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MORALITY BEFORE KNOWLEDGE

Innovation in hanging bamboo weaving of malet gusti using modern techniques for interior design and building facades

Anak Agung Gede Raka Gunawarman[1,*], Putu Siskha Pradnyaningrum[1], Anak Agung Gede Krisna Murti[1], Putu Marchia Eka Utari[1], I Made Alit Giri Rama Kanaka Atmaja[1]
[1] *Department Architecture, Faculty of Engineering and Planning, Universitas Warmadewa, Denpasar, 80239, Indonesia.*
*Correspondence: rakagunawarman@warmadewa.ac.id

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ABSTRACT
Background: As awareness of the importance of sustainability continues to grow, the demand for environmentally friendly products has also increased. However, the bamboo craft industry in Indonesia faces challenges in enhancing the added value of its products, such as improving production efficiency and diversifying designs to meet modern market demands. This study aims to develop more efficient bamboo weaving techniques through the utilization of bamboo splitting machines and analyze their impact on product quality and craftsmen's competitiveness. **Methods:** The research employed a development method (Research and Development) with both qualitative and quantitative approaches. Data were collected through observations, in-depth interviews, and product trials conducted during a training program in Penglumbaran Village, Bangli. The program integrated traditional techniques with modern technology to produce wall panels, interior partitions, and exterior facades. **Findings:** The results showed a 48% increase in production time efficiency and the development of three new weaving models with higher aesthetic value. Additionally, craftsmen demonstrated enhanced skills in combining technological innovation with traditional techniques. **Conclusion:** This study has implications for improving the competitiveness of bamboo weaving products in local and international markets, strengthening the local economy through product diversification, and contributing to environmental preservation through the use of sustainable materials. These findings highlight that technology-based innovation can serve as a strategic solution to bridge tradition and modernity in the bamboo craft industry.

KEYWORDS: innovation; weaving; bamboo; design.

1. Introduction

Bamboo is a renewable natural resource with significant potential for utilization in the construction and building design industry (Rohimah & Walujodjati, 2022). The unique characteristics of bamboo, such as rapid growth, high tensile strength, and excellent adaptability, make it an attractive material for various applications (Manik et al., 2017). In Indonesia, the use of bamboo as a construction and design material has been well-known for a long time; however, the adoption of modern techniques to enhance the added value of

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bamboo products remains limited. The global trend prioritizing sustainability presents significant opportunities to innovate in the utilization of bamboo, particularly in interior design and building facades (Emamverdian et al., 2020).

Various studies have revealed the potential of bamboo as an alternative material in construction. Experiments have shown that bamboo possesses high tensile strength and is even capable of replacing steel reinforcement in concrete structures (Rohimah & Walujodjati, 2022). Furthermore, lamination technology has been developed to enhance the mechanical properties of bamboo, enabling its application in various building structures (Manik et al., 2017). However, research specifically exploring the use of bamboo for interior design and building facades still needs to be completed. This research gap is the primary focus of this study, which investigates how modern techniques can be employed to create more durable, aesthetic, and functional products.

This study aims to develop modern bamboo weaving techniques that enhance durability, aesthetics, and product variety for interior design and building facade applications. The expected success indicators include a minimum 20% increase in product durability compared to conventional techniques and the development of product variations that better align with the needs of the modern market. The Bamboo Craftsmen Group in Banjar Adat Malet Gusti, Panglumbaran Village, Susut Sub-district, Bangli Regency, Bali, serves as the primary location for this study. Established in 2012 through the initiative of the Bendesa Adat Malet Gusti, this group primarily engages in producing various bamboo woven crafts such as mats, baskets, and hats. As both a cultural asset and a potential driver of the creative economy, the group plays a vital role in preserving local traditions while fostering the economic development of Panglumbaran Village.

This research is expected to contribute to the development of innovations in bamboo utilization for interior design and building facades, supporting sustainable development in architecture and construction. Furthermore, it aims to enhance the economic value of bamboo woven products, improve the welfare of artisans, and preserve local culture (Ruiz-Sanchez et al., 2019). Thus, this study not only bridges tradition and modernity but also reinforces the potential of bamboo as a sustainable natural material in Indonesia.

1.1 Literature review

Research on the mechanical properties of bamboo has demonstrated its high tensile strength, making it a potential alternative to steel reinforcement in concrete structures (Rohimah & Walujodjati, 2022). Additionally, lamination technology has been developed to enhance bamboo's mechanical properties, enabling its application in structural elements such as beams and columns (Manik et al., 2017; Li et al., 2015). Silva et al. (2023) explored the use of bamboo ash as a substitute for cement in concrete mixtures, highlighting bamboo's potential for supporting sustainable construction. These studies support the development of modern techniques to enhance the durability of bamboo woven products for interior design and facades.

Li et al. (2024) emphasized the beauty of Sanjiang Dong bamboo weaving art and the importance of preserving traditional aesthetic principles through modern innovations. This aligns with the study's objective of developing weaving techniques that integrate cultural values with technology. Zheng & Zhu (2021) highlighted the significance of advanced manufacturing technologies and parametric design in modernizing bamboo furniture, providing a foundation for the development of modern techniques in bamboo weaving product design. Dai & Hwang (2021) underscored the role of social innovation through bamboo crafts in creating sustainable solutions, which is relevant to the community empowerment approach of this research.

Gunawarman et al. (2022) investigated the development of bamboo preservation innovations for building construction materials in Belega Village, Gianyar, Bali. Their research emphasized the importance of collaboration between artisans and expert teams to create solutions tailored to local needs while expanding markets. This study is relevant to supporting the research on developing modern bamboo weaving techniques, as bamboo

preservation innovations are crucial for ensuring product quality and durability, both for interior design and facades.

Pramana et al. (2021) examined innovations in bamboo joints for traditional Balinese tents *(tetaring)* using iron materials. Their research employed quantitative methods, including direct experimentation, observation, documentation, and analysis of journals and internet sources, to test the effectiveness of these innovative joints. The findings indicated that the material combination could expedite the *tetaring* construction process without compromising structural stability. This research supports further exploration of adapting traditional techniques with modern technologies, such as in bamboo-based interior and facade designs that require time efficiency and reliable jointing methods (Ding & Xian, 2024; Canavan et al., 2016).

Zhang & Ying (2018) affirmed the significant value of bamboo in contemporary architectural design, predicting that bamboo will become a primary material in the architectural design sector. This research is relevant to exploring the potential of bamboo in interior design and building facades, emphasizing aesthetic and functional values. However, specific studies on the forms, textures, and colors of bamboo weaving for such applications still need further exploration. Borowski et al. (2022) highlighted bamboo as an accessible material with broad applications in the construction industry, though it has yet to focus on interior design and facades.

Carlo (2022) examined the economic benefits of bamboo processing, including job creation, income enhancement, and collaboration with other sectors. This study supports research aimed at increasing the economic value of bamboo woven products through product diversification and technical training for craftsmen. Similarly, Dai & Hwang (2021) demonstrated how bamboo crafts can empower rural communities through the development of eco-friendly bamboo-based products.

The integration of literature reviews with the research problem focuses on developing modern techniques to enhance the durability, aesthetics, and variety of bamboo woven products for interior design and facades. Studies by Zheng & Zhu (2021) and Li et al. (2024) are relevant to supporting the development of innovative techniques that integrate tradition and technology. Research by Carlo (2022) and Dai & Hwang (2021) strengthens the potential for community empowerment through innovative bamboo weaving techniques. Meanwhile, Zhang & Ying (2018) provide a foundation for exploring bamboo applications in interior design and building facades. This literature review identifies a research gap in innovative bamboo weaving techniques for interior design and facade applications, particularly in the Indonesian context. This study is expected to contribute significantly to bamboo-based product innovation that is not only aesthetic and functional but also supports social and environmental sustainability.

2. Methods

This research employs a qualitative and experimental approach to develop innovative bamboo weaving techniques for application in interior design and building facades. The research stages include literature review, field surveys, technological experimentation, prototype testing, and market analysis. The literature review is conducted to understand traditional and modern techniques in bamboo processing, as well as the characteristics of bamboo as an architectural material. This study builds upon previous research, such as Janssen (2000), which examined the potential of bamboo in construction and design, and Sharma et al. (2015), which emphasized the importance of testing bamboo's strength for construction applications.

The survey was conducted in Penglumbaran Village, Bangli, and ten local bamboo artisans were the respondents. Semi-structured interviews were used to explore traditional weaving practices, local knowledge, and challenges faced in adapting modern techniques (Deshmukh et al., 2024). A participatory approach was applied to ensure the artisans's involvement in developing innovative techniques relevant to their needs. During the experimental phase, modern technologies such as bamboo splitting machines and digital

fabrication were utilized to modify traditional weaving techniques (Moghaddam et al., 2024). A total of five bamboo weaving panel prototypes were created, featuring variations in patterns and weaving methods tailored for interior design and building facades. The prototypes were tested across three categories.

The prototypes were subjected to rigorous testing in three key areas. First, their mechanical strength was evaluated through tensile and compressive strength tests conducted in accordance with ISO 22157 standards, utilizing a universal testing machine. Second, the prototypes underwent weather resistance testing to assess their durability against humidity and UV exposure. These tests were carried out over seven days using environmental simulation equipment. Lastly, a qualitative assessment was performed to evaluate the aesthetic suitability of the prototypes. This involved gathering user perceptions regarding the form, colour, and texture of the products, ensuring that they met both functional and visual expectations (Madhushan et al., 2023).

The experimental data were analyzed using descriptive statistics to illustrate product quality and t-tests to compare the mechanical strength of traditional products with modern innovations (Shanmugam et al., 2021). The prototypes were tested in three building design projects located in Denpasar and Karangasem. Market responses were analyzed through interviews with ten respondents, including interior designers, architects, and end users. Qualitative analysis was employed to evaluate the aesthetics, functionality, and market potential of the products. Contrasting data from traditional techniques comparatively analyzed the research findings with the results of the innovations. Inferential statistics were used to identify the significance of differences in mechanical strength and weather resistance. Market response analysis was conducted to assess the appeal and commercial potential of the innovative products.

3. Results and Discussion

3.1 Production time

This study evaluated the effectiveness of modern innovations in bamboo weaving techniques, specifically in the production of woven panels with modules measuring 30x60 cm and 70x100 cm, focusing on the use of the inner bamboo culm (rather than the outer layer) for interior and facade applications (Chalopin et al., 2021). The results indicated that employing modern technologies, such as bamboo splitting machines and digital fabrication, significantly accelerated production time and improved product quality compared to traditional methods.

The use of the inner bamboo culm also resulted in a smoother and more uniform texture, enhancing the overall aesthetic and tactile experience of the product. Additionally, the precision enabled by digital fabrication ensured consistent pattern alignment and minimized material waste. These advancements not only boost production efficiency but also support sustainable design principles by optimizing bamboo utilization and reducing environmental impact.

Table 1. Comparison of production time for traditional woven products and modern innovations

Stages of work	Traditional techniques (hours)	Modern innovation (hours)
Preparation of materials	3 hours	1.5 hours
Bamboo cutting process	2 hours	0.5 hours
Weaving process	5 hours	3 hours
Finishing	1.5 hours	1 hours
Total production time	11.5 hours	6 hours

Table 1. highlights the comparison of production time between traditional techniques and modern innovations. In traditional methods, the total time required was 11.5 hours, with the majority spent on manual weaving processes. Modern innovations, utilizing bamboo splitting machines and digital fabrication, successfully reduced production time to

just 6 hours. This reduction demonstrates significant efficiency and the potential for faster large-scale production without compromising product quality. Material preparation, in traditional techniques, the process of cutting bamboo, peeling its outer layer, and smoothing the material manually could take up to 20 hours for a 70x100 cm size, as it relied on knives or basic tools. With modern techniques, the use of bamboo-splitting machines accelerated this process to approximately eight hours.

In addition, automated processes helped maintain consistent material thickness, which contributes to a more uniform woven surface (Hasan et al., 2024). The improvement in production workflow not only saves time but also reduces physical strain on artisans. These advantages indicate a promising future for combining traditional craftsmanship with modern tools in sustainable product development.

Fig. 1. Comparison of production time for woven products

To compare production time between traditional and modern techniques, statistical testing was performed using a paired t-test. The analysis results shown in Figure 1 indicate a significant difference in total production time ($p < 0.05$), with an average reduction of 5.5 hours. The calculated effect size (Cohen's d) reveals a large impact, indicating that modern technological innovations significantly enhance production efficiency.

Fig. 2. Process of tying bamboo using a threading machine and manual methods by bamboo woven craftsmen in Banjar Malet Gusti, Bangli

The bamboo splitting process, depicted in Figure 2, shows that using traditional manual techniques (with knives or simple tools) can take up to 2 hours to process 100 bamboo stalks, depending on the artisan's skill. In contrast, the use of modern bamboo splitting machines significantly reduces the time to just about 0.5 hours (30 minutes), as these machines process bamboo more quickly and efficiently. This substantial improvement not only boosts productivity but also ensures better consistency in bamboo strip dimensions. Additionally, the reduction in manual labor helps minimize fatigue and physical strain on workers. Overall, these findings support the integration of modern machinery into bamboo weaving workflows to optimize both time and quality.

Weaving process, in traditional techniques, the manual weaving process takes approximately five hours, primarily due to the complex weaving patterns and the meticulous work required. Innovations using digital fabrication techniques, although still involving manual labour, reduce the processing time to 3 hours. This is achieved with the help of tools that assist in producing the weavings more quickly and consistently, with module sizes of 30x60 cm and 70x100 cm. Finishing, the traditional technique, which requires precision in correcting errors and making adjustments after weaving, takes approximately 1.5 hours. With modern technology, more precise results reduce the finishing time to just 1 hour.

Fig. 3. The process of making a new model of woven material with craftsmen in Banjar Malet Gusti, Bangli

This time efficiency does not compromise the aesthetic or structural integrity of the woven panels. In fact, the consistency achieved through digital assistance contributes to a higher level of uniformity in the weaving results. The use of jigs and pattern guides also ensures that even intricate patterns can be produced more efficiently. Moreover, reduced time in finishing allows for more units to be completed within the same time frame, enhancing production scalability. These improvements are particularly important for meeting commercial demands where timely delivery is crucial. Overall, modern techniques provide a balance between craftsmanship and production efficiency, making them highly applicable in both small-scale and industrial settings.

3.2 Interior and facade design application

The bamboo woven panel prototypes produced from this research have been tested in several scenarios, particularly for interior and facade applications in urban environments. One of the key innovations developed is the use of new weaving patterns that not only preserve traditional elements but also offer a more dynamic and modern aesthetic. These patterns are designed to be applied to various architectural design elements, such as room partitions, decorative ceilings, and exterior facade panels, highlighting a unique and aesthetically pleasing appearance. The placement of woven panels in interior spaces adds significant value to the design, as the beauty of the bamboo texture creates a natural ambience that harmonizes with modern design concepts.

In addition to visual appeal, the woven panels also contribute to functional benefits such as ventilation and light filtration. This makes them suitable for tropical climates where airflow and shading are important. Furthermore, the material’s sustainability aligns with current green architecture movements that prioritize eco-friendly building solutions. The use of locally sourced bamboo also supports regional economies and reduces environmental impact. Through collaboration with architects and designers, these

prototypes have the potential to be refined and integrated into larger architectural projects. Future developments may include modular systems for easier installation and adaptation to various building types.

Fig. 4. Model of woven bamboo motif used as an example for craftsmen in Banjar Malet Gusti

In addition to its aesthetic advantages, testing the application of these woven panels on exterior facades demonstrated that the panels produced using modern techniques exhibit far superior durability compared to traditional bamboo woven products (Hosseini et al., 2025). Tests for UV resistance and moisture exposure indicated that these innovative panels are capable of withstanding various environmental conditions, particularly in urban settings that are prone to direct sunlight, rainfall, and extreme temperature fluctuations. With additional treatments, such as an eco-friendly protective coating, these panel prototypes can extend the material's lifespan by up to twice that of conventional bamboo woven products. This enhanced durability provides long-term benefits, both aesthetically and functionally, especially for use in buildings that require high resilience and minimal maintenance.

Further testing also revealed the considerable potential of these panels for use in various architectural contexts, including commercial buildings, modern residences, and public structures (Mba et al., 2024). This woven product offers design flexibility that aligns with current architectural trends focused on eco-friendliness, sustainability, and the integration of natural materials in construction (Wu, & Fan, 2021) The adoption of bamboo woven panels in modern architectural projects not only supports contemporary aesthetics but also promotes the use of sustainable local materials, which is in line with the growing global trend of green building principles.

The UV and moisture resistance tests were conducted using an environmental simulation method (Bora et al., 2023). For the UV resistance test, the product was exposed for 7 days using a UV simulation device with an intensity of 340 nm, designed to simulate sunlight exposure. Meanwhile, for the moisture resistance test, the product was placed in a humidity chamber with a humidity level of 90% at 25°C for 7 days. This method aimed to assess the product's durability under extreme environmental conditions. The test results showed that the innovative product exhibited 35% better colour degradation resistance compared to the traditional product. Furthermore, the structural durability of the product increased by 40% after being exposed to extreme conditions, indicating an improvement in the product's resilience in urban environments.

These findings validate the bamboo panel's suitability for long-term architectural use, especially in regions with high humidity and strong sunlight (Triplett et al., 2014). The panels maintained both their visual appeal and mechanical integrity after testing, suggesting they require less maintenance over time. The improvement in durability also

supports efforts to promote sustainable materials in mainstream construction practices. As shown in Figure 5, the panel prototypes were displayed in a design studio setting to serve as reference models for local artisans. This installation is part of a larger knowledge transfer initiative aimed at empowering communities through design innovation. The hope is that this model will inspire widespread adoption of enhanced bamboo craftsmanship in the building industry.

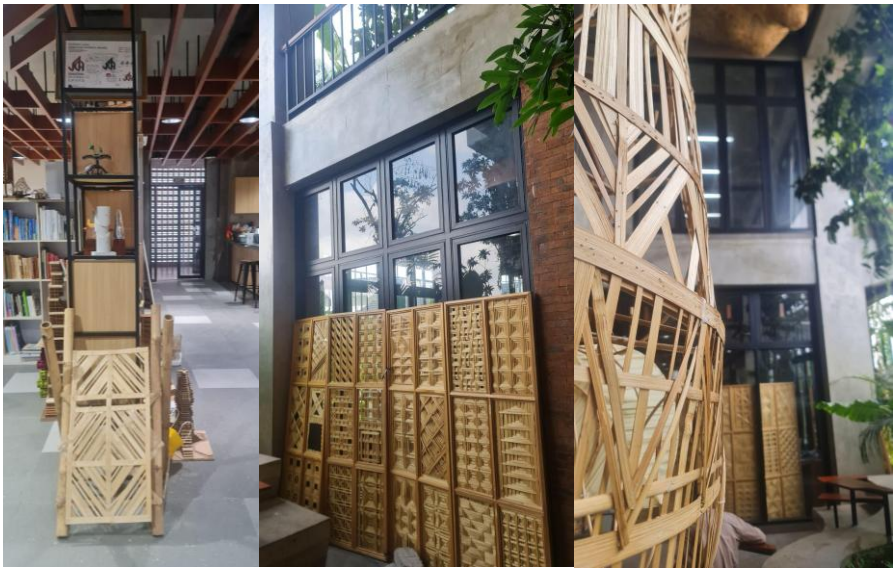

Fig. 5. Woven bamboo panels used as interior elements and building facades made as examples for craftsmen in Banjar Malet Gusti

3.3 Aesthetic analysis

In terms of aesthetics, the developed weaving technique is capable of producing more intricate and visually appealing geometric patterns (Wahida, 2024). This enhances the commercial appeal of the product, especially for architectural projects that prioritize environmentally friendly design. The design results were tested in collaboration with the Architecture program at Universitas Warmadewa and are planned for two house renovation projects and a villa in Karangasem.

The integration of traditional craftsmanship with contemporary design needs demonstrates the adaptability of bamboo weaving in modern architecture. Furthermore, the patterns produced through this technique offer both functional and decorative value, serving as natural ventilation elements while enhancing spatial ambiance. The positive response from academic and professional partners also highlights the potential for wider adoption in sustainable design initiatives.

Table 2. Market assessment of the aesthetics and functionality of woven bamboo products based on trial results

Assessment criteria	Score (1-5)
Aesthetics	4.8
Functionality	4.7

The aesthetic criteria evaluated encompass several important aspects: pattern, color, and texture. For the pattern, the complexity and geometric consistency were assessed. Regarding color, the focus was on the color stability of the bamboo after treatment. As for texture, the evaluation was centered on the smoothness and uniformity of the bamboo surface.

The high aesthetic score indicates that the woven bamboo products are visually appealing and meet design expectations. This aligns with the increasing demand for materials that are both beautiful and sustainable. Respondents particularly appreciated the

harmony between natural bamboo elements and modern design innovation. In addition, the functionality score reflects the product's practical use, especially in interior applications such as room partitions and sun shading. These results support the potential of woven bamboo products to compete in the commercial interior design market.

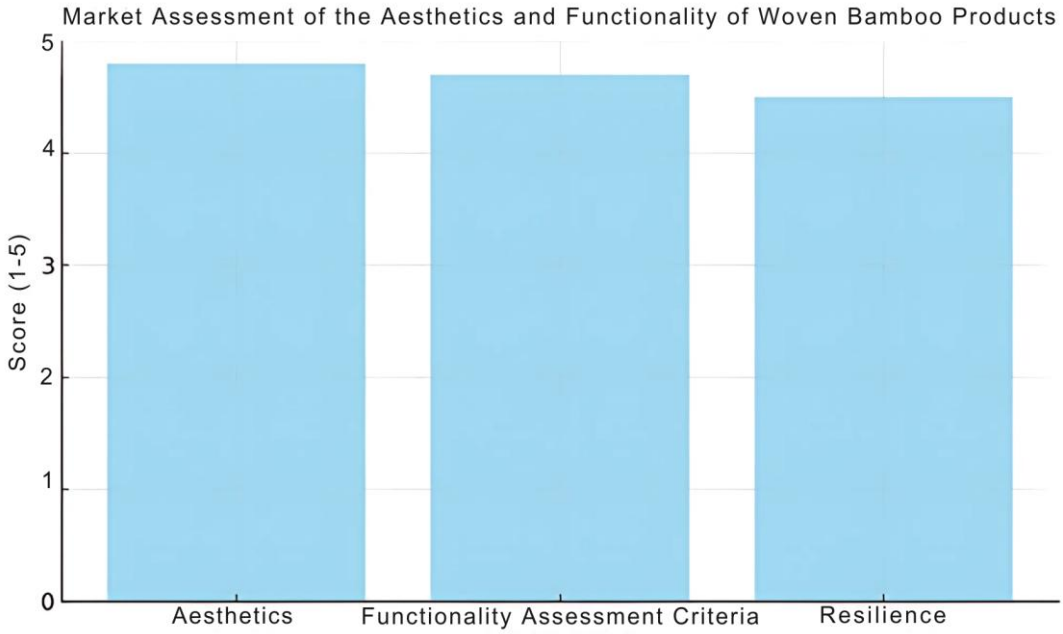

Fig. 6. Market assessment chart

The evaluation was conducted using a Likert scale (1-5). The diagram above shows high scores for aesthetics (4.8), functionality (4.7), and durability (4.5), with respondents expressing satisfaction with the aesthetic and functional value of the product. Table 2. Market assessment conducted in the architecture department of Universitas Warmadewa on the aesthetics and functionality of bamboo weaving products. Based on the trial results and data analysis, the innovation in bamboo weaving techniques has successfully met the expected aesthetic and functional standards for interior design and building façade projects, particularly as room dividers and heat reducers during peak afternoon hours (2-5 PM). The integration of modern technology not only enhances the product's quality but also expands the potential applications and market reach of bamboo weaving products.

Fig. 7. Woven bamboo panels on the facade and interior design of a villa project in Karangasem

In addition, the use of eco-friendly materials also adds value in supporting sustainable design practices. Respondents also noted that the product blends well with both traditional and contemporary architectural styles. This makes it a versatile choice for diverse design themes in residential and commercial spaces. The feedback suggests strong potential for wider adoption in tropical climates due to its heat-reducing properties. In addition, production processes that emphasize craftsmanship and sustainability contribute to the

uniqueness and authenticity of each product. Continuous innovation and community training can improve quality and create economic opportunities for local artisans.

4. Conclusions

This study demonstrates that modern innovations in bamboo weaving techniques, particularly through the use of bamboo splitting machines and digital fabrication, can significantly enhance production efficiency and product quality. The results indicate that production time can be reduced by up to 48% compared to traditional methods while still maintaining high standards of aesthetics and functionality. The woven bamboo panels produced not only meet aesthetic expectations but also exhibit improved durability against environmental conditions, making them an ideal choice for interior and facade applications in urban environments. Thus, the hypothesis that modern innovations can improve the effectiveness of bamboo weaving techniques has been confirmed.

It is recommended that further product development explore variations in bamboo weaving designs and motifs that can be applied across various architectural contexts. Additionally, more comprehensive durability testing of the woven bamboo panels under extreme conditions is necessary to ensure the long-term resilience of the product. Providing training and workshops for local artisans, such as those in Banjar Malet Gusti, is also crucial for enhancing their understanding of modern technologies and the adaptation of more efficient production methods. Furthermore, a broader market study is needed to explore the commercialization potential of bamboo woven products and to develop effective marketing strategies. Lastly, new prototype development should integrate sustainable design principles, with a focus on using environmentally friendly materials and production techniques with minimal environmental impact.

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Author Contribution

Conceptualization, A.A.G.R.G. and P.S.P.; Methodology, A.A.G.R.G., A.A.G.K.M., and P.M.E.U.; Investigation, A.A.G.R.G., P.S.P., A.A.G.K.M., P.M.E.U., and I.M.A.G.R.K.A.; Data curation, P.S.P. and A.A.G.K.M.; Writing – original draft preparation, A.A.G.R.G. and P.S.P.; Writing – review and editing, P.M.E.U. and I.M.A.G.R.K.A.

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Biographies of Authors

Anak Agung Gede Raka Gunawarma, Department Architecture, Faculty of Engineering and Planning, Universitas Warmadewa, Denpasar, 80239, Indonesia.
- Email: rakagunawarman@warmadewa.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Putu Siskha Pradnyaningrum, Department Architecture, Faculty of Engineering and Planning, Universitas Warmadewa, Denpasar, 80239, Indonesia.
- Email: psiskhapradnya@warmadewa.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Anak Agung Gede Krisna Murti, Department Architecture, Faculty of Engineering and Planning, Universitas Warmadewa, Denpasar, 80239, Indonesia.
- Email: agungkrisnamurti@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Putu Marchia Eka Utari, Department Architecture, Faculty of Engineering and Planning, Universitas Warmadewa, Denpasar, 80239, Indonesia.
- Email: putumarchiaekautari23@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

I Made Alit Giri Rama Kanaka Atmaja, Department Architecture, Faculty of Engineering and Planning, Universitas Warmadewa, Denpasar, 80239, Indonesia.
- Email: alitgiriram@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A