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Optimizing Super Teak Wood Furniture Design through a Biophilic Approach: An Experimental Study of Ergonomic Performance at PT Bima Moriesya Anugerah

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ABSTRACT
Sustainable furniture design requires the integration of aesthetic, functional, ergonomic, and environmental considerations. This study aimed to develop and evaluate super teak wood furniture designs using an integrated biophilic and ergonomic approach at PT Bima Moriesya Anugerah, Indonesia. A sequential mixed-methods design was employed, involving structured interviews with 30 premium furniture consumers and consultations with five industry experts. Three design configurations were evaluated using computer-aided design and manufacturing simulations, digital human modeling, and life cycle assessment. The evaluation considered user preferences, ergonomic performance, and environmental impact. Configuration B was identified as the preferred alternative, achieving a reported Biophilic-Ergonomic Index (BEI) score of 8.7. Additional results included a Biophilic Design Index score of 8.9 out of 10, a seat pressure distribution value of 12.5 kPa, a Rapid Upper Limb Assessment score of 2, and a carbon footprint of 52.1 kg CO_2 equivalent. The findings indicate that integrating biophilic principles with ergonomic and environmental criteria can support the evaluation and selection of furniture design alternatives. However, the interpretation of these results depends on the transparent definition of the assessment indicators and the validation of the proposed index. The study provides a design evaluation framework that may inform further research and practical development in the Indonesian furniture industry.

Keywords: Biophilic Design, Furniture Design Optimization, Ergonomics, Life Cycle Assessment, Sustainable Furniture Design.

I. Introduction

The furniture industry faces the challenge of developing products that combine aesthetic quality, functional performance, user comfort, and environmental responsibility. As sustainability becomes an increasingly important consideration in product development, furniture design needs to move beyond visual appeal and material selection toward a more comprehensive evaluation of product performance throughout its life cycle. Life cycle assessment (LCA) provides a systematic framework for examining environmental impacts associated with material acquisition, manufacturing, distribution, use, and end-of-life management (International Organization for Standardization [ISO], 2006). Recent research has demonstrated the relevance of life cycle approaches to identifying environmental hotspots and evaluating alternative production

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strategies in the furniture industry (Sakib et al., 2024). Consequently, sustainable furniture development requires design decisions that consider environmental performance alongside functional and human-centred requirements.

Within this context, biophilic design offers a potential approach to incorporating human–nature connections into product and environmental design. Biophilic design encompasses more than the use of natural materials; it also involves natural forms, sensory experiences, spatial relationships, and other characteristics that can strengthen connections between people and nature (Browning et al., 2014). A critical review by Zhong et al. (2022) identified potential contributions of biophilic design to human well-being and sustainability while highlighting continuing conceptual and methodological challenges. Similarly, Wijesooriya and Brambilla (2021) argued that biophilic design and environmentally sustainable design can complement each other, although their integration requires clearer frameworks and evaluation criteria. These findings suggest that biophilic principles may provide a useful foundation for furniture development, provided that their application is evaluated systematically rather than treated solely as an aesthetic feature.

Ergonomic performance represents another essential dimension of furniture quality because furniture must accommodate users' physical characteristics, postures, and activities. Anthropometric considerations are particularly important when translating human body measurements into product dimensions and design specifications. Dianat et al. (2018) identified continuing challenges in applying anthropometric information to ergonomic product and environmental design. More specifically, Bai et al. (2024) found that furniture ergonomics research employs different assessment approaches and identified gaps concerning domestic furniture, gender-related differences, and cultural contexts. These findings indicate that ergonomic assessment should be integrated into the design process rather than conducted only after a product configuration has been selected. Combining ergonomic evaluation with biophilic principles and environmental assessment may therefore support a more comprehensive comparison of furniture design alternatives.

These considerations are particularly relevant to wooden furniture, for which material properties, manufacturing processes, durability, and environmental impacts can influence overall product performance. Although wood can provide desirable aesthetic and functional characteristics, its environmental implications cannot be determined by material identity alone. Ali et al. (2022) demonstrated the usefulness of life cycle assessment in examining the environmental performance of wooden furniture production, while Bianco et al. (2021) developed LCA-based tools to support environmental assessment and ecodesign decisions for wooden furniture. Yang et al. (2025) further examined the life cycle impacts of furniture across multiple product categories, reinforcing the importance of evaluating furniture through a broader sustainability perspective. These studies establish a relevant foundation for assessing wooden furniture, but environmental performance must still be considered alongside ergonomic requirements and design characteristics when selecting among alternative configurations.

The present study focuses on PT Bima Moriesya Anugerah, a furniture manufacturer located in Makassar, South Sulawesi, Indonesia, and examines the development of super teak wood (*Tectona grandis*) furniture. The research context provides an opportunity to investigate how biophilic principles, ergonomic requirements, and environmental considerations can be incorporated into a design evaluation process for a specific manufacturing setting. However, the available manuscript does not establish a documented company-specific baseline demonstrating the extent of existing design deficiencies. Accordingly, the research problem is framed as the need to develop and evaluate an integrated design approach, rather than as an assumption that the company already experiences particular ergonomic or environmental failures. This distinction is important for ensuring that the research claims remain proportionate to the available evidence.

Despite developments in biophilic design, furniture ergonomics, and life cycle assessment, these areas are often examined through different conceptual and methodological frameworks. Biophilic design research has identified difficulties in translating qualitative nature-related principles into consistent assessment criteria (Wijesooriya & Brambilla, 2021; Zhong et al., 2022). Furniture ergonomics research has also highlighted variation in assessment methods and limitations in the coverage of particular user groups and

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contexts (Bai et al., 2024). Meanwhile, LCA-based furniture studies primarily address environmental performance and production-related impacts (Bianco et al., 2021; Sakib et al., 2024). Taken together, these findings indicate a need for a more integrated evaluation process that considers biophilic characteristics, ergonomic performance, and environmental impacts when comparing furniture design alternatives. The specific contribution of the present study is to investigate this integration within the context of super teak wood furniture development at an Indonesian manufacturing company.

Accordingly, this study aims to develop and evaluate alternative super teak wood furniture designs through an integrated biophilic and ergonomic approach, examine their performance using digital design and ergonomic simulation alongside life cycle assessment, and identify a preferred configuration based on multiple evaluation criteria. The study also seeks to establish an integrated evaluation framework that can inform design decisions in the manufacturing context under investigation. By connecting user requirements with ergonomic and environmental assessment, this research is intended to contribute to the practical evaluation of sustainable furniture design. Its contribution should be interpreted in relation to the methods, indicators, and validation evidence reported in the study, rather than as a claim that the proposed framework is universally applicable to all furniture products or manufacturing settings.

II. Literature Review and Hypothesis Development

2.1. Biophilic Design in Furniture Development

Biophilic design is grounded in the relationship between humans and nature and seeks to incorporate natural characteristics into designed environments. Rather than treating nature as a decorative element, this approach considers how natural materials, forms, patterns, and sensory experiences may contribute to human well-being. Browning et al. (2014) proposed fourteen patterns of biophilic design, organized into three categories: nature in the space, natural analogues, and nature of the space. These patterns provide a conceptual foundation for translating nature-related characteristics into design considerations. However, their application to furniture requires adaptation because the original framework primarily addresses the built environment rather than individual products. Research has increasingly examined the relationship between biophilic design and human responses. Gillis and Gatersleben (2015) reviewed the psychological literature on biophilic design and highlighted the importance of natural features in shaping environmental experiences. Similarly, Yin et al. (2020) investigated physiological and cognitive responses to biophilic indoor environments, providing empirical evidence relevant to the relationship between environmental characteristics and human performance. Nevertheless, findings from indoor environmental studies cannot be directly generalized to furniture without considering differences in exposure, interaction, and product use.

The relationship between biophilic design and sustainability has also attracted scholarly attention. Wijesooriya and Brambilla (2021) discussed opportunities for integrating biophilic principles with environmentally sustainable design, emphasizing the importance of considering human well-being alongside environmental performance. Zhong et al. (2022) further demonstrated that biophilic design encompasses physical, sensory, material, morphological, and symbolic dimensions. Their critical review also identified conceptual ambiguities and methodological limitations that complicate the evaluation of biophilic interventions. For wooden furniture, biophilic principles may be represented through visible wood grain, natural surface finishes, organic geometry, and material authenticity. These characteristics offer potential design attributes that can be assessed through user preferences and expert evaluation. However, the use of natural wood does not automatically establish biophilic effectiveness or environmental sustainability. Consequently, biophilic furniture design requires explicit criteria that distinguish material appearance, user perception, and environmental performance.

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2.2. Ergonomic Principles and Furniture Performance

Ergonomics concerns the interaction between people and the products, systems, and environments they use. In furniture development, ergonomic design seeks to accommodate human body dimensions, movement, posture, and task requirements. Human-centred design principles emphasize understanding users and their activities, evaluating design alternatives, and refining solutions through an iterative process (International Organization for Standardization [ISO], 2019). Anthropometry provides an important foundation for ergonomic furniture design. Dianat et al. (2018) reviewed the application of anthropometric data in product and environmental design and identified challenges in translating population measurements into practical design specifications. Their findings indicate that collecting body measurements is insufficient unless these data are appropriately incorporated into product dimensions and evaluation procedures.

Furniture ergonomics also requires assessment of how users interact with products during intended activities. Bai et al. (2024) systematically reviewed ergonomic assessment approaches used in sitting and working furniture research. Their findings highlighted methodological diversity and continuing limitations in the evaluation of different furniture categories and user populations. This suggests that ergonomic assessment should combine dimensional compatibility with relevant performance indicators rather than relying on a single measurement. Postural evaluation is particularly relevant when furniture influences seated positioning and upper-body alignment. ISO 11226 (2000) provides guidance for evaluating static working postures, while ISO 9241-210 (2019) establishes human-centred design principles for interactive systems. Although these standards address different applications, they offer complementary considerations for evaluating human–product interactions. The Rapid Upper Limb Assessment method provides another established approach to assessing posture-related ergonomic exposure, although its interpretation must remain consistent with the activities and conditions being evaluated.

Digital Human Modeling (DHM) can support ergonomic assessment by representing human body dimensions and postures within a virtual design environment. Chaffin (2007) discussed the potential of digital human modeling to support ergonomic analysis while identifying challenges concerning model validity and the representation of human variability. More recently, Yazdani et al. (2021) demonstrated how computational ergonomic models can support postural assessment and optimization in simulated human–robot interactions. Although this application differs from furniture design, it illustrates the potential of computational methods for evaluating ergonomic characteristics before physical implementation. For super teak wood furniture, ergonomic performance may therefore be evaluated through dimensional compatibility, posture-related risk, seat pressure characteristics, and user requirements. Integrating these indicators during design development can support comparisons among alternative configurations. Nevertheless, simulation outputs should not be interpreted as direct evidence of long-term comfort or health outcomes without appropriate empirical validation.

2.3. Sustainable Furniture Design and Life Cycle Assessment

Sustainable furniture design requires consideration of environmental consequences associated with material extraction, processing, manufacturing, transportation, product use, and disposal. Life Cycle Assessment provides a structured approach to examining these consequences across defined product systems. ISO 14040 (2006) establishes the principles and framework for LCA, while ISO 14044 (2006) specifies methodological requirements and guidance for conducting assessments. Together, these standards emphasize goal and scope definition, life cycle inventory analysis, impact assessment, and interpretation. The environmental performance of wooden furniture depends on multiple factors, including timber sourcing, manufacturing efficiency, energy consumption, surface treatment, product durability, and end-of-life management. Bianco et al. (2021) developed LCA-based tools for the ecodesign of wooden furniture, demonstrating how environmental assessment can inform design decisions. Ali et al. (2022) examined

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environmental sustainability in wooden furniture production, illustrating the relevance of life cycle analysis to manufacturing practices.

The relationship between design choices and environmental impacts is particularly important because improvements in one performance dimension may create disadvantages in another. For example, increasing structural components may improve mechanical performance while increasing material consumption. Similarly, additional finishing processes may enhance appearance or surface protection but introduce further environmental burdens. These relationships demonstrate why environmental performance should be assessed in conjunction with product requirements rather than independently. Sakib et al. (2024) examined sustainable strategies in furniture manufacturing through a life cycle analysis approach, reinforcing the importance of considering production-related environmental consequences. Yang et al. (2025) extended furniture-related environmental assessment across multiple product categories, highlighting the value of comparative life cycle perspectives in sustainable design. Such studies provide a basis for evaluating environmental trade-offs, although comparisons remain dependent on functional units, system boundaries, inventory assumptions, and impact assessment methods. In the context of super teak wood furniture, environmental evaluation should therefore account for the specific characteristics of the material and the manufacturing processes under investigation. Carbon footprint estimates can contribute to this assessment, but they represent only one environmental impact indicator. A comprehensive sustainability interpretation requires transparency regarding assessment boundaries, assumptions, and the environmental categories included.

2.4. Multi-Criteria Evaluation and Integrated Design Optimization

Furniture design involves decisions across criteria that are not necessarily measured using comparable units. Biophilic characteristics may be evaluated through perception-based ratings, ergonomic performance through physical or computational indicators, and environmental impacts through life cycle measurements. Integrating these dimensions therefore requires a transparent evaluation procedure. The Analytic Hierarchy Process (AHP) provides a structured method for addressing decisions involving multiple criteria. Saaty (2008) explained that AHP uses pairwise comparisons to derive relative priorities and supports the evaluation of alternatives involving quantitative and qualitative considerations. In furniture design, this approach can help establish the relative importance of biophilic characteristics, ergonomic performance, environmental impact, and manufacturing feasibility.

However, the usefulness of multi-criteria evaluation depends on the quality of its underlying indicators and weighting procedures. The Organisation for Economic Co-operation and Development and Joint Research Centre (2008) emphasized that composite indicators require clear theoretical foundations, appropriate normalization, justified weighting, and sensitivity analysis. Without these procedures, an aggregated score may conceal uncertainty or produce rankings that are sensitive to methodological choices. An integrated Biophilic-Ergonomic Index (BEI) can be considered as a proposed framework for combining selected design indicators. Conceptually, such an index should define its dimensions, establish the direction and scale of each indicator, specify weighting procedures, and demonstrate how component scores are aggregated. Environmental criteria may also be included in the broader evaluation framework, provided their relationship to the BEI is explicitly defined. Importantly, a high composite score does not independently demonstrate the validity of an evaluation instrument. Validation requires evidence concerning indicator selection, measurement consistency, weighting assumptions, and the robustness of alternative rankings. Thus, an integrated index should initially be understood as a decision-support mechanism whose performance must be evaluated within the research context.

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2.5. Research Synthesis and Conceptual Framework

The literature indicates that biophilic design, ergonomics, and environmental assessment provide complementary perspectives on furniture development. Biophilic design emphasizes human–nature relationships and perceptual characteristics, ergonomic evaluation addresses physical compatibility and interaction, and LCA examines environmental consequences across product systems. Each perspective contributes important information, but none independently captures all relevant dimensions of furniture performance. Existing research has established conceptual foundations for biophilic design and identified methodological challenges in its evaluation (Gillis & Gatersleben, 2015; Zhong et al., 2022). Ergonomic studies have demonstrated the importance of anthropometric compatibility and systematic assessment methods (Dianat et al., 2018; Bai et al., 2024). Meanwhile, furniture-related LCA research has provided approaches for identifying environmental impacts and informing ecodesign decisions (Bianco et al., 2021; Sakib et al., 2024).

The research opportunity lies in examining how these established approaches can be combined within a single design evaluation process. This integration is particularly relevant when alternative furniture configurations must be compared using criteria that reflect user requirements, physical performance, environmental impacts, and manufacturing considerations. Accordingly, the present study adopts a conceptual framework in which user needs and biophilic design characteristics inform the development of super teak wood furniture alternatives. The alternatives are subsequently evaluated through ergonomic simulation, environmental assessment, and multi-criteria decision analysis. The proposed BEI serves as an integrated assessment component, while AHP supports the prioritization and comparison of design criteria. Applied to PT Bima Moriesya Anugerah, this framework is intended to support the systematic evaluation of three furniture design configurations and the identification of a preferred alternative. Its contribution lies in the contextual integration and evaluation of existing design approaches rather than the assumption that each individual method is novel. The applicability of the resulting framework beyond the study context remains dependent on further empirical testing and validation.

III. Research Method

3.1. Research Design and Setting

This study employed a mixed-methods approach to examine the development and evaluation of super teak wood furniture designs through the integration of biophilic design, ergonomics, and environmental assessment. The research was conducted over ten months at the manufacturing facility and research laboratories of PT Bima Moriesya Anugerah in Makassar, South Sulawesi, Indonesia. The methodological framework comprised three interconnected phases: exploratory investigation, computational design and performance assessment, and analytical integration. The exploratory phase was intended to identify user requirements and relevant design considerations. The second phase involved the development and evaluation of alternative furniture configurations using digital design tools, ergonomic simulation, and life cycle assessment. The final phase integrated the resulting evidence to compare the alternatives and identify a preferred design configuration. This structure was intended to connect user needs with technical performance and environmental considerations.

3.2. Participants and Data Collection

The study involved 30 premium furniture consumers and five industry experts. Consumer interviews were used to identify preferences and requirements relevant to furniture design, while expert consultations provided additional perspectives on design feasibility and manufacturing considerations. The resulting information informed the development and assessment of three alternative design configurations. Data collection included structured or semi-structured interviews, expert consultations, and computational

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simulations. Interview data were intended to capture preferences concerning material finishes, organic forms, ergonomic features, and environmental considerations. The technical assessment examined the performance of the alternative configurations using the designated digital tools. The sampling procedures, participant eligibility criteria, recruitment process, interview duration, and demographic characteristics should be reported to establish the basis for interpreting the collected evidence. These details must reflect the procedures actually used during the study.

3.3. Materials and Computational Tools

The research used grade A super teak wood (*Tectona grandis*) supplied by PT Bima Moriesya Anugerah. The material was reported to have Sustainable Forest Management Certification. The specific certification scheme, certificate identification, and supporting documentation should be provided to substantiate this designation. Three computational tools were identified for the technical assessment. Autodesk Fusion 360 was used for parametric design development, Siemens Jack version 9.0 for ergonomic simulation, and SimaPro version 9.3 for life cycle assessment. These tools supported the development of alternative furniture configurations and the examination of their respective design characteristics. The three configurations should be described in terms of their dimensions, material specifications, structural characteristics, and distinguishing biophilic and ergonomic features. To support a meaningful comparison, the study should also specify which design characteristics were held constant and which were deliberately varied between configurations.

3.4. Design Development and Ergonomic Assessment

The design development process combined user requirements with the biophilic and ergonomic considerations identified during the exploratory phase. Three alternative configurations were prepared for comparative assessment. Biophilic considerations included the use and presentation of natural materials, organic design characteristics, and other nature-related features incorporated into the proposed furniture. Ergonomic performance was assessed through digital human modeling and relevant design indicators. The reported assessment included seat pressure distribution and the Rapid Upper Limb Assessment (RULA) score. These indicators were used to examine selected aspects of physical interaction between the user and the furniture. For reproducibility, the study should report the anthropometric model, user dimensions, simulated posture, furniture dimensions, loading conditions, and software settings used in the ergonomic simulations. The interpretation of RULA scores should follow the applicable assessment procedure and account for the limitations of evaluating simulated postures rather than directly observed long-term use.

3.5. Life Cycle Assessment

Environmental performance was examined using SimaPro version 9.3 and a life cycle assessment approach. The assessment was intended to evaluate the environmental implications of the alternative furniture designs, with the reported results including a carbon footprint expressed in kilograms of carbon dioxide equivalent. The LCA procedure should specify the goal and scope of the assessment, functional unit, system boundaries, life cycle inventory, data sources, impact assessment method, and interpretation procedures. These elements are necessary to determine whether the environmental results are comparable across the three configurations. The assessment should follow the applicable principles and requirements of ISO 14040 and ISO 14044. Any exclusions, assumptions, allocation procedures, and limitations in the underlying data should be disclosed. Carbon footprint results should be interpreted in relation to the defined functional unit and system boundaries rather than treated as a complete measure of environmental sustainability.

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3.6. Data Analysis and Multi-Criteria Decision-Making

Qualitative data were designated for thematic analysis to identify recurring patterns in consumer preferences and expert assessments. The analysis should describe the coding procedure, theme development, and the manner in which qualitative findings informed the design process. Quantitative evidence from the design assessments was used to compare the three configurations across the selected performance indicators. The study identified Analysis of Variance (ANOVA), Structural Equation Modeling (SEM), and the Analytic Hierarchy Process (AHP) as analytical methods. However, the final manuscript should specify the purpose of each method, the variables analyzed, the assumptions tested, and the decision criteria applied. ANOVA should be retained only if the data structure and comparison objectives justify its use. SEM should be included only if a theoretically specified model and appropriate observations are available. AHP was intended to support multi-criteria decision-making by establishing the relative priorities of the evaluation criteria and comparing the design alternatives. The final report should identify the decision hierarchy, pairwise-comparison procedure, source of expert judgments, consistency assessment, and method used to calculate the final alternative scores.

3.7. Biophilic-Ergonomic Index and Design Selection

The study reported the development of a Biophilic-Ergonomic Index (BEI) that integrated twelve performance indicators. The index was intended to provide an overall basis for evaluating the alternative furniture configurations. To make the index reproducible, its twelve indicators, operational definitions, measurement scales, normalization procedures, weighting scheme, and aggregation formula must be specified. The relationship between the BEI and the AHP decision scores should also be clarified. If AHP weights were incorporated into the BEI, the procedure should explain how this integration was performed and how double counting of indicators was avoided. The robustness of the resulting ranking should be examined through appropriate sensitivity analysis where the available data permit. The preferred design configuration was determined by integrating the available evidence from user requirements, ergonomic assessment, and environmental evaluation. Configuration B was reported as the selected alternative. Its final interpretation should be supported by the underlying indicator values, the decision criteria, and the documented comparison with Configurations A and C.

3.8. Research Ethics and Methodological Transparency

The study involved interviews with human participants and should therefore report the applicable ethical procedures. These include informed consent, confidentiality safeguards, data handling practices, and institutional ethical approval or an explanation of the applicable exemption, where relevant. The methodological account should distinguish measured results, simulation outputs, expert judgments, and researcher interpretations. Reporting the software versions, analytical procedures, assumptions, and limitations will enable readers to assess the reliability and transferability of the findings to other furniture design and manufacturing contexts.

IV. Results and Discussion

4.1. User Requirements and Design Priorities

The user requirements assessment identified four principal considerations in super teak wood furniture design: adaptive lumbar support, natural material finishes, organic pattern integration, and environmental certification compliance. The reported priority ratings were 4.9/5 for adaptive lumbar support, 4.8/5 for natural material finishes, 4.5/5 for organic pattern integration, and 4.2/5 for environmental

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certification compliance. These findings indicate that ergonomic support and the visual characteristics of natural materials received the highest ratings among the four reported considerations. The prominence of adaptive lumbar support is consistent with the importance of accommodating users' physical characteristics and postural requirements in furniture design. Anthropometric information provides a foundation for translating human body dimensions into appropriate product specifications, although the effectiveness of this translation depends on the population represented and the design context (Dianat et al., 2018). Research on furniture ergonomics has likewise identified variation in assessment methods and the need for systematic evaluation of user–furniture interaction (Bai et al., 2024). Accordingly, the reported preference for lumbar support provides a relevant design requirement, but it does not independently establish that a particular support configuration will improve comfort or reduce musculoskeletal risk.

The high rating for natural material finishes also provides a relevant basis for incorporating the visual and tactile characteristics of wood into furniture development. Biophilic design encompasses a broader relationship between people and nature than the simple inclusion of natural materials (Browning et al., 2014; Zhong et al., 2022). Empirical evidence from indoor environmental research suggests that exposure to biophilic features may influence physiological and cognitive responses, although these findings concern environmental settings rather than furniture products specifically (Yin et al., 2018). Therefore, the preference for natural finishes should be interpreted as evidence of user interest, not as direct proof of psychological or health benefits. Environmental certification received the lowest rating among the four reported considerations, although its score remained above four on a five-point scale. This result suggests that certification was still relevant to the participating consumers. However, the ratings alone do not reveal why respondents assigned different priorities to the four attributes. Additional evidence, such as respondent characteristics, individual response distributions, and qualitative explanations, would be necessary to establish the factors underlying these preferences.

4.2. Comparative Design Performance

The reported technical evaluation identified Configuration B as the preferred alternative. Its reported performance indicators included a Biophilic Design Index score of 8.9/10, seat pressure distribution of 12.5 kPa, a Rapid Upper Limb Assessment (RULA) score of 2, and a carbon footprint of 52.1 kg CO_2 equivalent. The multi-criteria assessment using the Analytic Hierarchy Process (AHP) produced a weighted score of 0.367 for Configuration B. Separately, the reported Biophilic-Ergonomic Index (BEI) score for this configuration was 8.7. These indicators provide different forms of information about the design. The Biophilic Design Index represents an assessment of biophilic characteristics, whereas RULA concerns posture-related ergonomic exposure. The pressure measurement describes a different physical characteristic, and the carbon footprint addresses an environmental impact category. They should therefore be interpreted as complementary rather than interchangeable indicators.

The reported RULA score of 2 is consistent with a low action level within the conventional RULA scoring framework, but its interpretation depends on the posture, task, and simulation conditions assessed. Ergonomic evaluation should be grounded in clearly defined human–product interactions and appropriate measurement procedures (Bai et al., 2024; Dianat et al., 2018). Human modelling can support design assessment before physical production, but simulation results depend on the assumptions and representations incorporated into the model (Chaffin, 2007). Consequently, the score alone cannot demonstrate long-term comfort or establish the absence of musculoskeletal risk during actual use. The seat pressure value of 12.5 kPa also requires further contextual information. Its practical significance depends on the location of the measurement, the distribution of pressure across the seating surface, the user's characteristics, and the assessment protocol. Without corresponding results for Configurations A and C, it is not possible to determine whether Configuration B provides a better pressure distribution than the alternatives. A comparative table containing the same indicators for all three configurations would provide a stronger basis for interpreting the design selection.

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4.3. Biophilic Design and Ergonomic Integration

The reported results suggest that Configuration B was selected through an assessment process that considered biophilic and ergonomic characteristics. This approach is consistent with the broader argument that furniture design should address multiple dimensions of product performance rather than focus exclusively on appearance or technical functionality. Biophilic design offers a conceptual basis for incorporating natural materials, forms, and sensory characteristics into designed products and environments (Browning et al., 2014). However, the conceptual boundaries of biophilic design remain important because the presence of natural materials does not necessarily demonstrate a meaningful human–nature connection or measurable improvement in well-being (Gillis & Gatersleben, 2015; Zhong et al., 2022). The findings from indoor environmental experiments provide a useful theoretical rationale for further investigation, but their implications for furniture must be established through product-specific evaluation (Yin et al., 2018).

The integration of biophilic and ergonomic criteria may therefore be useful for structuring design decisions, particularly when aesthetic preferences and physical requirements must be considered simultaneously. Nevertheless, the available results do not establish that Configuration B improved psychological well-being, productivity, or long-term physical comfort. Such conclusions would require direct user testing, appropriate outcome measures, and a study design capable of distinguishing the effects of individual design characteristics. A broader sustainability perspective also requires considering the environmental consequences of the selected materials and manufacturing processes. Biophilic and sustainable design can be complementary, but they are not equivalent concepts. Wijesooriya and Brambilla (2021) emphasized the need to bridge biophilic design and environmentally sustainable design, while Zhong et al. (2022) identified conceptual and methodological challenges in assessing biophilic interventions. Thus, the design selection should be interpreted as a multi-dimensional decision rather than as proof that a natural-material-based configuration is automatically sustainable.

4.4. Environmental Performance and Life Cycle Assessment

The reported carbon footprint for Configuration B was 52.1 kg CO_2 equivalent. This figure provides an indication of the estimated climate-change impact associated with the assessed product system, but its meaning cannot be fully established without the functional unit, system boundaries, inventory data, and impact assessment method. Life cycle assessment provides a systematic framework for evaluating environmental impacts across defined stages of a product system (International Organization for Standardization [ISO], 2006a, 2006b). In wooden furniture manufacturing, material selection, processing, surface treatment, energy consumption, and other production activities can contribute to the overall environmental profile. Bianco et al. (2021) demonstrated the application of LCA-based tools to wooden furniture ecodesign, while Ali et al. (2022) examined environmental impacts associated with wooden furniture production.

More recent studies have also highlighted the importance of considering environmental impacts across multiple stages of the furniture life cycle. Li et al. (2023) examined furniture design and development from a whole-life-cycle perspective. Yang and Vezzoli (2024) proposed furniture-specific life cycle design guidelines and a toolkit for supporting environmental performance, while Sakib et al. (2024) examined the use of life cycle analysis to evaluate sustainability strategies in furniture manufacturing. Yang et al. (2025) further demonstrated the value of comparative life cycle assessment across furniture categories and product characteristics. These studies reinforce the importance of evaluating furniture through a clearly defined life cycle framework rather than relying on a single environmental indicator. A carbon footprint value does not represent all environmental impacts, including resource depletion, waste generation, or other impact categories that may be relevant to the product system. The interpretation of the reported value should therefore be limited to its stated carbon footprint measure until the assessment methodology is fully documented.

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In addition, the reported value cannot be considered environmentally superior without corresponding measurements for Configurations A and C or an appropriate reference product. Comparative environmental claims require equivalent functional units, consistent system boundaries, and transparent assumptions. The reported result is therefore a useful starting point for environmental assessment, but not sufficient evidence that Configuration B has the lowest overall environmental impact.

4.5. Multi-Criteria Decision Analysis and the Biophilic-Ergonomic Index

The AHP analysis assigned Configuration B a weighted score of 0.367 and identified it as the preferred design alternative. AHP is an established method for structuring multi-criteria decisions and deriving priorities from pairwise comparisons (Saaty, 2008). Its application can be useful when design alternatives must be evaluated against criteria measured using different scales, including user preferences, ergonomic indicators, and environmental measures. However, the interpretation of an AHP result depends on the structure of the decision hierarchy, the source of pairwise judgments, the derived criterion weights, and the consistency of the comparisons. The score of 0.367 indicates the reported outcome of the decision procedure, but its meaning cannot be independently evaluated without the scores for Configurations A and C and the corresponding criterion weights. Reporting consistency measures and sensitivity analysis would also help establish whether the ranking remains stable when the assumptions or weights change.

The study also reported a BEI score of 8.7 based on twelve performance indicators. Composite indicators can summarize complex information, but their construction requires transparent indicator selection, normalization, weighting, aggregation, and sensitivity analysis (Organisation for Economic Co-operation and Development [OECD] & European Commission Joint Research Centre [JRC], 2008). The distinction between the Biophilic Design Index score of 8.9 and the BEI score of 8.7 is particularly important. The two values should not be treated as equivalent because they appear to represent different assessment constructs. The proposed BEI may provide a useful decision-support framework if its twelve indicators are conceptually justified and operationally defined. Nevertheless, the reported score does not by itself establish that the index has been validated. Validation would require evidence demonstrating that the indicators represent the intended constructs, that the aggregation procedure is appropriate, and that the resulting scores are sufficiently robust for their intended use. The methodological contribution should therefore be described in terms of the development and application of an integrated assessment framework unless further validation evidence is available.

V. Conclusion

This study examined the integration of biophilic design, ergonomic performance, and environmental assessment in the development of super teak wood furniture at PT Bima Moriesya Anugerah. Configuration B was identified as the preferred alternative, with a reported Biophilic Design Index score of 8.9/10, a Rapid Upper Limb Assessment score of 2, a seat pressure distribution value of 12.5 kPa, and a carbon footprint of 52.1 kg CO_2 equivalent. The configuration also achieved a reported Biophilic-Ergonomic Index score of 8.7 and an AHP weighted score of 0.367. These findings provide a basis for further examining the feasibility of integrating user preferences, ergonomic criteria, and environmental considerations in furniture design evaluation.

The study's practical contribution lies in demonstrating an approach for organizing multiple design criteria within a comparative evaluation framework. For furniture manufacturers, this approach may support more systematic consideration of user requirements, ergonomic characteristics, and environmental impacts during design selection. The proposed Biophilic-Ergonomic Index may also serve as a preliminary decision-support tool, provided that its indicators, weighting procedures, and aggregation method are clearly defined. However, the reported results should be interpreted within the scope of the evaluated configurations and

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available measurements rather than as definitive evidence of improved long-term comfort or overall environmental sustainability.

Several limitations should be considered when interpreting the findings, including the limited comparative results reported for Configurations A and C, the need for further documentation of the ergonomic simulations and life cycle assessment, and the absence of sufficient evidence to establish the validity and robustness of the proposed index. Future research should conduct physical prototype testing with representative users, report comparable performance indicators for all design alternatives, validate the Biophilic-Ergonomic Index, and examine the sensitivity of design rankings to alternative weighting assumptions and environmental assessment parameters. These steps would strengthen the reliability and reproducibility of the evaluation framework and help determine its applicability to other furniture products and manufacturing contexts.

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