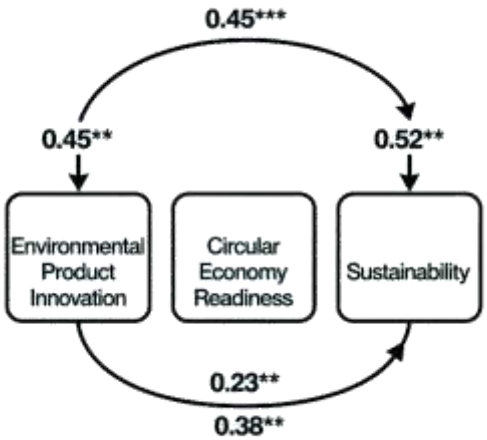


Figure 1. Diagram of the mediator mediation path between environmentally friendly product innovation and sustainability.

The path diagram image explains the relationship between the three main variables in the research, namely Green Product Innovation, Circular Economy Readiness, and Urban Sustainability. It can be seen that environmentally friendly product innovation has a significant direct influence on the readiness of the circular economy, with a path coefficient of 0.45. This means that the higher the innovation of green products carried out, the greater the readiness of the organization or city to adopt and implement circular economy principles. Furthermore, product innovation also has a direct effect on urban sustainability with a coefficient value of 0.38, which shows that environmentally friendly product innovation contributes positively to the achievement of sustainability in urban areas. Thus, the readiness of the circular economy also shows a strong direct influence on urban sustainability, with a coefficient value of 0.52. This indicates that when systems and stakeholders are ready to implement a circular economy, the impact of eco-friendly innovations can be optimized to significantly improve urban sustainability. There is an important mediation path,

namely the readiness of the circular economy as a mediator between environmentally friendly product innovation and urban sustainability. The mediation coefficient of 0.23 shows that part of the influence of product innovation on sustainability runs through circular economy readiness. In other words, institutional readiness and circular economy systems become the link that strengthens the positive relationship between product innovation and overall urban sustainability outcomes.

CONCLUSION AND RECOMMENDATIONS

Circular economy readiness has an important role as a mediator that strengthens the influence of environmentally friendly product innovation on urban sustainability. This finding is based on a quantitative analysis where circular economy readiness is not only a supporting variable, but also a strategic link that allows green innovation to have a real and optimal impact on sustainable urban development. The implications of this research are significant, especially for policymakers, industry players, and city governments. First, increasing circular economy readiness must be made a priority in sustainable development strategies, because only with mature readiness can environmentally friendly product innovations really have an impact on reducing waste, resource use efficiency, and achieving environmental targets in cities. Second, the industrial sector needs to strengthen its capabilities and internal resources in order to be able to adopt the principles of the circular economy effectively, especially in the service sector and MSMEs, which still show a relatively low level of readiness.

Thus, this research underscores the need for more intensive multi-stakeholder collaboration, recognizing that the readiness of the circular economy is also influenced by relationships and synergies among stakeholders, including the government, the private sector, and the community. Increasing literacy and socialization related to the circular economy is also crucial to building awareness and active participation in the implementation of holistic and systemic circular economy principles. Thus, eco-friendly product innovation is not only limited to technological aspects, but is integrated in a sustainable urban socio-economic ecosystem.

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