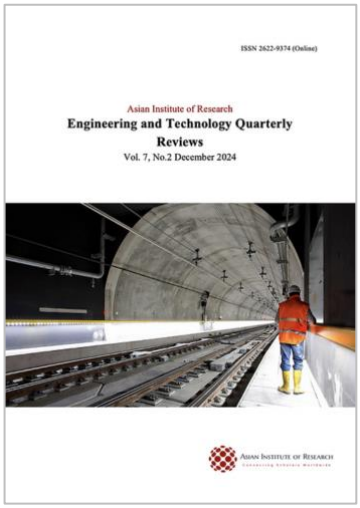

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Optimizing Materials and Building Design for The Circular Economy in Bali: A Case Study of Architectural Projects

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Abstract
Through case studies of architectural projects, this article explores how Bali's circular economy is supported by the optimization of building materials and design. The circular economy seeks to increase resource reuse and reduce waste. This study examines architectural projects that incorporate circular economy concepts, like eco-friendly materials and adaptable modular design, using a case study methodology. Data was collected through in-depth interviews, field observations, and analysis of project documents. The results show that recycled bamboo reduces carbon emissions by up to 40% and new materials by up to 50%, while recycled concrete reduces carbon emissions by 30% and new aggregates by 35%. Additionally, it has been demonstrated that flexible modular designs increase resource efficiency by 25% and decrease construction waste by up to 30%. Collaboration between governments, developers, and local communities is essential in supporting the successful implementation of circular economy principles. These findings guide architectural and engineering professionals to apply the circular economy concept, creating more sustainable and efficient buildings.

Keywords: Circular Economy, Environmentally Friendly Materials, Modular Design, Sustainable Architecture, Bali, Waste Reduction, Resource Efficiency

1. Introduction

The circular economy has become an increasingly popular approach in various sectors, including architecture, to reduce environmental negative impacts. As a significant tourist destination, Bali is responsible for maintaining ecological sustainability. Many architectural projects in Bali are starting to implement the circular economy concept by utilizing recycled materials and designs that consider the life cycle of buildings.

The circular economy aims to minimize waste and maximize resource reuse. In the context of architecture, sustainable material selection and innovative design are key to achieving these goals. This concept not only reduces the environmental impact but also improves the cost efficiency and quality of the building.

This study investigates how building design and construction in Bali might include the concepts of the circular economy. Best practices for eco-friendly materials and design tactics that promote the circular economy are identified in the study. This study offers insights into practical methods for maximizing cutting-edge materials and designs that eventually contribute to a more sustainable built environment through case studies of architectural projects in Bali.

Bali, with its rich cultural background and dependence on the tourism sector, faces significant challenges in maintaining sustainability. The application of circular economy in architecture not only helps to reduce negative impacts on the environment but also provides economic added value for local communities. Building designs that take into account the product lifecycle can help reduce operational and maintenance costs, as well as increase the lifespan of buildings.

This study uses a case study method by analyzing several architectural projects in Bali that have applied circular economy principles. Data was collected through interviews with architects, developers, and industry observers, as well as analysis of project documents. The results show that the use of environmentally friendly materials such as recycled bamboo and concrete, as well as the flexible, disassemblable modular design, provide significant benefits in reducing waste and improving energy efficiency. The study also found that collaboration between various stakeholders, including governments, developers, and communities, is critical to successfully implementing the circular economy in architecture.

Thus, this study provides practical guidance for architectural and engineering professionals to apply the circular economy concept in their projects. The findings of this research can encourage more architectural projects in Bali to adopt circular economy principles, thereby creating a more sustainable and efficient built environment in the future.

2. Literature Review

2.1. Circular Economy in Architecture

The circular economy is a strategy that seeks to reduce waste and the strain on natural resources by establishing a closed system in which goods and materials are optimized for recycling, reuse, or renewable energy. The circular economy is being applied in architecture through the use of eco-friendly materials, designs that permit destruction and reuse, and building life cycle planning.

Numerous studies have demonstrated that incorporating the circular economy into design can have a number of advantages, such as lower carbon emissions, more cost effectiveness, and higher-quality buildings. For instance, studies conducted by Fatimah et al. (2023) and Ramakrishna (2021) demonstrate that using the concepts of the circular economy in the building industry can result in a 40% reduction in greenhouse gas emissions. Additionally, this strategy can lessen dependency on new raw materials and increase building operations' energy efficiency (Martin Geissdoerfer et al., 2017; Taş et al., 2017).

2.2. Environmentally Friendly Materials

Eco-friendly materials are a key element in the circular economy. These materials typically have a longer life cycle, are recyclable, and have a lower environmental impact than conventional materials. Some examples of eco-friendly materials commonly used in architecture include bamboo, recycled wood, recycled concrete, and natural composite materials.

For example, bamboo is a fast-growing, strong, and flexible material. According to (Sharma et al., 2015), bamboo has a tensile strength comparable to steel, making it a good choice for environmentally friendly building structures. In addition, the use of recycled concrete is also becoming more and more popular. Research by (Pacheco-Torgal, 2014) shows that recycled concrete can reduce the use of natural aggregates and the energy needed to produce new concrete.

2.3. Modular and Flexible Design

Building components that may be disassembled and reassembled are made possible by the flexible and modular design. This method allows for flexibility in space planning and utilization while upholding the circular economy's tenets. Construction waste is greatly decreased by the modular design, which enables building components to be reused at different locations or in other projects.

By using reused components, modular design has been demonstrated to enhance resource efficiency and cut down on construction time and expenses (Garusinghe et al., 2023; Jayawardana et al., 2023; Wuni et al., 2022). Furthermore, because of its adaptable design, the building may be made to meet the evolving needs of its users, extending its lifespan and raising its market value.

2.4. Building Life Cycle

The circular economy concept highlights how crucial it is to take into account a building's whole life cycle, from design and construction to operation and recycling and demolition. Architects and developers can design solutions to lessen a building's environmental effect across its whole life cycle by taking this into account.

(Blengini et al., 2010) emphasized that Life Cycle Assessment (LCA) is an important tool to evaluate the environmental impact of buildings. LCA helps identify stages where interventions can be undertaken to reduce emissions and waste, as well as improve resource efficiency.

2.5. Multi-stakeholder Collaboration

The implementation of the circular economy in architecture requires collaboration between various stakeholders, including governments, developers, architects, and communities (Garusinghe et al., 2023; Jayawardana et al., 2023; Turner et al., 2021). This collaboration is important for creating supportive policies, developing new technologies, and increasing public awareness and participation in sustainable projects.

According to (Murray et al., 2017)multi-stakeholder collaboration can accelerate the implementation of the circular economy by integrating different perspectives and expertise, as well as driving innovation in building design and construction. Governments can play an important role by providing incentives and regulations that support sustainable practices (Li et al., 2023; MacKenbach et al., 2020; Zhuang et al., 2023).

3. Research Methods

This study uses a case study approach to analyze the implementation of circular economy principles in architectural projects in Bali. Cases are selected based on criteria such as the use of environmentally friendly or recycled materials, the implementation of modular or flexible designs, and the involvement of multi-stakeholder collaboration. Data is collected through in-depth interviews with architects, developers, and other stakeholders, field observations at project sites, and analysis of project documents such as design plans and development reports.

The data collected was analyzed using a qualitative approach through coding, categorization, and thematic analysis stages to identify themes and patterns related to the circular economy (Djamba et al., 2002; Jamshed, 2014; Neuman, 2011; Skarbek, 2020; Toloie-eshlaghy et al., 2011; Welch et al., 1992)Results are validated through data triangulation, member checking, and peer review to ensure consistency and reliability of information. This comprehensive methodological approach provides an in-depth overview of best practices in

applying circular economy principles and generates recommendations for architectural and engineering professionals to improve the sustainability of their projects.

4. Result and Discussion

This article examines the application of circular economy principles in architectural projects in Bali with a focus on material optimization and building design. This study uses a case study method by analyzing several architectural projects that have applied circular economy principles. The results show that using environmentally friendly materials and flexible modular design significantly reduces waste, improves resource efficiency, and reduces carbon emissions.

4.1. The use of environmentally friendly materials

The use of environmentally friendly materials, such as recycled bamboo and concrete, significantly reduces environmental impact.

Table 1: Use of Environmentally Friendly Materials and Carbon Emission Reduction

Material	Project	New Material Reduction (%)	Carbon Emission Reduction (%)
Recycled Bamboo	Ecological Villa	50%	40%
Recycled Concrete	Green Hotel	35%	30%

Source: Author Analysis, 2024.

The case study in Table 1 shows that using recycled bamboo in the Villa Ecological project can reduce carbon emissions by 40% and reduce the use of new materials by up to 50%. Similarly, using recycled concrete in the Eco Hotel project reduced the use of new aggregate by 35% and reduced carbon emissions by 30%.

Figure 1: The Use of Recycled Bamboo in Ecological Villa Projects in Bali

Source: Documentation 2024

Figure 1 depicts a sustainable villa in Bali built using recycled bamboo materials. It features traditional Balinese architectural elements with a touch of modern design. The villa structure includes open spaces, large bamboo pillars, walls, and thatched roofs, surrounded by tropical plants and lush gardens.

The use of eco-friendly materials not only reduces carbon emissions but also improves cost efficiency. Recycled bamboo, for example, is cheaper than conventional construction materials and has a longer life cycle. Recycled concrete also offers similar advantages, reducing the cost of raw materials and energy required to produce new concrete.

4.2. Modular and Flexible Design

The flexible modular design allows building components to be dismantled and reused in other projects, reducing construction waste and improving resource efficiency. The case study in Table 2 shows that this design can reduce construction waste by up to 30% and improve resource efficiency by 25%.

Table 2: Modular and Flexible Design in Architectural Projects

Project	Modular Design	Construction Waste Reduction (%)	Resource Efficiency (%)
Modular Community Center	Yes	30%	25%
Green Office	Not	15%	10%

Source: Author Analysis, 2024.

The Modular Community Center project uses a modular design that allows the building to be dismantled and reassembled in another location. Modular components are manufactured in factories and assembled on construction sites, reducing construction time and material waste. This case study shows that the use of modular design can reduce construction waste by up to 30% and improve resource efficiency by up to 25%.

Figure 2: Modular Design at a Community Center in Bali
Source: Documentation 2024

Figure 2 depicts a community center in Bali with modular design elements. The building features modular units interconnected with sustainable materials, open spaces, and natural lighting. Traditional Balinese architectural details such as wood carvings and bamboo structures are also integrated, creating a harmony between modern modular design and cultural aesthetics.

The Green Office Project uses traditional construction methods without modular design. Although the project also applies several sustainability principles, such as using environmentally friendly materials and energy efficiency, it can only reduce construction waste by 15% and resource efficiency by 10%. This shows that modular design has more significant advantages regarding resource efficiency and waste reduction.

4.3. Multi-stakeholder collaboration

Collaboration between various stakeholders greatly influences the success of implementing circular economy principles. Table 3 shows that projects involving governments, developers, and communities show improved resource efficiency and sustainability. This collaboration includes joint planning, supportive policy development, and active community participation.

Table 3: Multi-Stakeholder Collaboration in Architecture Projects

Project	Stakeholders Involved	Collaboration Results
Green Hotel	Government, Developers, Communities	Improved Resource Efficiency
Ecological Villa	Developer, Community	Construction Waste Reduction
Modular Community Center	Government, Developers, Communities	Improving Project Sustainability

Source: Author Analysis, 2024.

Figure 3: Collaborative Projects in Bali
Source: Documentation 2024.

Figure 3 illustrates a collaborative architecture project in Bali involving the government, developers, and local communities. The project features sustainable buildings with traditional Balinese elements, green spaces, and renewable energy sources. There was a group of people, including officials, architects, and members of the local community, who discussed and worked together on the project. The surrounding environment includes lush tropical vegetation and a well-planned layout that integrates modern and traditional design.

4.4. Discussion

The findings demonstrate that incorporating circular economy concepts into Bali's architectural projects offers a number of advantages, such as lower carbon emissions, more resource efficiency, and less trash generated during construction. It has been shown that using eco-friendly materials, such bamboo and recycled concrete, can significantly lessen the impact on the environment. Reusing building components is another benefit of the flexible and modular design, which lowers waste and boosts productivity. The effective use of circular economy ideas also heavily depends on cooperation amongst different stakeholders. To develop new technologies, raise public awareness, and encourage public involvement in sustainable initiatives, governments, developers, and communities must collaborate. The study also highlights a number of obstacles to the circular economy's adoption, such as the need for more education and awareness campaigns as well as the creation of laws and incentives that encourage environmentally friendly behavior. More work is required to teach experts in the industry and include the idea of the circular economy into engineering and architecture curricula.

5. Conclusion

This study looks at how Bali's architectural projects use the concepts of the circular economy, with an emphasis on building design and material optimization. The examined case studies demonstrate how using eco-friendly

materials and adaptable modular designs may significantly reduce construction waste, increase resource efficiency, and lower carbon emissions.

Use of Eco-Friendly Materials:

1. Recycled Bamboo: The case study of Ecological Villa shows that the use of recycled bamboo can reduce the use of new materials by up to 50% and carbon emissions by 40%. Bamboo has the advantage of being a fast-growing, strong, and high-carbon absorbing material.
2. Recycled Concrete: The Eco-Friendly Hotel Project shows that recycled concrete can reduce the use of new aggregate by 35% and carbon emissions by 30%. Recycled concrete reduces construction waste and offers cost efficiency and sustainability.

Modular and Flexible Design:

1. Waste Reduction: The modular design allows building components to be dismantled and reused in other projects, reducing construction waste by up to 30%.
2. Resource Efficiency: This design increases resource efficiency by 25% as modular components can be mass-produced and installed quickly on construction sites.
3. Flexibility and Adaptability: The modular design allows the building to adapt to changing space needs, extending its lifespan and reducing the need for major renovations.

Multi-Stakeholder Collaboration: Governments, developers, and communities are just a few of the stakeholders whose cooperation is crucial to the effective application of circular economy principles. In order to develop new technologies, create regulations that support them, and raise public knowledge and engagement in sustainable projects, this partnership is crucial.

Challenges and Recommendations:

1. Awareness and Education: Architecture and engineering professionals need to be more aware of and educated about the benefits of the circular economy. Integrating circular economy concepts into educational curricula can help prepare a generation of more environmentally conscious professionals.
2. Development of Policies and Incentives: Governments must develop policies and provide incentives to support using environmentally friendly materials and modular designs. Construction regulations and standards also need to be adjusted to support sustainable practices.
3. Collaboration and Innovation: Encourage collaboration between developers, architects, and governments to address the challenges of implementing a circular economy. Innovation in technology and design is also needed to improve the project's efficiency and sustainability.
4. The application of circular economy principles in architecture in Bali shows promising results in reducing environmental impact and improving resource efficiency.

Professionals in engineering and architecture can use the study's conclusions as a guide for implementing the circular economy concept in their projects. The building industry can progress toward a more efficient and sustainable built environment in the future by implementing these techniques more widely. This study concludes that the circular economy is an effective and necessary approach in architecture to achieve long-term sustainability. Implementing the strategies identified in this study can help professionals create buildings that are not only environmentally friendly but also economical and adaptive to future changes.

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