



Sustainable adaptive reuse of heritage architecture in Vredeburg Fortress

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ABSTRACT

Background: Adaptive reuse has become an essential strategy in heritage conservation, particularly within postcolonial contexts where architecture embodies both cultural memory and historical conflict. In Indonesia, this approach is increasingly used to reinterpret colonial heritage as part of a national identity narrative, transforming spaces of domination into venues for learning and reconciliation. However, most existing studies and practices focus primarily on architectural restoration and tourism functions, with limited attention to the broader social, cultural, and policy dimensions of sustainability. This study aims to develop a multi-scalar framework for analyzing sustainable adaptive reuse that integrates building-level conservation with urban governance and cultural identity. **Methods:** The research employs a qualitative, document-based method that relies exclusively on secondary data, including archival records, policy documents, and scholarly publications. The case of Vredeburg Fortress in Yogyakarta serves as a lens for examining how sustainability operates across architectural, social, and spatial scales. **Findings:** Findings reveal that Vredeburg's adaptive reuse supports sustainability through three interlinked levels: micro (building), meso (site), and macro (urban policy). **Conclusion:** The study concludes that adaptive reuse in postcolonial contexts must be understood as a multidimensional process that connects tangible and intangible values. **Novelty/Originality of this article:** The article's originality lies in extending adaptive reuse discourse beyond the architectural scale, offering a transferable model for multi-scalar sustainable heritage management in Southeast Asia.

KEYWORDS: adaptive reuse; colonial heritage; sustainable architecture.

1. Introduction

Heritage architecture serves as one of the most tangible connections between the collective memory of societies and their aspirations for future development. It embodies not only the physical remains of history but also the cultural values, identities, and meanings embedded within architectural form and urban space. In recent decades, the global discourse on sustainability has redefined the role of heritage architecture from the static preservation of monuments to a dynamic process of adaptive reuse that aligns with contemporary environmental, social, and economic needs (Bogdan et al., 2022; Fayez, 2024). Heritage architecture represents a critical link between historical identity and contemporary sustainability goals (Bertolin & Loli, 2018; Erkan, 2018; Grazuleviciute-Vileniske et al., 2021). The growing concern over climate change, resource scarcity, and the loss of cultural distinctiveness has led to the recognition that existing buildings constitute a critical asset in achieving the United Nations Sustainable Development Goals (SDG 11.4),

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which emphasize the protection and safeguarding of the world's cultural and natural heritage (Palmer, 2015; Misirlisoy & Günçe, 2016; Djebbour & Biara, 2020).

Heritage architecture refers to the physical manifestations of cultural identity, collective memory, and historical continuity that are embodied in the built environment. It encompasses structures, spaces, and urban forms that possess architectural, historical, aesthetic, social, and cultural significance. As articulated in international conservation charters such as the Venice Charter (1964) and the Nara Document on Authenticity (1994), heritage architecture represents more than the preservation of material fabric, it signifies the safeguarding of values, meanings, and traditional knowledge embedded within buildings and sites. Scholars have emphasized that heritage architecture must be understood as a living system that evolves through the interaction between people, place, and time, maintaining its authenticity while adapting to contemporary contexts (Smith, 2006; Harrison, 2013; Lucchi, 2022). As a result, heritage architecture serves not only as a record of the past but also as an active agent in shaping sustainable cultural and spatial futures. This interpretation allows heritage architecture to actively contribute to sustainability through reuse, reinterpretation, and continuous engagement with contemporary communities.

Within this context, adaptive reuse has emerged as a leading paradigm that bridges conservation and sustainability. Rather than treating historic buildings as static artifacts, adaptive reuse allows for functional transformation while maintaining heritage significance. It is considered one of the most resource-efficient and culturally sensitive strategies for sustainable development in the built environment (Plevoets & Cleempoel, 2019). Adaptive reuse reduces the environmental impact of demolition and new construction while extending the life cycle of existing structures (Foster, 2019; Lucchi, 2022). At the same time, it revitalizes the social and cultural relevance of heritage sites, transforming them into spaces that serve contemporary needs without erasing their historical identity. It represents the essential ideas of sustainable architecture, such as social inclusion, cultural continuity, and embodied energy preservation (Department of the Environment and Heritage, 2004; Asman et al., 2019; Ibrahim & Eltarabishi, 2021).

Adaptive Reuse in heritage buildings refers to the process of changing the function of an old building or structure to suit new needs or uses, and aims to give new life to a building that may no longer be used for its original function, while respecting and maintaining the historical and cultural value of the structure (Plevoets & Cleempoel, 2019; Armstrong, 2021; Pickerill, 2021). This research are emphasizing that sustainability in heritage buildings goes beyond simple material or technical preservation (Yildirim & Turanm 2012; Wang & Yang, 2022; Vardopoulos, 2023). Therefore, the more adaptive reuse occurs, the greater the chance to have a beneficial impact on the long-term growth of the natural, social, and cultural environments.

Previous studies have demonstrated that the adaptive reuse of cultural heritage can significantly contribute to sustainable development, particularly when applied to historic buildings with complex social and cultural histories (Rodwell, 2015; Mohamed et al., 2017). Its contribution includes sustainability's environmental, social, cultural, and economic aspects in alongside material conservation (Conejos et al., 2016; Elrod & Fortenberry, 2017; Mohamed et al., 2017; Foster, 2020). Environmentally, adaptive reuse minimizes waste generation and conserves embodied energy by retaining existing structures rather than replacing them (Foster, 2020). Socially, it enhances inclusivity and strengthens community identity through continued public use of heritage spaces (Elrod & Fortenberry, 2017). Culturally, it maintains the continuity of collective memory and reinterprets historical narratives, while economically it stimulates local revitalization through heritage-based tourism and creative reuse initiatives (Conejos et al., 2016; Mohamed et al., 2017).

While numerous studies have explored adaptive reuse from the perspective of architecture and environmental performance, fewer have examined its operation across multiple spatial and institutional scales. Yet sustainability is inherently multi-scalar, extending from the material and building scale (micro) to the community and site scale (meso), and finally to the urban policy and governance scale (macro) (Salameh et al., 2022;

Sharma et al., 2024; Abdul Huq & Puthuvayi, 2024). These interconnected levels form what this paper refers to as a molecular-to-landscape conservation framework.

At the micro scale, sustainability concerns the conservation of materials, structural integrity, and energy performance of the building. At the meso scale, it addresses the role of heritage in fostering community identity, cultural expression, and inclusive social functions. At the macro scale, it involves integration into heritage management systems, urban policy, and creative economies that sustain heritage over time. Understanding these interrelations is essential for developing comprehensive conservation strategies.

In Indonesia, adaptive reuse has emerged as an important strategy to reinterpret colonial heritage within a national narrative, reflecting efforts to transform symbols of control into spaces of learning and reconciliation. However, many conservation initiatives remain confined to the architectural level, focusing primarily on physical restoration or tourism-oriented reuse. Colonial heritage buildings such as Nasional Gallery of Indonesia, Jakarta; De Tjolomadoe, Central Java; Benyamin Sueb Park, Jakarta and also colonial houses in Indonesia have shown that adaptive reuse can successfully integrate historical, cultural, environmental, and human aspects of sustainability (Ardhiati et al., 2020; Triratma et al., 2023; Devina et al., 2025). However, these studies frequently view sustainability as a building-scale phenomenon, ignoring the wider relationships between cultural landscapes, urban policy, and heritage sites. This limitation creates a research gap in understanding how sustainability operates across multiple scales ranging from materials and building performance to city-wide heritage management.

To address this gap, this study investigates the adaptive reuse of Vredenburg Fortress in Yogyakarta, provides a compelling example for exploring sustainability across scales. Built in the late eighteenth century during Dutch colonial rule, the fortress was originally designed as a military outpost intended to monitor the nearby Kraton Palace of Yogyakarta. Today, it has been transformed into the Museum Benteng Vredenburg Nasional, a public institution dedicated to the history of Indonesia's independence.

The fortress's location along Yogyakarta's Philosophical Axis, a north-south cosmological alignment that links Mount Merapi, the Kraton, and the Indian Ocean, represents the Javanese philosophy of Sangkan Paraning Dumadi, or the beginning and purpose of life. This axis' Outstanding Universal Value (OUV), which combines cosmology, cultural identity, and geographical planning, led to its official designation as a UNESCO World Heritage Site in 2023. Vredenburg serves as a cultural boundary in this urban setting, bridging between colonial past and postcolonial identity, as well as between material conservation and intangible heritage.

The objective of this research is to analyze the sustainable adaptive reuse of Vredenburg Fortress through a molecular-to-landscape conservation perspective that links material authenticity, cultural continuity, and urban governance. The study applies a qualitative approach based on qualitative analysis of archival, documentary, and policy-related secondary data to construct a multi-scale sustainable adaptive reuse framework. While previous studies have examined adaptive reuse as an architectural practice, few have analyzed it within the multi-scalar system of urban heritage, where buildings interact with landscape, policy, and community structures. The present study addresses this gap by investigating how sustainability principles manifest across three analytical levels such as (1) the micro scale of building and materials, (2) the meso scale of site and social functions, and (3) the macro scale of urban and policy integration.

2. Methods

2.1 Research methodology

The architecture of colonial heritage is complicated. Along with tangible architectural elements, we also need to consider intangible elements such as value, meaning, and context that can be used as resources to enhance local communities' quality of life by integrating concepts from previous cultural identities into a future vision. (Deacon, 2018; Gustafsson &

Ripp, 2022; Nassir et al., 2022; Alghamdi et al., 2023). This study adopts a qualitative case study approach (Yin, 2018), which is appropriate for exploring the contextual and interpretive dimensions of architectural conservation. The qualitative approach allows for an in-depth understanding of how and why sustainability principles manifest across multiple scales.

The study adopts an interpretive paradigm, recognizing that heritage sustainability is constructed through social, cultural, and institutional processes rather than purely physical conservation. Through this approach, Vredeburg Fortress is treated not merely as a preserved building, but as a living cultural system embedded in Yogyakarta's urban and historical landscape.

2.2 Parameter of study

Based on the previous explanation, the main aspects of the contributions of adaptive reuse to sustainable development are environmental, social, cultural, and economic. The focus of this study is restricted to the sustainable adaptive reuse of Colonial-era historic buildings, based on SDG 11 indicator, which is then modified to align with the regional action plan for Yogyakarta (Palmer, 2015). All four aspects of Sustainable Adaptive Reuse of Colonial Historic Buildings will be explained across multiple scales: micro (building), meso (site), and macro (urban policy) (Boeren, 2019; Zainudin et al., 2020). Table 1 displays the following outcomes of the parameters that were developed.

Table 1. Parameters of sustainable adaptive reuse of colonial historic buildings

Scale	Focus area	Indicators
Micro	Building & materials	Energy efficiency, material reuse, environmental design, authenticity
Meso	Site & community	Social function, cultural meaning, accessibility, participation
Macro	Urban & policy	Integration with heritage corridors, governance, and the tourism economy

2.3 Data collection

This study relies primarily on secondary data sources to analyze the sustainable adaptive reuse of Vredeburg Fortress within the broader cultural and urban framework of Yogyakarta's Philosophical Axis. The use of secondary data is justified by the richness and accessibility of archival, documentary, and scholarly materials related to the site's historical transformation and current conservation policies. Secondary data also provide a comprehensive basis for multi-scalar analysis, allowing the research to link material, architectural, and policy dimensions of sustainability without the limitations imposed by time-bound field surveys.

The primary data corpus consists of archival documents and historical records obtained from publicly available repositories and institutional archives. These include early colonial maps, architectural drawings, and restoration documentation from the Museum Benteng Vredeburg Nasional, the Yogyakarta Cultural Heritage Office/*Balai Pelestarian Cagar Budaya Daerah Istimewa Yogyakarta* (BPCB DIY), and the National Archives of Indonesia/*Arsip Nasional Republik Indonesia* (ANRI). These materials were examined to trace the fortress's morphological evolution, identify major restoration interventions, and assess the degree of authenticity maintained throughout its adaptive reuse. The documents provide detailed insights into the building's spatial structure, material composition, and the transition of functions from military fortification to museum.

The research framework integrates molecular-to-landscape conservation principles, connecting material-level interventions with broader socio-cultural and policy dimensions. This framework emphasizes that sustainability in heritage architecture emerges from the

synergy between physical conservation, cultural continuity, environmental responsiveness, and human participation.

3. Results and Discussion

3.1 Overview of Vredenburg Fortress as an adaptive reuse instrument

Vredenburg Fortress occupies a central position in the historical and cultural landscape of Yogyakarta, making it a compelling case for examining adaptive reuse within a sustainable heritage framework. Constructed in the late eighteenth century during the early consolidation of Dutch colonial power in Java, the fortress was strategically positioned facing the Kraton Ngayogyakarta Hadiningrat to function as a surveillance post and a symbol of political control. This spatial relationship reveals the colonial agenda of territorial control and visual dominance, typical of 18th-century fortification design in the Dutch colonial network (Lombard, 2005; Kemendikbudristek, 2012). This fortress has a shape that reflects the typical European defense strategy of its time, adapted to local geographical and climatic conditions. Its geometric bastion form, defensive moat, and thick masonry walls reflect the standardized fortification typology employed by the Dutch East Indies, revealing the military logic and territorial anxieties embedded in colonial urban planning. Over more than two centuries, the fortress has undergone significant functional transformations, from a colonial defense structure, to a Japanese military base during World War II, to a post-independence military office, and finally to its current role as the Museum Benteng Vredenburg Nasional. These transitions illustrate how the building has continually adapted to shifting sociopolitical narratives, while maintaining its architectural integrity and symbolic presence in the urban fabric of Yogyakarta.



Fig. 1. Vredenburg Fortress

Following Indonesia's independence, the fortress underwent a gradual process of reinterpretation, culminating in its conversion into the Fort Vredenburg Museum in 1992 (Kemendikbudristek, 2012). This conversion of Vredenburg Fortress into Museum Benteng Vredenburg Nasional represents one of Indonesia's most significant adaptive reuse interventions involving colonial heritage. Rather than erasing the structure's colonial legacy, the adaptive reuse process reinterprets the fortress within a postcolonial narrative that foregrounds resistance, negotiation, and national identity. This transformation mirrors broader trends in Southeast Asian heritage discourse, where formerly oppressive colonial infrastructures are recontextualized as cultural assets and educational resources. In this

sense, Vredeburg functions as a mediating space where historical trauma, collective memory, and contemporary civic identity intersect.

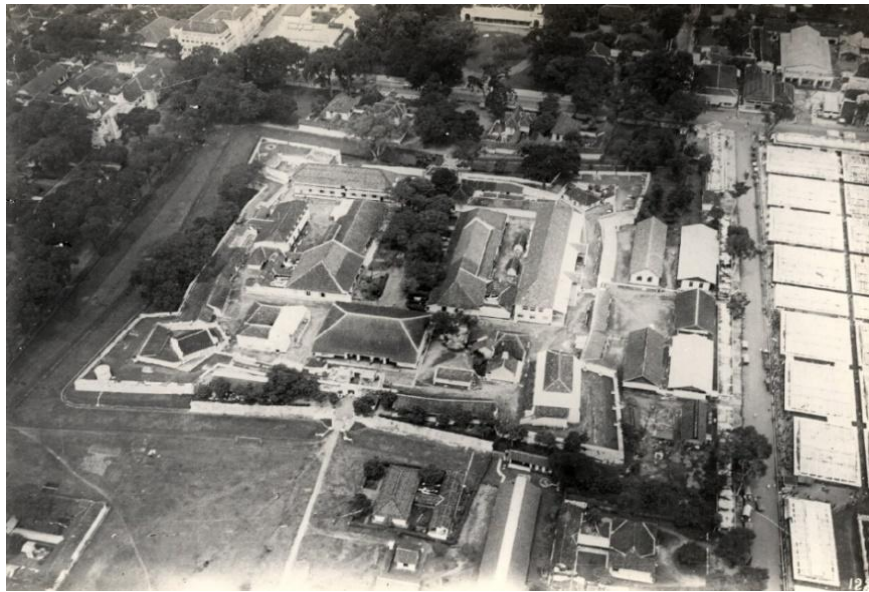


Fig. 2. Vredeburg Fortress in 19 centuries
(Tropenmuseum, 2024)

The adaptive reuse of Vredeburg Fortress began as a national effort to reinterpret colonial heritage within the framework of cultural education and sustainable urban development. The transformation was driven by the awareness of the fortress's historical significance and its strategic location at the heart of Yogyakarta, adjacent to Malioboro Street and the Kraton Palace. In accordance with UU No. 11 of 2010 on Cultural Heritage, the adaptive reuse of Vredeburg reflects Indonesia's broader conservation policy that allows heritage buildings to evolve in function while maintaining their authenticity and historical integrity.

Architecturally, the fortress retains a high degree of authenticity. Restoration work has preserved its original masonry, roof systems, gate structures, bastions, and moat, following the principles of minimal intervention and material compatibility emphasized in the Venice Charter (1964) and Nara Document on Authenticity (1994). These conservation choices reflect a commitment to maintaining both tangible and intangible heritage values, ensuring that the material fabric of the building continues to communicate its historical and cultural significance. Furthermore, the fortress's passive climatic strategies, such as thick walls, deep eaves, natural ventilation openings, and courtyard organization, demonstrate the environmental intelligence embedded in colonial-era architecture in the tropics, allowing the adaptive reuse process to leverage traditional bioclimatic performance for contemporary sustainability objectives.

At the urban scale, Vredeburg's location on Yogyakarta's Philosophical Axis adds another layer of significance. The fortification is included into a larger cultural environment that connects Mount Merapi, the Keraton, and the Southern Ocean as part of this UNESCO World Heritage Site. This symbolic positioning emphasizes the fortress's longstanding role as a threshold between authority and the public sphere, and its adaptive reuse strengthens the continuity between cultural heritage and civic life. Its contemporary function as a museum, public gathering space, and cultural venue positions it as an active participant in urban sustainability, contributing to cultural tourism, local economic development, and heritage-based education.

The significance of Vredeburg's adaptive reuse is further reinforced by its multifaceted heritage values, including historical, aesthetic, social, scientific, architectural, and rarity dimensions. These values extend beyond the physical structure and shape the fortress's broader role as a cultural resource. They also provide an analytical foundation for

evaluating sustainability across micro, meso, and macro scales. As a product of adaptive reuse, Vredeburg exemplifies how colonial heritage can be reimagined through material conservation, social activation, and policy integration, offering insights into the dynamic relationship between historic architecture and sustainable development (see Table 2).

Table 2. Significance values of Vredeburg Fortress

No	Significant value	Description
1	Historical value	Witness to Dutch colonial history and VOC surveillance of the Yogyakarta Sultanate; over 200 years old since its construction in 1756
2	Aesthetic value	Preserves authenticity through restoration with similar materials; integrates new landscape features, such as gardens, while retaining the original moat and gate structures
3	Social value	Functions as a museum that revives historical and artistic traditions; supports local smes and cultural events
4	Scientific value	Provides opportunities for research in architecture, history, and cultural studies; serves as a knowledge resource about Indonesian independence history
5	Architectural value	Displays Indische architectural style with Dutch design influence by Frans Haak; combines European military typology with Javanese elements
6	Rarity value	Represents a rare example of preserved colonial fortification typology in Indonesia, twin to Fort Vastenburg in Surakarta

These layered significance values (Table 2) form the foundation for understanding Vredeburg as a model of sustainable adaptive reuse. Its transformation illustrates how heritage buildings can retain historical meaning while acquiring new social and educational functions. More importantly, the fortress exemplifies how sustainability extends beyond environmental strategies to encompass cultural resilience, public engagement, and policy integration. By preserving its material fabric, reprogramming its spatial functions, and embedding it within heritage governance frameworks, Vredeburg demonstrates a form of sustainability that is multi-dimensional and multi-scalar.

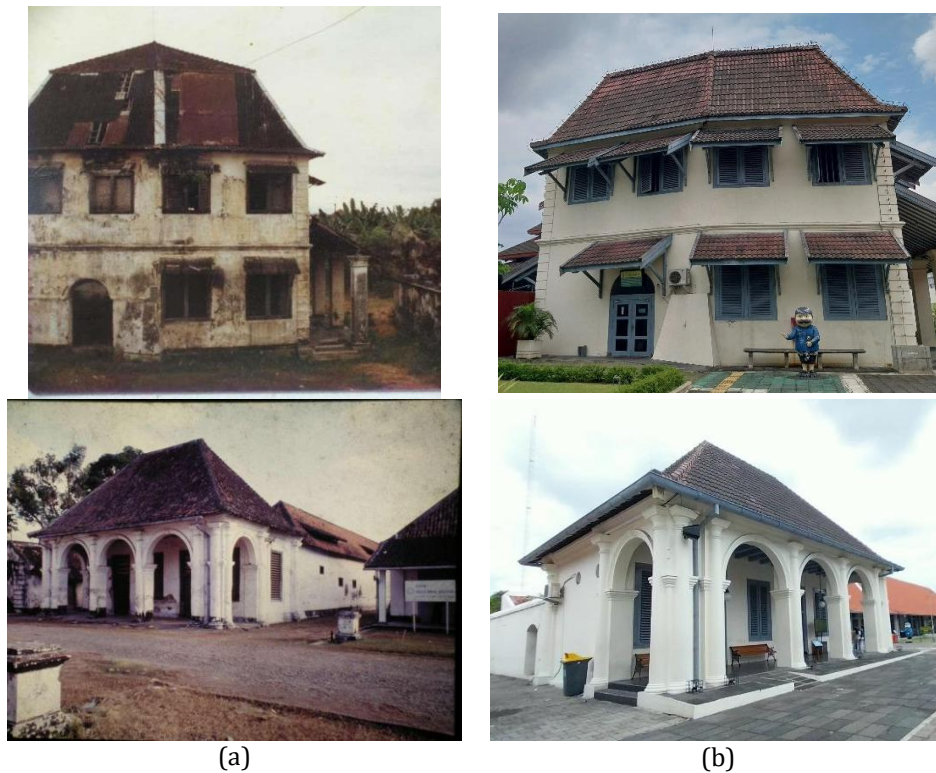
In this way, Vredeburg Fortress is not only a physical artifact of the past but also a living institution that continues to evolve alongside Yogyakarta's cultural and urban development. Its adaptive reuse serves as a model for how postcolonial cities can transform inherited architectural legacies into instruments for sustainable futures to bridging memory, identity, and development within a coherent heritage framework.

3.2 Micro scale: Building & materials

At the micro scale, sustainability concerns the physical and environmental aspects of the building from its materials, structure, and climatic performance. The conservation of Vredeburg Fortress demonstrates how traditional construction techniques and material authenticity can contribute to environmental sustainability by reducing waste, conserving embodied energy, and ensuring long-term resilience.

The fortress's thick masonry walls, high ceilings, and internal courtyards create stable microclimatic conditions, reducing the need for artificial heating or cooling. This demonstrates how traditional colonial construction aligns with the principles of low-carbon design and energy efficiency. In conservation practice, the use of original materials and repair techniques reduces waste and preserves the embodied energy of the structure, supporting a circular-economy approach to heritage maintenance. Regular upkeep using compatible materials ensures durability and minimizes the ecological footprint of interventions. However, since the fortress now functions as a museum, some of the historical collections must be properly preserved by controlling the temperature of the

museum room to prevent the objects from being damaged quickly, including the use of air conditioning.



(a) (b)
Fig. 3. Vredeburg buildings in (a) 1970; (b) 2025
(Leiden University Digital Collections KITLV, 2024)

The restoration work adheres to the Venice Charter (1964) principles, emphasizing repair over replacement. Materials were sourced or produced using methods that match the historical texture and composition, ensuring that modern interventions remain reversible and distinguishable. This approach extends the building's lifecycle while maintaining material authenticity, an essential tenet of sustainable heritage management.



Fig. 4. The moat at Vredeburg Museum

The adaptive reuse project integrates landscape revitalization by adding gardens, open spaces, and water elements while preserving the original moat system. These interventions strengthen environmental quality, enhance biodiversity, and improve thermal comfort through evaporative cooling. The moat, once a defensive barrier, now functions as part of the site's ecological infrastructure, symbolically transforming a colonial artifact of division into an element of environmental sustainability. These efforts align with the circular economy framework and highlight that sustainability in heritage reuse can derive from respecting and optimizing existing ecological and architectural systems rather than imposing entirely new technologies (Lucchi, 2022).

From an economic aspect, the micro-scale approach demonstrates the cost-efficiency of adaptive reuse. Reusing existing materials and infrastructure avoids the financial and environmental costs of demolition and reconstruction. The minimal-intervention philosophy aligns with long-term asset management strategies that balance operational sustainability with heritage integrity. In this sense, the micro scale establishes the foundational layer of sustainability, where building performance, material conservation, and economic efficiency converge to create a resilient architectural system.

Therefore, at the micro scale, Vredenburg Fortress exemplifies the principle that environmental and material conservation are inseparable from social accessibility and economic prudence. The building's physical resilience and low-energy performance represent the first dimension of a multi-scalar sustainability framework that supports its continued adaptation over time.

3.3 Meso scale: Site function, social engagement, and cultural continuity

At the meso scale, sustainability is expressed through the interaction between architecture, community, and cultural meaning. This level involves not only the building itself but also its immediate site, users, and interpretive functions. The adaptive reuse of Vredenburg into the Fort Vredenburg Museum represents a profound social and cultural transformation from a symbol of colonial surveillance to a space of national education and public reflection.

The museum attracts diverse audiences, from students, tourists, scholars, and local residents, serving as a space for both learning and leisure. Its programming includes educational exhibitions, historical reenactments, and art festivals that reinterpret national history from multiple perspectives. Through these activities, Vredenburg contributes to social inclusivity by creating accessible cultural experiences and by fostering shared ownership of the past.

Local vendors and small-scale enterprises/*Usaha Mikro, Kecil, dan Menengah* (UMKM) operate around the fortress, supported by tourism flows. This contributes to local economic sustainability while embedding the museum within Yogyakarta's everyday urban fabric. The adaptive reuse of Vredenburg thus supports not only heritage conservation but also community-based development, in line with the participatory principles of UU No. 11 of 2010 on Cultural Heritage. The fortress attracts thousands of visitors annually, generating demand for accommodation, dining, and crafts in the surrounding Malioboro area. Informal vendors and small enterprises benefit from this visitor flow, integrating the fortress into Yogyakarta's creative economy. The site thus functions not merely as a museum but as an anchor for local livelihoods. By linking conservation with socio-economic activity, Vredenburg contributes to the sustainable development of its urban district. Importantly, this scale also involves institutional collaboration. The museum's management engages with local government, universities, and cultural organizations for exhibitions and conservation projects. Such partnerships exemplify a participatory governance model where heritage management becomes a shared social enterprise rather than a top-down administrative function.

The public accessibility of the fortress is a critical component of this sustainability. Entrance fees are kept affordable, and events are open to schools and local communities. The surrounding open spaces, such as courtyards, lawns, and shaded perimeters have

become social nodes where residents gather, children play, and cultural events occur. These informal uses extend the function of the museum beyond its curatorial purpose, transforming it into a living heritage environment.

Culturally, the fortress operates as a site of memory and reconciliation by transforming colonial power architecture into a space of collective remembrance. The reinterpretation of its function from military fortification to museum emphasizes reclaiming colonial structures as instruments of education and cultural expression. Exhibits that narrate Indonesia's struggle for independence and the city's role in the national revolution situate the building within a broader cultural narrative of transformation and resilience. The preservation of spatial order, such as the symmetrical courtyard, bastions, and gateways, allows visitors to experience continuity between historical form and contemporary use. This spatial authenticity, combined with interpretive content, creates what Smith (2006) calls a "performative heritage space," where meaning is constantly renegotiated through public interaction.

From an environmental perspective, meso-scale interventions focus on the landscape and ecological functions of the fortress precinct. The retention of the surrounding moat and introduction of vegetation enhance the site's environmental quality and mitigate urban heat. Courtyards act as natural ventilation corridors, contributing to urban cooling and improving microclimatic comfort for visitors. These design elements illustrate how cultural landscapes can support urban ecological resilience. As an educational institution, Vredeburg contributes to the production and dissemination of historical knowledge. It supports research in history, architecture, and conservation, functioning as a knowledge hub that bridges academic, governmental, and community interests. The museum's archives and exhibitions demonstrate the scientific significance of heritage reuse—not only as a conservation act but as a mechanism for interdisciplinary learning and cultural resilience.

At the meso scale, Vredeburg exemplifies cultural sustainability, in which heritage is continuously reinterpreted and reintegrated into present-day social life. This transformation from a symbol of control to a platform of dialogue underscores the potential of adaptive reuse to foster reconciliation and intercultural understanding.

3.4 Macro scale: Urban integration and heritage governance

At the macro scale, the sustainability of Vredeburg Fortress extends beyond the site, encompassing the urban, regional, and policy contexts that support its adaptive reuse. The fortress's location along Yogyakarta's Philosophical Axis situates it within a broader spatial narrative that connects Mount Merapi, the Kraton (palace), and the Southern Sea. This alignment symbolizes the Javanese cosmological relationship between human life and the universe, a relationship now formally recognized through the UNESCO World Heritage designation of the Philosophical Axis in 2023. Within this framework, Vredeburg serves as both a physical and ideological anchor in the city's heritage landscape.

The fortress's management under the Museum Benteng Vredeburg Nasional falls within Indonesia's national framework for cultural heritage preservation. Policies emphasize adaptive reuse as a sustainable alternative to demolition, promoting reuse of colonial buildings for educational, cultural, and economic functions. The museum's success in maintaining public relevance illustrates the potential of heritage governance that integrates cultural policy, tourism strategy, and local economy. Vredeburg contributes to Yogyakarta's creative economy through cultural events, exhibitions, and collaborations with artists and universities. These initiatives align with UNESCO's 2030 Agenda for Sustainable Development, particularly Target 11.4, which focuses on protecting cultural heritage as a resource for inclusive growth. The fortress thus operates as a cultural catalyst, linking heritage conservation to urban innovation and social equity.

From an environmental perspective, the macro scale emphasizes heritage-based urban sustainability. Vredeburg is integrated into Yogyakarta's green heritage zones, which aim to preserve open spaces, control development intensity, and maintain ecological continuity. This approach aligns with the concept of heritage urbanism, which integrates conservation

into broader spatial planning. The fortress contributes to citywide environmental goals by functioning as a green lung in the dense urban fabric and supporting climate-responsive urban form.

Vredeburg contributes to inclusive heritage governance on a social level. Indonesia's Law No. 11 of 2010 on Cultural Heritage and the Yogyakarta City Regulation No. 1 of 2020 mandate collaborative management between national institutions, regional authorities, and local communities. Community participation in festivals, exhibitions, and advocacy programs reflects the democratization of heritage, where social capital becomes a form of sustainability.

In terms of the cultural aspect, the fortress's role in the Philosophical Axis reinforces Yogyakarta's identity as a heritage city. The fortress embodies the continuity between colonial and postcolonial histories, becoming a mediator between memory and modernization. Through state-supported programs and educational initiatives, Vredeburg contributes to the transmission of cultural values across generations. It also serves as a diplomatic and symbolic site, hosting international exhibitions and heritage dialogues that position Yogyakarta within global networks of cultural exchange.

On Economic aspect, the macro scale positions Vredeburg within the heritage tourism economy. The fortress is a major node in Yogyakarta's cultural corridor, attracting domestic and international visitors. This contributes to the local GDP and employment sectors through tourism-related industries, creative production, and infrastructure investment. As part of a UNESCO World Heritage site, the fortress benefits from international attention and funding, further strengthening its financial sustainability. However, this success also brings challenges, especially the risk of over-tourism, which can strain infrastructure and erode authenticity if not carefully managed.

To mitigate these risks, heritage governance frameworks emphasize balanced development, where cultural tourism is accompanied by conservation standards and capacity management. The integration of Vredeburg into citywide mobility and tourism planning illustrates how adaptive reuse can support sustainable urban economies without compromising heritage values.

At this scale, sustainability involves aligning the fortress's adaptive reuse with policy coherence and economic resilience. The fortress operates within a network of public and private partnerships that ensure maintenance funding, programming diversity, and urban integration. Its adaptive reuse thus transcends architecture, becoming a model of how heritage assets can anchor sustainable urban transformation.

3.5 Multi-scalar sustainable adaptive reuse of colonial heritage architecture

The adaptive reuse of Vredeburg Fortress reveals that sustainability in heritage architecture operates as a multi-scalar system that integrates environmental performance, cultural continuity, social inclusivity, and governance coherence. Rather than existing as separate dimensions, these aspects interact dynamically across spatial and institutional scales, producing a holistic framework of heritage resilience. This study proposes a multi-scalar model of sustainable heritage, where adaptive reuse is understood as an interconnected process extending from the material level of conservation to the landscape level of cultural policy.

At the micro scale, the analysis underscores the critical role of material authenticity and environmental responsiveness in sustaining heritage. The conservation of original materials embodies what Lucchi (2022) describes as embedded sustainability: the inherent efficiency and adaptability of traditional building systems. These materials not only retain embodied energy but also preserve historical craftsmanship and local knowledge. The fortress's passive ventilation, thermal massing, and natural lighting illustrate that colonial-era architecture in the tropics had already achieved a balance between cultural expression and climatic adaptation long before modern environmental design frameworks emerged. Thus, micro-scale sustainability demonstrates that material conservation is not a nostalgic act but a rational strategy that bridges historical intelligence and ecological performance.

Moving to the meso scale, sustainability manifests through the activation of social, educational, and cultural functions that give new meaning to the heritage site. The adaptive reuse of Vredenburg into a national museum exemplifies how colonial structures can be reinterpreted within a postcolonial narrative of inclusivity and dialogue. This aligns with Smith's (2006) concept of performative heritage, where meaning is continually recreated through public engagement. The museum fosters community participation, educational programs, and cultural events that transform the fortress from a symbol of domination into a participatory civic space. The site's social vitality ensures that heritage is not frozen in time but remains embedded in the cultural life of the city. This level of sustainability is fundamentally socio-cultural, linking tangible conservation with intangible processes of identity formation and collective memory.

At the macro scale, the adaptive reuse of Vredenburg is situated within broader urban and policy frameworks that define heritage as a driver of sustainable development. Its inclusion within Yogyakarta's Philosophical Axis illustrates how individual buildings contribute to the collective identity and cosmological order of the city. This integration reflects what Rodwell (2015) terms heritage urbanism, where conservation is embedded in urban planning, governance, and economic policy. The fortress not only preserves material authenticity but also supports the creative economy through tourism, education, and cultural industries. Policy coherence among local, national, and international institutions, ranging from Law No. 11 of 2010 on Cultural Heritage to ICOMOS charters, ensures the site's long-term viability. (ICOMOS, 1964; ICOMOS, 1994) The Vredenburg case thus demonstrates that macro-scale sustainability depends on multi-level governance, consistent policy alignment, and community-driven management.

These three scales should not be understood as hierarchical layers but as interdependent systems. The success of adaptive reuse depends on the feedback between these scales: material conservation at the micro level, enhances social relevance at the meso level, while supportive governance at the macro level ensures the continuity of both. This interconnection aligns with the concept of polycentric sustainability, where multiple agents such as, architects, communities, institutions, and policymakers collectively sustain heritage as a shared resource.

From a theoretical perspective, this study extends the discourse of sustainable heritage by reframing adaptive reuse as a multi-scalar practice of transformation rather than mere preservation. The findings support the argument by (Conejos et al., 2016; Elrod & Fortenberry, 2017; Mohamed et al., 2017; Foster, 2020) that heritage sustainability requires systemic thinking that bridges environmental, cultural, and economic domains. By analyzing Vredenburg Fortress through a molecular-to-landscape lens, the research reveals that sustainability emerges not from isolated interventions but from the continuous chain of actions that connect the conservation of matter with the regeneration of meaning.

Moreover, this case highlights how colonial heritage can be reinterpreted as a site of reconciliation and innovation. By transforming symbols of domination into inclusive public institutions, adaptive reuse enables societies to confront historical complexities while envisioning sustainable futures. The summary of findings is described in Table 3 below.

The multi-scalar model proposed here consists of three interlinked dimensions; 1) Molecular sustainability (micro), maintaining material and environmental integrity through conservation and passive design, 2) spatial and social sustainability (meso), reprogramming spaces to accommodate new social and cultural functions while retaining historical form, 3) institutional sustainability (macro), embedding adaptive reuse within governance systems, urban policy, and cultural economies that ensure long-term management.

These factors collectively form a framework in which adaptive reuse operates as a process of cultural metabolism. Within this framework, buildings are not treated as static objects, but as dynamic entities shaped through continuous negotiation between preservation and transformation. This ongoing process reflects the need to balance historical value with contemporary functional demands. In this sense, the concept aligns with Plevoets & Cleempoel's (2019) argument that adaptive reuse constitutes an evolving

dialogue between past and present, allowing architecture to remain both historically grounded and socially relevant.

Table 3. The summary of the findings

Aspects	Scale		
	Micro	Meso	Macro
Environment	Preservation of materials, passive design, energy efficiency	Courtyard and vegetation support microclimate comfort and biodiversity	Heritage-based urban ecology, sustainable tourism mobility
Social	Accessible interior design and adaptive circulation for contemporary users.	Public engagement via museum education programs and heritage events	Community participation in cultural festivals and conservation governance; heritage supports the local economy and creative industry.
Cultural	Preservation of colonial-era structure and material (masonry walls, bastions, gates). Restoration prioritizes authenticity and structural integrity.	Reinterpretation of space through exhibitions, community art, and local cultural storytelling.	National symbol of memory and resistance; cultural policy emphasizes heritage-based education and identity building
Economic	Efficient resource use and cost-effective preservation	The fortress functions as a cultural and educational facility that stimulates local economic activity	Vredeburg plays a strategic role in regional economic development and heritage-based urban revitalization

These factors collectively form a framework in which adaptive reuse operates as a process of cultural metabolism. Within this framework, buildings are not treated as static objects, but as dynamic entities shaped through continuous negotiation between preservation and transformation. This ongoing process reflects the need to balance historical value with contemporary functional demands. In this sense, the concept aligns with Plevoets & Cleempoel's (2019) argument that adaptive reuse constitutes an evolving dialogue between past and present, allowing architecture to remain both historically grounded and socially relevant.

Moreover, this study demonstrates that colonial heritage, often burdened with ambivalent meanings, possesses untapped potential as a catalyst for sustainable development. By transforming Vredeburg from a colonial outpost into a space of education and cultural exchange, the project redefines heritage as a medium of reconciliation. It exemplifies how postcolonial cities can reinterpret inherited architectures of power as instruments for inclusive urban futures.

In practice, the multi-scalar framework provides a tool for evaluating and guiding adaptive reuse projects beyond the architectural scale. It encourages policymakers, conservationists, and designers to assess how each decision, whether related to material restoration, spatial programming, or institutional management, contributes to the broader sustainability ecosystem. For instance, the conservation of Vredeburg's moat supports micro-level environmental balance, while its integration into the UNESCO-recognized urban axis reinforces macro-level governance coherence.

Ultimately, this discussion affirms that adaptive reuse operates as a holistic sustainability mechanism. The success of Vredeburg lies not only in architectural

conservation but in the ability to sustain environmental integrity, social inclusion, cultural vitality, and economic continuity across interconnected scales. In the final analysis, the adaptive reuse of Vredenburg Fortress illustrates how colonial heritage can be transformed into a living system of sustainability, where architecture, culture, and governance coalesce to produce resilient and inclusive urban futures.

4. Conclusions

The study of Vredenburg Fortress in Yogyakarta reveals that sustainable adaptive reuse of colonial heritage must be understood as an integrated process that connects material conservation, social function, and cultural governance. The transformation of the fortress from a colonial military outpost into a national museum demonstrates how adaptive reuse can preserve tangible heritage while revitalizing its intangible meanings. The preservation of the original masonry, spatial configuration, and passive climatic design supports environmental sustainability by conserving embodied energy and reducing construction waste. At the same time, the fortress has evolved into a dynamic cultural and educational space that fosters public engagement and strengthens collective memory, contributing to social and cultural sustainability.

The adaptive reuse of Vredenburg Fortress demonstrates that colonial heritage can be sustained and reinterpreted through a multi-scalar framework that integrates environmental, social, cultural, and economic dimensions. At the micro scale, the fortress's material authenticity and passive environmental design illustrate how traditional construction methods can achieve ecological efficiency and longevity without high-energy interventions. At the meso scale, the fortress's transformation into a museum of national struggle activates social and cultural sustainability, enabling inclusive participation, educational functions, and reinterpretation of colonial narratives. At the macro scale, its integration into Yogyakarta's Philosophical Axis and heritage-based urban policies situates Vredenburg within a broader model of sustainable governance and creative economic growth.

The findings suggest that sustainability in heritage architecture is not a singular technical condition but a relational system operating across spatial, cultural, and institutional scales. Vredenburg Fortress embodies the notion of living heritage, where conservation and reuse are continuous processes of adaptation rather than endpoints. This study contributes to the theoretical discourse on sustainable heritage by proposing a multi-scalar framework that connects the molecular level of material performance with the landscape level of cultural policy and urban identity. Ultimately, the adaptive reuse of Vredenburg provides a model for how colonial heritage in postcolonial cities can be sustained and reinterpreted, not as static relics of the past but as evolving agents of sustainable, inclusive, and culturally grounded futures.

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Author Contribution

The author solely contributed to the conception, design, data collection, analysis, and writing of this manuscript. All parts of the research and publication process were independently completed by the author.

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This research was conducted independently by the author and did not involve human participants, animals, or sensitive personal data. Therefore, formal ethical approval was not required. All data used in this study were obtained from publicly available secondary sources, archival documents, and scholarly publications. The author confirms that the study was carried out in accordance with recognised ethical principles and standards of academic research integrity.

Informed Consent Statement

Not available.

Data Availability Statement

Data sharing is not applicable to this article as no new datasets were created or analysed during the study. All information and materials used are derived from publicly available sources and literature.

Conflicts of Interest

The author declare no conflict of interest

Declaration of Generative AI Use

The author used AI-based language tools, including Quillbot and Grammarly, solely to assist with correcting grammar, improving clarity, and refining the manuscript's readability. The research design, analysis, interpretation, and all intellectual content are entirely the author's original work.

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