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Editorial Introduction

We express our sincere gratitude to God Almighty for His blessings, which have enabled the publication of Jurnal Permukiman, Volume 21 Number 1, May 2026. This edition presents a collection of scholarly articles addressing contemporary and critical issues in housing and sustainable human settlements, including the transformation of public rental housing under neoliberal urbanism, the influence of livable housing on community quality of life, spatial disparities in housing backlog and socioeconomic inequality, the reliability of materials and structural systems in precast modular housing technology, as well as the potential utilization of greywater through a circular economy approach in urban areas.

The first article, "A Review of Public Rental Housing Under Neoliberal Urbanism: From Welfare to Precarity" by Santi Vidyandani and Joko Adianto, critically examines the transformation of public rental housing within the context of neoliberal urban governance. The study highlights how the shift toward market-oriented approaches has contributed to increasing housing precarity, characterized by tenure insecurity, economic vulnerability, and social exclusion.

The second article, "Effects of Livable Housing on Community Quality of Life: A Macro-Micro Study" by Widy R. Atmojokusumo and Christina Ruth Elisabeth, investigates the relationship between livable housing indicators and quality of life. The findings demonstrate that adequate housing significantly influences human development outcomes at both macro and micro levels, reinforcing the importance of strengthening housing policies and programs.

The third article, "Spatial Clustering of Housing Backlog and Socioeconomic Inequality: Evidence from the Special Region of Yogyakarta" by Fahril Fanani, A. Yunastiawan Eka Pramana, and Ayu Candra Kurniati, explores the spatial dimensions of housing backlog and its correlation with socioeconomic disparities. The study reveals that housing deficits are structurally concentrated in specific areas, underscoring the need for spatially targeted and evidence-based policy interventions.

Furthermore, "Study on the Reliability of Materials and Structures of Simple Pre-cast Modular Houses (Case Study: RUCAST Technology)" by Muhammad Aprilia Devino, Muhammad Rusli, and Ferri Eka Putra evaluates the performance of RUCAST precast modular housing technology. The research highlights its structural reliability, cost efficiency, and adaptability to seismic conditions, demonstrating its potential as an affordable and resilient housing solution.

As a closing article, "The Potential of Greywater Utilization Through Circular Economy Approach in Urban Areas" by Ario Wisnu Wicaksono examines the optimization of greywater reuse within a circular economy framework. The study emphasizes its role in enhancing water conservation, reducing environmental impacts, and supporting sustainable urban infrastructure through integrated technological and policy approaches.

The Editorial Board hopes that this issue will contribute to the advancement of knowledge and professional practice in the fields of housing and human settlements, building construction, and environmental health. Furthermore, we expect this publication to serve as a valuable reference for academics, researchers, practitioners, and policymakers in promoting sustainable, inclusive, and resilient built environments.

We trust that readers will find the articles in this issue informative, relevant, and enriching.

Editorial Board
Bandung, May 2026

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A Review on Public Rental Housing Under Neoliberal Urbanism: From Welfare to Precarity

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Abstract

This paper investigates the transformative role of Public Rental Housing (PRH) in addressing housing precarity, drawing on a systematic review of scholarly literature. It critically analyzes how neoliberal governance and housing commodification have eroded the foundational promise of PRH to deliver secure, affordable, and socially inclusive homes. The study delineates the multidimensional nature of housing precarity encompassing tenure insecurity, economic vulnerability, and social exclusion while simultaneously underscoring the emancipatory potential of PRH when structured through equitable and participatory frameworks. Comparative insights from Europe, Asia, and the Global South reveal the pitfalls of residualized housing regimes and the enduring promise of rights-based, de-commodified alternatives. These findings carry significant implications for emerging contexts such as Indonesia, where state-led housing provision must grapple with market logics and democratic deficits. The paper calls for a reconfiguration of PRH as a universal, tenure-secure institution anchored in long-term leases, democratic governance, and robust legal protections. Ultimately, the study contends that reimagining PRH not as a residual safety net but as a fundamental pillar of social citizenship is imperative to resist deepening precarity in contemporary urban housing landscapes.

Keywords: Public Rental Housing, housing Precarity, decommodification, neoliberalism, tenure insecurity.

Abstrak

Artikel ini mengeksplorasi peran transformatif Hunian Sewa Publik (Public Rental Housing/PRH) dalam mengatasi ketidakamanan tempat tinggal, berdasarkan tinjauan sistematis terhadap literatur akademik. Kajian ini secara kritis menganalisis bagaimana tata kelola neoliberal dan komodifikasi perumahan telah mengikis tujuan utama PRH untuk menyediakan hunian yang aman, terjangkau, dan inklusif secara sosial. Penelitian ini menjabarkan sifat multidimensional dari ketidakamanan perumahan meliputi ketidakpastian status kepemilikan, kerentanan ekonomi, dan eksklusi sosial serta menyoroti potensi emansipatoris dari PRH apabila dirancang melalui kerangka kerja yang adil dan partisipatif. Wawasan perbandingan dari Eropa, Asia, dan Global Selatan mengungkap kelemahan residualisasi perumahan publik serta menjanjikan alternatif pendekatan berbasis hak dan bebas dari komodifikasi. Temuan ini membawa implikasi penting bagi konteks negara berkembang seperti Indonesia, di mana penyediaan perumahan oleh negara harus bergulat dengan logika pasar dan defisit demokratis. Makalah ini menyerukan rekonfigurasi PRH sebagai institusi universal dengan jaminan kepemilikan, berlandaskan sewa jangka panjang, tata kelola demokratis, dan perlindungan hukum yang kuat. Pada akhirnya, studi ini menekankan bahwa kita perlu melihat PRH bukan sekedar sebagai jaring pengaman residual, melainkan sebagai dasar penting terwujudnya keadilan sosial bagi warga negara, untuk melawan berkembangnya ketidakamanan dalam lanskap perumahan perkotaan masa kini.

Kata Kunci: *Perumahan Sewa Publik, Ketidakpastian Perumahan, Dekomodifikasi, Neoliberalisme, Ketidakamanan Kepemilikan.*

INTRODUCTION

Public housing, long conceived as a social safety net for low-income groups, is now increasingly restructured under the influence of neoliberal reforms, market-oriented logics, and financialization processes. It faces persistent challenges, including chronic under-supply, deteriorating infrastructure, and systemic mismanagement (Faulkner et al., 2021; Teo et al., 2024). Although originally intended to offer stability, affordability, and dignity, emerging dignity, emerging research suggests that public rental housing (PRH) has become a site of housing precarity characterized by tenure insecurity, temporal instability, constrained access, and the systemic marginalization of tenant needs and participation. Housing precarity denotes the condition of instability and vulnerability within housing arrangements, impacting both individual households and broader urban territories (Debrunner et al., 2024; Litvintsev, 2025).

Theoretical discussions highlight how neoliberal restructuring transforms housing from a fundamental right into a tradable commodity, speculative asset, and accumulation strategy (Berry, 2023; Blackwell & Bengtsson, 2023), thereby eroding the stabilizing role of public housing. Initially conceived within the welfare state paradigm, public housing was a state intervention to ensure dignified shelter for vulnerable populations. Comparative welfare studies demonstrate the inconsistent relationships between welfare regimes and housing systems, necessitating ongoing recalibration (Stephens, 2016). In England, Fitzpatrick and Watts (2017) demonstrate how PRH has been reshaped by conditionality and temporal insecurity. In Sweden, Grander and Kozlovic (2025) critique the "New Public Housing" model for masking selective access beneath universalist rhetoric similar to Sweden's universal public housing (allmännyttan) (Grander, 2017). Even Vienna's celebrated housing model is increasingly permeated by market imperatives (Kumnig & Litschauer, 2025).

While these neoliberal transformations are well-documented in Europe, similar logics have also reshaped housing systems in Southeast Asia, though with distinct historical trajectories and institutional configurations. As in Indonesia, housing has long been defined broadly to include both rental and owner-occupied subsidised housing (Vitriana et al., 2025; Jibril & Maretta, 2019). Provision has long been dominated by single-family ownership, while rental housing receives minimal state funding. Jakarta's government-owned rental apartments (GORAs) demonstrate this tension: despite improved physical features, residents face mounting arrears, declining incomes, loss of home-based enterprises, and alienation from rigid tenancy rules (Adianto & Gabe, 2022; Adianto et al., 2023). Legal protection is limited, with evictions often occurring informally (Vols & Kusumawati, 2020). In Malaysia, weak enforcement of low-cost housing quotas enables developers to evade obligations through fee substitution or project-splitting, deepening the shortage of affordable units (Ebekozien et al., 2021). By contrast, Singapore demonstrates the opposite trajectory: a state-led housing model where over 80% of the population lives in the government's Housing and Development Board (HDB) flats and homeownership rates exceed 90% (Chuang, 2022; Ebekozien et al., 2020). Yet even here, public housing has been a tool of state control, with resettlement historically accompanied by deep social disruption (Chuang, 2022; Ebekozien et al., 2020).

Housing precarity is multidimensional affecting affordability, tenure security, housing quality, neighborhood ties, and psychosocial wellbeing (Debrunner et al., 2024; Grimes et al., 2024; Sørvoll, 2023). Precarity materializes not only in substandard dwellings and overcrowding but also through legal ambiguity, protracted waiting periods, and psychological stress under shifting regulatory environments (Chien et al., 2025; Fiitzpatrick & Watts, 2017; Grimes et al., 2024; Morris et al., 2025; Sørvoll, 2023; Teo et al., 2024; Vols & Kusumawati, 2020). Its causes are rooted in economic instability, precarious labor markets, migratory flux, and the financialization of housing (Adianto et al., 2023; Kumnig & Litschauer, 2025; Morris et al., 2025; Preece et al., 2020; Teo et al., 2024). Precarity reflects deeper socio-economic stratification, undermining social mobility and communal solidarity.

The right to housing, affirmed in Article 25 of the Universal Declaration of Human Rights, has been extended in contemporary debates into broader demands for spatial justice and urban citizenship. Scholars such as Vols & Kusumawati (2020), Swannie (2023), and Preston & Reina (2021) emphasize rights-based housing approaches, yet in practice, legal protections for PRH tenants remain weak. Leviten-Reid et al. (2025) further highlight how framing housing as a human right demands policy tools beyond market subsidies, underscoring the inadequacy of current neoliberal frameworks.

Recent academic literature critically reveals how neoliberal housing policies have restructured the public housing sector, often worsening problems of affordability, accessibility, and socio-spatial inequality. These shifts have transformed PRH from a source of stability into a conditional and temporary form of welfare, intensifying precarity

among vulnerable groups (Fitzpatrick & Watts, 2017; Grander, 2017). Despite growing attention to housing precarity and PRH, most literature focuses on mature welfare states in the Global North. Systematic evidence from the Global South remains limited, especially in emerging contexts like Indonesia, where commodification unfolds rapidly amid regulatory gaps, informality, and uneven state capacity. Moreover, while tenure insecurity and affordability are well-documented, few studies interrogate the nexus between temporality, waiting, and structural exclusion in PRH systems, particularly as they relate to ontological (in)security (Morris et al., 2025; Chien et al., 2025).

This systematic literature review (SLR) aims to trace evolving scholarly trajectories on public rental housing (PRH) and housing precarity, identifying dominant themes, conceptual frameworks, and main findings. It highlights recurring manifestations of tenure insecurity, social exclusion, and the commodification of housing within PRH regimes across diverse contexts. Moreover, it interrogates the extent to which PRH systems under commodified housing regimes can effectively address precarity, focusing in particular on the limitations posed by short lease terms and insecure tenancy arrangements. The novelty of this review lies in mapping the multidimensionality of precarity in PRH and situating Southeast Asian perspectives within a field dominated by Global North research. This study situates Indonesia's PRH within neoliberal urbanism (Adianto & Gabe, 2022; Adianto et al., 2023; Vitriana et al., 2025; Jibril & Maretta, 2019; Vols & Kusumawati, 2020), thereby offering grounded insights for reimagining PRH as a tenure-secure and rights-based institution in the Global South.

These issues are unpacked through critical guiding questions: How is precarity conceptualized within housing discourse? What structural and policy-related obstacles confront public housing systems? In what ways do these systems reinforce or mitigate precarity? Ultimately, the study aspires to offer empirically grounded recommendations that caninform more just, inclusive, and durable public housing models in the Global South, especially in urban contexts such as Indonesia.

METHOD

This study employs a systematic literature review (SLR) methodology, designed to rigorously identify, evaluate, and synthesize research on public rental housing (PRH) and housing precarity. The SLR approach enables a structured, evidence-based aggregation of insights, reducing selection bias while strengthening the analytical robustness of findings. To ensure methodological transparency and replicability, the review adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework as articulated by Page et al. (2021) and adopted in related housing studies (Teo et al., 2024). The PRISMA protocol guided the systematic identification, screening, and analysis of relevant literature. The review was conducted through three interrelated stages. The initial phase defined the research objectives and identified appropriate academic databases and search strings. The second phase applied inclusion and exclusion criteria, involving the screening of titles and abstracts and the subsequent full-text assessment. The final phase focused on extracting key data, conducting thematic analysis, and synthesizing results.

The data identification and collection process utilized targeted searches within the Scopus and Taylor & Francis databases. A comprehensive and purposive strategy was employed to locate studies directly engaging with the intersections of public rental housing and housing precarity. The literature search was configured to capture works that included pre-specified keywords within their titles, abstracts, or keywords. Boolean operators "OR" and "AND" were strategically deployed to construct a refined search string that filtered the most pertinent academic sources.

Table 1 outlines the logic behind the search string formulation, while Figure 1 presents the PRISMA flow diagram detailing each stage of the search, screening, and selection process.

To ensure the review's comprehensiveness and analytical precision, clearly defined inclusion and exclusion criteria were established. Inclusion criteria prioritized peer-reviewed journal articles and conference proceedings published between 2015 and 2025, capturing contemporary debates and evolving policy trajectories in public rental and social housing. Only publications in English were selected to ensure analytical coherence and linguistic consistency. Eligible studies were required to explicitly examine public rental or social housing and engage with at least one domain of housing precarity.

Table 1 Search String Logic

Databases	Key Word Search
Scopus	"public housing" AND ("insecure tenure" OR "precarity" OR "temporality")
Taylor & Francis	"public housing" AND ("precarity" OR "temporality" OR "precarious" OR "insecurity")
Remote-lib.ui	"public housing" AND ("precarity" OR "insecurity") AND "Indonesia" AND ("Southeast Asia" OR "Malaysia" OR "Singapore")
Google Scholar	"public housing" AND ("precarity" OR "temporality" OR "insecurity")

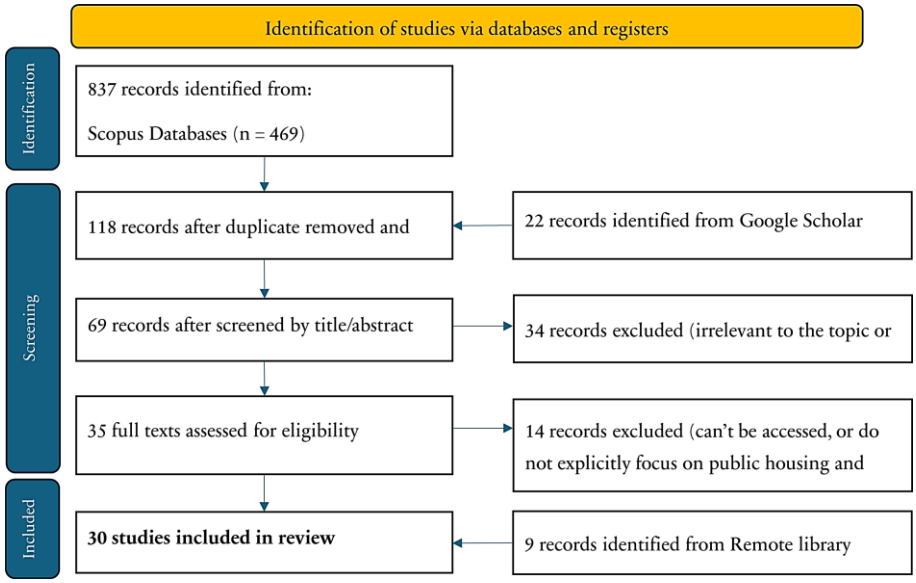

Figure 1 PRISMA Diagram of Literature Search

Table 2 Example of Article Analysis

Journal/ Year	Authors	Article Title	Location	Key Themes	Key Findings
Housing Studies 2017	Suzanne Fitzpatrick & Beth Watts	Competing visions: security of tenure and the welfarisation of English social housing	Inggris	Tenure Insecurity	FTT decisions encompass ideological and ethical considerations some still viewing social housing as "a safe home for life
International Journal of Housing Policy 2025	Sarah Kumnig & Katharina Litschauer	Decommodified housing under pressure: contested policy instruments and provisioning practices in Vienna	Vienna, Austria	housing decommodification, housing policy, and market outcomes	Housing conditions are influenced by commodity form and provisioning practices. Decommodification requires focusing on housing quality and need
Housing, Theory and Society	Jing Zhou & Richard Ronald	Housing and Welfare Regimes: Examining the Changing Role of Public Housing in China	Beijing dan Chongqing, Tiongkok	public housing, welfare regimes, decommodification, stratification, state-market-family relations	The study compares housing systems through welfare state criteria decommodification, stratification, and state-market-family relations.

In contrast, non-peer-reviewed sources such as news media, opinion pieces, and blog posts were excluded to uphold academic rigor. Studies centered solely on private rental markets were also excluded, as the review concentrated on public housing frameworks. Additionally, articles lacking theoretical or empirical contributions to debates on public rental housing (PRH) and housing precarity were omitted to preserve analytical robustness. The initial search yielded 837 records across two major academic databases: 469 from Scopus and 368 from Taylor & Francis. These entries were exported as CSV files and screened systematically using Microsoft Excel. At this preliminary stage, 719 records were excluded due to duplication or thematic irrelevance based on titles and keywords.

In addition to Scopus and Taylor & Francis, supplementary searches were conducted through Google Scholar, and 22 potentially relevant publications were identified. Following the removal of duplicates, the remaining records underwent a relevance screening based on titles and abstracts. Seventy-one articles were excluded at this stage, as they did not directly address the study's thematic concerns regarding public rental housing and housing precarity. This screening phase was vital for refining the dataset to align with the study's objectives. Full-text reviews were conducted on 35 shortlisted studies to evaluate their conceptual engagement with public housing regimes, tenure arrangements, and forms of precarity. Fourteen publications were subsequently excluded for failing

to meet inclusion criteria, primarily due to the absence of empirical or theoretical engagement with the PRH-precarity nexus.

To ensure broader coverage and minimize the risk of publication bias, the database was expanded by incorporating the Remote Library (RemoteLib) Universitas Indonesia portal, which provides access to multiple databases, including JSTOR, ProQuest, Sage Journals, etc. Ultimately, 30 publications were retained for the final analysis. This methodologically rigorous process ensured the inclusion of only high-quality, thematically relevant literature, thereby reinforcing the study's analytical depth and scholarly credibility.

The search was finalized in June 2025, which serves as the cut-off date for included publications. Inter-rater reliability was established by having the first author serve as the primary coder, with the second author acting as an independent reviewer of a random sample of included studies. Discrepancies were discussed and reconciled through consensus.

Data extraction of each article, coded according to (a) study context (country/region), (b) key themes, (c) key findings: how it related to the conceptualization of housing precarity and systemic investigation of public rental housing. Table 2 illustrates the example of the data extraction analysis, which generated key themes and key findings that served as the foundation for formulating the thematic coding. A thematic coding process was applied iteratively: initial open coding identified recurring concepts, which were then grouped into broader categories (e.g., tenure insecurity, legal protection, commodification, temporality). Axial coding was employed to establish connections between categories, enabling the synthesis of seven core thematic clusters presented in the Results section. This multi-stage process ensured that the synthesis was both transparent and replicable, providing a robust foundation for identifying patterns and divergences across the literature on PRH and housing precarity.

RESULTS AND DISCUSSION

Thematic Findings

This systematic literature review critically investigates the capacity of public rental housing (PRH) schemes to mitigate housing precarity amid commodified housing systems. Through thematic analysis of 30 peer-reviewed studies, seven principal clusters of recurring themes were identified. These findings directly address the guiding research questions regarding: (RQ1) the conceptualization of precarity, (RQ2) the structural obstacles and policy interventions shaping housing outcomes, and (RQ3) how PRH systems reinforce or mitigate precarity.

Table 3 illustrates the categorization of key themes according to the three research questions.

Temporal and Structural Precarity

The experience of temporal and structural precarity is powerfully depicted by Morris et al. (2025), who highlight the emotional and material toll of "chronic waiting" for social housing in Australia. Applicants endure extended and indefinite periods on housing waitlists without any guarantee of placement, a situation that fosters psychological stagnation, disempowerment, and a sense of "permanent temporariness." This form of liminality is deeply rooted in broader trends of welfare retrenchment

Table 3 Key Themes Categorization

Research Question	Thematic Cluster	Representative Studies
RQ1. How is precarity conceptualized within housing discourse	Temporal & Structural Precarity	Morris et al. (2025); Debrunner et al.(2024); Litvintsev (2025); Puszka (2022); Vitriana et al. (2025)
	Subjective Experience & Symbolic Security	Chien et al. (2025); Fitzpatrick & Watts, 2017; Grander & Kozlovic (2025); Puszka (2022); Sørvoll (2023)
RQ2. What structural and policy related obstacles confront public housing systems?	Commodification & Market Logic in PRH	Blacwell&Bengtsson (2023); Ebekozien et al.,(2021); Fenton et al. (2013); Kumnig & Litschauer (2025); Lee and Carlisle (2024); Zhou & Ronald (2017)
	Legal Protection, Eviction & Vulnerability	Chien et al. (2025); Jibril & Maretta (2019); Lee & Carlisle (2024); Preston & Reina (2021); Swannie (2023); Vols & Kusumawati (2020)
	Social Inclusion vs. Moralized Access	Chuang (2022); Du et al. (2024); Ebekozien et al.(2020); Grander (2017); Grander and Kozlovic (2025); Puszka (2022)
RQ3. In what ways do PRH systems reinforce or mitigate precarity?	Tenure Insecurity & Lease Limitations	Adianto et al. (2023); Adianto&Gabe (2022); Fitzpatrick & Watts (2017); Grimes et al. (2024); Preece et al. (2020); Sorvol (2023); Swannie (2023); Vols & Kusumawati (2020)
	Welfare Retrenchment & Policy Evolution	Adianto et al. (2023); Beier (2023); Chuang (2022); Ebekozien et al. (2020, 2021); Leviten-Reid et al. (2025); Morris et al. (2025); Vitriana et al. (2025)

and the declining availability of social housing, which together institutionalize housing insecurity. Puszka (2022) further enriches this discourse by demonstrating how housing precarity disrupts the temporal rhythms of care for Yolŋu renal patients in Darwin. In this case, inadequate housing obstructs ongoing care practices that are vital for health and survival, reflecting systemic neglect of interdependent care relationships.

Debrunner et al. (2024) define housing precarity as a multidimensional state of uncertainty involving affordability, tenure security, housing satisfaction, neighborhood quality, and community cohesion. Their survey across European and North American cities shows that renters are more precarious than homeowners, with households with children and minorities experiencing added vulnerabilities. Litvintsev (2025) expands on this in the Russian context with the concept of "double precarity," highlighting the risks of losing both employment and housing. His Regional Housing Precarities Index reveals strong connections between housing insecurity, migration patterns, and housing satisfaction, emphasizing the structural roots of precarity.

Similar forms of prolonged uncertainty are also present in Indonesia, where path dependence in housing policy has produced structural delays and uneven access (Vitriana et al., 2025). Both studies emphasize that housing precarity is not merely a matter of inadequate shelter; rather, it constitutes a chronic condition shaped by institutional timeframes and policy oversights that destabilize daily life and undermine long-term well-being. This cluster responds to RQ1 (How is precarity conceptualized within housing discourse?) by illustrating how temporality and structural delays shape housing as an ongoing condition of insecurity, rather than a one-off event.

Subjective Experience and Symbolic Security

This theme also responds to RQ1, examining how public housing tenants perceive their homes as vital to their identity, stability, and emotional security. Research illustrates that public rental housing significantly influences tenants' ontological a stable self-concept grounded in predictability and symbolic security, which pertains to the psychological and emotional significance of "home" (Fitzpatrick & Watts, 2017; Sørvoll, 2023).

Puszka (2022) analyzes the impact of neoliberal policies in Darwin, Australia, which frame reliance on public assistance as a personal failure, fostering shame and diminishing subjective security. Conditional tenancies based on behavioral compliance turn housing stability into a performance rather than a right. This shift undermines the perception of home as an unconditional refuge. Chien et al. (2025) further expand this discourse by examining the symbolic aspects of home for Baltimore's public housing residents facing relocation. They argue that ontological security relies on spatial continuity and community ties, disrupted by policies like the Choice Neighborhood Initiative, leading to "root shock"a trauma from severed emotional connections. This issue is compounded by systemic neglect, particularly in marginalized communities. Grander and Kozlovic (2025) investigate the Swedish rental market, revealing that norms of the "ideal tenant" impose self-surveillance, eroding tenants' sense of belonging and framing homes as privileges contingent on behavior. Together, these studies show that public rental housing systems shape identity and emotional stability. As conditionality becomes entrenched, tenants increasingly navigate their homes as psychologically unstable spaces, undermining their sense of security.

Commodification and Market Logic in PRH

The commodification of public rental housing (PRH) signifies a pivotal shift in housing governance, transforming it from a social good into a financial asset. This thematic examination highlights how PRH systems are increasingly prioritizing exchange value price and profitability over use value, which addresses essential shelter needs. Kumnig and Litschauer (2025) argue, through a Marxist lens, that even decommodified systems like Vienna's are succumbing to deregulation, rising land costs, and market logic. Limited-profit housing associations (LPHAs) face constraints from cost-coverage principles that fail to counteract market pricing, thereby nudging these systems toward commodification. In China, Zhou and Ronald (2017) describe PRH as revitalized not only for low- and middle-income renters but also as a means to stimulate economic growth, often marginalizing informal workers. Similarly, Lee and Carlisle (2024) note that neoliberal accounting practices in the UK prioritize asset maximization and rent recovery, increasing eviction risks for tenants.

Fenton et al. (2013) emphasize the negative impact of commodification on urban spatial justice, where housing policies lead to the displacement of vulnerable populations and undermine their "rights to the city." Grander (2017) and Grander & Kozlovic (2025) highlight a similar trend in Sweden, where Municipal Housing Companies (MHCs) are compelled to operate under market return expectations, leading to selective tenant screening and reduced low-income housing construction. Blackwell and Bengtsson (2023) contextualize these dynamics as part of a broader decline in the

welfare state's housing role, with social housing increasingly marginalized. In Southeast Asia, commodification also emerges in policy frameworks: Malaysia's weak enforcement of low-cost housing quotas enables developers to substitute obligations, reducing affordable supply (Ebekozien et al., 2021).

This cluster engages with RQ2 (What structural and policy-related obstacles confront public housing systems?), demonstrating how market logics and commodification processes transform PRH from a safeguard for shelter into a vehicle for capital generation, thereby exacerbating affordability crises and undermining its role as a universal safety net.

Legal Protection, Eviction, and Vulnerability

This thematic cluster also addresses RQ2, highlighting the erosion of legal protections for Public Rental Housing (PRH) tenants, particularly marginalized populations at increased risk of eviction. Swannie (2023) highlights that vulnerable groups in Australia, including the elderly, disabled, low-income individuals, and refugees, face elevated eviction risks that may contravene international human rights standards, particularly if they lead to homelessness. While frameworks like the ACT's Residential Tenancies Act (1997) offer progressive protections, jurisdictions such as Victoria impose rigid legal processes that fail to consider tenant vulnerabilities.

In the U.S., Preston and Reina (2021) note that subsidized housing provides greater eviction protections compared to market-rate options, primarily due to good-cause eviction laws. However, protections are inconsistent; properties under the Low-Income Housing Tax Credit (LIHTC) face heightened vulnerability when subsidy restrictions lapse. Lee and Carlisle (2024) discuss the UK's shift toward utilizing public housing as a financial asset, exacerbating tenant vulnerabilities through rising rents and welfare reforms. Their study of a credit union (pseudonym Selond) illustrates how community-based financial institutions can help mitigate eviction risks while balancing member benefits with regulatory constraints. Although Selond's initiatives markedly aid families, their impact remains minimal compared to the broader eviction crisis. Chien et al. (2025) contextualize the vulnerability of public housing residents in Baltimore, arguing that historical racially exclusionary policies contribute to economic disinvestment, substandard living conditions, and entrench health inequities and psychological distress. In Indonesia, limited legal guarantees mean evictions often occur informally, leaving displaced households without recourse. Those relocated to public rental housing face higher living costs and job losses, leading to rent arrears and the threat of eviction (Vols & Kusumawati, 2020; Jibril & Maretta, 2019).

Collectively, these studies reveal that legal protections for tenants are uneven and increasingly compromised by market forces, procedural complexities, and residualization. Despite some programs aimed at mitigating eviction risks, structural vulnerabilities for marginalized groups persist.

Social Inclusion vs. Moralized Access

This cluster expands the understanding of RQ2, analyzes the shift from inclusive public housing access based on social need to moralized access defined by behavioral and economic criteria. Traditionally, public rental housing aimed for universal access, but contemporary literature highlights a transition to meritocratic standards, epitomized by Grander's concept of the "ideal tenant." In Sweden, Grander (2017) notes how the 2011 reform of allmännyttan (municipal housing) introduced stricter access criteria, such as minimum income thresholds, disproportionately affecting "inbetweeners" households with unstable incomes. The expectations for tenant behavior have intensified, with Grander and Kozlovic (2025) arguing that qualities like neighborly conduct now overshadow traditional financial assessments.

Similarly, Puszka (2022) describes how Darwin's housing policies reflect a neoliberal "philosophy of care," framing reliance on social housing as a personal failure and linking support to self-care compliance. In contrast, Du et al. (2024) highlight the benefits of secure public housing in Guangzhou, reinforcing the case for inclusive policies. In Singapore, Chuang (2022) shows how HDB housing functions not only as shelter but as a tool for shaping disciplined, self-reliant citizens. In Malaysia, Ebekozien et al. (2020) note how inconsistent enforcement of low-cost housing policy erodes inclusivity, privileging market-driven outcomes.

In summary, this thematic cluster shows how moralized access criteria based on financial fitness and behavior erode the foundations of inclusive public housing, favoring individualized deservingness and further marginalizing those in precarious socioeconomic situations.

Tenure Insecurity and Lease Limitations

This theme examines how PRH systems either worsen or alleviate precarity (RQ3), focusing on instability from insecure housing, often due to short-term leases or the absence of long-term tenancy guarantees. Fitzpatrick and Watts (2017) argue that policy reforms in England have shifted the role of public housing from a long-term social entitlement to a short-term welfare solution, making fixed-term tenancies the norm, with

renewals reliant on factors such as income level, employment status, household composition, and tenant behavior. This legal and procedural structure undermines ontological security by introducing persistent uncertainty and risk of displacement. Sørvoll (2023) identifies a similar trend in Oslo, where social housing is selectively targeted and means-tested, leaving tenants facing unclear eligibility assessments and arbitrary decisions about tenancy renewal. These practices foster "residential alienation," increasing insecurity, especially as improvements in health or income can lead to eviction. Preece et al. (2020) further highlight how reforms in England enforce strict affordability assessments under the Affordable Rent scheme, effectively pricing out the most vulnerable populations and using non-renewal threats for compliance. These reforms frame affordability as an individual responsibility, thereby masking structural inequalities.

Grimes et al. (2024) provide a counterpoint from New Zealand, where public housing offers greater tenure security, with tenants reporting higher levels of subjective well-being than owner-occupiers, underscoring the psychological and social benefits of secure housing. Notably, the study cautions against policies that reduce tenure security even for tenants labeled as "anti-social," emphasizifigurng the essential protective role PRH can play.

Evidence from Indonesia shows similar pressures: Jakarta's government-owned rental apartments (GORAs) often impose rigid tenancy rules, leading to arrears and alienation (Adianto et al., 2023; Adianto & Gabe, 2022; Vols and Kusumawati, 2020). Collectively, these studies critically examine how PRH systems can either mitigate or amplify housing precarity depending on the surrounding legal and policy context.

Welfare Retrenchment and Policy Evolution

This thematic cluster also addresses RQ3, examines structural shifts in public housing policy influenced by neoliberal reforms and fiscal austerity. The studies illustrate how welfare retrenchment marked by a reduced state role and increased market reliance has transformed public rental housing (PRH) from a foundational welfare state element into a temporary safety net rather than a guaranteed social right.

Morris et al. (2025) analyze the Australian context, revealing that budget cuts for social housing have resulted in extended waiting periods for eligible applicants, who must now demonstrate significant disadvantage. This shift to conditional access reflects a departure from universalism, as housing assistance becomes targeted and rationed, leaving numerous vulnerable households in prolonged uncertainty. The emotional and existential repercussions are substantial, with serious implications for low-income individuals and families facing stalled housing pathways. Leviten-Reid et al. (2025) critique the transition from supply-side to demand-side housing support, exemplified by the Canada Housing Benefit (CHB).

Although positioned as a policy innovation, the CHB illustrates the neoliberal paradigm wherein the state withdraws from direct housing provision, offering subsidies for private market use instead. Resulted in many recipients living in worse conditions than before due to inadequate regulations and insufficient housing supply. Beier (2023) explores the phenomenon of "missing people" those excluded from housing programs which underscores how enhanced tenure insecurity and rigid program designs push vulnerable populations back into informal settlements.

Recent studies from Southeast Asia reveal similar challenges. In Indonesia, Adianto et al. (2023) find that reforms prioritize building units over tenant welfare, further marginalizing vulnerable communities. Vitriana et al. (2025) trace the historical neglect of PRH, suggesting that this leads to ongoing exclusion. In Malaysia, Ebekozien et al. (2020, 2021) find that weak regulations and inconsistent policies create gaps in affordable housing. In Singapore, Chuang (2022) highlights how the HDB program, while extensive, has been shaped by state control and disciplinary logics rather than universal rights. Together, these studies illuminate the ideological transformation of PRH policy under welfare retrenchment, shifting from a collective good to a conditional commodity, diminishing the protective role of PRH, and leaving the most disadvantaged without adequate protection or recourse.

Discussion of Findings

The selected literature offers not only a critique of housing policy shifts but also reflects tenants' lived experiences of exclusion, instability, and resilience. The following discussion synthesizes insights from the thematic analysis and is structured around seven critical domains that capture how housing precarity manifests and evolves within public rental housing (PRH) systems.

Public Rental Housing under Commodified Regimes

Historically conceived as a foundational social safety net, PRH has undergone profound transformations that compromise its capacity to ensure stable and secure accommodation for vulnerable populations (Fitzpatrick & Watts, 2017).

Across many high-income nations, PRH has shifted from a universal entitlement to a residualized mechanism targeting only the most disadvantaged. This transition is deeply entwined with neoliberal restructuring, wherein fiscal austerity, managerialism, and market-based instruments supersede commitments to social protection.

Sweden's retreat from the *allmännyttan* model a cornerstone of non-profit, inclusive housing toward market-oriented practices exemplifies this shift (Grander, 2017). Grander & Kozlovic (2025) further observe that municipalities now prioritize profitability and parity with private rents, undermining universal housing provision. Similar recalibrations occur across Western Europe and North America, where public housing authorities adopt corporate mandates emphasizing financial self-sufficiency over social obligations (Blackwell & Bengtsson, 2023). The reconfiguration of PRH as emergency accommodation rather than a pillar of inclusive urbanism is reinforced by the proliferation of demand-side subsidies such as the Canada Housing Benefit further weakening public housing systems by channeling funds to private rentals, eroding permanence and affordability (Leviten-Reid et al., 2025).

Moreover, commodified regimes also use fixed-term tenancies (FTTs) as seen in England (Fitzpatrick & Watts, 2017) and Oslo (Sørvoll, 2023) which reposition PRH as provisional welfare. Periodic reviews of tenants' income, employment, and behavior create ontological insecurity by preventing long-term stability. In Sweden, "social contracts" with short leases impose strict behavioral conditions and limited pathways toward permanent tenancy (Grander, 2017). Simultaneously, the phenomenon of 'renovictions' using renovations to displace tenants and raise rents further exacerbates insecurity. In Sweden and Denmark, such practices circumvent tenant protections under the guise of modernization, displacing low-income residents, revalorizing assets (Blackwell & Bengtsson, 2023).

Housing Precarity: Multidimensional and Intersectional

Housing precarity must not be narrowly construed as mere vulnerability to homelessness or eviction; rather, it constitutes a multidimensional matrix of insecurities. Economic precarity includes unsustainable rent-to-income ratios and income volatility that render even subsidized housing unaffordable (Adianto et al., 2023; Debrunner et al., 2025; Leviten-Reid et al., 2025; Morris et al., 2025; Preece et al., 2020). Legal precarity is exacerbated in contexts where tenancy rights are conditional, limited, or ambiguously defined, leaving tenants in a perpetual state of uncertainty (Kumnig & Litschauer, 2025; Morris et al., 2025; Puszka, 2022; Preston & Reina, 2021; Sørvoll, 2023; Swannie, 2023; Vols & Kusumawati, 2020). Spatial precarity emerges through forced displacement, gentrification, and peripheral housing that isolates residents from jobs, schools, and infrastructure (Adianto et al., 2023; Chien et al., 2025; Ebekozien et al., 2020, 2021; Fenton et al., 2013; Vitriana et al., 2025).

Debrunner et al. (2024) conceptualize precarity across five dimensions: affordability, tenure security, housing satisfaction, neighborhood quality, and community cohesion, showing renters and minorities face consistent disadvantages. Litvintsev (2025) introduces "double precarity," where employment and housing insecurities reinforce each other, limiting mobility and housing satisfaction. Housing precarity is also gendered and racialized. Women especially single mothers face risks shaped by wage disparities, caregiving burdens, and exposure to domestic violence (Morris et al., 2025; Leviten-Reid et al., 2025). Migrant and racialized groups endure systemic exclusion and discrimination that deepen precarity (Chien et al., 2025; Grander & Kozlovic, 2025; Puszka, 2022).

Moreover, the literature foregrounds a symbolic dimension of housing precarity, wherein insecurity is not solely external but internalized. The chronic threat of displacement corrodes individual dignity, inhibits long-term aspirations, and weakens democratic engagement (Du et al., 2024; Fitzpatrick and Watts, 2017; Morris et al., 2025; Sørvoll, 2023). The stigma attached to public housing often framed through moralizing policy discourses that depict residents as deficient or deviant functions as a powerful mechanism of social exclusion. Precarity, therefore, must be understood not only in terms of material deprivation but also as a profound assault on recognition, belonging, and civic legitimacy.

PRH as a Protective Mechanism and Platform for Wellbeing

Amid persistent challenges, research highlights PRH's potential as a foundation for both individual and collective well-being. When adequately funded and grounded in a rights-based approach, PRH can insulate tenants from market volatility, ensure affordability, and facilitate social cohesion (Adianto et al., 2023; Du et al., 2024; Fitzpatrick & Watts, 2025; Kumnig & Liitschauer, 2025; Leviten-Reid et al., 2025; Teo et al., 2024). In New Zealand, tenants in state housing report higher life satisfaction due to secure tenure, stable rents, and integrated support services (Grimes et al., 2024).

Holistic delivery models that embed health, education, and welfare services within housing frameworks have proved especially impactful for structurally marginalized groups, including individuals with disabilities and those with

experiences of chronic homelessness. China presents a salient case of institutional commitment to PRH stability through enforceable leasing and rent regulation. The renewable five-year lease contracts have not only enhanced long-term household planning but also strengthened intergenerational caregiving networks. Furthermore, the spatial integration of PRH within urban masterplans rather than relegating such developments to peripheral areas has mitigated social segregation and normalized inclusive urban living (Du et al., 2024; Zhou & Ronald, 2017).

Innovative models have also emerged in financial empowerment. In London, collaborations between housing authorities and community-based financial institutions such as credit unions and cooperative banks provide emergency lending and budgeting support, reducing eviction risks due to arrears (Lee & Carlisle, 2024). It highlights the role of PRH in counteracting broader vectors of socio-economic exclusion. Conversely, the commodification of PRH through portable housing benefits and market-calibrated vouchers in Canada and the United States has often undermined tenant stability (Grimes et al., 2024; Leviten-Reid et al., 2025). These demand-driven subsidies may inflate rental prices and incentivize landlord discrimination, thereby perpetuating, rather than alleviating, the structural conditions of housing precarity.

Policy Recommendations and Implications for Developing Contexts

While this SLR provides important insights, it is important to acknowledge its limitations. Much of the literature remains concentrated in the Global North, with relatively limited representation from the Global South, including Southeast Asia and Indonesia. In addition, the database coverage, though it has been made to compile a comprehensive database through sources such as Scopus, Taylor & Francis, Google Scholar, and remote library UI access, notable gaps remain, especially in coverage from other pivotal databases like Web of Science or JSTOR. These constraints require caution in generalizing findings but still allow for evidence-based inferences that can guide actionable policy recommendations.

First, evidence across contexts demonstrates the inadequacy of market-driven housing strategies. Reliance on speculative land markets and demand-side subsidies typically fails to produce affordable and secure housing (Leviten-Reid et al., 2025; Grander, 2017). Singapore's Housing and Development Board (HDB) further illustrates the transformative potential of large-scale, centrally planned housing provision, which has successfully reduced slums and expanded access to affordable housing (Chuang, 2022). For Indonesia, this underscores the urgency of strengthening **state-led public rental housing provision**, supported by consistent investment and robust regulatory frameworks that protect against speculative market fluctuations.

Second, security of tenure emerges as a decisive factor in shaping well-being. Short-term or conditional lease agreements cultivate uncertainty, while longer-term contracts such as New Zealand's state housing or China's five-year renewable leases enhance ontological security and enable better life planning (Grimes et al., 2024; Du et al., 2024). Indonesian programs such as government-owned rental apartments (GORAs) could integrate similar tenure protections to reduce "residential alienation" (Adianto et al., 2023; Vols & Kusumawati, 2020).

Third, reforming legal and institutional protections is essential. Evictions whether formal or informal undermine the protective role of PRH and disproportionately harm marginalized groups (Swannie, 2023; Preston & Reina, 2021). Embedding **rights-based frameworks** into Indonesian housing law, including enforceable anti-eviction provisions and access to grievance mechanisms, could significantly reduce vulnerability among affected tenants.

Fourth, spatial integration must be prioritized. Evidence demonstrates that PRH located in remote or under-resourced areas exacerbates exclusion and reproduces informal settlements (Beier, 2023; Vitriana et al., 2025). Housing policy in Indonesia must therefore prioritize **well-located, connected housing that is linked to essential services** that link residents to employment, education, and transportation.

Finally, **participatory governance** strengthens housing resilience. Establishing tenant councils, fostering community partnerships, and implementing shared management practices contribute to enhanced accountability and help to diminish the stigma often associated with public housing (Grander & Kozlovic, 2025; Puszka, 2022). Incorporating these mechanisms into Indonesian PRH initiatives would empower tenants, positioning them not as passive recipients of housing but as active participants in shaping their housing futures.

In summary, while primarily informed by the Global North literature, these lessons underscore that **robust state intervention, a tenure-secure, rights-based framework, spatial inclusion, and participatory governance** represent the most effective pathways to mitigate housing precarity in Indonesia and the broader Global South.

CONCLUSION

This systematic review contributes a novel synthesis by situating public rental housing (PRH) and housing precarity within a multidimensional and comparative framework, bridging Global North scholarship with emerging insights from Southeast Asia, including Indonesia. Unlike prior studies that focus narrowly on affordability or tenure, this review demonstrates that precarity is simultaneously temporal, structural, legal, symbolic, and intersectional. The analysis also highlights how PRH functions ambiguously: it can serve as both a buffer against and a driver of precarity, depending on institutional design and policy orientation.

The research questions structured the analysis across seven thematic clusters, whose relationships are mutually reinforcing. RQ1 (precarity conceptualization) is addressed through evidence of temporal delays, symbolic insecurity, and multidimensional vulnerabilities that extend beyond material deprivation (Debrunner et al., 2024; Litvintsev, 2025; Puszka, 2022). RQ2 (structural and policy-related obstacles) is illuminated by commodification processes, exclusionary access criteria, and weak legal protections, showing how market logics undermine the universalist ethos of PRH (Fenton et al., 2013; Grander, 2017; Kumnig & Litschauer, 2025; Vols & Kusumawati, 2020). Finally, RQ3 (PRH as a mitigating or amplifying force of precarity) reveals that systems with long-term leases, integrated welfare services, and participatory governance such as New Zealand, China, and to a limited extent Singapore offer crucial lessons on how PRH can enhance wellbeing and social inclusion (Grimes et al., 2024; Du et al., 2024; Chuang, 2022). These interconnections show that conceptual understandings of precarity (RQ1) directly inform the identification of structural barriers (RQ2), which in turn condition whether PRH amplifies or mitigates precarity (RQ3). This study also acknowledges several limitations. Although database triangulation was undertaken through Scopus, Taylor & Francis, Google Scholar, and RemoteLib UI, the representation of Global South perspectives particularly from Southeast Asia beyond Indonesia remains relatively limited.

Nevertheless, this synthesis yields important policy implications. First, lessons from the Global North caution against overreliance on demand-side subsidies and short-term leases, which tend to exacerbate precarity rather than resolve it (Leviten-Reid et al., 2025; Fitzpatrick & Watts, 2017). Second, examples from East Asia highlight the value of renewable, long-term tenancy agreements and integrated welfare systems that foster stability and intergenerational wellbeing (Du et al., 2024; Zhou & Ronald, 2017; Chuang, 2022). Third, for Indonesia and similar developing contexts, policy reform must prioritize decommodified provision, legal security, participatory governance, and spatial inclusion to prevent housing from becoming a cyclical site of displacement and marginalization.

Future research should deepen comparative inquiry by centering Global South experiences, especially within Southeast Asia, where state-led housing systems coexist with persistent informality. Such studies could further explore the localized meanings of precarity and tenant resilience, while examining innovative policy designs that integrate rights-based frameworks with context-sensitive governance. By broadening both geographic scope and methodological tools, subsequent research can strengthen the global relevance of PRH scholarship and contribute to more equitable and secure housing futures.

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Effects of Livable Housing on Community Quality of Life: A Macro-Micro Study

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Abstract

Starting from the issue that access to adequate housing had only reached 38.3% by the year 2019, as evaluated through four basic parameters in the Sustainable Development Goals (SDGs). This study investigates the extent to which the livable housing indicators in SDGs influence the overall quality of life. The quality of life is assessed at the macro level using the Human Development Index parameters and at the micro level through the outcomes of government assistance programs. The results of multiple linear regression indicate that most livable housing parameters exert a strong, significant influence on the community's quality of life at the macro level. Meanwhile, the micro-community's perception in the research sample confirms Bappenas's findings and the SDGs. Considering that all parameters of livable houses significantly influence quality of life at the macro level, the research sample unit at the micro level has provided adequate confidence in most aspects of livable housing. Through this study, the authors expect that the Government can maximize the program's effectiveness in expanding household access to adequate housing, thereby achieving the target of at least 74% accessibility by 2029.

Keywords: Human development index, livable house, quality of life, household, Sustainable Development Goals (SDGs)

Abstrak

Dimulai dari permasalahan bahwa akses terhadap perumahan yang layak huni hanya mencapai 38,3% pada tahun 2019, berdasarkan empat parameter utama dalam Sustainable Development Goals (SDGs). Studi ini mengevaluasi pengaruh indikator perumahan layak huni dalam SDGs terhadap kualitas hidup secara keseluruhan, dengan menilai di tingkat makro melalui Indeks Pembangunan Manusia dan di tingkat mikro berdasarkan hasil program bantuan pemerintah. Hasil regresi linier berganda menunjukkan bahwa mayoritas parameter perumahan layak huni memiliki pengaruh signifikan terhadap kualitas hidup masyarakat di tingkat makro. Sementara itu, persepsi dari masyarakat secara mikro dalam sampel penelitian mendukung temuan Bappenas dan SDGs. Mengingat semua parameter rumah layak huni secara signifikan memengaruhi kualitas hidup di tingkat makro, sampel penelitian di tingkat mikro memperlihatkan kepercayaan yang cukup terhadap kebanyakan aspek perumahan layak huni. Melalui penelitian ini, penulis berharap Pemerintah dapat meningkatkan efektivitas program guna memperluas akses rumah tangga terhadap perumahan layak huni, sehingga target minimal 74% akses tercapai pada tahun 2029.

Kata Kunci: *Indeks pembangunan manusia, rumah layak huni, kualitas hidup, rumah tangga,* Sustainable Development Goals (SDGs).

INTRODUCTION

Housing provision is based on the number of households to determine needs. Between 2015 and 2025, the number of Indonesian households rose steadily, from over 65 million in 2015 to more than 72 million in 2020 (BPS, 2021). According to the population projection equation in the recent government census, Indonesia is projected to have more than 74 million households by 2030 and over 83 million by the end of 2050 (BPS, 2023). By 2050, Statistics Indonesia (*Badan Pusat Statistik*/BPS) projected that approximately 60% of Indonesia's population will live in urban areas and 40% in rural areas. Moreover, 45.9% of Indonesian households still live in uninhabitable houses (Bappenas, 2020). The target is to reduce this number to 30% by 2024 and 26% by the end of 2029, in both urban and rural areas.

Sustainable Development Goals (SDGs), as defined by the United Nations (UN), are a set of global policy targets intended for local implementation by member states to eradicate extreme poverty and achieve sustainable development (Rassanjani, 2018). Adequate housing encompasses: adequate privacy; adequate space; physical accessibility; adequate security; security of tenure; structural stability and reliability; adequate lighting, heating, and ventilation; adequate basic infrastructure, including water supply, sanitation, and waste management facilities; suitable environmental quality and health-related factors; and an accessible location in relation to work and basic facilities (Golubchikov & Badyina, 2012). Furthermore, implementing sustainable housing is crucial for future benefits, as it offers a wide range of opportunities to promote economic growth, protect the environment, enhance quality of life, and ensure social equity.

Aini et al. (2024), for example, argue that housing livability, particularly in densely populated urban areas, strongly influences community quality of life. The main novelty of this research is that it is among the few Indonesian studies to assess the significance of meeting livable housing parameters for achieving the SDGs in terms of quality of life, as measured by the human development index (HDI) at the national level. This research uses the HDI as a proxy for quality of life, as it measures human development through improvements in subjective well-being, alongside other global indicators.

Housing challenges may include poor dwelling quality, housing unaffordability, and overcrowding (Winston, 2021). According to Setiawan and Nawangsari (2023), as cited in Harahap et al. (2024), a house serves as a place to live, a shelter, and a means of meeting the basic needs of individuals and their families. A house is considered livable (*Rumah Layak Huni,* RLH) based on four basic parameters outlined in the SDGs. The term "livability" refers to the quality of life or living standards (Fouladi et al., 2024).

A house is generally considered uninhabitable if one or more of its components or materials are damaged, potentially damaged, or fail to meet building safety standards. This can also be determined by the size of the house and the health of its residents (Wicaksono et al, 2023). Besides building quality, having adequate living space is a key aspect of the Sustainable Development Goals (SDGs) related to decent and livable housing. According to Gholib (2019), the design quality of a house and the provision of adequate living space, adapted to healthy environmental conditions, shape residents' satisfaction in communities in dense urban areas.

The following aspects of a livable house are water and sanitation. Proper access to clean water and adequate sanitation are basic human needs that have a direct impact not only on health but also on social, economic, and environmental welfare (Pamungkas et al, 2022) and have broad implications for the quality of life of society (Harlin et al, 2024), as stated in Fatristya et al (2025).

Based on one of the strategic issues in the 2020-2024 National Medium-Term Development Plan (*Rencana Pembangunan Jangka Menengah Nasional* – RPJMN): Housing and Settlements, 61.7% of households occupy housing that meets at least one criterion of unfitness. According to the 2017 National Socio-Economic Survey (Bappenas, 2020), some of these households live in slum settlements, indicating that only 38.3% of households have access to adequate housing.

Within the framework of the latest 2025-2029 RPJMN, adequate housing is an integral component of fundamental human rights and remains a key indicator for achieving one of the Sustainable Development Goals (BPS, 2025). In line with the implementation of SDG indicators to measure the percentage of households with access to adequate housing, BPS data show that the rate declined significantly from 95.70% in 2018 to 56.51% in 2019 (Figure 1). This illustrates a situation in which the Government seeks more comprehensive data on households with access to adequate housing that meets all four parameters: physical durability of building construction, sufficient living space, access to clean drinking water, and access to proper sanitation, as depicted in the image below. Additionally, the SDGs define adequate housing as access to essential services such as electricity, heating, and clean cooking fuel, which improve living conditions and quality of life.

Each parameter is assigned a weight for assessing a house's suitability and includes its own technical

details, although these are not examined in depth in this study. The discussion of each parameter is at the level of general understanding of livable housing (RLH) achievement.

The target is increased to 74% for the 2025-2029 RPJMN period, up from 65.25% as shown in Figure 1. Various government interventions, implemented by the Ministry of Public Works and Housing in the last administration and now by the Ministry of Housing and Settlements, have addressed housing and residential areas through a series of programs and activities. One of these programs aims to address uninhabitable houses (*Rumah Tidak Layak Huni*/RTLH) by transforming them into habitable houses (*Rumah Layak Huni*/RLH).

Examples of government programs include the Self-Help Housing Stimulus Assistance (*Bantuan Stimulan Perumahan Swadaya*/BSPS), Community Sanitation (*Sanitasi Masyarakat-Sanimas*), and the Drinking Water Supply Program (*Sistem Penyediaan Air Minum-SPAM*). These programs are the result of the Indonesian government's calculation to support the achievement of the SDGs target for the proportion of households with access to adequate housing nationally.

Table 1 Percentage of Livable House Achievement Based on National Socio-Economic Survey of 2017. (Source: Bappenas, 2020)

		Parameters				
		Physical durability of Building Construction	Adequate Living Space	Access to Clean Water	Access to Sanitation	Amount (%)
	RLH	√	√	√	√	**38,30**
RTLH	**1 Indicator Less**	x	√	√	√	6,28
		√	x	√	√	2.03
		√	√	x	√	20,65
		√	√	√	x	8,62
	2 Indicator Less	√	x	x	√	1,39
		√	√	x	x	6,90
		√	x	√	x	1,10
		x	√	x	√	4,07
		x	√	√	x	3,18
		x	x	√	√	1,07
	3 Indicator Less	√	x	x	x	1,05
		x	√	x	x	3,09
		x	x	√	x	0,70
		x	x	x	√	0,78
	4 Indicator Less	x	x	x	x	0,79
		TOTAL OF RTLH				**61,70**
		TOTAL OF RLH				**38,30**
		TOTAL PERCENTAGE OF HOUSEHOLD				**100,00**

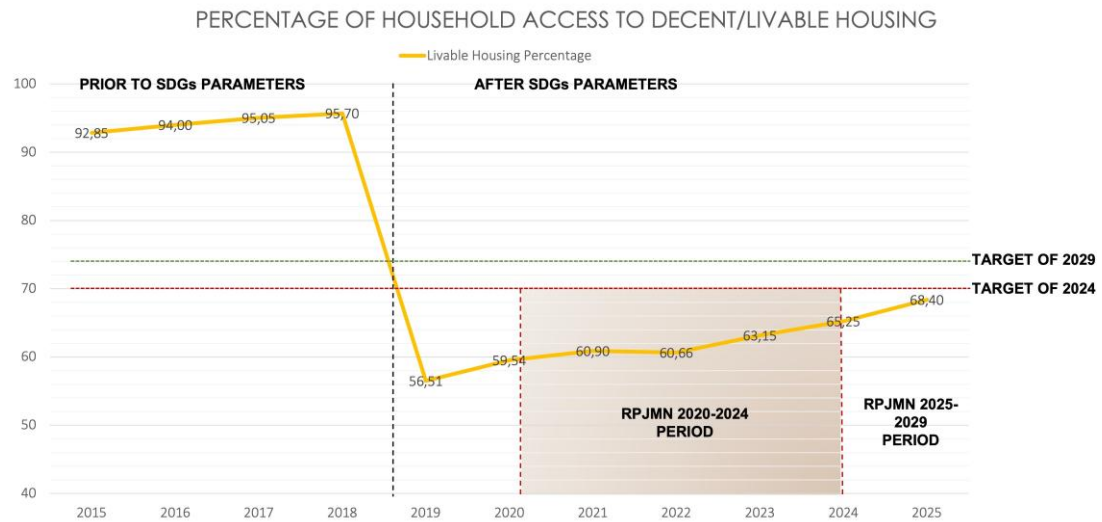

Figure 1 Percentage of Household Access to Livable Housing. (Source: BPS, 2025)

Houses or residential buildings that still lack at least one parameter will be assessed as unsuitable for sheltering, as illustrated in Table 1.

Housing conditions significantly affect people's quality of life (Balestra & Sultan, 2013), providing individuals and families with a sense of privacy, security, stability, and control when adequate. On the other hand, poor-quality housing, inadequate access to basic sanitation, and overcrowding contribute to health problems. Studies have found that overcrowding is linked to physical illness, including infectious diseases such as tuberculosis and respiratory infections (Krieger & Higgins, 2002). As families with relatively fewer financial resources are more likely to experience unhealthy and unsafe housing conditions, they are also less equipped to address them, and unhabitable housing contributes to widening health disparities across socio-economic groups (Dunn, 1999).

Ownership of a habitable house is a key factor in assessing quality of life (Streimikiene, 2015). Based on the approach taken by the Rural Alberta Development Fund (RADF) in measuring quality of life, the aspects used are: 1) Emotional Well-Being, 2) Interpersonal Relations, 3) Material Well-Being, 4) Personal Development, 5) Physical Well-Being, 6) Self-Determination, and 7) Social Inclusion (Appulembang & Dewi, 2017). In the Material Well-Being dimension, there are three leading indicators: sufficient income, the quality of the home one lives in, and expenditure (Howard Research & Management Consulting Inc., 2009). Furthermore, Streimikiene (2015) also explains that there are three important indicators for housing in improving the quality of life, namely: 1) housing quality; 2) housing environment; and 3) housing expenditure burden. In addition, Clapham et al. (2018) found that the physical condition of a house, housing tenure, and status influence subjective well-being.

Subjective well-being measures can be divided into three main categories that require independent measurement and explanation: life evaluations, positive emotions, and negative emotions (Helliwell & Barrington-Leigh, 2010). These can also be assessed by examining their correlations with other individual characteristics and their predictive validity (Kahneman & Krueger, 2006).

In the World Happiness Report 2020, Helliwell et al. (2020) compare various global indicators. These include the SDG Index, the Human Development Index (HDI), the Index of Economic Freedom (IEF), the Global Peace Index (GPI), the Global Competitiveness Index (GCI), and GDP per capita. The findings show that the HDI is the most strongly correlated indicator of welfare. From a quality-of-life perspective, the Human Development Index is an essential annual indicator, published both in Indonesia and globally.

Mahbub ul Haq (1995) believes that human development is the process of expanding choices, including political freedom, participation in community life, education, survival, health, and a decent standard of living. Furthermore, the United Nations Development Program (UNDP) defines human development as comprising three basic ideas: people, opportunities, and choices. Statistics Indonesia (BPS), through its publication of the 2024 (2025) Human Development Index, assesses the HDI across three dimensions. These three dimensions are as follows.

1. Longevity and a healthy life
2. Knowledge
3. Decent standard of living

The close relationship between the three HDI dimensions and the provision of livable housing to the community, as explained in the quality-of-life indicator, is that one of the objectives of such housing is to ensure the health and mental development of the inhabitants. This can also be described in terms of longevity and healthy living, as measured by the extent of household access to clean water and adequate sanitation. Beyond longevity and healthy living, knowledge acquisition is strongly influenced by residence size, which supports learning and experimentation (Streimikiene, 2015). The final dimension is a decent standard of living, measured in part by community income and expenditure indicators.

BPS (2025) reports that during the COVID-19 pandemic in 2020-2021, global HDI growth declined, primarily due to deterioration in human health and life expectancy. The decline was further exacerbated by restrictions on economic and educational activities, which contributed to a global recession. The decrease in average income and expenditure among most Indonesians limited their access to adequate employment, education, healthcare, and housing, resulting in a decline in the standard of living, particularly in urban communities, which, according to Checa-Olivas et al. (2021), negatively affects the HDI at higher rates of overcrowding. Following the crisis, Indonesia's HDI trended upward. However, growth stagnated after 2022, as shown in Figure 2.Based on the description of various conditions mentioned above, this research aims to determine whether the high number of uninhabitable houses affects the community's quality of life, as measured by the Human Development Index, by identifying the following problems:

1. How do the macro parameters of livable housing influence the Human Development Index as a measure of quality of life?
2. How do households perceive the quality of life index in their community after receiving assistance for livable housing?

By identifying these problems, this research aimed to analyze the significance of livable housing parameters for the Human Development Index, a measure of quality of life, at the macro level. At the micro level, it examined households' perceptions of the community quality-of-life index following receipt of assistance to make their housing livable.

Furthermore, this research expands on the role of livable housing in shaping people's quality of life from a different perspective. While many studies on human quality of life aim to identify the concrete dimensions that shape it, few have examined in depth the effects of livable housing on residents' quality of life at the micro level and on the general public at the macro level. The intended outcome is the positive implications of providing a livable housing environment that meets all applicable parameters, both nationally and globally.

METHOD

To achieve the research objectives and address the problems, this study employs two quantitative analytical approaches: macro-level analysis using secondary data and micro-level analysis using primary data. Secondary data analysis involves examining data collected by others for a different primary purpose and is a viable option for researchers with limited time and resources, as it uses existing data (Johnston, 2014).

Macro-level analysis of secondary data directly assesses the significance of habitable housing parameters in influencing quality of life, as measured by the human development index. Meanwhile, microanalysis examines household perceptions of attaining habitable housing attributes after receiving government assistance under a habitable housing program.

The government's Self-help Housing Stimulant Assistance (BSPS) program, used as the primary data source in this study, aims to regulate and stimulate self-built housing and housing improvement. This is a common strategy to improve the affordability of the housing supply (Golubchikov & Badyina, 2012) through funding and community empowerment. The research framework is depicted in Figure 3.

The HDI was selected not only because it has the strongest correlation with aspects of global well-being, but also because of its dimensions. It is beneficial for contextualizing micro-level quality-of-life outcomes within broader structural conditions. While individual quality of life is shaped by household-level factors (such as housing quality or access to services), these factors are embedded within macro-level development environments characterized by differing levels of health infrastructure, educational systems, and economic opportunity. HDI therefore functions as a structural control, helping explain why similar household conditions may produce different quality-of-life outcomes across regions. The macro and micro data analysis approaches within this research framework each have distinct transmission routes, as described in Figure 4, based on related prior studies and findings.

The chart illustrates a situation in which government policies in the housing and residential areas sector are implemented extensively to improve the achievement of each livable/ house (RLH) parameter. It is assumed that each parameter influences at least one HDI dimension, thereby increasing the dimension's value at the macro level.

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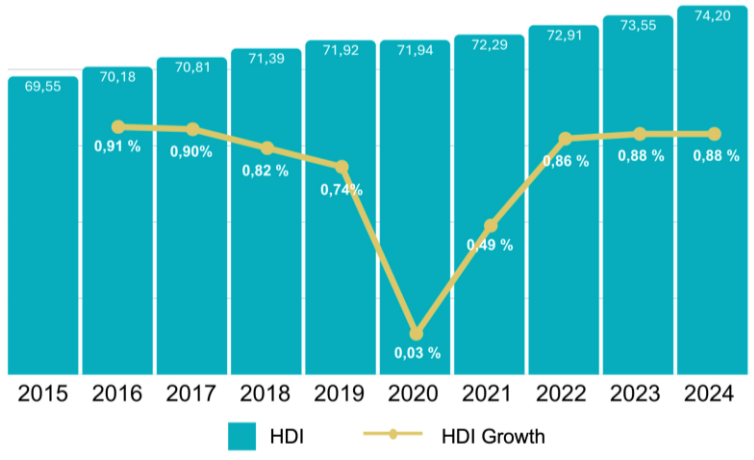

Figure 2 Indonesia's HDI, 2015-2024. (Source: BPS, 2025)

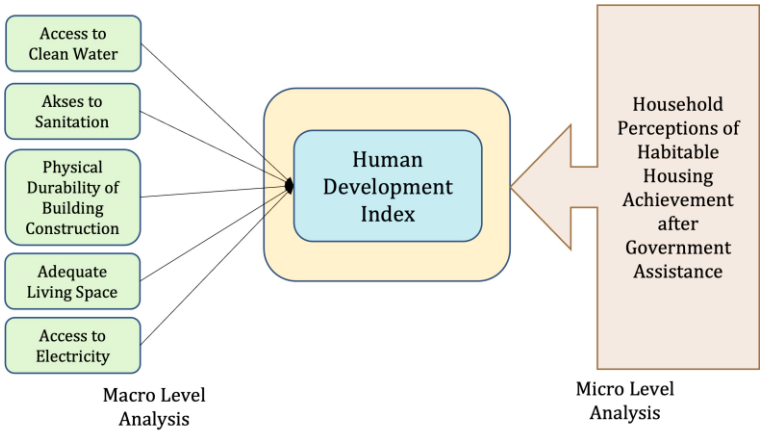

Figure 3 Research Framework.

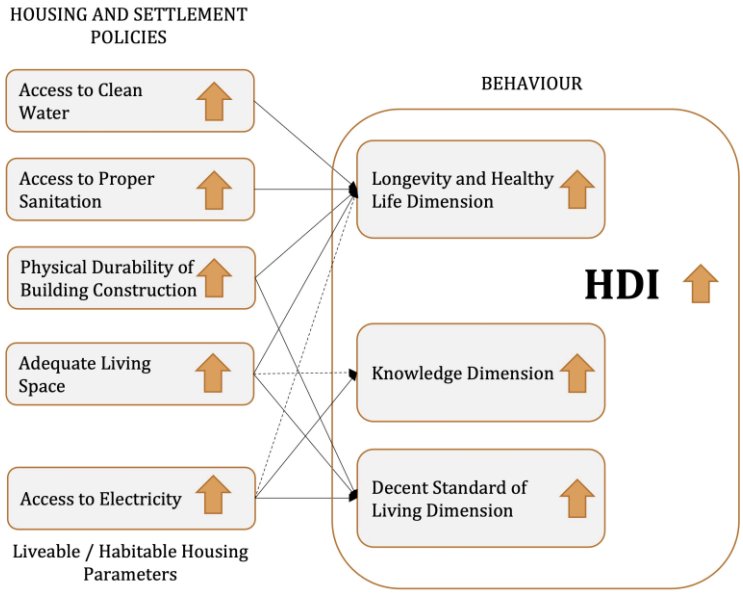

Figure 4 Macro Policy Transmission Process to Human Development Index.

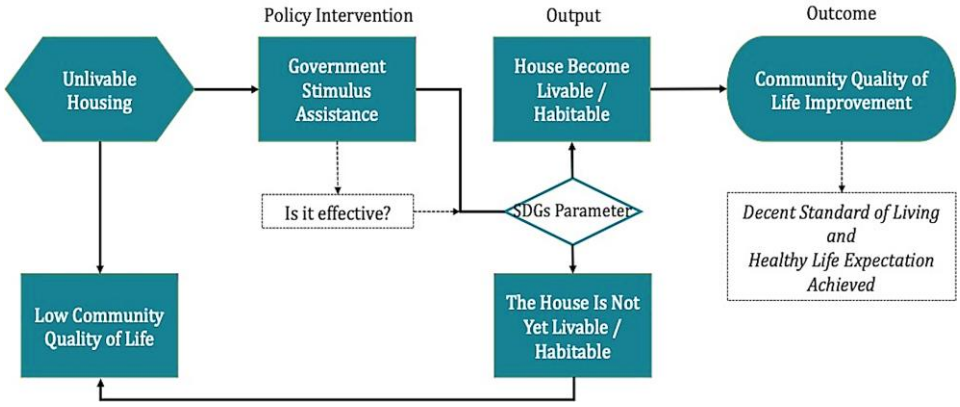

Figure 5 Micro Transmission Process of the RLH Assistance Program.

At the micro level, the effectiveness of implementing programs or activities within housing and settlement policy is reviewed, as illustrated in Figure 5.

The chart above illustrates the condition of the community/households occupying uninhabitable houses (RTLH) that, in the context of this research, have not fulfilled the four parameters of the Sustainable Development Goals (SDGs), tend to have a low quality of life, particularly in terms of health, and have not fulfilled a decent standard of living.

To transform RTLH into livable/habitable housing (RLH), the government is intervening through

policies and stimulus assistance programs to improve their quality and facilitate their conversion to RLH. The effectiveness of these government interventions will be assessed against the SDGs.

If the RTLH object receiving government stimulus assistance meets the four RLH parameters of the SDGs, the government program intervention can be considered adequate. However, if, after receiving the RTLH program intervention, it does not fully meet the four parameters, the government stimulus assistance program cannot be considered adequate. It may continue to contribute to a low quality of life in the community.

This research will analyze the influence of RLH aspects on quality of life, providing a reference for stakeholders in maximizing the effectiveness of the RLH provision policy. The independent variable in this study is the achievement of aspects of livable housing, measured by four SDGs parameters: adequate living space, physical durability of building construction, access to clean water and sanitation, and access to electricity, as shown in Table 2. The dependent variable is quality of life, measured by the Human Development Index (HDI).

In addition to the livable housing aspects, which serve as independent variables, this study employs control variables. These variables, which can be observed or estimated, help eliminate heterogeneity and ensure the independence of treatment when conditioning on them (Newey & Stouli, 2021). This approach avoids biased estimates and preserves the causal relationship between the independent and dependent variables, ultimately yielding a better empirical model, as summarized below. Based on the research variables outlined above, the empirical model for macro data analysis in this study is illustrated in the following equation.

$$HDI_{it} = \alpha + \beta_1 CleanWater_{it} + \beta_2 Sanitation_{it} + \beta_3 PhysicalDurability_{it} + \beta_4 AdequateSpace_{it} + \beta_5 Electricity_{it} + \beta_6 GDP\_PerCapita_{it} + \beta_7 Poverty_{it} + \beta_8 Unemployment_{it} + \varepsilon \quad (1)$$

- This research uses balanced panel data, least squares (OLS) processing
- Time interval used: 2015-2020
- Using secondary data sourced entirely from publications of Statistics Indonesia (BPS)
- The number of cross-sectional observations in the study was 34 provinces throughout Indonesia
- The estimate of the coefficients of all independent variables is $\beta > 0$

This study's microdata analysis uses primary data from a direct survey of decent housing assistance program recipients, which involved a questionnaire with the following instruments:

- A 2020 sample of RTLH Program Recipients with a size of 74 respondent units
- Randomly distributed to represent regions in Sumatra (3 provinces, four regents/cities), Java (2 provinces, four regents/cities), Kalimantan (2 provinces, three regents/cities), and Sulawesi (1 province, one regent).
- Questions/statements refer to research variables
- Responses based on a Likert scale

Table 2 Research Variables.

Variable List	Description	Source
Dependent Variable		
Human Development Index (HDI)	The measure of quality-of-life achievement built using a basic three-dimensional approach includes: 1) longevity and healthy life; 2) knowledge; and 3) decent standard of living.	BPS, 2021
Independent Variables		
Access to Clean Water	Percentage of households using clean water services (drinking water) that are managed safely	BPS, 2021
Access to Sanitation	Percentage of households that have access to adequate and sustainable sanitation services	BPS, 2021
Physical durability of Building Construction	Percentage of households that have houses with roof-floor-wall material quality that falls into the decent category	BPS, 2021
Adequate Living Space	Percentage of households occupying residential houses with a size of ≥ 7.2 m² per capita	BPS, 2021
Access to Electricity	Percentage of households occupying residential houses that have been connected to electricity facilities by PLN (additional RLH variable outside the SDGs parameters)	BPS, 2021
Control Variables		
GDP per Capita	Gross regional domestic product value at constant prices by expenditure (Base Year 2010) divided by the projected population	BPS, 2021
Poverty Rate	Percentage of poor population (P0) by province and region	BPS, 2021
Unemployment Rate	Percentage of open unemployment rate by province	BPS, 2021

Table 3 Robust Test Output.

VARIABLES	(1) HDI (OLS)	(2) HDI (FE)	(3) HDI (RE)	t-Statistic (Prob)	T Statistic in Parentheses	Conclusion
Access_Clean_W	0,02657	0,02656***	0,02977***	0,0000		Very
ater	(0,1556)	(0,0000)	(0,0000)			Significant
Access_Sanitation	0,04675*	0,01774**	0,01805***	0,0007		Very
	(0,0191)	(0,0011)	(0,0007)			Significant
Physical_Durability	-0,09327*	-0,03628***	-0,03709***	0,0001		Very
	(0,0105)	(0,0001)	(0,0001)			Significant
Adequate_Space	0,04433	0,12015***	0,11469***	0,0000		Very
	(0,1834)	(0,0000)	(0,0000)			Significant
Access_Electricity	0,18972***	0,06544***	0,07517***	0,0000	* p<0,05	Very
	(0,0000)	(0,0000)	(0,0000)		** p<0,01	Significant
LogGDP_PerCapita	1,85255***	3,36594***	2,83090***	0,0000	*** p<0,001	Very
	(0,0000)	(0,0000)	(0,0000)			Significant
Poverty_Rate	-0,17311***	-0,32087***	-0,28307***	0,0000		Very
	(0,0000)	(0,0000)	(0,0000)			Significant
Unemployment_	-0,02738	-0,01949	-0,00242	0,9370		Not
Rate	(0,7444)	(0,5507)	(0,9370)			Significant
Constant	29,68683***	1,41550	6,96219	0,3893		-
	(0,0001)	(0,8868)	(0,3893)			
Observations	204	204	204			
R-Squared	0,759652	0,995148	0,893739			
Adj. R-Squared	0,749792	0,993920	0,889380			
Prob (F-Statistic)	0,000000	0,000000	0,000000			

Each question is answered on a Likert scale from 1 to 10. The higher the scale value, the more the respondent agrees with or is certain of each statement or question. The questions in each variable complement one another, providing the basis for examining the micro-impact of the RTLH support program on quality of life with respect to SDG parameters. Due to the author's limited resources for obtaining research samples, the interpretations of the microdata processing results to date reflect only the characteristics of the sample obtained. They may not yet represent the entire 2020 RTLH assistance/BSPS program recipient population, potentially introducing bias.

RESULTS AND DISCUSSION

After ensuring that the regression model meets classical assumptions, we develop a community quality-of-life model that incorporates the Human Development Index (HDI) as a parameter. This resulted in the following hypotheses:

H0 = The parameters of livable/habitable housing do not impact the quality of life of the community

H1 = The parameters of livable/habitable housing have a positive influence on the quality of life of the community

The Random Effect Model (REM) was selected as the best model after conducting the Chow, Hausman & Breusch, and Pagan Lagrangian Multiplier tests to analyze the results of the macro impact estimation of the influence of SDGs parameters on the provision of livable/habitable housing on the quality of life of the community, as measured by the Human Development Index. The regression result depicted in the robust test output table, which shows three scenarios: (1) without control variables, (2) with two control variables, and (3) with three control variables, as shown in Table 3.

In the HDI estimation model, the adjusted R-squared with a random effect is 0.889380 (approximately 88.93%). This means that, at the macro level, 88.93% of the variation in the Human Development Index (HDI) is explained by variation in the five independent variables related to livable/habitable housing.

The remaining 11.07% of the variation in the HDI is attributed to other factors outside the model. With an F-statistic (P-value) less than the α level of 0.05, the independent variable, in the form of habitable housing parameters, has a significant simultaneous effect on the community's quality of life at the macro level. From the table above, it is clear that, at the macro level, all independent variables of RLH parameters significantly influence the community's quality of life, specifically access to clean water, access to sanitation, adequate living space, the physical durability of building construction, and access to electricity. Among the control variables, only the unemployment rate has no significant effect on the community's quality of life. The output of the multiple linear regression equation of the HDI model is as follows.

$$\begin{aligned} HDI_{it} = {} & 6{,}962186 + 0{,}029769 CleanWater_{it} \\ & + 0{,}018046 Sanitation_{it} \\ & - 0{,}037090 PhysicalDurabili \\ & + 0{,}114692 AdequateSpace_{it} \\ & + 0{,}075175 Electricity_{it} \\ & + 2.830901 GDPperCapita_{it} \\ & - 0.283069 Poverty_{it} \\ & + 0{,}002423 Unemployment_{it} \end{aligned} \quad (2)$$

The magnitude of the coefficient follows the magnitude of the T statistic. The larger the T statistic, the larger the coefficient. Thus, at the macro level, the variables with the most significant coefficients, in order, are adequate living space, access to PLN electricity, access to clean water, and access to adequate sanitation. Meanwhile, the physical durability of building construction has a negative coefficient. However, the coefficient on this variable has the lowest p-value, indicating that its effect is smaller than that of the other independent variables.

In HDI model estimation, all parameters of livable/habitable housing (RLH) aligned with the SDGs significantly influence the quality-of-life value measured by the HDI. Among RTLH parameters aligned with the SDGs, those with the most significant positive influence (Prob. ≤ 0.001) are adequate living space, access to electricity, access to clean water, and access to sanitation. Each 1-level increase in the achievement of adequate living space, access to electricity, access to clean water, and access to sanitation increases the quality of life (HDI) by 0.1147, 0.0752, 0.0298, and 0.0181 points, respectively. This underscores the importance of fulfilling RLH parameters to improve quality of life. In the HDI model, the RLH dimension plays an essential role in the Health, Education, and Decent Standard of Living dimensions.

These four RLH parameters collectively have a significant macro-level impact on the community's quality of life. In the macro impact analysis, the government program is relevant if it aims to increase RLH and growth in the Human Development Index, a measure of quality of life. Consistent with Indayani & Sadriah's (2020) findings, government assistance was positively correlated with poverty eradication. As for the micro impact analysis, the government program in the form of RLH stimulus assistance (BSPS) in the research sample units produced findings that confirmed the results of the Bappenas evaluation regarding the achievement of RLH parameters of the SDGs nationally, which indicates that the existing housing programs need to be remodeled to contribute maximally to the achievement of all SDGs indicators.

Adequate living space and access to electricity, as parameters added to support RLH, are the most significant variables in driving the quality of life (health dimensions, knowledge dimensions, and decent living standards in the HDI) of the community at the macro level, and have a level of confidence in government programs that is adequate at the micro level. Therefore, this is in line with the findings of the Rural Alberta's Development Fund survey in Howard Research & Management Consulting Inc. (2009) where a decent and comfortable home is one of the determinants of the Material Well-Being aspect in the components that form quality of life and with Streimikiene (2015) where the main element of a decent house is the availability of sufficient space because it has a significant impact on the quality of life, especially in terms of health and education. These findings are also consistent with Checa-Olivas *et al.* (2021), who hypothesize that living in overcrowded conditions limits people's ability to achieve the life they want and directly influences a country's human development.

The implication also extends to public health. Adequate living space facilitates healthier living conditions, including better sleep quality, reduced exposure to communicable diseases, and greater opportunities for physical activity within the home. During periods of crisis, such as pandemics or natural disasters, the importance of adequate living space becomes even more pronounced, as people spend extended periods indoors and rely on their homes to support work, education, and social life.

Although a family is classified as a Low Income Community (*Masyarakat Berpenghasilan Rendah*/MBR), the need for a house with sufficient area and adequate electricity connections has become a primary priority. Lower prices for essential electronic devices mean that low-income families can also afford them, supporting their daily activities. Moreover, internet access is necessary, particularly during and after the 2020-2021 pandemic, when the Government of Indonesia issued a school digitalization policy to expand access and improve learning quality.

According to the T-test results for the HDI multiple linear regression model, the third- and fourth-position parameters correspond to access to clean water and access to sanitation, respectively. According to the community, clean water is a fundamental necessity. Bathing, washing, and cooking are crucial to people's quality of life. These parameters, although they have a significant macro-level impact on quality of life (as dimensions of health and decent living standards in the HDI), have only reached a "sufficient" level of confidence in government programs at the micro level in the research sample units.

This result indicates that some respondents believe the government assistance program still has shortcomings and hope that this assistance also addresses adequate sanitation and access to electricity to maximize outcomes. In line with Sekarningrum *et al* (2023), explaining that environmental sanitation conditions in their study area indicate that particular factors, such as the

physical environment, are determining factors in the level of public health.

At the macro level, the sanitation access parameter is less significant than clean water access in driving the HDI. According to community members, limited access to sanitation can be addressed through alternative solutions, such as shared toilets with neighboring houses or conducting these activities in unsuitable locations, even though this is unhealthy. However, the lack of access to clean water in the house cannot be addressed together with other issues, such as toilets and bathrooms. Each home has its own clean-water needs, so there is no alternative to providing clean water access for all RLH that will be built.

The significant influence of access to clean water and proper sanitation on people's quality of life underscores the foundational role of basic infrastructure in human well-being. Reliable access to safe water and adequate sanitation directly supports physical health by reducing exposure to waterborne diseases, improving hygiene practices, and preventing chronic health conditions. As health status is a core component of quality of life, these services contribute to overall well-being both directly and indirectly.

Regarding the RLH aspect, although physical durability in building construction is also highly significant in influencing quality of life, this study found a negative relationship. This result may be due to the primary data used in this macroeconomic analysis being the BPS composite, which comes

from various sources. However, the building's physical durability is supported by sufficient confidence in the government program at the micro level within the research sample units.

These findings align with those of Grimes et al. (2024), who found that housing quality, particularly reduced dampness and cold, influenced tenants' subjective well-being. Also, as reported in Harahap *et al.* (2024), Muta'ali and Nugroho (2019) explain that improving housing quality to enhance livability is often the lowest priority for low-income families. Nevertheless, enhanced living environments positively impact health and increase life expectancy by reducing exposure to health hazards, promoting healthy behaviors, and improving access to healthcare. Factors like clean air and water, access to sanitation, and safe housing directly reduce disease transmission and exposure to toxins (Carp, 1977).

From a subjective well-being perspective in health, well-constructed houses are better at preventing dampness, mold growth, pest infestations, and exposure to extreme temperatures, all of which are associated with respiratory illness and other adverse health outcomes. By reducing health risks, durable housing indirectly enhances quality of life by lowering medical expenses, reducing sick days, and improving daily functioning.

Based on microdata analysis from primary questionnaires in this study, the collective field conditions across the research sample units corroborated the findings of Bappenas and the SDGs. This is reflected in general confidence in the implementation of the livable/decent housing assistance program, which is considered reasonable by the community receiving assistance, in this case, the research sample units. However, there are still aspects of RLH that require improvement.

One improvement that needs to be addressed is assessing the house's physical durability: not only should the materials (walls, floors, and roof) be evaluated, but structural issues should also be considered. A frequent problem in obtaining microdata is that most respondents wanted their houses in the best possible condition, especially regarding brick walls and steel/iron structures. In line with Wuryanti (2012) and Esariti *et al.* (2020), who find that panel houses and brick wall houses with standard reinforced concrete frame construction are the designs most expected by the Indonesian public. An overview of the research findings from macro- and micro-data analyses, addressing the research questions, is presented in Table 4.

The HDI model, as discussed previously, has several determinants: variables that are positively correlated with HDI and have a high explanatory power for the Y variable (HDI). There are four determining variables as parameters of an RLH in total in this model, as follows:

1. Adequate Living Space
2. Access to Electricity
3. Access to Clean Water, and
4. Access to Proper Sanitation

The four variables above are macro-determinants of the HDI in a region. The HDI is constructed using the indicators described in the previous paragraph. The relationships and justifications between the HDI indicators and the determinants are presented in Table 5.

CONCLUSION

Residential houses that meet SDG parameters at the 95% confidence level significantly affect community quality of life, particularly in terms of adequate living space, which strongly influences well-being at both macro and micro levels. For households receiving assistance, physical durability and perceived space adequacy are key determinants, emphasizing the importance of minimum space standards in housing regulations. Satisfaction with

living space often depends more on layout and design than size alone, reflecting subjective peceptions of control, comfort, and functionality.

Durable housing, constructed from strong materials and with environmental resistance, enhances physical security and long-term stability, thereby reducing stress and promoting well-being. Access to clean water and sanitation, vital for health, often remains insufficient in assistance programs and requires greater focus to improve the quality of life. Policies should prioritize water and sanitation infrastructure as integral to housing, urban development, and poverty alleviation, particularly in rapidly urbanizing areas and informal settlements, to prevent health disparities and reduce multidimensional poverty.

Table 4 Macro and Micro Analysis Data Pairing.

Measurement Aspects	Macro Data Analysis	Micro Data Analysis
Sustainable Access to Clean Water	Has a significant positive impact on quality of life (HDI)	The average level of confidence of the research sample units falls into the "Quite Confident" category.
Proper Access to Sanitation	Has a significant positive impact on quality of life (HDI)	The average level of confidence of the research sample units falls into the "Less Confident" category
Physical durability of Building Construction	Has a significant negative impact on quality of life (HDI)	The level of confidence of the average research sample unit falls into the "Confident" category.
Adequate Living Space in a House Building	Has a significant positive impact on quality of life (HDI)	The level of confidence of the average research sample unit falls into the "Confident" category.
Access to Electricity from PLN	Has a significant positive impact on quality of life (HDI)	The average level of confidence of the research sample units falls into the "Less Confident" category
Human Development	Significantly influenced by the achievement of SDGs livable house parameters	The level of confidence of the average research sample unit falls into the "Confident" category

Table 5 Determining Variables in the Formation of the HDI Indicator.

Determining Variables (RLH Parameters)	Justification of RLH Parameters Relation with HDI Indicators
Adequate Living Space (positive impact)	Adequate space per capita house building area (≥ 7.2 m² according to the SDGs mandate or ≥ 9 m² according to the mandate of Law No. 1 of 2011) is considered to play a very important role in human growth and development and health from early childhood to adulthood because it supports sufficient space for movement and circulation for activities, creativity, and expression. Adequate living space also contribute a positive influence for resident's psychological needs such as privacy, teritory, and stress minimizing that might caused by limited space crowding effect. Apart from that, the health factor of a building can also be determined by the amount of light that enters and the circulation of air through ventilation (something that is minimal for houses/buildings with inadequate space to achieve).
Access to Clean Water (positive impact)	Public health based on the existence and continuity of clean water is highly positively correlated. Proper bathing, washing and cooking activities can support public health through body cleanliness and adequate nutrition.
Access to Proper Sanitation (positive impact)	The availability of access to proper sanitation, whether in the form of hand washing facilities, domestic wastewater management, or defecation facilities, is highly correlated with the health requirements of both individuals and communities. With the availability of a good sanitation system, the community can reduce the risk of disease and improve the quality of life.
Access to Electricity from PLN (positive impact)	A decent standard of living is described through the balance between people's expenditure and income. Access to electricity in a livable house is considered to be able to support community productivity in the form of utilizing technology that makes daily activities easier so that a decent standard of living can be achieved.
Physical durability of Building Construction (negative impact)	One of the important roles of residential buildings, apart from being a place of shelter from hot weather, rain and cold temperatures, is how the building can protect the lives of its residents during natural disasters such as earthquakes and floods. Furthermore, the strength of the building structure of a RLH greatly influences the health and longevity of the people living in it also can be determined by the amount of light that enters and the circulation of air through ventilation. However, these two components will be difficult to create without a solid building structure.

Despite minor shortcomings in interpreting macro-level data, the results indicate that the government has substantial potential to meet the expected targets for providing people with access to adequate, livable housing. These outcomes will be feasible, especially if accompanied by greater effectiveness through improvements in areas that remain amenable to change.

This research has limitations that warrant further study. First, conduct a calculation using a specific weighting scheme for the physical durability of building construction parameters, accounting for their composite nature. Second, if similar research is planned, a larger sample will yield a more accurate and comprehensive picture of public perception of the government's RLH program's achievements. Finally, conduct similar research using more comprehensive quality-of-life measures beyond the Human Development Index, or employing alternative analytical methods.

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Spatial Clustering of Housing Backlog and Socioeconomic Inequality: Evidence from the Special Region of Yogyakarta

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Abstract

Housing backlog remains a critical challenge in Indonesia, particularly for low-income communities. However, existing mitigation policies often rely on aggregate data, overlooking the spatial concentration of poverty and housing needs. This study investigates the spatial clustering of housing backlogs and its correlation with socioeconomic status in the Special Region of Yogyakarta. Utilizing a quantitative spatial approach, the study employs Global Moran's I and Local Indicators of Spatial Association (LISA) to diagnose geographic disparities. The analysis reveals a significant positive spatial autocorrelation (Moran's I = 0.643), identifying distinct "hotspots" where high housing deficits significantly overlap with low socioeconomic clusters. Unlike conventional descriptive studies, these findings demonstrate that housing vulnerability is not randomly distributed but structurally trapped in specific zones. The study concludes that "one-size-fits-all" subsidies are insufficient and advocates for spatially targeted interventions to address these entrenched inequalities effectively.

Keywords: Housing Backlog, spatial clustering, LISA, socioeconomic inequality, Yogyakarta.

Abstrak

Backlog perumahan tetap menjadi tantangan kritis di Indonesia, khususnya bagi Masyarakat Berpenghasilan Rendah (MBR). Namun, kebijakan mitigasi yang ada saat ini sering kali bergantung pada data agregat, sehingga mengabaikan konsentrasi spasial kemiskinan dan kebutuhan perumahan. Penelitian ini menyelidiki pengelompokan spasial backlog perumahan dan korelasinya dengan status sosial ekonomi di Daerah Istimewa Yogyakarta. Dengan menggunakan pendekatan spasial kuantitatif, penelitian ini menerapkan Global Moran's I dan Local Indicators of Spatial Association (LISA) untuk mendiagnosis disparitas geografis. Analisis tersebut mengungkapkan adanya autokorelasi spasial positif yang signifikan (Moran's I = 0,643), serta mengidentifikasi "hotspot" yang jelas, di mana defisit perumahan yang tinggi secara signifikan tumpang tindih dengan klaster sosial ekonomi rendah. Berbeda dengan studi deskriptif konvensional, temuan ini menunjukkan bahwa kerentanan perumahan tidak terdistribusi secara acak, melainkan terjebak secara struktural pada zona-zona tertentu. Studi ini menyimpulkan bahwa kebijakan subsidi yang bersifat umum (one-size-fits-all) tidaklah memadai dan merekomendasikan adanya intervensi berbasis spasial yang tertarget untuk mengatasi ketimpangan yang mendalam ini secara efektif.

Kata Kunci: *Backlog perumahan, pengelompokan spasial, LISA, ketimpangan sosial ekonomi, Yogyakarta.*

INTRODUCTION

Despite various government interventions, the gap between housing demand and supply remains a persistent challenge in Indonesia. Recent data from the National Socioeconomic Survey (Susenas) indicates that the housing backlog for home ownership stood at 9.9 million households in 2023 (Central Bureau of Statistics, 2023).

While the government's strategic 'One Million Houses Program' (Program Sejuta Rumah) successfully delivered approximately 1.21 million units in the same year (Ministry of Public Works and Housing, 2024), this supply barely keeps pace with the annual formation of 700,000 to 800,000 new families. This disparity is disproportionately felt by low-income communities, where affordability constraints exacerbate the shortage. The government is constitutionally mandated to provide housing for low-income communities, but faces significant resource limitations, with its financing capacity estimated to cover only 20-30% of the required Rp780 trillion for the housing sector between 2020-2024 (Ministry of Public Works and Housing, 2019).

The Special Region of Yogyakarta , a province with high population density and rapid urbanization, presents a compelling case for examining this issue. Its unique socio-economic landscape, characterized by a dense urban core surrounded by extensive rural areas, creates complex and spatially varied housing market dynamics. While the provincial government has established a strategic plan for housing and settlement development (RP3KP), the on-the-ground impact of these policies appears uneven.

While foundational studies have extensively examined housing affordability and distribution dynamics (Gilbert, 2004; Malpezzi & Green, 1996), a critical methodological gap persists in the context of Indonesian housing research. Existing studies predominantly rely on aspatial, aggregate statistics or descriptive urban planning approaches (Bramley & Karley N K, 2007). These conventional methods often treat administrative regions as homogeneous units, failing to capture the spatial dependency and 'neighborhood effects' where socioeconomic disadvantages cluster geographically. Consequently, current literature lacks a rigorous quantitative spatial analysis that explicitly links housing backlogs with localized socioeconomic inequalities.

This study advances the existing body of knowledge by integrating Local Indicators of Spatial Association (LISA) with Socioeconomic Status (SES) profiling. Unlike previous descriptive studies, this research moves beyond identifying how much housing is needed to statistically diagnosing where the need is structurally concentrated. By quantifying the spatial autocorrelation of low-income households, this study offers a novel diagnostic framework that challenges uniform policy interventions, providing the empirical basis for spatially targeted housing strategies in the Special Region of Yogyakarta."

Recent scholarship has increasingly adopted spatial econometrics to dissect socioeconomic disparities and housing inequalities. For instance, (Anwar, 2022) utilized LISA and Spatial Autoregressive Models (SAR) to map poverty concentrations in Central Java, demonstrating that poverty is not spatially random but significantly influenced by neighboring regions. Similarly, (Sholihin et al., 2025) confirmed the persistence of spatial dependence in poverty distribution, highlighting the necessity of cluster-based policy interventions rather than uniform approaches. Furthermore, spatial analysis has proven critical in identifying multidimensional deprivation zones, as shown by (Noviyanti et al., 2023), who applied spatial regression to determinant factors of poverty across Indonesian provinces. These studies collectively underscore the urgency of moving beyond aspatial aggregate data to understand the localized dynamics of housing and socioeconomic needs.

METHOD

This study employs a quantitative spatial analysis approach to assess the housing conditions for low-income communities in the Special Region of Yogyakarta. The research design integrates SES classification with spatial autocorrelation analysis to identify and interpret the geographical distribution of housing needs.

The research utilizes both primary and secondary data:

- Primary Data: Obtained from questionnaire responses from communities regarding the criteria for low-income households and field observations concerning their distribution.
- Secondary Data: Sourced from literature studies on housing, low-income communities criteria, and institutional data from Statistics Indonesia (BPS), including population counts, socioeconomic indicators (SUSENAS 2020), and regional minimum wage regulations.

To classify households based on their economic capacity, the Socioeconomic Status (SES) theory is applied. The SES categorization is determined by several key variables as indicators of a household's economic standing: (a) monthly household routine expenditure; (b) number of household members; (c)

primary source of drinking water; and (d) primary source of cooking fuel. Based on these indicators, households are classified into categories ranging from Upper (A, B) to Middle (C1, C2) and Lower (D, E). The criteria for low-income communities are defined based on government regulations, specifically the income and expenditure thresholds stipulated in Regulation of the Minister of Public Works and Housing No. 10/2019 Concerning Criteria for Low-Income Communities.

To identify local spatial clusters and spatial outliers, this study employs the Local Indicators of Spatial Association (LISA) statistic, originally developed by (Anselin, 1995). This method decomposes the global Moran's I into local contributions, allowing for the detection of significant spatial patterns at the district level. The LISA statistic for each observation i is defined as:

$$I_i = \frac{x_i - \bar{x}}{\sum(x_j - \bar{x})} \sum_j w_{ij}(x_j - \bar{x}) \qquad (1)$$

where x_i is the attribute for feature i, $\bar{x}$ is the mean of the corresponding attribute, and w_{ij} is the spatial weight between feature i and j. The core of the spatial analysis is the use of Local Indicators of Spatial Association (LISA). This method was chosen to identify local clusters of districts with similar values for the proportion of low-income communities households.

First, a global Moran's I statistic was calculated to test for the presence of overall spatial autocorrelation across the study area. Moran's I measures the degree to which districts with high (or low) low-income communities populations are located near other districts with similarly high (or low) values. A positive and significant Moran's I value indicates spatial clustering, while a negative value suggests spatial dispersion.

Second, a LISA analysis was performed. LISA is a decomposition of the global Moran's I statistic, which allows for the identification of the significant contribution of each individual observation to the global value (Anselin, 1995). It assesses the similarity of a specific location (e.g., district A) to its neighboring locations based on a chosen variable (e.g., percentage of low-income communities). The analysis classifies each district into one of four significant cluster types:

- High-High: A district with a high low-income communities proportion surrounded by neighboring districts with high low-income communities proportions (a "hotspot").
- Low-Low: A district with a low low-income communities proportion surrounded by neighboring districts with low low-income communities proportions (a "coldspot").
- High-Low: A district with a high low-income communities proportion surrounded by neighbors with low values (a spatial outlier).
- Low-High: A district with a low low-income communities proportion surrounded by neighbors with high values (a spatial outlier).

The analytical process involved defining a spatial weights matrix (queen contiguity) to establish neighborhood relationships between districts. The LISA results were then visualized using a cluster map generated in GeoDa software to illustrate the spatial distribution of hotspots, coldspots, and spatial outliers.

RESULTS AND DISCUSSION

Socioeconomic Profile of the Special Region of Yogyakarta

In 2020, the population of the Special Region of Yogyakarta was 3,671,189, distributed across five regencies/cities. Sleman Regency had the highest population (29.49%), while Kulon Progo Regency had the lowest (12.07%). Population density varies dramatically, from 12,803 individuals/km^2 in the highly urbanized Yogyakarta City to 521 individuals/km^2 in the predominantly rural Gunungkidul Regency (Table 1). Based on national survey data (SUSENAS 2020) and local regulations, the average low-income communities population in the Special Region of Yogyakarta is estimated to be 2,421,113 individuals (Table 2).

Global Spatial Autocorrelation and Clustering Tendencies

Housing accessibility is closely linked to economic capacity and social stratification. According to Bramley & Karley N K (2007), housing affordability varies based on income distribution, government subsidies, and land-use policies. The affordability crisis is exacerbated by urban expansion and rising property values, particularly in densely populated areas such as Yogyakarta City. Economic factors such as inflation, mortgage rates, and household income influence housing affordability, creating disparities that disproportionately affect low-income communities.

Previous studies have highlighted that low-income households often experience limited access to adequate housing due to financial constraints and discriminatory lending practices (Mukhija, 2004).

Economic theories suggest that housing affordability is primarily determined by income elasticity and housing supply constraints, both of which have been found to be significant factors in Indonesian urban areas (Malpezzi & Green, 1996).

Table 1 Area, Population, and Population Density by Regency/City in the Special Region of Yogyakarta (2020). (Source: BPS DIY, 2021)

No.	Regency/City	Area (km²)	Population	%	Households	%	Density (p/km²)
1	Kulon Progo	586,28	443.003	12,07	152.251	12,21	755,6
2	Bantul	506,85	954.706	26,01	329.616	26,42	1.883,6
3	Gunungkidul	1.485,36	774.609	21,10	256.786	20,59	521,5
4	Sleman	574,82	1.082.754	29,49	368.213	29,52	1883,6
5	Yogyakarta	32,50	416.117	11,33	140.527	11,27	12.803,6
Special Region of Yogyakarta		3.185,81	3.671.189	100,00	1.247.393	100,00	1.152,4

Table 2 Average Estimated Population of Low-Income Communities by Regency/City.

No	Regency/City	Population of Low-Income Communities (Expenditure Category)	Population of Low-Income Communities (Decile Aggregation)	Average Population of Low-Income Communities
1	Kulon Progo	579,186	480,258	529,722
2	Bantul	286,182	274,662	280,422
3	Gunungkidul	727,262	591,918	659,590
4	Sleman	727,083	671,307	699,195
5	Yogyakarta	282,615	257,993	270,304
Special Region of Yogyakarta		2,566,089	2,276,137	2,421,113

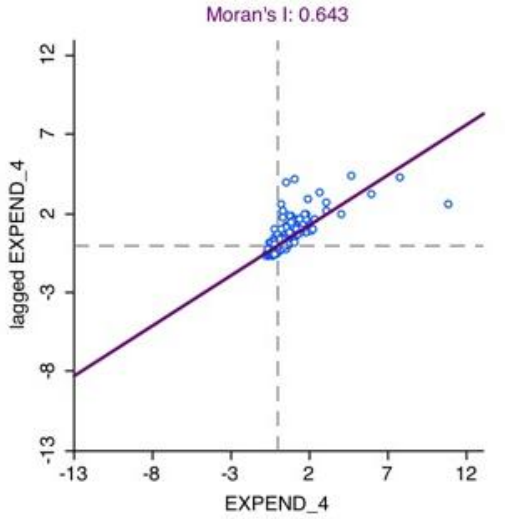

Figure 1 Moran Scatterplot of Proportions of Low-Income Communities in the Special Region of Yogyakarta.

The spatial analysis commences by testing for global spatial autocorrelation. The calculated Moran's I statistic for the proportion of low-income households per district is 0.643 (pseudo p-value <0.001). This strong, positive, and statistically significant value unequivocally rejects the null hypothesis of spatial randomness. It indicates a powerful tendency for districts with similar proportions of low-income community populations to cluster together geographically. This finding is consistent with broader patterns of socio-spatial segregation observed in other major Indonesian urban regions, where economic development often exacerbates spatial inequality (Winarso et al., 2015). The Moran scatterplot (Figure 1) visually corroborates this, with a majority of observations falling within the High-High and Low-Low quadrants, confirming the dominance of positive spatial autocorrelation over spatial heterogeneity.

Local Patterns of Spatial Association: Hotspots, Coldspots, and Policy Mismatches

While the global Moran's I confirms that clustering exists, the LISA analysis reveals where it occurs, providing granular insights crucial for policy formulation. The resulting cluster map (Figure 2) uncovers a stark spatial dichotomy in the distribution of the housing backlog, which we interpret through the lens of urban economic theory and policy analysis.

- High-High (HH) Clusters: Urban Poverty Pockets
  The analysis identifies statistically significant High-High clusters (hotspots) concentrated in the urban core and the suburbanizing fringe of Yogyakarta City, Sleman, and Bantul regencies. These hotspots represent what can be termed "urban poverty pockets," where a high concentration of low-income households is reinforced by surrounding districts with similar characteristics. This phenomenon aligns with classic theories of residential segregation and spatial sorting, where low-income groups are concentrated in specific areas due to market forces, such as high land values in central locations, and social stratification (Brueckner, 2000; Glaeser & Gyourko J, 2005). More recent studies in Southeast Asian cities suggest that rapid urbanization without adequate affordable housing provision often leads to such concentrated disadvantages (Kidokoro et al., 2022). In these hotspots, the challenge for housing provision is immense, constrained by land scarcity and soaring property prices,

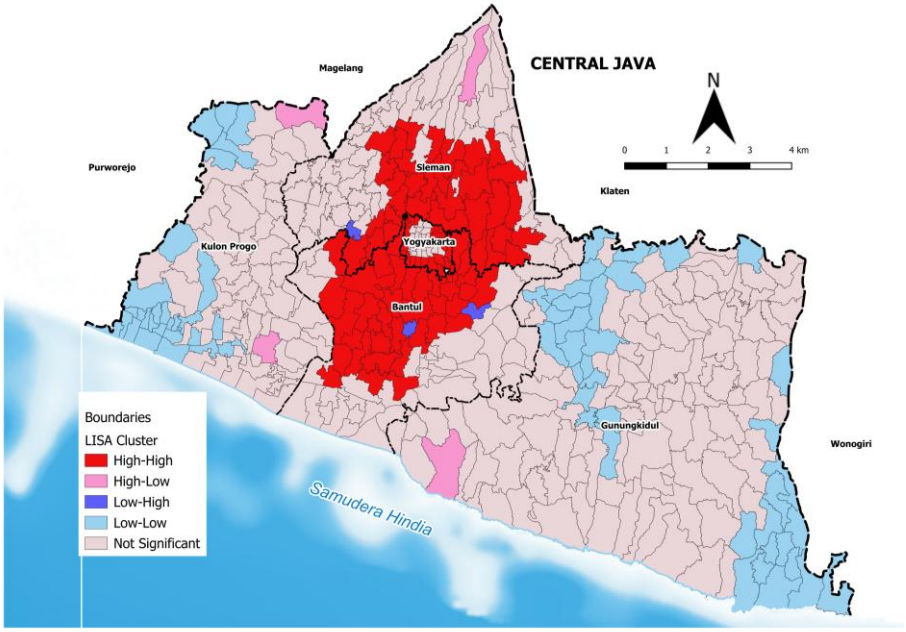

Figure 2 LISA Cluster Map of the Distribution of Low-Income Communities in the Special Region of Yogyakarta.

rendering conventional landed housing programs for low-income communities economically unfeasible.

- Low-Low (LL) Clusters: Rural Disadvantage and Different Needs. Conversely, significant Low-Low clusters (coldspots) dominate the predominantly rural regencies of Kulon Progo and Gunungkidul. It is critical to interpret this finding with caution. A "coldspot" does not imply widespread prosperity; rather, it indicates a lower relative concentration of low-income communities compared to the urban core and a different socio-economic structure, often agrarian-based. The housing challenges in these areas are distinct from the urban backlog. They typically relate to the quality of the existing housing stock, access to basic services and infrastructure (clean water, sanitation), and limited economic opportunities, rather than a quantitative shortage of units (Rukmana, 2018). Applying urban-centric backlog reduction strategies in these cold spots would represent a significant policy mismatch.

Implications for Theory and Housing Policy in Indonesia

The findings challenge the efficacy of aspatial, "one-size-fits-all" housing policies prevalent in Indonesia. The clear spatial structure of the housing backlog in the Special Region of Yogyakarta provides empirical support for the application of spatially differentiated policy interventions. The concentration of HH clusters underscores the failure of existing policies, such as the *Satu Juta Rumah* (One Million Houses) program, to adequately penetrate high-density, high-cost urban markets where the need is most acute.

- Policy Recommendations for Urban Hotspots: For the identified HH clusters, policy must shift away from landed housing models. Interventions should prioritize high-density solutions such as subsidized vertical public housing (*rusunawa*), rental assistance vouchers to leverage the existing private rental market, and the implementation of inclusionary zoning policies. The latter would mandate that new private residential developments allocate a percentage of units for affordable housing, a strategy proven effective in other contexts for fostering mixed-income communities (Turok et al., 2024).
- Policy Recommendations for Rural Coldspots: In the LL clusters, the focus should be on improving the quality of the existing housing stock. Programs like *the Bantuan Stimulan Perumahan Swadaya* (BSPS), a self-help housing improvement stimulus, are far more relevant here. Furthermore, housing policy in these areas must be integrated with broader rural development strategies aimed at enhancing infrastructure, improving access to essential services, and creating local economic opportunities to prevent distress-driven migration to the already overburdened urban core.

Theoretically, this study demonstrates the utility of spatial econometrics in moving beyond simplistic measures of housing deficit. By quantifying and mapping spatial dependency, it provides a robust evidence base for policy design that is both

equitable and efficient. The primary contribution of this research is its clear demonstration that an effective housing strategy for a region as diverse as Yogyakarta and by extension, Indonesia must be explicitly spatial in its diagnosis and prescription.

CONCLUSION

This study successfully demonstrates the existence of significant spatial correlation in the distribution of the low-income housing backlog in the Special Region of Yogyakarta. The LISA analysis provides robust evidence of geographical clustering, moving beyond simple descriptive statistics to reveal a distinct spatial structure of housing inequality. The primary finding is the identification of a clear spatial pattern: significant High-High clusters (hotspots) of low-income communities are concentrated in the urban agglomeration of Yogyakarta, Sleman, and Bantul, while Low-Low clusters (coldspots) are located in the rural regencies of Kulon Progo and Gunungkidul. This confirms that the housing backlog is not randomly distributed but is a geographically embedded phenomenon.

These findings have critical policy implications. The current approach to housing provision, as outlined in regional plans, appears insufficient because it does not account for this spatial heterogeneity. A uniform policy is unlikely to succeed in a region with such diverse local conditions. Therefore, this study strongly recommends a shift towards spatially targeted interventions. For the urban hotspots (HH clusters), policies should focus on solutions suitable for dense environments, such as vertical housing, rental assistance programs, or land value capture mechanisms to fund affordable housing. In contrast, for the rural coldspots (LL clusters), interventions could prioritize self-help housing improvement programs (*"Bantuan Stimulan Perumahan Swadaya*") and infrastructure development to support local livelihoods.

This research is limited by its use of data aggregated at the district level. Future research could achieve higher granularity by using village-level or even point-data to perform a more detailed analysis of neighborhood-level dynamics. Nonetheless, this study provides a crucial spatial-analytical framework for policymakers to design more effective, equitable, and geographically informed housing policies for low-income communities.

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Study on the Reliability of Materials and Structures of Simple Pre-cast Modular Houses (Case Study: RUCAST Technology)

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Abstract
RUCAST (PreCAST Concrete Main Frame) is a precast concrete housing system developed to provide more flexible and affordable landed houses. Unlike many existing precast technologies that have rigid panel sizes and limited floor-plan flexibility, RUCAST allows flexible beam-column positioning and flat wall columns, resulting in more efficient space usage and adaptable interior layouts. RUCAST is designed as a confined masonry structural system, where the walls carry structural loads while beams and columns function mainly as wall restraints. The system uses a concrete mix ratio of 1:2:3 (cement:fine aggregate:coarse aggregate) to ensure practical construction and consistent field quality. Beam and column dimensions are 100 × 100 mm^2, with mechanical connections using steel threads and plates, making the frame unsuitable as a moment-resisting system. The study evaluated material properties, structural components, structural behavior, and production costs. Tests included concrete compressive strength, reinforcing steel strength, mortar strength, masonry bond strength, flexural testing of structural components, and cyclic testing of wall systems. Results indicate that RUCAST can be applied in 37 of Indonesia's 38 provincial capitals for hard, medium, and soft soil conditions, with adequate performance for areas having S_{DS} ≤ 1.38g. RUCAST production costs are also approximately 25.28% lower than comparable precast housing technologies.

Keywords: Confined masonry, 1:2:3 concrete mix, earthquake resistant house, precast landed house, RUCAST.

Abstrak
RUCAST (Rangka Utama beton preCAST) merupakan teknologi rumah sederhana pracetak yang dikembangkan untuk memberikan fleksibilitas desain dan biaya yang lebih ekonomis dibandingkan teknologi rumah pracetak yang sudah ada. Berbeda dengan sistem pracetak konvensional yang memiliki keterbatasan akibat ukuran panel yang kaku, RUCAST memungkinkan fleksibilitas posisi kolom–balok dan penggunaan kolom rata dinding sehingga tata ruang menjadi lebih efisien, luas, dan mudah disesuaikan dengan kebutuhan pengguna. RUCAST dirancang sebagai sistem struktur dinding terkekang, di mana dinding berfungsi menerima beban struktur, sedangkan balok dan kolom hanya berperan sebagai pengekang dinding. Material beton menggunakan campuran volumetrik 1:2:3 untuk mempermudah pelaksanaan di lapangan dan menjaga kualitas konstruksi. Dimensi balok dan kolom sebesar 100 × 100 mm^2 dengan sambungan mekanik sederhana menyebabkan sistem ini tidak direkomendasikan sebagai portal pemikul momen. Penelitian mencakup pengujian material, komponen struktur, perilaku struktur, dan analisis biaya produksi. Hasil penelitian menunjukkan bahwa RUCAST mampu diterapkan pada 37 dari 38 ibu kota provinsi di Indonesia dengan kapasitas gempa memadai untuk lokasi dengan S_{DS} ≤ 1,38g. Selain itu, biaya produksi RUCAST sekitar 25,28% lebih murah dibandingkan teknologi rumah pracetak sejenis.

Kata Kunci: *Pasangan dinding pengekang, beton campuran 1:2:3, rumah tahan gempa, rumah tapak pracetak, RUCAST.*

INTRODUCTION

The rapid growth of the urban population has led to a high demand for housing, yet this demand is not matched by the pace of landed house construction, thereby increasing the housing backlog in Indonesia. According to data from the Central Bureau of Statistics in 2025, the housing backlog has reached 15 million units, up from 9.9 million units previously (Bahfein and Alexander, 2025). In an effort to reduce this backlog, the Ministry of Public Works has developed simple landed houses using precast structural systems, with various technologies introduced from the era of the Building Research Institute (LPMB) to the Center for Research and Development of Housing and Settlements (Puskim) (Direktorat Bina Teknik Permukiman dan Perumahan, 2018). However, further innovations are still needed to meet market demands, as previous systems are considered too costly and offer limited design flexibility due to the rigid dimensions of their structural panels.

According to SNI 1979-1990 on Spatial Specifications for Residential Houses, the standard space requirement for housing is 9 m^2 per person. However, when observing the current earthquake-resistant precast houses available on the market, such as RISHA (Direktorat Bina Teknik Permukiman dan Perumahan, 2021), although they provide a floor area of 9 m^2, the net usable area is only 7.84 m^2.

In addition, the layout of the type-36 houses offered by existing simple precast housing systems still appears rigid, as they typically adopt a rectangular configuration divided into four rooms of uniform size. Therefore, future precast housing systems need to be developed to meet the required housing space standards while also offering more flexible interior layouts.

Another challenge in developing simple precast housing in Indonesia is the uneven quality of building materials, especially in remote and hard-to-reach areas. The distribution of materials to frontier, remote, underdeveloped, and outermost regions still depends on long and complex sea and land routes, with minimal intermodal integration and limited infrastructure such as unloading ports, storage warehouses, and local distribution fleets (Berlianto et al., 2025).

This situation results in inconsistent availability of standard materials in the field, making it necessary to formulate precast component materials that are more adaptive and easier to obtain across various production locations. In response to these market challenges, we have developed a new simple precast housing system that we call RUCAST.

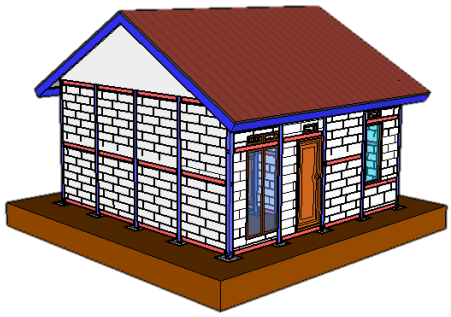
RUCAST (Rangka Utama Beton preCAST) is a simple housing system that uses precast reinforced concrete as its structural framework and is designed as a one-story landed house. RUCAST consists of beam and column components made of reinforced concrete with dimensions of 100 × 100 mm^2, incorporating a mechanical connection system using steel plates and anchor bolts.

The RUCAST beam has a length of 1400 mm, reinforced with 4Ø8 main bars and Ø8-100 stirrups, and is referred to as Beam B140. The RUCAST column has a length of 3150 mm, reinforced with 4Ø10 main bars and Ø8-100 stirrups, and is referred to as Column K315. The mechanical connection in RUCAST uses a UNP 75.40.5.7 steel profile welded to Ø10 reinforcement embedded in the beam. A detailed illustration of the building unit and the structural component design of the RUCAST system can be seen in Figure 1.

RUCAST is designed as a structure with a confined masonry system, in which the wall elements are restrained by horizontal and vertical confining members on all four sides (Schacher and Hart, 2015). The vertical confining elements in this system are the K315 Columns, while the horizontal confining elements are the B140 Beams. The K315 Columns and B140 Beams are intended to behave monolithically with the wall; therefore, their connections are designed using Ø10 reinforcement bars embedded between the wall and the columns. The wall component in this system uses lightweight concrete blocks with a thickness of 100 mm.

The concrete materials used in the RUCAST system are designed with a volumetric mix ratio of 1:2:3 for cement, sand, and aggregate, respectively, to ensure that the formulation is easy to apply in the field. In addition, this study is limited to the use of lightweight concrete blocks and instant mortar adhesive, considering that modern housing construction is now more familiar with these materials. These limitations also allow the research to focus on evaluating the structural performance and production costs of precast houses in a manner that is realistic and relevant to current construction practices.

To meet diverse floor plan needs tailored to the owner's wishes, RUCAST is present with the flexibility of column and beam positions, as the distance between columns is 1.5 meters. Thus, in addition to the typical 6x6 m floor plan, the house floor plans using RUCAST technology will be more varied according to the user's needs. However, it is still necessary to comply with the structural irregularity rules that refer to SNI 1726:2019 article 7.3.2. Figure 2 shows a comparison of a typical landed house floor plan with a variation floor plan that can be applied using RUCAST tecnology.



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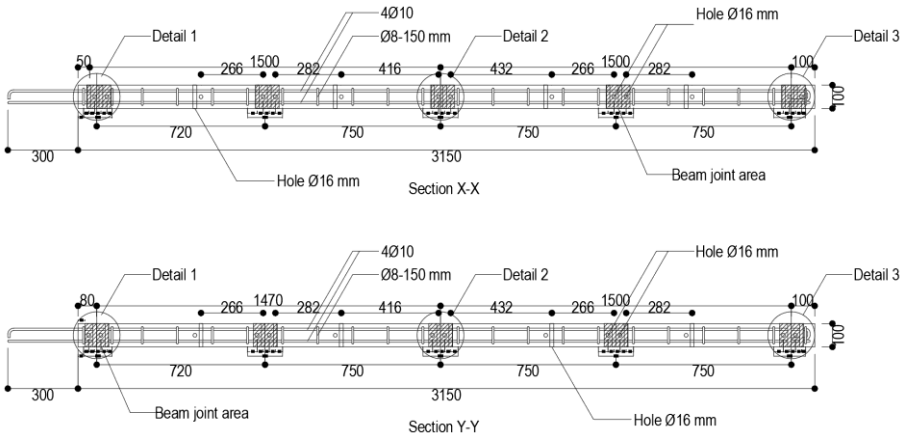

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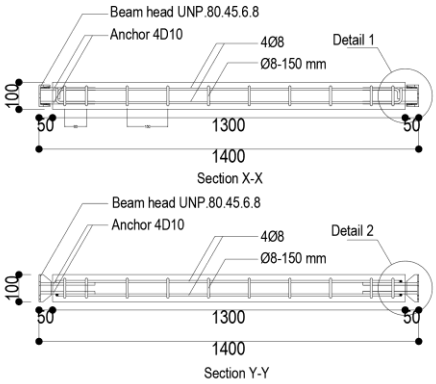

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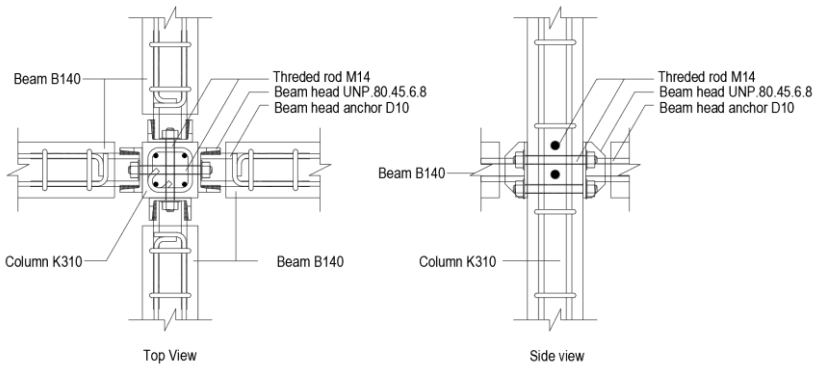
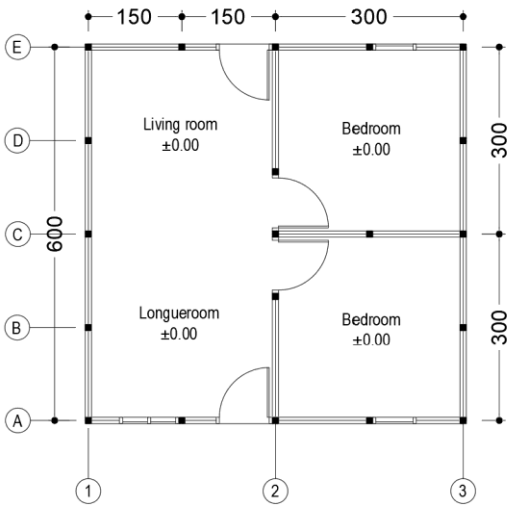


(d)

Figure 1 Sketch of The RUCAST Unit and Confining Element Components (a) Building Unit (b) K315 Column (c) B140 Beam (d) Beam–Column Connection System.



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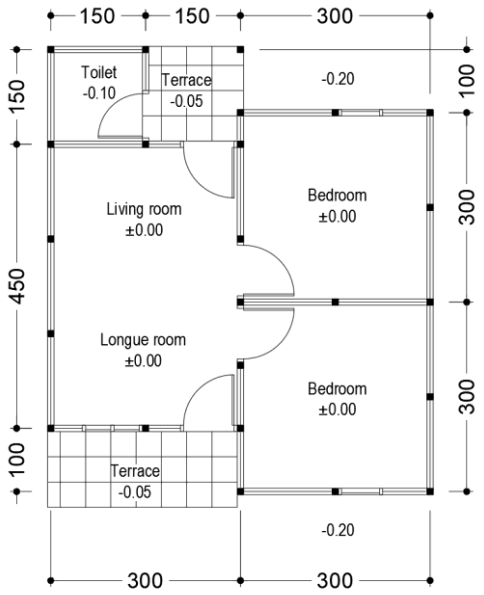

(b)

Figure 2 Simple House Floor Plan (a) Typical Floor Plan (b) Variation Floor Plan .

METHOD

This research specifically focuses on evaluating the performance of the RUCAST structural system, demonstrated through experimental testing in the form of a two-dimensional cyclic wall test to assess the structural response and capacity under repeated lateral loading as a simulation of earthquake forces. Furthermore, capacity tests of beam, column, joint, and wall shear components were conducted to verify that these elements cannot act independently, but instead function as confinement elements within a confined masonry system, where the primary structural component is the wall. This verification is essential to ensure that the RUCAST system adheres to the working principles of a reliable confined masonry structure

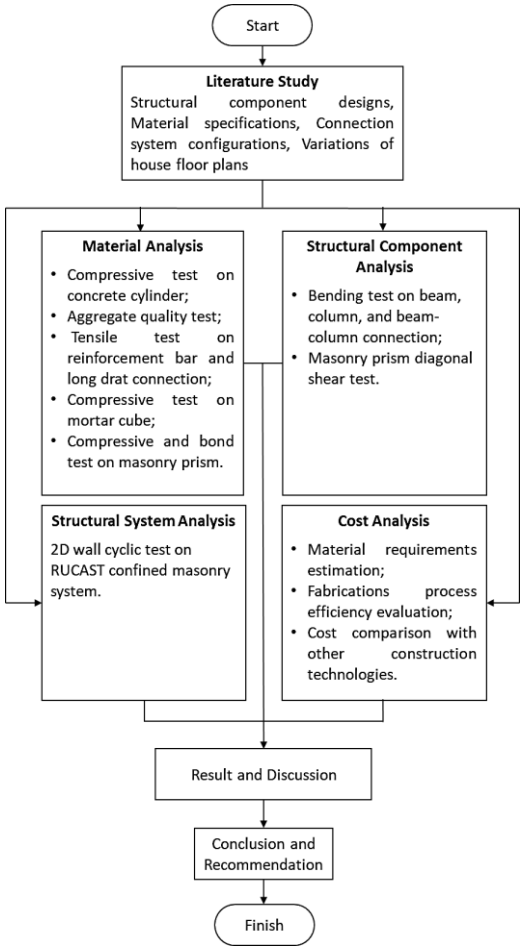

Figure 3 Research Methodology Workflow.

under lateral loads. In addition, this study includes a series of material quality tests such as concrete compressive strength, reinforcing-steel tensile strength, and mortar compressive and adhesion tests to demonstrate that the RUCAST system can be produced using simple materials that are readily available on site. The research also encompasses an analysis of production costs, including material requirement estimation, fabrication-process efficiency evaluation, and cost comparison with other construction technologies to assess the system's economic viability. Thus, this research not only evaluates structural performance but also establishes technical feasibility, the availability of local materials, and cost efficiency as a foundation for the broader application of RUCAST technology.

The initial stage of this research began with a literature study to identify the innovation needs for precast simple-housing systems. This stage resulted in the establishment of the preliminary RUCAST system design, covering structural-component dimensions, material specifications, joint-system configurations, and possible variations of housing layouts. After the basic design was determined, a material-aspect analysis was conducted through a series of experimental tests, including concrete cylinder compressive strength tests, aggregate

quality tests, tensile tests on reinforcement and threaded connectors, mortar adhesion tests on lightweight brick masonry, and compressive tests on lightweight brick mortar joints.

The next stage involved analyzing the structural-component aspects through flexural testing of B140 beams, K315 columns, beam–column joints, and diagonal shear-strength testing of lightweight brick walls. Subsequently, a structural-system analysis was carried out through cyclic testing of two-dimensional (2D) walls to evaluate the overall structural performance under repeated lateral loading. The final stage of the research comprised a production-cost analysis, including material requirement estimation, fabrication-process efficiency assessment, and cost comparison with other construction technologies. Overall, the research methodology workflow can be seen in Figure 3.

Material Analysis

The analysis of material aspects was carried out through a series of tests, including the compressive strength test of concrete cylinders. The concrete compressive strength value was obtained using the following equation.

$$f_c' = \frac{P}{A} \quad (1)$$

Where P is the compressive load applied by the esting machine and A is the cross-sectional area of the concrete specimen. The compressive test specimens were concrete cylinders with a diameter of 150 mm and a height of 300 mm. Two variations of concrete mix proportions were used in this study, namely 1:2:3 and 2:3:5 for cement, fine aggregate, and coarse aggregate. Each mix was prepared with three different water contents determined by water–cement ratios of w/c = 0.5 according to SNI 2847:2019, w/c = 0.6, and a slump value of ±12 cm. The number of specimens was set at 5 variations with concrete ages of 7, 14, 28, and 56 days, where each variation and age consisted of 5 specimens. In total, 120 concrete cylinders were tested.

In addition, an analysis of the characteristics of coarse and fine aggregates was carried out. The tests included determination of moisture content (SNI 1971:2011), specific gravity and water absorption (SNI 1970:2016 and SNI 1969:2016), as well as gradation analysis using sieve tests (SNI C136:2012), which were evaluated against ASTM C33 aggregate-quality requirements. Each test was performed in triplicate to obtain representative and consistent values, ensuring that the aggregates met quality standards and reflected actual field conditions.

Simultaneously, tensile tests were also performed on reinforcing steel bars and threaded steel used in the beam–column connection of RUCAST reinforced-concrete components. These tests aimed to determine the actual characteristics of the reinforcing steel and threaded rods used in beams, columns, and beam–column joints. The reinforcing bars used were plain bars with diameters of 10 mm (for column K315) and 8 mm (for beam B140), while the threaded rods used in beam–column connections had a diameter of 13 mm. Each reinforcing bar and threaded rod specimen was prepared at a length of 500 mm, and each test was performed in triplicate to obtain representative results.

In addition, to determine the average quality of the mortar used in lightweight brick masonry, a compressive strength test was conducted. This test used three types of instant mortar commonly available on the market Mortar A, Mortar B, and Mortar C. The purpose was to assess the extent of compressive-strength differences among the three products. The testing method referred to SNI 6825:2002 and ASTM C109-02. The water content used followed the usage instructions for each mortar type (Mortar A = 425 ml/2 kg; Mortar B = 437.5 ml/2 kg; Mortar C = 462.5 ml/2 kg). The specimens were cast in cube form with dimensions of 50 × 50 mm and tested using a compression machine at the age of 28 days. A total of 5 specimens were prepared for each type of instant mortar, resulting in 15 specimens overall.

To determine the compressive strength and bond strength of brick masonry prism components, tests were conducted using specimens consisting of three stacked lightweight bricks measuring 200 mm in length, 200 mm in width, and 100 mm in thickness, with a 3 mm layer of mortar between them. Two types of lightweight bricks (Brick 1 and Brick 2) and three types of instant mortar (Mortar A, Mortar B, and Mortar C) were used in the testing, resulting in six specimen variations. The purpose was to identify the potential quality levels of masonry constructed from various material combinations commonly found in the field. Each variation was tested in triplicate, resulting in a total of 36 specimens. The compressive and adhesion strength test of brick masonry prism documentation can be seen in Figure 8.

Structural Component Analysis

The structural component analysis was conducted to determine the characteristics and capacities of each structural component in the RUCAST system, namely the B140 beam, K315 column, beam–column joint, and masonry wall. The tests performed on the B140 beam, K315 column, and

beam–column joint were flexural tests. The testing referred to SNI 4431:2011, in which the specimen is placed transversely on two simple supports and then loaded with a compressive force applied through a load spreader consisting of two rollers, as shown in Figure 4. Two specimens were tested for each of the B140 beams, K315 columns, and beam–column joints. The calculation of the flexural strength of the beam component (M) is presented in the following equation.

$$M = 0.5 \times (P + W) \times x \quad (2)$$

where:
P = Force (kN)
W = specimen + load spreader + load cell (kN)
x = length of support to load roll (m)

The RUCAST component connection, which is a mechanical joint using a UNP 80.45.6.8 profile on the B140 Beam and connected with a 13 mm diameter threaded steel rod, is expected to exhibit semi-rigid behavior that can be analyzed through the joint rotation value (ϕ) at the beam–column connection, as shown in Figure 5. Joint rotation is defined as the slope of the deflection curve relative to the load-arm length (Görgün, 1997). The joint rotation value can be calculated using the following equation.

$$\phi = \delta / L \quad (3)$$

where:
ϕ = joint rotation
δ = deflection at the load point
L = load arm length

From the joint rotation results, the Secant Stiffness (K_s) can be calculated. According to AISC 360-16, K_s is the joint stiffness determined from the service

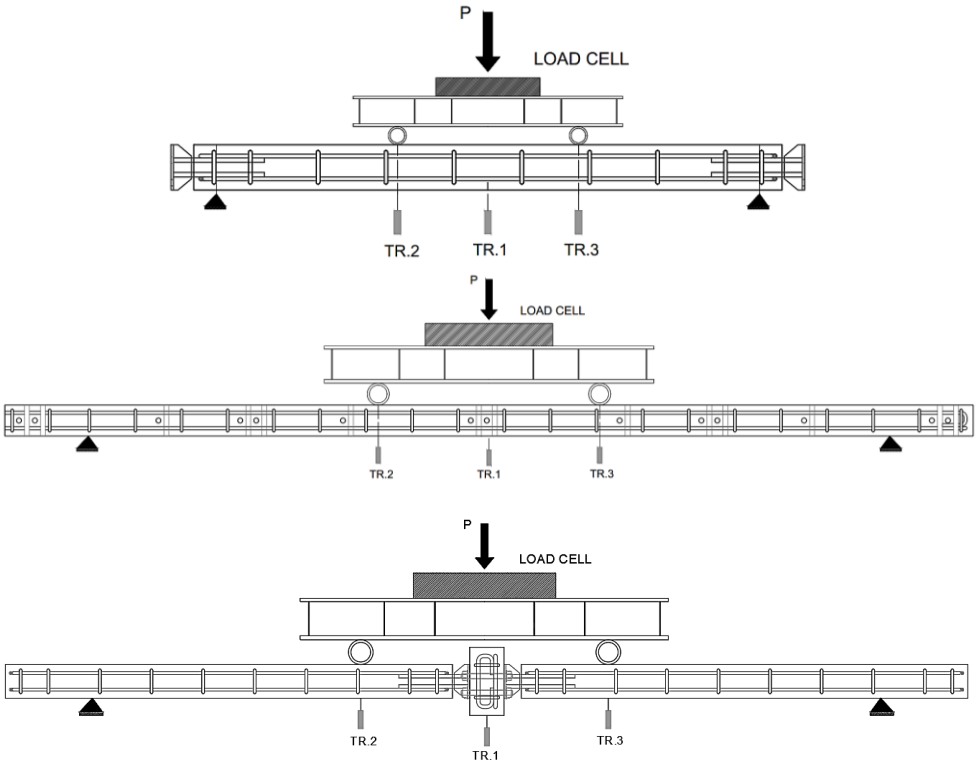

Figure 4 Flexural Test of Structural Component in Laboratory.

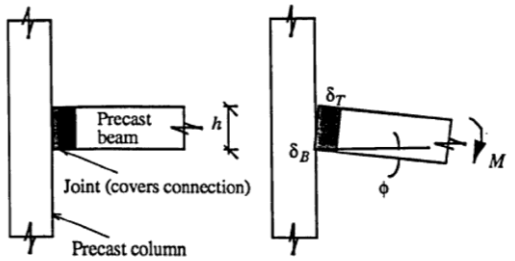

Figure 5 Illustration of Joint Rotation Values at Component Connection. (Source: Görgün, 1997)

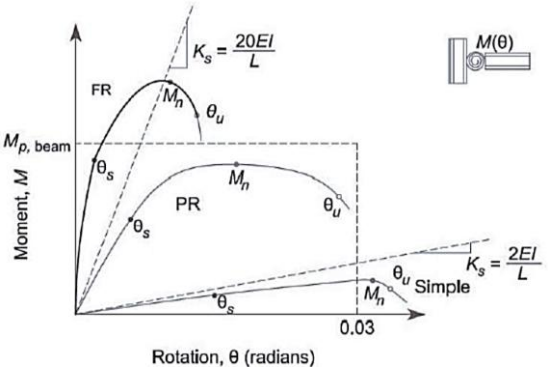

Figure 6 Rigidity Connection Classification Curve. (Source: AISC 360-16, 2016)

load divided by the resulting joint rotation (K_s = $M_s/Ø_s$). If $K_sL/EI \geq 20$, the joint can be classified as fully restrained (FR), meaning it can maintain rotational compatibility between components. If $K_sL/EI \leq 2$, the joint is classified as a pin connection (a joint that rotates without contributing to moment resistance). Joint stiffness values falling between these limits are categorized as partially restrained (PR), as shown in Figure 6. This analysis was conducted to evaluate the behavior of the beam–column connection in the RUCAST system.

The final variable in the structural component analysis is the diagonal shear capacity testing of lightweight brick masonry wall components, using an analytical method referring to NTC-M 2004. This test was conducted to determine the shear capacity and vertical shear failure pattern of lightweight masonry walls as one of the components of the RUCAST system. The analysis was performed by applying a diagonal compressive load to the lightweight brick masonry wall partition specimen (Meli et al., 2011), as shown in Figure 7. The bricks used in the specimens were lightweight bricks of types 1 and 2, measuring 60 × 20 × 10 cm, while the mortar used was instant mortar type A with a joint thickness of 3 mm (according to manufacturer specifications).

The diagonal shear strength (v_m) was analyzed from the results of the diagonal compression test on square masonry wall specimens, which were then loaded monotonically along their diagonal axis. Essentially, vm is influenced by the type of wall material and the mortar used. The shear strength of the wall (v) has acceptance criteria referring to NTC-M 2004, using the following equation.

$$v = (0.5v_m + 0.3\sigma) \leq 1.5v_m \quad (4)$$

where:
v_m = diagonal shear strength obtained from laboratory testing
σ = wall compressive stress

$$\sigma = \frac{W_T}{\Sigma A_w} \quad (5)$$

where:
W_T = total building weight
A_w = cross-sectional area of a wall on a floor

Structural System Analysis

The structural analysis conducted was a two-dimensional cyclic wall test using materials and structural components that had been previously analyzed. This analysis aimed to determine the performance and behavior of the prototype specimen particularly the two-dimensional wall in the in-plane direction under cyclic lateral loading as a simulation of earthquake-induced lateral forces, using a hydraulic jack as the mechanical instrument to apply the load, as shown in Figure 8. Referring to SNI 7834:2012 and ASTM E2126-11, a displacement-control loading protocol consisting of cyclic lateral loads was applied in both push and pull directions with progressively increasing displacement targets. For the initial loading cycles, small displacement targets were used to observe the behavior of the wall within the elastic range, as illustrated in Figure 9.

The cyclic test was carried out using one RUCAST

confined masonry specimen. The specimen details can be seen in Figure 10 along with the construction specifications as follows.

1. Confining frame consists of K315 and B140 elements, each with dimensions of 100 × 100 mm^2. The column has a length of 3150 mm with main reinforcement of 4Ø10 and stirrups of Ø8-100. The beam has a length of 1400 mm with main reinforcement of 4Ø8 and stirrups of Ø8-100. Both are made from a 1:2:3 mix concrete with 0.5 w/c ratio.
2. The RUCAST system connection uses a mechanical joint consisting of a UNP 80.45.6.8 steel profile welded to Ø10 reinforcement bars embedded at both ends of the B140 beam. The UNP steel profile is connected to the column using a 13 mm diameter threaded steel rod.
3. The wall is constructed from lightweight bricks of Type 2 with dimensions of 60 × 20 × 10 cm. The adhesive between the bricks uses instant mortar Type A with a thickness of 3 mm. The wall surface is finished with a plaster layer made of a 1:3 cement-to-fine aggregate mixture with a thickness of 3 mm.
4. The anchor at the connection between column K315 and the specimen foundation uses Ø10 reinforcement with a depth of 300 mm, which is the main continuous column reinforcement embedded into the foundation. Meanwhile, the anchor between the column and the wall is connected using Ø8 reinforcement with a depth of 300 mm, installed during the lightweight brick masonry construction process.

The RUCAST structure, which is a confined masonry system, has its performance predominantly governed by strength. Strength verification is carried out by comparing the lateral resistance capacity ($V_{capacity}$) with the seismic base shear (V), which is calculated based on the design earthquake specified in SNI 1726:2019 using the following equation.

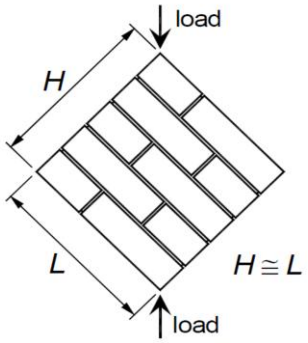

Figure 7 Illustration of Diagonal Shear Strength Test of a Masonry Wall. (Source: Seismic Design Guide for Low-Rise Confined Masonry Buildings, 2011)

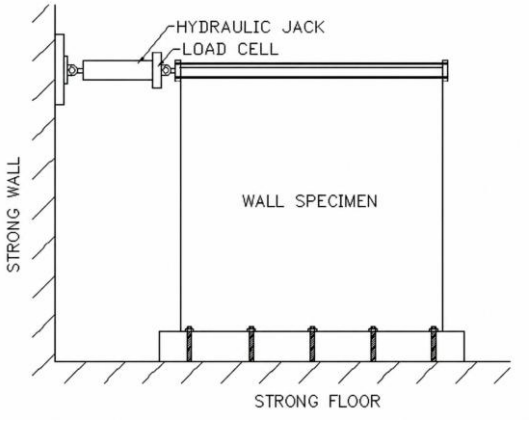

Figure 8 Typical 2D Wall Cyclic Testing.

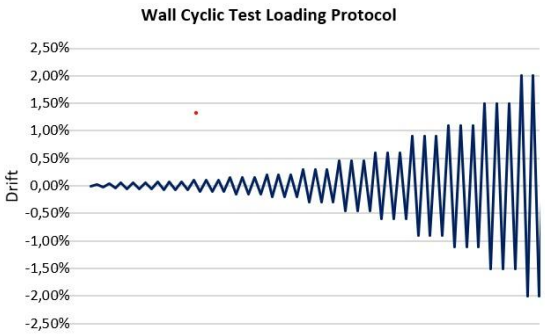

Figure 9 Cyclic Wall Test Loading Graph

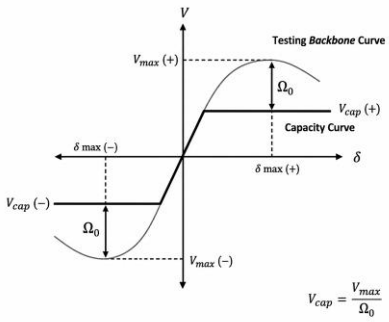

Figure 11 Backbone Curve Testing in Determining Structural Capacity.

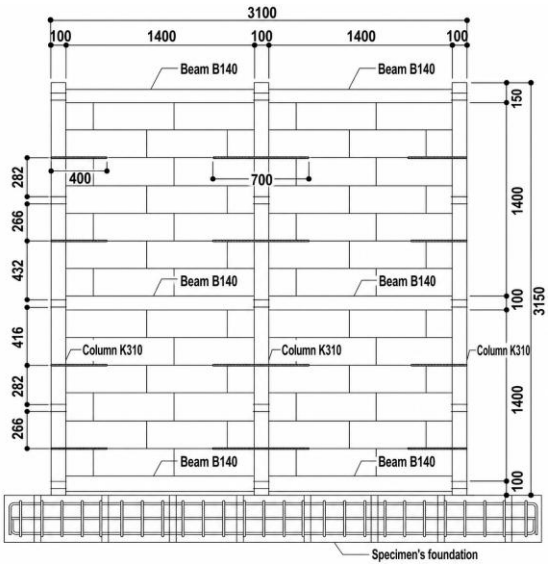

Figure 10 RUCAST Cyclic Wall Test Specimen.

$$V = C_s \times W \quad (6)$$

where:

C_s = seismic response coefficient

W = effective seismic weight

The effective seismic weight (W) consists of the structure's self-weight, dead loads, and other applicable loads in accordance with the provisions of SNI 1726:2019 Section 7.7.2. The seismic coefficient (C_s) is influenced by the design earthquake acceleration parameters (S_{DS} dan S_{D1}), the response modification factor (R), the importance factor (I), and the structural period (T), as specified in SNI 1726:2019 Section 7.8.1.1.

The lateral resistance capacity ($V_{capacity}$) is calculated based on the backbone curve obtained

from the cyclic test, using an offset equal to the maximum push–pull lateral load (V_{max}) that the structure can withstand before failure, divided by the structural overstrength factor (Ω_0), as illustrated in Figure 11. The lateral capacity of the structure used for evaluation is the smaller value between the push and pull capacities. The structural system is considered adequate to resist seismic loads if its capacity exceeds the demand or the induced earthquake load, which can be expressed mathematically as follows.

Cost Analysis

Production cost analysis was carried out to accurately estimate budget requirements, minimize the risk of cost overruns, and improve the efficiency of fabrication and construction processes. This analysis method includes identifying all production cost components required for manufacturing RUCAST precast elements, including material, labor, equipment, and fabrication processes. In addition, an evaluation of mass construction costs was conducted to assess the economies of scale that could be achieved if the RUCAST system is implemented on a large scale. The analysis also includes a cost comparison between using timber and steel formwork to determine the most economical and sustainable option. Finally, RUCAST production costs were compared with those of other precast technologies to evaluate the economic competitiveness of this system relative to existing alternatives.

RESULTS AND DISCUSSION

Material Aspect

The quality of concrete on site is influenced by the composition of cement, fine aggregates, coarse aggregates, and water content. To anicipate factors that may cause the concrete quality to fall below standards and to ensure ease of implementation in the field, this study used simplified concrete mix proportions of 1:2:3 and 2:3:5 with water–cement ratios of 0.5 and 0.6, as well as a slump value of ±12 cm. Each variation was tested at concrete ages of 7, 14, 28, and 56 days. The concrete cylinder compressive strength test was conducted according to SNI 1974:2023 using cylindrical molds with a diameter of 15 cm and a height of 30 cm. The compressive strength results for each mix variation can be seen in Table 1 and Figure 12.

The curve shows that the 2:3:5 mix with 0.5 w/c ratio has higher compressive strength compared to the other mixes. However, at 56 days, the 1:2:3 mix with 0.5 w/c ratio exhibits a capacity nearly equal to that of the 2:3:5 mix with the same w/c ratio. Therefore, the 1:2:3 mix with 0.5 w/c ratio is selected as the concrete material for the RUCAST components, due to the 1:2:3 mix is more commonly used in construction on site.

To determine the material characteristics of the concrete mixture used in RUCAST, tests on coarse and fine aggregates were conducted based on SNI ASTM C136:2012, with the results presented in Table 2 and Figure 13. Based on the analysis of

moisture content, silt content, specific gravity, and bulk density, both coarse and fine aggregates were found to not meet the acceptance criteria for concrete aggregates according to ASTM C33/C33M-13. The sieve analysis results show a similar issue: both the coarse and fine aggregates exhibit uniform gradation and do not meet the requirements for concrete aggregates. These conditions have the potential to reduce the compressive strength and durability of the concrete. Overall, this negatively affects the quality and production efficiency of RUCAST concrete. Therefore, further technical actions are necessary in the research, such as adjusting the mix design, improving aggregate quality, or evaluating alternative material sources, to ensure the required performance of RUCAST concrete can be achieved.

The tensile strength of reinforcement steel for beam component B140, column component K315, and threaded steel rod used in the beam–column connection was analyzed in the laboratory to determine the actual characteristics of the reinforcement steel according to the SNI 8389:2017method. The results of the tensile strength analysis for the reinforcement steel and threaded steel can be seen in Table 3 and Figure 14. Based on the analysis, the average tensile strength of the reinforcement steel with an 8 mm diameter is 495 MPa, and for a 10 mm diameter is 598 MPa. Meanwhile, the average tensile strength of the 13 mm threaded steel is 535 MPa. Referring to SNI 2052:2024, the reinforcement used for the B140 beam component and K315 column component meets the minimum tensile strength specification of 350 MPa. Similarly, the threaded steel meets the factory specification with a minimum tensile strength of 460 MPThe results of the mortar compressive strength analysis are presented in Figure 15. Based on the test results, it can be observed that there is a significant difference among the mortars. A notable difference is seen between Mortar type A (7.83 MPa) and type B (2.03 MPa), which have a disparity of 74%. These results indicate substantial variability in material quality, which will affect the consistency of construction work in the field, increase the risk of bond failure in lightweight brick masonry, and ultimately reduce the overall performance of the structural system.

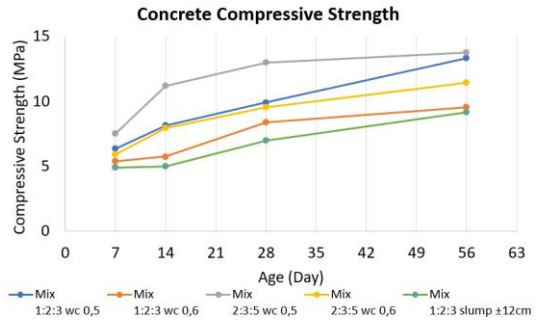

Figure 12 Concrete Compressive Strength Curve Based on Age.

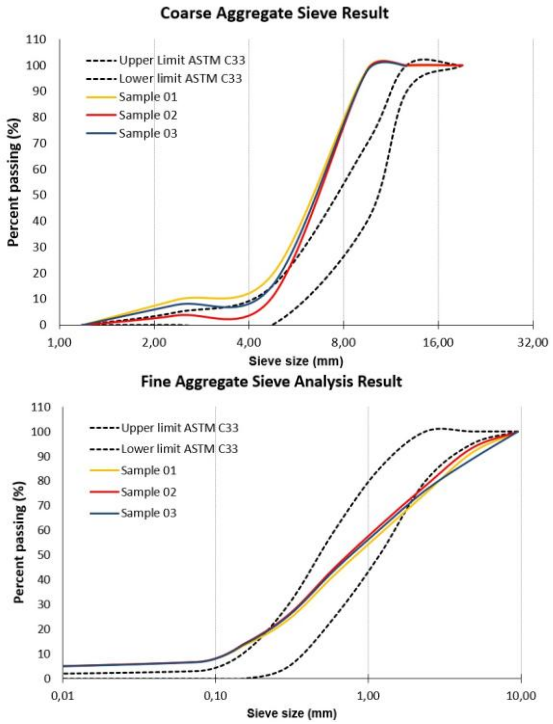

Figure 13 Sieve Analysis Graphs (a) Coarse Aggregate (b) Fine Aggregate.

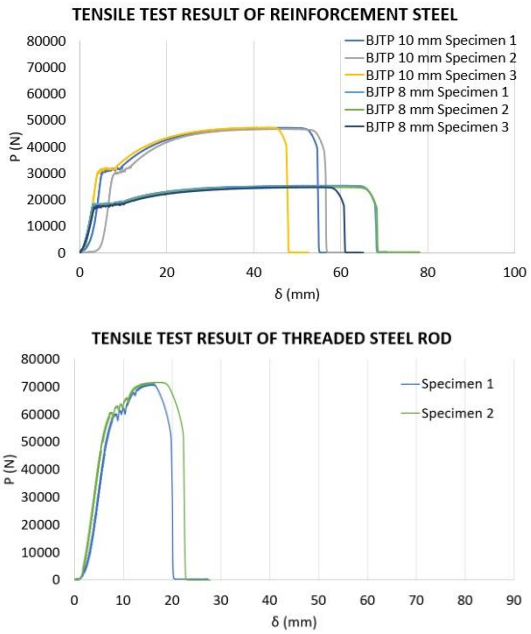

Figure 14 Tensile Test Result Graphs (a) Reinforcement Steel (b) Threaded Steel Rod Joints.

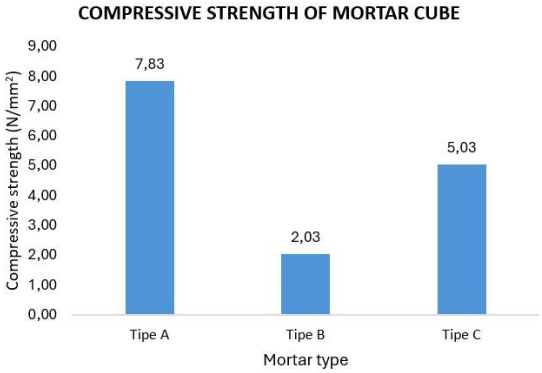

Figure 15 Mortar Compressive Strength Graph.

Table 1 Compressive strength analysis result

No	Mix variation	Mix ratio	Age (days)	Comp. strength (MPa)	Standard deviation
1	Mix of 1:2:3 w/c 0,5	8 cement + 16 fine ag. + 24 coarse ag. + 4 water	7	6,34	0,92
			14	8,12	0,69
			28	9,88	0,96
			56	13,29	0,30
2	Mix of 1:2:3 w/c 0,6	8 cement + 16 fine ag. + 24 coarse ag. + 6 water	7	5,34	0,33
			14	5,72	0,28
			28	8,35	0,28
			56	9,54	0,48
3	Mix of 2:3:5 w/c 0,5	cement + 15 fine ag. + 25 coarse ag. + 5 water	7	7,50	0,76
			14	11,18	0,92
			28	12,98	0,94
			56	13,72	0,93
4	Mix of 2:3:5 w/c 0,6	8 cement + 12 fine ag. + 20 coarse ag. + 4 water	7	5,89	0,38
			14	7,92	0,37
			28	9,53	0,69
			56	11,39	0,49
5	Mix of 1:2:3 slump ±12 cm	8 cement + 16 fine ag. + 24 coarse ag. + 4 water	7	4,87	0,27
			14	4,96	0,97
			28	6,97	0,72
			56	9,16	0,97

In the long term, this inconsistency may also masonry components. The strength of lightweight brick masonry prism is evaluated based on its compressive strength and bond strength characteristics, as shown in the graphs in Figure 16. Based on these graphs, lightweight brick masonry prism using brick type 2 demonstrate higher average compressive and bond strength compared to brick type 1. The graphs also show that although mortar B does not exhibit higher compressive strength than mortar A, mortar B actually provides better bond strength. This finding indicates that mortar B has more effective adhesion properties, contributing more to the bonding capacity and stability of the masonry wall than to its ability to resist compressive loads. This enhanced adhesion plays a more dominant role in maintaining wall performance under service conditions than its ability to resist compressive loads alone.

Structural Component Aspect

Flexural strength analysis was conducted on Column K315 and Beam B140, with the results presented in Table 4 and Figure 17. Based on these data, it is known that Beam B140 and Column K315 have relatively small moment capacities, with values of 1.83 kNm and 2.34 kNm, respectively. This finding indicates that these two elements are not designed to carry large flexural loads but instead function as components that do not resist significant moments. Therefore, Beam B140 and Column K315 cannot be used as standalone structural elements, they must be applied as wall-confined components in the RUCAST system.

Based on the results of the RUCAST connection system analysis presented in Table 5, secant stiffness (Ks) values of 6.84 and 5.66 were obtained. Referring to AISC 360-16, these values satisfy the $2 \leq KsL/EI \leq 20$ criteria, so that the RUCAST connection can be categorized as semi-rigid or partially restrained. The relatively low stiffness shows that the connection behavior tends to be as a hinge, meaning its moment-resisting capacity is limited. This condition affects the lateral stability of the system because the connection is unable to provide adequate moment resistance against significant seismic. Therefore, RUCAST should not be used as a standalone structural element but instead must be supported by lightweight brick masonry as infill walls within the beam–column frame. The results of the diagonal shear strength test of the lightweight masonry wall can be seen in Table 6 Based on these results, the wall component

Table 2 Analysis of aggregate material characteristics

No.	Description		Coarse Aggregate			Fine Aggregate		
			Test Result	Quality Requirement	Remarks	Test Result	Quality Requirement	Remarks
1	Moisture content	%	7.75	Max 1	NOT OK	4.58	Max 3	NOT OK
2	Silt content	%	8.63	Max 1	NOT OK	25.87	Max 3	NOT OK
3	Bulk density							
	- Loose condition	kg/L	1.96	Min 3	NOT OK	2.34	Min 1.2	OK
	- Compacted condition	kg/L	2.04	Min 3	NOT OK	2.47	Min 1.2	OK
4	Specific gravity and water absorption							
	- Oven dry specific gravity	gr/cc	1.55	Min 2,5	NOT OK	2.39	Min 2.5	NOT OK
	- SSD specific gravity	gr/cc	1.79	Min 2,5	NOT OK	2.49	Min 2.5	NOT OK
	- Apparent specific gravity	gr/cc	1.86	Min 2,5	NOT OK	2.66	Min 2.5	NOT OK
	- Water absorption	%	5.37	Min 2,5	OK	4.21	Min 2.5	OK

Table 3 Result of tensile strength analysis of reinforcement steel and threaded steel rod joints

No	Specimen Length (mm)	Diameter (mm)	Tensile Force (N)	Yield Stress (MPa)	Tensile Stress (MPa)
	BJTP 10 mm				
1	499	10	47162	392	600
2	498	10	46712	383	594
3	500	10	47228	386	601
	BJTP 8 mm				
4	498	8	25330	361	503
5	498	8	24780	346	492
6	499	8	24716	346	491
	THREADED STEEL ROD				
7	495	13	70703	467,41	532,68
8	497	13	71492	456,17	538,62

Table 4 Beam and column flexural strength analysis result

No	Component	P (kN)	W (kN)	x (m)	M (kNm)
1	Beam B140	10.54	0.99	0.33	1.92
2	Beam B140	9.46	0.99	0.33	1.74
3	Column K315	3.72	1.39	0.9	2.30
4	Column K315	3.96	1.36	0.9	2.39

Table 5 Semi-rigid connection analysis

No	P (kN)	W (kN)	M (kN.m)	L (m)	δ (m)	$\phi = \delta/L$	Ks = M/Ø
1	0,86	1,37	0,89	0,4	0,052	0,13	6,84
2	0,75	1,37	0,85	0,4	0,059	0,15	5,66

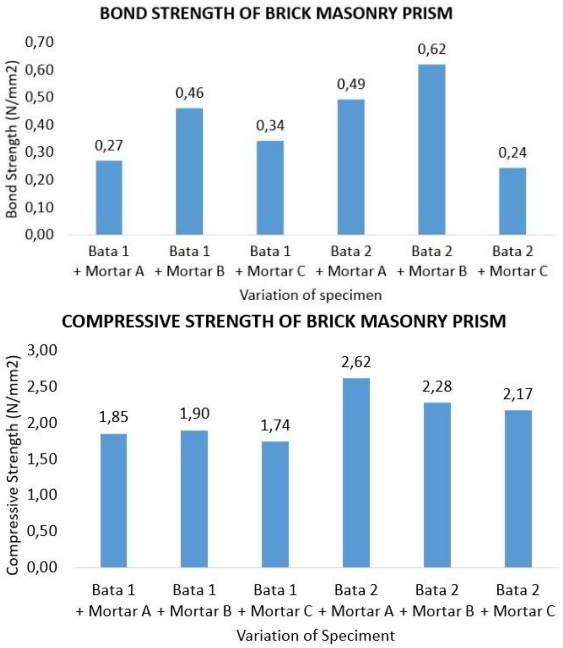

Figure 16 Brick Masonry Prism Test Result Graph (a) Compressive Strength (b) Bond Strength.

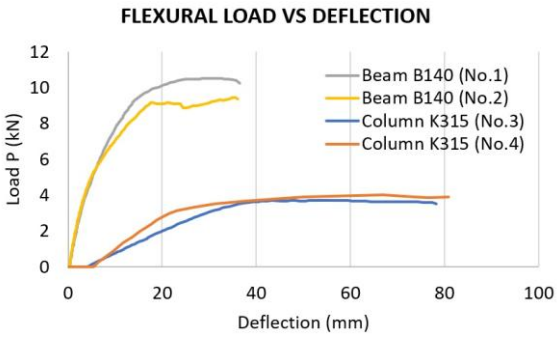

Figure 17 Beam B140 and Column K315 Flexural Strength Comparison Graph.

Figure 18 RUCAST 2D Wall Cyclic Test Setup.

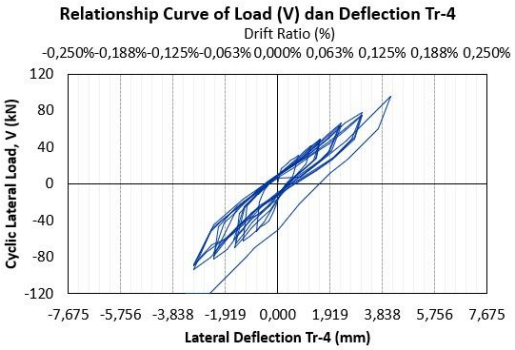

Figure 19 Hysteretic Curve.

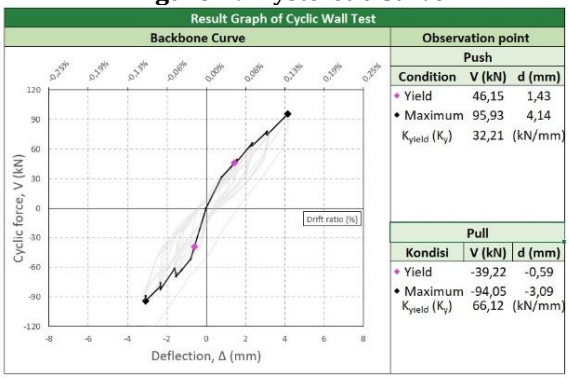

Figure 20 Backbone Curve.

Table 6 Diagonal shear strength analysis of masonry wall

No	Condition	Specimen 1	Specimen 2
1	Weight (kg)	55	60
2	Height (m)	1.2	1.2
3	Width (m)	1.2	1.2
4	Thickness (m)	0.099	0.099
5	Density (kg/m^3)	385.8	420.9
6	P max (kN)	32.8	23.2
7	Area (m^2)	0.1188	0.1188
8	v_m (6/7) (MPa)	0.276	0.195
9	A_w (m^2)	3.3	3.3
10	W_T (kN)	108.2	108.2
11	σ (10/9) (MPa)	0.033	0.033
12	v	0.148	0.107
13	1.5 v_m	0.414	0.293
	Cek v < 1.5v_m	**OK**	**OK**

has an average diagonal shear stress capacity (v_m) of 0.23 MPa. This value meets the acceptance criteria of NTC-M 2004, namely $v \leq 1.5v_m$,

Table 7 Seismic weight calculation

No	Component	Tributary area weight (kN)
1	Roof component	1.05
2	Masonry component	15.86
3	Column component	3.71
4	Beam component	5.44
5	Non-structural accessories	0.99
	TOTAL	**27.05**

indicating that the wall has sufficient shear capacity to resist the diagonal shear forces that occur without experiencing premature failure.

Structural System Aspect

The RUCAST structural system is a confined masonry system applied to both the interior and exterior walls of the building. The cyclic test results of the 2D wall specimen are presented in the form of

a hysteresis curve (hysteretic loop), which illustrates the relationship between the load and deformation experienced by the specimen during cyclic loading, observed at a specific measurement point. In this test, the observation point was taken from transducer TR-4, as shown in Figure 18. The resulting hysteresis curve, shown in Figure 19, is then used for structural capacity analysis. Furthermore, the hysteresis curve is used to determine the backbone curve based on key points such as the yield point and maximum load point, as illustrated in Figure 20. This backbone curve represents the strength and stiffness behavior of the RUCAST structural system.

Based on the obtained backbone curve, as well as the yield and maximum points in both tension and compression (push and pull conditions), the RUCAST confined masonry structure demonstrates a maximum push capacity of 95.93 kN and a maximum pull capacity of 94.05 kN. In determining the design seismic capacity ($V_{capacity}$), the smaller value from both maximum capacity must be divided by an overstrength factor (Ω_0), which value is taken from SNI 1729:2019 Section 7.2.2, namely 2.5 (for bearing wall systems). Thus, the seismic capacity of the RUCAST structural system is 37.62 kN which is subsequently referred to as $V_{capacity}$.

Push lateral capacity:

$$V_{capacity+} = \frac{V_{max+}}{\Omega_0} = \frac{95{,}93}{2{,}5} = 38{,}37\ kN \qquad (7)$$

Pull lateral capacity:

$$V_{capacity-} = \frac{V_{max-}}{\Omega_0} = \frac{94{,}05}{2{,}5} = 37{,}62\ kN \qquad (8)$$

According to SNI 1726:2019 Section 7.7.2, the calculation of the effective seismic weight (W) consists of the self-weight of the structure and the

Table 8 Demand vs capacity (DCR) evaluation of 38 provincial capital locations in Indonesia

No	Location	SS	S1	Site Class SC						Site Class SD						Site Class SE					
				S_{DS}	KDS	Cs	V (kN)	DCR	Status	S_{DS}	KDS	Cs	V (kN)	DCR	Status	S_{DS}	KDS	Cs	V (kN)	DCR	Status
1	Merauke	0.03	0.04	0.03	A	0.03	0.81	0.02	OK	0.03	A	0.03	0.81	0.02	OK	0.05	A	0.05	1.35	0.04	OK
2	Palangka-raya	0.05	0.04	0.04	A	0.04	1.08	0.03	OK	0.05	A	0.05	1.35	0.04	OK	0.08	A	0.08	2.16	0.06	OK
3	Tanjung pinang	0.07	0.11	0.06	A	0.06	1.62	0.04	OK	0.08	A	0.08	2.16	0.06	OK	0.11	A	0.11	2.98	0.08	OK
4	Banjar baru	0.12	0.05	0.05	B	0.05	1.35	0.04	OK	0.09	B	0.09	2.43	0.06	OK	0.19	B	0.19	5.14	0.14	OK
5	Samarinda	0.12	0.10	0.11	B	0.11	2.98	0.08	OK	0.13	B	0.13	3.52	0.09	OK	0.19	B	0.19	5.14	0.14	OK
6	Pangkal-pinang	0.14	0.13	0.12	B	0.12	3.25	0.09	OK	0.15	B	0.15	4.06	0.11	OK	0.23	B	0.23	6.22	0.17	OK
7	Pontianak	0.18	0.05	0.15	B	0.15	4.06	0.11	OK	0.19	B	0.19	5.14	0.14	OK	0.28	B	0.28	7.57	0.20	OK
8	Makassar	0.22	0.11	0.19	B	0.19	5.14	0.14	OK	0.24	B	0.24	6.49	0.17	OK	0.36	C	0.36	9.74	0.26	OK
9	Palembang	0.29	0.25	0.25	B	0.25	6.76	0.18	OK	0.31	B	0.31	8.39	0.22	OK	0.44	C	0.44	11.90	0.32	OK
10	Tanjung selor	0.32	0.14	0.27	B	0.27	7.30	0.19	OK	0.33	C	0.33	8.93	0.24	OK	0.47	C	0.47	12.71	0.34	OK
11	Jambi	0.33	0.26	0.29	B	0.29	7.84	0.21	OK	0.34	C	0.34	9.20	0.24	OK	0.48	C	0.48	12.98	0.35	OK
12	Pekanbaru	0.38	0.30	0.33	C	0.33	8.93	0.24	OK	0.37	C	0.37	10.01	0.27	OK	0.51	D	0.51	13.80	0.37	OK
13	Medan	0.66	0.36	0.54	D	0.54	14.61	0.39	OK	0.56	D	0.56	15.15	0.40	OK	0.63	D	0.63	17.04	0.45	OK
14	Surabaya	0.68	0.30	0.55	D	0.55	14.88	0.40	OK	0.57	D	0.57	15.42	0.41	OK	0.64	D	0.64	17.31	0.46	OK
15	Mamuju	0.69	0.25	0.56	D	0.56	15.15	0.40	OK	0.57	D	0.57	15.42	0.41	OK	0.64	D	0.64	17.31	0.46	OK
16	Kendari	0.70	0.20	0.57	D	0.57	15.42	0.41	OK	0.58	D	0.58	15.69	0.42	OK	0.67	D	0.67	18.12	0.48	OK
17	Jakarta	0.78	0.38	0.63	D	0.63	17.04	0.45	OK	0.62	D	0.62	16.77	0.45	OK	0.67	D	0.67	18.12	0.48	OK
18	Bandar lampung	0.87	0.43	0.70	D	0.70	18.93	0.50	OK	0.67	D	0.67	18.12	0.48	OK	0.70	D	0.70	18.93	0.50	OK
19	Serang	0.89	0.44	0.71	D	0.71	19.21	0.51	OK	0.68	D	0.68	18.39	0.49	OK	0.71	D	0.71	19.21	0.51	OK
20	Semarang	0.91	0.39	0.73	D	0.73	19.75	0.52	OK	0.69	D	0.69	18.66	0.50	OK	0.71	D	0.71	19.21	0.51	OK
21	Denpasar	0.96	0.40	0.77	D	0.77	20.83	0.55	OK	0.71	D	0.71	19.21	0.51	OK	0.73	D	0.73	19.75	0.52	OK
22	Kupang	1.04	0.37	0.83	D	0.83	22.45	0.60	OK	0.75	D	0.75	20.29	0.54	OK	0.74	D	0.74	20.02	0.53	OK
23	Manado	1.03	0.46	0.83	D	0.83	22.45	0.60	OK	0.75	D	0.75	20.29	0.54	OK	0.74	D	0.74	20.02	0.53	OK
24	Mataram	1.03	0.40	0.83	D	0.83	22.45	0.60	OK	0.75	D	0.75	20.29	0.54	OK	0.74	D	0.74	20.02	0.53	OK
25	Sofifi	1.06	0.45	0.85	D	0.85	22.99	0.61	OK	0.76	D	0.76	20.56	0.55	OK	0.75	D	0.75	20.29	0.54	OK
26	Ambon	1.08	0.39	0.87	D	0.87	23.53	0.63	OK	0.77	D	0.77	20.83	0.55	OK	0.75	D	0.75	20.29	0.54	OK
27	Yogyakarta	1.11	0.51	0.89	D	0.89	24.07	0.64	OK	0.78	D	0.78	21.10	0.56	OK	0.75	D	0.75	20.29	0.54	OK
28	Bandung	1.12	0.49	0.90	D	0.90	24.34	0.65	OK	0.79	D	0.79	21.37	0.57	OK	0.75	D	0.75	20.29	0.54	OK
29	Padang	1.12	0.57	0.90	D	0.90	24.34	0.65	OK	0.79	D	0.79	21.37	0.57	OK	0.75	D	0.75	20.29	0.54	OK
30	Banda aceh	1.43	0.56	1.17	D	1.17	31.65	0.84	OK	0.98	D	0.98	26.51	0.70	OK	0.79	D	0.79	21.37	0.57	OK
31	Nabire	1.49	0.60	1.19	D	1.19	32.19	0.86	OK	0.99	D	0.99	26.78	0.71	OK	0.80	D	0.80	21.64	0.58	OK
32	Bengkulu	1.50	0.60	1.20	D	1.20	32.46	0.86	OK	1.00	D	1.00	27.05	0.72	OK	0.80	D	0.80	21.64	0.58	OK
33	Gorontalo	1.50	0.60	1.20	D	1.20	32.46	0.86	OK	1.00	D	1.00	27.05	0.72	OK	0.80	D	0.80	21.64	0.58	OK
34	Jayawijaya	1.50	0.60	1.20	D	1.20	32.46	0.86	OK	1.00	D	1.00	27.05	0.72	OK	0.80	D	0.80	21.64	0.58	OK
35	Jayapura	1.50	0.62	1.20	D	1.20	32.46	0.86	OK	1.00	D	1.00	27.05	0.72	OK	0.80	D	0.80	21.64	0.58	OK
36	Palu	1.50	0.60	1.20	D	1.20	32.46	0.86	OK	1.00	D	1.00	27.05	0.72	OK	0.80	D	0.80	21.64	0.58	OK
37	Sorong	1.60	0.65	1.28	D	1.28	34.62	0.92	OK	1.07	D	1.07	28.94	0.77	OK	0.85	D	0.85	22.99	0.61	OK
38	Manokwari	2.51	0.85	2.01	E	2.01	54.37	1.45	**Not OK**	1.67	E	1.67	45.17	1.20	**Not OK**	1.34	E	1.34	36.25	0.96	OK

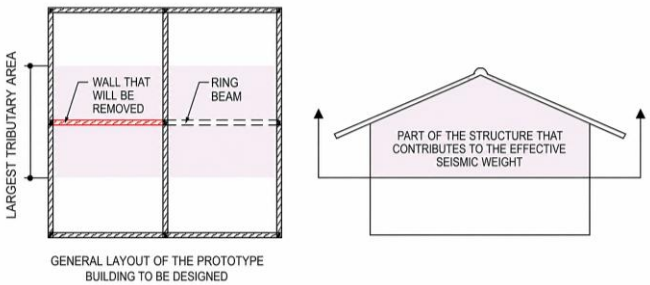

Figure 21 Illustration of Tributary Area In Effective Seismic Weight Calculation.

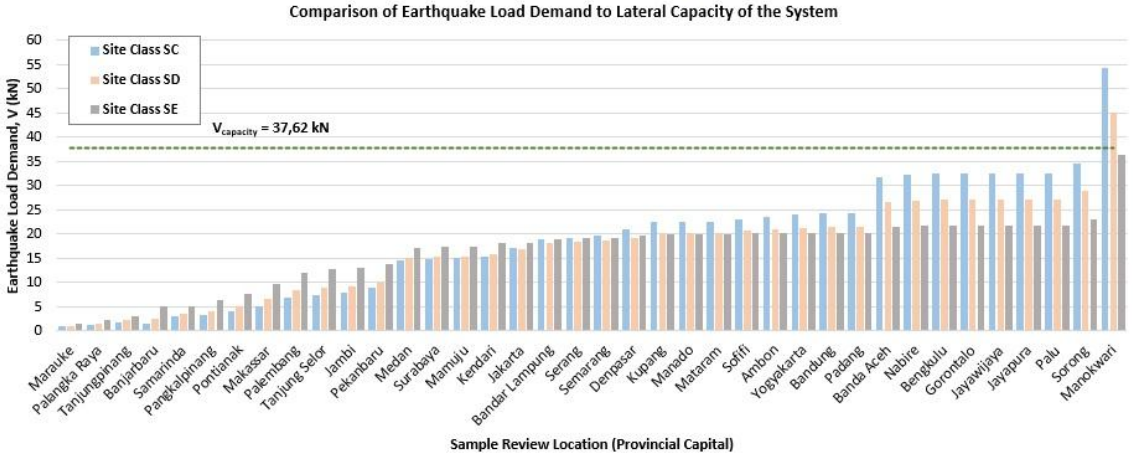

Figure 22 Graphical presentation of demand vs capacity check

weight of secondary components attached to the structure. Since the test specimen used is a wall segment, the structural weight considered is adjusted based on the tributary area carried by the wall. The illustration and calculation of tributary area is shown in Figure 21 and Table 7.

The structural strength assessment of the RUCAST system was carried out using a Demand vs Capacity Ratio (DCR) analysis. The analysis was performed by comparing the capacity ($V_{capacity}$) with the design earthquake load (V), represented as an equivalent static seismic force calculated using the equation $V = C_s \times W$. In this study, the sample locations used for calculating V included 38 provincial capital cities, considering soil site classes hard soil (SC), medium soil (SD), and soft soil (SE). RUCAST wall structural system will be considered to have adequate in-plane shear (earhquake force) resistance if $V_{capacity} \geq V$ or if the DCR value is less than 1. The DCR calculation results for the sampled locations are presented in Table 8, while Figure 22 shows the graphical evaluation of the DCR values. Based on the analysis, it can be concluded that RUCAST possesses sufficient seismic capacity for 37 out of 38 provincial capital locations in Indonesia,for soil site classes SC, SD, and SE. The RUCAST wall structural system is adequate for locations with $S_{DS} \leq 1.38g$.

Deformation and damage occurring during the testing process were continuously monitored. As shown in Figure 23, the wall damage pattern is marked with blue lines (tension cracks) and black lines (compression cracks). The first crack appeared at the interface between the bottom tie beam (sloof) and the foundation. This occurred because no anchor connection was provided between the bottom tie beam and the foundation. This was followed by minor cracking in the hydraulic jack area during the pushing phase due to the weak confinement of the column–beam assembly in resisting localized loads. Subsequently, horizontal (sliding) and diagonal (shear) cracks appeared on the lower right and left sides of the wall, followed by cracking in the upper area that was not in contact with the hydraulic jack. These observations reinforce the hypothesis that when a 3 × 3 m confined masonry wall panel is subdivided by a central column and beam, shear cracking patterns will form in each of the four smaller wall segments created by the column–beam partition.

As loading increased, at a drift of 0.15%, localized damage around the hydraulic jack grew more severe, causing the tie strap to detach from the wall and forcing the test to be stopped. Based on these observations, the RUCAST wall structure exhibited the expected damage pattern shear cracking across the wall panel, characterized by diagonal cracks forming an angle of approximately 45°. Although the crack widths were not large, these diagonal cracks were visible in all four smaller wall segments separated by the column and beam in the middle of the 3 × 3 m wall panel.

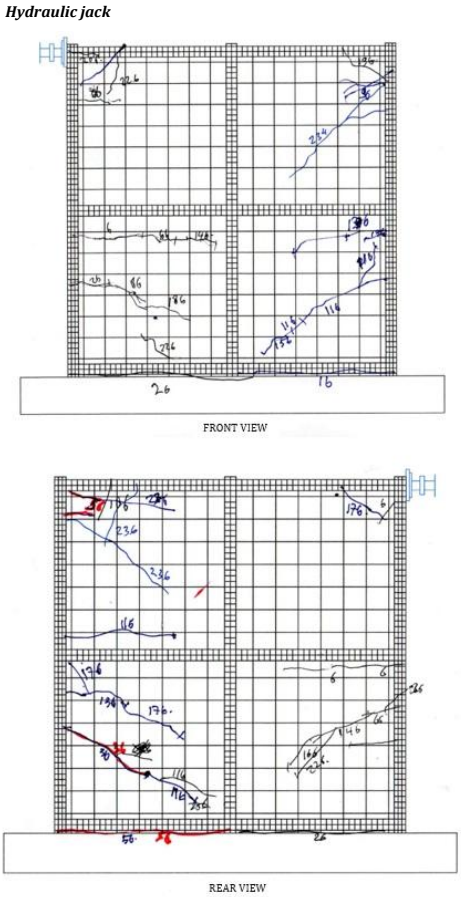

Figure 23 Damage Patterns on Wall Specimen.

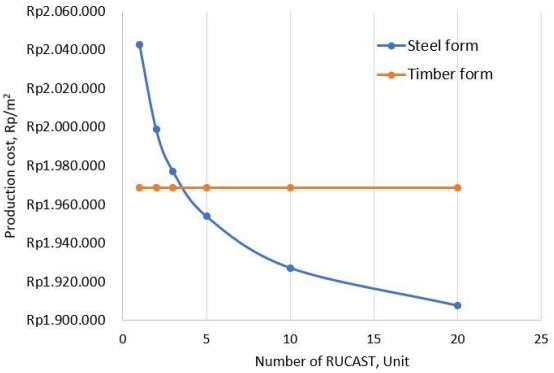

Figure 24 Diagram of Relationship between the number of units and RUCAST production cost

Table 9 Comparison of RUCAST construction costs based on steel and wood formwork

Number of units	Number of B140 form	Number of K315 form	cost/m² for steel form (IDR)	cost/m² for timber form (IDR)
1	10	3	2.042.938	1.968.763
2	10	3	1.998.777	1.968.763
3	12	3	1.977.174	1.968.763
5	17	5	1.953.859	1.968.763
10	20	6	1.927.133	1.968.763
20	27	8	1.907.587	1.968.763

Cost Aspect

The comparison between steel and timber formwork for optimizing mass production of the RUCAST system has been carried out in this study. Based on the construction cost calculations, the cost of RUCAST using steel formwork is Rp. 2.042.938,- per square meter, while using timber formwork results in a cost of Rp. 1.968.763,- per square meter.

Table 9 shows the most efficient number of steel panel molds required to produce RUCAST components in each production cycle. If the number of formwork molds used is lower than this efficient amount, the construction cost of RUCAST will likely increase due to reduced work productivity. Conversely, if the number of molds exceeds the efficient amount, the construction cost will also.increase because of the higher quantity of formwork materials. Table 9 also indicates that timber formwork is cheaper than steel formwork when producing a single RUCAST unit. However, for producing more than five units, steel formwork becomes more cost-effective compared to timber. The more units constructed, the more efficient and economical steel formwork becomes.

The unit–cost relationship chart in Figure 24 illustrates that for the construction of five RUCAST units, steel formwork becomes 1% cheaper than timber formwork, with the cost advantage increasing as the number of RUCAST units grows. A comparative cost analysis was carried out between RUCAST production and an existing similar technology, RISHA, using steel formwork and the same layout, as shown in Table 10. Based on the analysis results, the cost of constructing one unit of RISHA is Rp. 98.474.027,- while for one unit of RUCAST requires Rp. 73.582.241,-. Therefore, in general, the budget required to produce one RUCAST unit is lower than that of one RISHA unit.

CONCLUSION

This study demonstrates that the RUCAST structural system, with its slender beam–column components and a column spacing of 1.5 meters, is capable of providing flexible floor plans and spatial aesthetic advantages. Although the resulting concrete strength is low due to substandard aggregate quality, the reinforcing steel and mechanical connections meet SNI requirements. The performance of mortar and lightweight brick

Table 10 Comparation of RUCAST with RISHA Construction Cost

Construction Stage	Unit	Volume	Rucast Unit Price (Rp)	Rucast Total Price (Rp)	Risha Unit Price (Rp)	Risha Total Price (Rp)
A. PREPARATION STAGE						
A.1. Site cleaning	m^2	36.0	15,000.00	540,000.00	15,000.00	540,000.00
A.2. Measurement and installation of batter boards	m'	24.0	82,910.00	1,989,840.00	82,910.00	1,989,840.00
B. EARTHWORK						
B.1. Excavation	m^3	1.9	60,750.00	116,640.00	60,750.00	214,326.00
B.2. Stands backfill	m^3	0.4	305,142.86	123,033.60	305,142.86	123,033.60
C. FOUNDATION STRUCTURE WORK						
C.1. Working floor K-100	m^3	1.8	810,419.00	1,458,754.20	810,419.00	1,458,754.20
C.2. Stone foundation	m^3	1.9	711,978.57	1,366,998.86	711,978.57	2,511,860.40
D. SUPERSTRUCTURE WORK						
D.1. Panel B140/Panel 1	buah	68.0	140,105.82	9,527,195.58	258,137.38	20,134,715.70
D.2. Panel K310/Panel 2	buah	20.0	249,708.62	4,994,172.45	373,568.58	11,207,057.35
D.3. Panel P3 (RISHA)					227,627.79	6,828,833.77
E. ROOF WORK						
E.1. Roof frame installation	m^2	50.4	146,531.67	7,380,800.05	146,531.67	7,380,800.05
E.2. Roof covering installation	m^2	50.4	36,515.00	1,839,260.55	36,515.00	1,839,260.55
E.3. Roof tile installation	m^2	50.4	124,875.00	6,289,953.75	124,875.00	6,289,953.75
F. ARCHITECTURAL WORK						
F.1. Wall work						
F.1.1. Brick installation	m^2	79.2	151,278.57	11,981,262.86	151,278.57	11,981,262.86
F.1.2. Plastering	m^2	158.4	37,489.54	5,938,343.59	37,489.54	5,938,343.59
F.1.3. Smoothing/Acian	m^2	158.4	21,050.00	3,334,320.00	21,050.00	3,334,320.00
F.1.4. Painting	m^2	158.4	14,640.00	2,318,976.00	14,640.00	2,318,976.00
F.2. Ceiling work						
F.2.1. Ceiling frame installation	m^2	36.0	186,900.00	6,728,400.00	186,900.00	6,728,400.00
F.2.2. Gypsum installation	m^2	36.0	27,597.00	993,492.00	27,597.00	993,492.00
F.2.3. Ceiling painting	m^2	36.0	14,640.00	527,040.00	14,640.00	527,040.00
F.3. Flooring work	m^2	36.0	140,248.57	5,048,948.57	140,248.57	5,048,948.57
G. MECHANICAL, ELECTRICAL, AND PLUMBING WORK						
G.1. Lamp instalation	point	4.0	271,202.31	1,084,809.23	271,202.31	1,084,809.23
TOTAL				**73,582,241.29**	**TOTAL**	**98,474,027.62**
TOTAL/m^2				**2,043,951.15**	**TOTAL/m^2**	**2,735,389.66**

masonry is considered adequate based on compressive strength, bond strength, and shear strength, all of which remain within the acceptable limits of NTC-M 2004. Flexural analysis indicates that RUCAST beams and columns are not effective as moment-resisting elements, making them more suitable as wall-restraining components. Its mechanical connections are categorized as semi-rigid and require the support of masonry walls to improve system stiffness.

Overall, the shear wall capacity of RUCAST is deemed suitable for application in nearly all provincial capitals in Indonesia, with damage patterns aligning with expectations. From a cost perspective, mass production of RUCAST using steel molds proves more economical, up to 25.28% cheaper than comparable precast technologies such as RISHA. Considering these findings, it is recommended that variations in house layouts comply with the irregularity provisions of SNI 1726:2019 Article 7.3.2. Additional, in developing RUCAST housing typologies, structural analysis software can be utilized to refine calculations and increase safety factors to accommodate variability in concrete quality in real-field conditions. To prevent failure in field implementation, guidelines and manuals for RUCAST design and construction should be prepared.

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The Potential of Greywater Utilization Through Circular Economy Approach in Urban Areas: A review

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Abstract

The development of urban areas in Indonesia continues to accelerate in line with increasing urbanization and rapid population growth. Greywater which is domestic wastewater from activities such as bathing and washing, accounts for 60–70% of total household wastewater and holds significant potential for reuse. This paper examines the optimization of greywater utilization through a circular economy approach that emphasizes recycle, reuse, and resource efficiency. The use of greywater not only helps reduce clean water consumption and the burden on wastewater treatment systems but also supports urban irrigation, sanitation, building cooling, and fire suppression. The implementation model includes the design of greywater collection systems, treatment technologies, and distribution networks. Environmental impacts include water conservation, pollution reduction, and energy savings, while economic benefits consist of lower operational costs, increased property value, and job creation. For city-scale implementation, regulations, financial incentives, spatial planning integration, public education, and cross-sector collaboration are essential. The optimization of greywater is considered a strategic step in supporting sustainable infrastructure development and in realizing resilient and competitive cities in the future.

Keywords: Circular economy, greywater, urban areas, water conservation, water treatment.

Abstrak

Pembangunan wilayah perkotaan di Indonesia terus mengalami percepatan seiring dengan meningkatnya urbanisasi dan pertumbuhan populasi yang pesat. Air limbah domestik kategori greywater, berkontribusi sekitar 60–80% timbulan air limbah yang berpotensi besar untuk dimanfaatkan kembali. Pada studi ini mengkaji optimalisasi pemanfaatan greywater melalui pendekatan ekonomi sirkuler yang menekankan daur ulang, penggunaan ulang, dan efisiensi sumber daya. Pemanfaatan greywater tidak hanya mampu mengurangi konsumsi air dan beban sistem pengolahan limbah, tetapi juga mendukung irigasi perkotaan, sanitasi, pendinginan bangunan, serta pemadaman kebakaran. Model implementasi mencakup desain sistem pengumpulan, teknologi pengolahan, dan distribusi greywater. Dampak lingkungan berupa konservasi air, pengurangan polusi, dan penghematan energi, sedangkan manfaat ekonomi meliputi pengurangan biaya operasional, peningkatan nilai properti, dan penciptaan lapangan kerja. Untuk implementasi skala kota, diperlukan regulasi, insentif, integrasi tata ruang, edukasi publik, serta kolaborasi lintas sektor. Optimalisasi greywater dinilai strategis dalam mendukung pembangunan infrastruktur berkelanjutan dan mewujudkan kota yang tangguh serta berdaya saing di masa depan.

Kata Kunci: *Air limbah rumah tangga, ekonomi sirkular, kawasan perkotaan, konservasi air, pengolahan air.*

INTRODUCTION

The development of urban areas in Indonesia continues to accelerate in line with increasing urbanization and rapid population growth. This situation presents major challenges in resource management, particularly water, which is a vital element in sustaining urban life. The rising demand for clean water, compounded by climate change and the limited availability of water resources, necessitates innovation in urban water management. One potential approach that has begun to receive attention is the utilization of greywater, or household wastewater that does not contain human excreta (Oh et al., 2018).

Greywater, which originates from the use of water in bathtubs, showers, sinks, and washing machines, accounts for nearly 60–80% of total household wastewater (Jakhar & Styszko, 2025). When properly managed, greywater can serve as an alternative water source for various purposes, such as irrigation, sanitation, and even reuse within clean water systems after undergoing filtration processes. In this context, optimizing greywater utilization not only reduces pressure on clean water resources but also supports the concept of a circular economy, in which resources are used efficiently and waste is minimized (Fountoulakis et al., 2016).

The circular economy emphasizes principles of sustainability by reducing waste, recycling materials, and optimizing resource utilization. When applied to greywater management, this concept can create a more sustainable and resilient water management system, particularly in densely populated urban areas. The implementation of a circular economy in urban infrastructure can further support sustainable development goals, such as reducing greenhouse gas emissions, improving energy efficiency, and preserving aquatic ecosystems (Suarez-Eiroa et al., 2019).

METHOD

This study aims to examine the concepts of sustainability and environmental friendliness in greywater treatment infrastructure, as well as the circular economy approach for wastewater management in Indonesia's city for urban areas. In addition, this study considers the characteristics of cities that directly influence greywater generation and management. Urban areas are typically marked by high population density, rapid urbanization, extensive commercial and industrial activities, and intensive water consumption patterns.

These conditions result in a significant volume of greywater accounting for up to 60–80% of household wastewater originating from daily activities such as bathing, washing, and cleaning. The concentration of high-rise residential buildings, commercial facilities, and centralized infrastructure systems further creates both challenges and opportunities for implementing large-scale greywater collection, treatment, and reuse.

This study adopts a literature-based research method using a structured review of peer-reviewed scientific journal articles as primary sources. Relevant publications were identified through academic databases such as Scopus, Web of Science, and Google Scholar using keywords including "greywater utilization," "urban water reuse," "circular economy," and "sustainability." Articles were selected based on their relevance to urban areas contexts, publication quality, and focus on environmental, economic, or policy aspects of greywater reuse.

The selected literature was analyzed using a descriptive and comparative approach. Each study was systematically reviewed to identify key themes related to greywater utilization, including implementation models, technological approaches, environmental impacts, economic feasibility, and regulatory frameworks. The circular economy perspective was incorporated by examining how greywater reuse contributes to resource efficiency, waste reduction, and closed-loop water management systems.

Furthermore, sustainability aspects were assessed by categorizing findings into environmental, economic, and social dimensions. Based on this synthesis, the study evaluates the potential of greywater utilization in urban areas and formulates policy recommendations and implementation strategies that support sustainable urban water management.

RESULTS AND DISCUSSION

The findings from the literature review indicate that greywater utilization has a strong correlation with the optimization of infrastructure development oriented toward a circular economy, particularly in urban areas of Indonesia.

Potential of Greywater Utilization

The availability of greywater in urban areas can be estimated by calculating the volume of water used for domestic purposes, excluding water used for toilets and other activities that generate blackwater, as shown in Figure 1 (Filali et al., 2022). For instance, in a household with an average water consumption of 200 Liters per person per day, approximately 120–140 Liters can be categorized as greywater (Khajvand et al., 2022). With the

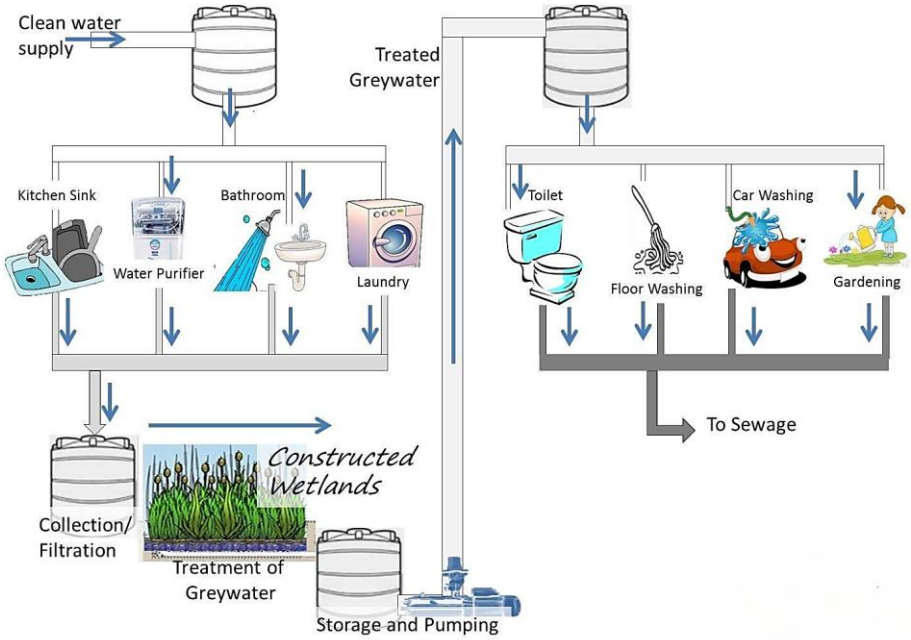

Figure 1 Illustration of Greywater Recycling. (Source: Naik, 2016).

Figure 2 Illustration of Urban Irrigation for Vegetation in Residential Areas. (Source: The Toro Company, 2022)

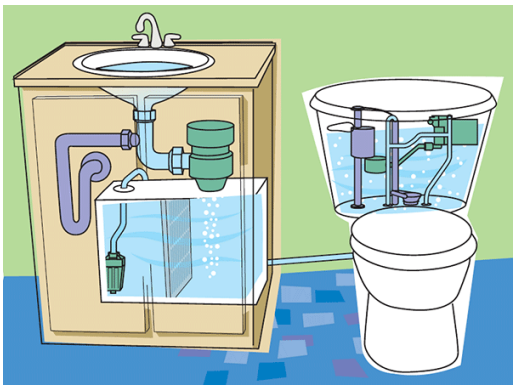

Figure 3 Illustration of Greywater Recycling for Toilet Flushing. (Source: INTERNachi, 2024)

population of Indonesia's cities reaching into the millions, the amount of available greywater is highly significant and offers substantial potential for reuse.

The potential of utilization of greywater in urban areas can provide considerable benefits across various aspects of basic urban infrastructure. The following are some of the potential applications of greywater: urban irrigation, sanitation and toilet systems, building cooling and fire suppression.

Greywater can be used for irrigating gardens, green spaces, and other forms of urban vegetation. This practice reduces the demand for clean water extracted from primary sources such as river intakes, thereby helping to conserve freshwater resources and reduce pressure on municipal distribution systems. Furthermore, since greywater contains nutrients such as phosphorus and nitrogen, which can benefit plant growth, it contributes to healthier vegetation without the need for additional fertilizers (Figure 2).

The reuse of greywater for sanitation systems, particularly toilet flushing, is one of the most common household-level applications. Utilizing greywater for this purpose can reduce clean water consumption in simple households by up to 30% (Radingoana et al., 2020).

To address water scarcity, a simple filtration technology is applied to remove physical and chemical impurities from greywater effluent, enabling its safe reuse for toilet flushing in accordance with minimum quality standards. As illustrated in Figure 3, this technology is cost-effective, easy to implement, and adaptable to local environmental conditions and community capacities. In addition to its technical benefits, the adoption of this system contributes to increased public awareness of sustainable wastewater management practices by promoting greywater utilization for sanitation purposes at both household and community levels. This approach demonstrates the potential of decentralized

greywater treatment systems to support water conservation efforts and enhance the resilience of urban water management systems.

In several commercial and industrial buildings, greywater can be utilized as cooling water for HVAC (Heating, Ventilation, and Air Conditioning) systems or for fire suppression purposes, as shown in Figure 4. This practice not only reduces the demand for potable water but also lowers the operational costs of buildings. Greywater reuse systems can reduce freshwater consumption by approximately 30–70% in residential and commercial buildings, depending on the scale of application and end-use purposes such as toilet flushing (Olanrewaju & Ilemobade, 2015). Such an approach is particularly relevant in cities characterized by a high concentration of high-rise buildings and industrial facilities.

The utilization of greywater provides not only environmental benefits but also economic advantages. By reducing clean water consumption, cities can lower water distribution costs, decrease the burden on wastewater treatment systems, and strengthen resilience against future water shortages (Handoko, 2016). However, effective implementation requires careful planning, appropriate technologies, and supportive regulations to ensure that greywater is used safely and efficiently.

Circular Economy System Approach

The circular economy is a paradigm aimed at optimizing resource use through the principles of recycling, reusing, and repurposing materials previously regarded as waste (Kaimal & Sajoy, 2020). In the context of greywater management in cities, this approach is highly relevant because it can transform wastewater into a valuable resource. The application of circular economy principles to greywater management encompasses several key steps, including: strategies such as reduction and reuse, recycling, and greywater recovery.

Reduction and reuse are two core concepts in the circular economy approach applied to greywater management in cities (Ramirez-Agudelo et al., 2021). The primary objective of this strategy is to significantly reduce clean water consumption while reusing greywater for various non-potable purposes, thereby minimizing waste and optimizing the use of available water resources. Reducing clean water consumption by reusing greywater for non-potable needs such as irrigation and sanitation systems not only lessens dependency on limited water resources but also decreases the burden on clean water distribution systems.

The process of recycling and recovering greywater involves a series of treatment stages designed to remove contaminants and restore water quality so that it can be safely reused in various non-potable applications (Hibatullah, 2019). The main principle of this approach is to transform waste into a valuable resource, reduce the strain on clean water sources, and minimize wastewater discharged into the environment.

Several key principles in greywater recycling and recovery include: contaminant reduction through treatment technologies, nutrient and resource recovery, integration with municipal wastewater and water systems.

Greywater treatment technologies are designed to remove solid particles, chemicals, and microorganisms that could pose health risks or

Figure 4 Illustration of HVAC System in Office Buildings. (Source: Envigaurd, 2025)

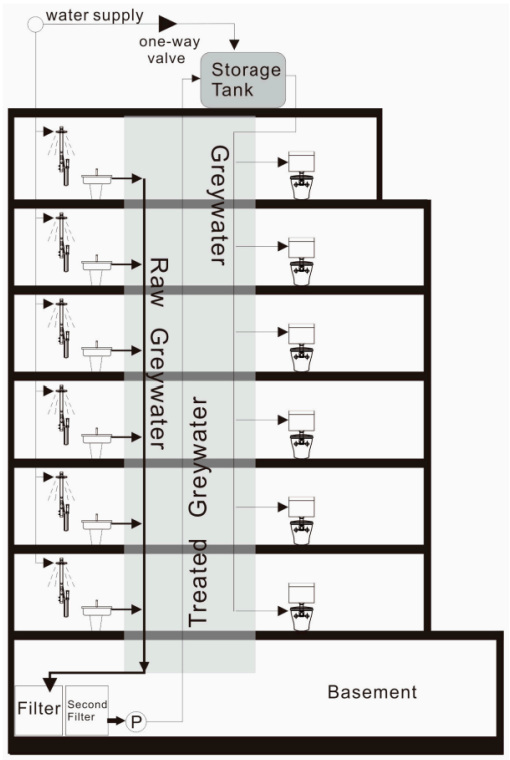

Figure 5 Scheme of greywater collection and distribution in Multi-Story Buildings. (Source: Juan et al., 2016)

cause environmental damage. Greywater contains nutrients such as phosphorus and nitrogen that, after treatment, can be reused for irrigation or urban agriculture. This nutrient recovery not only reduces the need for chemical fertilizers but also helps mitigate groundwater and surface water pollution. Furthermore, the treated greywater can be utilized for other purposes such as cooling or cleaning, thereby reducing the demand for clean water. Greywater recycling and recovery technologies should be integrated with existing wastewater and clean water management systems. This integration allows for greater efficiency in overall water resource management and ensures that treated water can be safely distributed and reused.

The implementation of circular economy systems in greywater management also involves collaboration among various stakeholders including government, industry, and communities to establish mutually beneficial value chains (Mbavarira et al., 2021).

Greywater Treatment and Distribution Systems

The application of greywater reuse on a urban scale requires efficient and effective treatment and distribution design. A well-designed system will produce outputs of higher quality for end use. The main components of a circular economy-based greywater implementation model include: greywater collection systems, greywater treatment technologies, distribution and reuse systems, as well as monitoring and maintenance.

Greywater collection begins at its source, such as households, commercial buildings, and public facilities. As shown in Figure 5, separate pipe installations channel greywater from bathtubs, sinks, and washing machines to storage tanks as the first step in the system. For households and multi-story buildings, the difference lies mainly in the quantity of inlet pipes and storage reservoirs prior to treatment. The design of the pipes and tanks must consider the volume of greywater generated and the temporary storage needs before processing. In addition, the system design should incorporate basic pretreatment measures, such as coarse screening or sedimentation, to prevent the accumulation of solids and organic matter that may affect downstream treatment performance. Proper hydraulic design is also essential to avoid stagnation and odor formation during storage, particularly in warm urban environments. Furthermore, routine maintenance and monitoring of storage tanks and pipe networks are required to ensure operational reliability and maintain the quality of greywater prior to treatment.

Greywater treatment technologies vary depending on the intended end use. For irrigation purposes, simple filtration may suffice, while applications in sanitation or cooling systems require more advanced technologies such as biofilters , membrane filtration. The selection of appropriate treatment technology should therefore be based on water quality requirements, system complexity, and operational and maintenance considerations to ensure safe and sustainable reuse. Technology choices must take into account energy efficiency, operational costs, and the quality of water produced. For example, if greywater is used only at the household scale and sourced primarily from sinks, simple granular filtration systems may be adequate (Figure 6). However, in building with diverse sources, more advanced technologies for treatment and disinfection process such as Ultra Violet (UV) systems or ozone method may be necessary (Wenjun et al., 2024) .

Once treated, greywater is redistributed through separate pipelines for various applications such as urban irrigation, sanitation, and building cooling. The distribution network design must consider the location of end users, required water meter, water pressure, water quality online monitoring and system maintenance (Adu-Manu et al., 2017). In addition, integration with municipal water management systems allows greywater to be flexibly used based on demand and availability. The implementation of greywater systems requires strict monitoring mechanisms to ensure that water quality remains safe and meets established standards. Automated monitoring systems can be used to detect contamination and assess system performance in real time. Routine maintenance is also essential to prevent deterioration in water quality and system failures (Ahmed et al., 2020).

Environmental and Economic Impacts of Greywater Utilization

The use of greywater as part of sustainable infrastructure development based on a circular economy system in cities has significant environmental and economic impacts. Proper implementation not only helps reduce pressure on clean water resources but also provides economic benefits that can foster long-term sustainability (Makanda et al., 2022). The environmental impact of greywater utlization identified from some literatures as follows: reduction in clean water consumption, the reduced burden on wastewater treatment systems, as well as the reduction of pollution and environmental contamination.

Greywater utilization directly decreases the demand for clean water, especially for non-potable purposes such as irrigation, toilet flushing, and cleaning. By lowering clean water demand, cities can maintain the balance of aquatic ecosystems and reduce pressure on scarce water resources. This is especially crucial in urban areas that often face

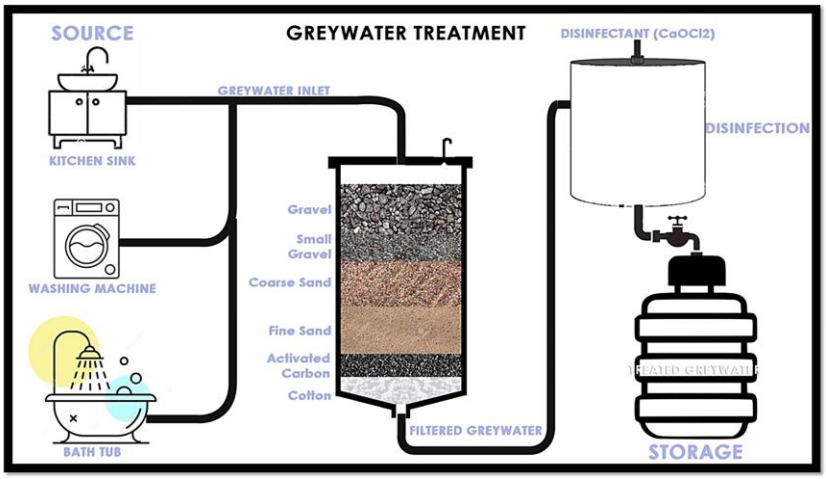

Figure 6 Scheme of filtration system for greywater treatment. (Source: Makhitha et al., 2021)

water availability challenges due to population growth and climate change (Stavenhagen et al., 2018).

Reusing greywater reduces the volume of wastewater that must be treated by municipal systems. This improves treatment efficiency and lowers the risk of water pollution caused by overloaded facilities. The reduced burden also has the potential to extend the lifespan of existing wastewater infrastructure and minimize the need for costly new investments (Tarpani & Azapagic, 2018). Properly Reduction of Pollution and Environmental Contamination treated greywater lowers the amount of wastewater discharged into sewer systems, thereby reducing the potential for groundwater and surface water contamination. By decreasing pollutants such as household chemicals, excessive nutrients, and pathogenic microorganisms in discharged wastewater, surrounding water quality can be preserved and aquatic ecosystems protected (Akhtar et al. 2021).

Energy Conservation and Carbon Footprint Reduction

The treatment and distribution of clean water require significant energy inputs. By reducing dependence on clean water through greywater utilization, energy consumption associated with water treatment also decreases (Zavala et al., 2016). Additionally, lower clean water usage and more efficient wastewater management contribute to reduced greenhouse gas emissions, helping cities achieve carbon footprint reduction targets. Alongside environmental impacts, greywater utilization also yields several economic benefits, including: operational cost savings, increased property and infrastructure value, job creation and new industries, reduced financial burden on water infrastructure, as well as enhanced economic resilience of cities.

One of the primary economic benefits of greywater utilization is substantial cost savings for both municipal governments and communities. By reusing greywater for non-potable applications, expenses associated with clean water procurement and treatment can be reduced. These savings may be redirected to fund other sustainability initiatives or to ease financial burdens on households through lower water tariffs (Brown et al., 2020). Properties equipped with greywater utilization systems often hold higher value than those without, as such systems demonstrate a commitment to sustainability and resource efficiency attributes increasingly valued by consumers. Moreover, city infrastructure that supports greywater reuse can attract investment and promote more sustainable economic development (Silva, 2023).

The development and implementation of greywater utilization technologies can stimulate new industries, such as greywater treatment equipment manufacturing, installation services, and maintenance providers. This fosters job creation in the green technology sector and enhances the skills of the local workforce in sustainability-related fields (Khan et al., 2025). By decreasing the volume of water that must be treated and distributed through municipal clean water systems, the financial strain on water infrastructure is reduced. This enables city governments to allocate resources to other pressing areas, such as infrastructure maintenance or the development of additional public services. Furthermore, this reduction can delay or even eliminate the need for costly water infrastructure expansion, thereby providing significant long-term savings (Pot, 2023). By reducing dependency on limited clean water resources, cities can strengthen their resilience against economic fluctuations caused by water crises, such as droughts or rising water costs (O'Connell, 2017). Such resilience is essential for maintaining urban economic stability

and ensuring that the population's basic needs continue to be met under diverse environmental and economic conditions.

Policy Recommendations and Implementation Strategies

The utilization of greywater in sustainable infrastructure development in cities is a strategic step toward optimizing limited water resources and reducing environmental impacts (Tansar et al., 2024). When integrated into urban water management planning, greywater reuse systems can also enhance water security and support long-term sustainability goals in densely populated areas. To achieve this goal, supportive policies and comprehensive implementation strategies are required. The following policy recommendations and implementation strategies can be applied.

Policy Recommendations

Municipal governments must establish clear and comprehensive regulations and standards for greywater quality. These regulations should include water quality requirements, treatment procedures, and guidelines for the reuse of greywater in various non-potable applications (Vuppaladadiyam et al., 2018). The standards must be based on comprehensive scientific research and adapted to local conditions and the specific needs of urban areas, including financial incentives for greywater technology implementation, integration of greywater into spatial planning and infrastructure development, public education and awareness campaigns, as well as the strengthening of cross-sectoral collaboration.

To encourage the adoption of greywater treatment technologies, municipal governments can provide financial incentives such as subsidies, tax reductions, or affordable financing schemes for communities, property developers, and industries that invest in greywater treatment infrastructure (Thaher et al., 2020). These incentives will reduce the initial investment burden and accelerate the adoption of greywater technologies citywide. Urban spatial planning policies must integrate greywater utilization as part of city water management strategies. This includes incorporating greywater treatment and distribution systems into new infrastructure designs, as well as upgrading existing infrastructure to support greywater use. Such integration should be reinforced by policies requiring greywater systems in new large-scale development projects (Finewood, 2016).

Effective policies must be supported by extensive public education campaigns to increase community awareness of the importance of greywater utilization. These programs should provide information on how to separate and treat greywater, explain the economic and environmental benefits of its use, and offer practical guidance for implementation at homes and workplaces. Education efforts may also involve collaboration with schools, universities, and research institutions (Sulaiman et al., 2025). Governments must establish cross-sector partnerships involving stakeholders such as the private sector, research institutions, and civil society. Such collaboration is essential for technology development, innovation, and knowledge exchange in greywater management. In addition, public-private partnerships can be utilized to finance and manage complex greywater infrastructure projects (Shahdadi et al., 2023).

Implementation Strategies

Implementation strategies must begin with the development of adequate greywater treatment infrastructure across the city. This includes the construction of small- to large-scale treatment facilities integrated with existing clean water and wastewater systems. The infrastructure must be designed for energy efficiency, minimal environmental impact, and adapted to the specific conditions of each urban area (Gong & Hu, 2017). Additional measures include pilot projects in urban areas, monitoring and evaluation, capacity building and training, the development of sustainable business models, as well as the adoption of innovative technologies. As an initial step, municipal governments can launch pilot projects in selected areas, such as residential districts, commercial buildings, or industrial zones. These projects serve as implementation models that can be evaluated and refined before broader citywide application. The outcomes of pilot projects can be used to improve broader policies and technical guidelines (Bundgaard & Borras, 2021).

Rigorous oversight and continuous evaluation are essential components of implementation strategies. Municipal governments should establish monitoring systems to oversee the quality of treated greywater, utilization rates, and its impacts on the environment and public health. Data collected from monitoring can be used to assess the effectiveness of existing policies and make necessary adjustments (Dube et al., 2016). Successful implementation requires technical capacity building and training for personnel involved in greywater management. Training should cover the operation of treatment technologies, infrastructure maintenance, and water quality monitoring. Additionally, training for regulators and policymakers is also necessary to ensure that they possess a deep understanding of the technical and regulatory aspects of greywater management (Kyriakopoulos, 2023).

Establishing sustainable business models is crucial to ensure the long-term viability of greywater utilization. These models may include water tariff

schemes that encourage reuse, partnerships with the private sector for facility operation, and waste management initiatives that integrate recycling and recovery. By creating appropriate economic incentives, municipal governments can ensure that greywater management systems remain both sustainable and profitable (Godyn, 2022). Urban areas must continue to adopt and innovate with the latest technologies in greywater treatment to improve efficiency and reduce environmental impacts (Sunny, 2024). Advanced biological treatment, the use of renewable energy in treatment systems, and real-time water quality monitoring should be explored and implemented in accordance with urban needs. These technologies must also be regularly evaluated to ensure effectiveness and relevance to local conditions.

CONCLUSION

This study set out to examine the sustainability aspects and circular economy approach in optimizing greywater utilization within cities in Indonesia. The review findings demonstrate that greywater, which constitutes 60–80% of domestic wastewater, holds significant potential as an alternative resource when supported by proper collection, treatment, and distribution systems. By adopting a circular economy perspective, greywater management can enhance resource efficiency, reduce clean water consumption, lower the burden on wastewater treatment facilities, and mitigate environmental pollution.

The analysis also confirms that sustainable greywater infrastructure contributes not only to environmental conservation but also to economic benefits such as operational cost savings, increased property value, and job creation. These outcomes align with the aims of the study by showing how circular economy principles can be practically applied to wastewater management to foster resilient, inclusive, and sustainable urban development. To fully realize this potential, cross-sectoral collaboration, enabling regulations, financial incentives, and continuous innovation are required. Ultimately, optimizing greywater utilization represents a strategic pathway toward sustainable infrastructure that answers both the environmental and economic challenges of urban areas growth in Indonesia.

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Jurnal Permukiman

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Abstract

DDC : 628.3
Ario Wisnu Wicaksono
Optimization of Greywater Utilization Through Circular Economy Approach
Jurnal Permukiman Vol. 21 No. 1, May 2026 p.: 53–63

The development of urban areas in Indonesia continues to accelerate in line with increasing urbanization and rapid population growth. Greywater which is domestic wastewater from activities such as bathing and washing, accounts for 60–70% of total household wastewater and holds significant potential for reuse. This paper examines the optimization of greywater utilization through a circular economy approach that emphasizes recycle, reuse, and resource efficiency. The use of greywater not only helps reduce clean water consumption and the burden on wastewater treatment systems but also supports urban irrigation, sanitation, building cooling, and fire suppression. The implementation model includes the design of greywater collection systems, treatment technologies, and distribution networks. Environmental impacts include water conservation, pollution reduction, and energy savings, while economic benefits consist of lower operational costs, increased property value, and job creation. For city-scale implementation, regulations, financial incentives, spatial planning integration, public education, and cross-sector collaboration are essential. The optimization of greywater is considered a strategic step in supporting sustainable infrastructure development and in realizing resilient and competitive cities in the future.

Keywords: Circular economy, greywater, urban areas, water conservation, water treatment.

DDC : 363.5
Fahril Fanani , A. Yunastiawan Eka Pramana dan Ayu Candra Kurniati
Spatial Clustering of Housing Backlog and Socioeconomic Inequality: Evidence from the Special Region of Yogyakarta
Jurnal Permukiman Vol. 21 No. 1, May 2026 p.: 28–34

Housing backlog remains a critical challenge in Indonesia, particularly for low-income communities. However, existing mitigation policies often rely on aggregate data, overlooking the spatial concentration of poverty and housing needs. This study investigates the spatial clustering of housing backlogs and its correlation with socioeconomic status in the Special Region of Yogyakarta. Utilizing a quantitative spatial approach, the study employs Global Moran's I and Local Indicators of Spatial Association (LISA) to diagnose geographic disparities. The analysis reveals a significant positive spatial autocorrelation (Moran's I = 0.643), identifying distinct "hotspots" where high housing deficits significantly overlap with low socioeconomic clusters. Unlike conventional descriptive studies, these findings demonstrate that housing vulnerability is not randomly distributed but structurally trapped in specific zones. The study concludes that "one-size-fits-all" subsidies are insufficient and advocates for spatially targeted interventions to address these entrenched inequalities effectively.

Keywords: Housing Backlog, spatial clustering, LISA, socioeconomic inequality, Yogyakarta.

DDC: 624. 1834
Muhammad Aprilia Devino, Muhammad Rusli, dan Ferri Eka Putra
Study on the Reliability of Materials and Structures of Simple Pre-cast Modular Houses (Case Study: RUCAST Technology)
Jurnal Permukiman Vol. 21 No. 1, May 2026 p.: 35–52

RUCAST (PreCAST Concrete Main Frame) is a precast concrete housing system developed to provide more flexible and affordable landed houses. Unlike many existing precast technologies that have rigid panel sizes and limited floor-plan flexibility, RUCAST allows flexible beam-column positioning and flat wall columns, resulting in more efficient space usage and adaptable interior layouts. RUCAST is designed as a confined masonry structural system, where the walls carry structural loads while beams and columns function mainly as wall restraints. The system uses a concrete mix ratio of 1:2:3 (cement:fine aggregate:coarse aggregate) to ensure practical construction and consistent field quality. Beam and column dimensions are 100 × 100 mm^2, with mechanical connections using steel threads and plates, making the frame unsuitable as a moment-resisting system. The study evaluated material properties, structural components, structural behavior, and production costs. Tests included concrete compressive strength, reinforcing steel strength, mortar strength, masonry bond strength, flexural testing of structural components, and cyclic testing of wall systems. Results indicate that RUCAST can be applied in 37 of Indonesia's 38 provincial capitals for hard, medium, and soft soil conditions, with adequate performance for areas having $S_{DS} \leq 1.38g$. RUCAST production costs are also approximately 25.28% lower than comparable precast housing technologies

Keywords: Confined masonry, 1:2:3 concrete mix, earthquake resistant house, precast landed house, RUCAST.

DDC : 363.585
Santi Vidyandani, Joko Adianto
From Welfare to Precarity: Public Rental Housing under Neoliberal Urbanism
Jurnal Permukiman Vol. 21 No. 1, May 2026 p.: 1–13

This paper investigates the transformative role of Public Rental Housing (PRH) in addressing housing precarity, drawing on a systematic review of scholarly literature. It critically analyses how neoliberal governance and housing commodification have eroded the foundational promise of PRH to deliver secure, affordable, and socially inclusive homes. The study delineates the multidimensional nature of housing precarity—encompassing tenure insecurity, economic vulnerability, and social exclusion—while simultaneously underscoring the emancipatory potential of PRH when structured through equitable and participatory frameworks. Comparative insights from Europe, Asia, and the Global South reveal the pitfalls of residualized housing regimes and the enduring promise of rights-based, decommodified alternatives. These findings carry significant implications for emerging contexts such as Indonesia, where state-led housing provision must grapple with market logics and democratic deficits. The paper calls for a reconfiguration of PRH as a universal, tenure-secure institution anchored in long-term leases, democratic governance, and robust legal protections. Ultimately, the study contends that reimagining PRH not as a residual safety net but as a fundamental pillar of social citizenship is imperative to resist deepening precarity in contemporary urban housing landscapes.

Keywords: Public Rental Housing, housing Precarity, decommodification, neoliberalism, tenure insecurity.

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Widy R. Atmojokusumo, Christina Ruth Elisabeth
Effects of Livable Housing on Community Quality of Life: A Macro-Micro Study
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Starting from the issue that access to adequate housing had only reached 38.3% by the year 2019, as evaluated through four basic parameters in the Sustainable Development Goals (SDGs). This study investigates the extent to which the livable housing indicators in the SDGs influence the overall quality of life. The quality of life is assessed at the macro level using the Human Development Index parameters and at the micro level through the outcomes of government assistance programs. The results of multiple linear regression indicate that most livable housing parameters exert a strong, significant influence on the community's quality of life at the macro level. Meanwhile, the micro-community's perception in the research sample confirms Bappenas's findings and the SDGs. Considering that all parameters of livable houses significantly influence quality of life at the macro level, the research sample unit at the micro level has provided adequate confidence in most aspects of livable housing. Through this study, the authors expect that the Government can maximize the program's effectiveness in expanding household access to adequate housing, thereby achieving the target of at least 74% accessibility by 2029.

Keywords: Human development index, livable house, quality of life, household, Sustainable Development Goals (SDGs)

Subject Index

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      Website:
      - Smith, J. (2021, March 15). Climate change impacts on urban areas. Environmental Research Online. Accessed on April 10, 2023, from https://www.environmentalresearch.org/climate-urban

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