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Status of Livability in Indonesian Affordable Housing

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Abstract: Indonesia is experiencing population growth, as well as urbanization, thus increasing the needs of housing. As a result, land prices are soaring, and the housing supply cannot meet the demand. The most recent measure to overcome housing problems is the One Million House Program, which aims to provide more than a million homes annually, with the majority of them being simple housing. The main characteristics of simple housing are limited space, limited facilities, and the use of basic materials. Regulation stated that any housing must satisfy the requirement of livable housing, which means the fulfilment of safety, health, and living-area requirements. This paper looks at affordability, livability, and sustainability criteria based on government regulation. It is found that the performance of housing cannot satisfy some of the requirements. The problems come from either inherently limited housing design, occupant requirements, or local climates. The existing research only focuses on one of three factors. Intertwined relationships between the three factors make an integrated approach necessary. A solution based on integrated performance modeling of the criteria is proposed.

Keywords: Indonesia; livability; affordable housing; simple housing; housing design

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1. Introduction

Indonesia is the world's fourth most populous country, ranked behind India, China, and the United States. The latest census in 2020 shows that the population is 270.2 million people [1]. Almost 70% of the population is between 15 and 64 years old, which is considered to be working age [2]. Furthermore, about 174 million of the population is under 40 years old, comprising millennials, generation Z, and post-generation Z [1]. The population structure implies that Indonesia is in the middle of demographic bonus, marked by the large proportion of working age [2].

The population of Indonesia grew in the last century. According to the first post-independence census in 1961, the population stood at 97.02 million. In the next decade, the number reached 119.21 million, and at the beginning of the millennium, the population passed the two-hundred-million mark [2]. The growth rate in the 1970s was about 2.31% and has decreased ever since. Nevertheless, the absolute number of population growth is in the order of tens of millions annually (see Figure 1).

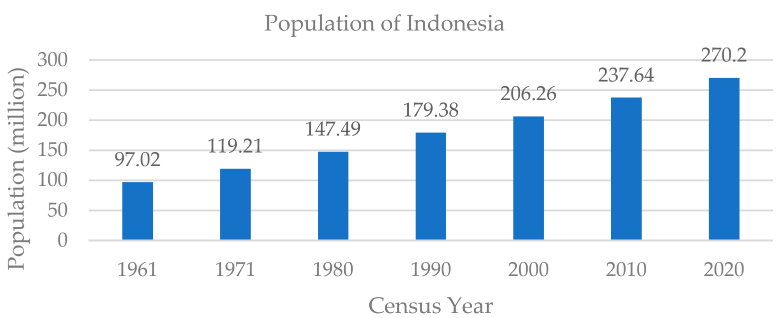

Figure 1. Population of Indonesia based on 1961–2020 census [1].

Aside from population growth, Indonesia is also experiencing urbanization. In the 1960s, only around 15% (8.6 million) of the total Indonesian population lived in urban areas. Seventy-four years later, in 2019, the number increased to 56% (154 million), and the United Nations predicted that, in 2045, more than 70% (220 million) of the population will live in urban areas. The average annual growth of urbanization peaked in the 1980s and 1990s, reached about 5.72% in 1982, and then the value dropped steadily over the years, standing at 2.23% in 2020 [3] (see Figure 2).

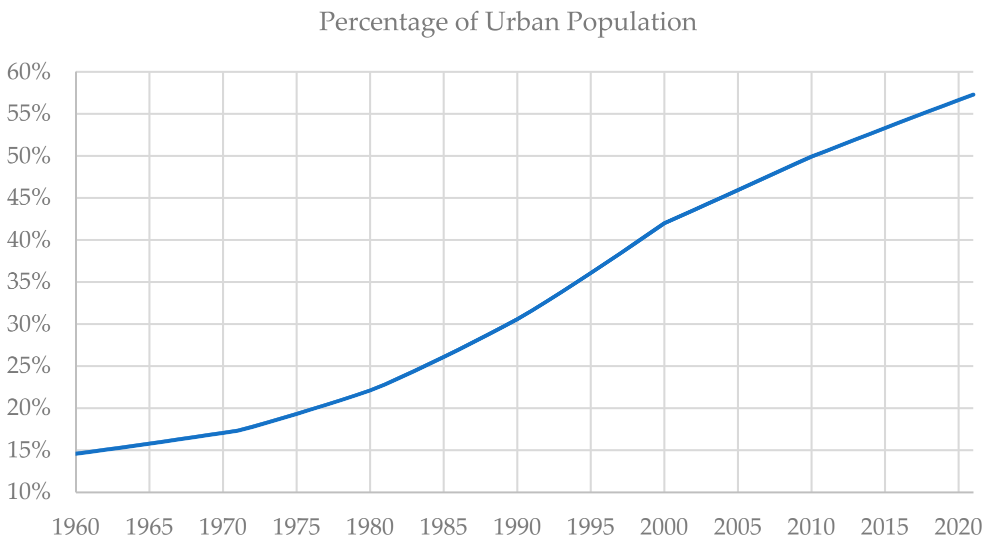

Figure 2. Percentage of Indonesian urban population 1960–2021 [3].

In general, there are two types of urbanization in Indonesia. The first type is population growth around urban centers, consisting of natural growth (37.6% of total urban population growth) and migration from rural areas (18.8%). Meanwhile, the second type is the development of rural areas, which were then re-classified into urban areas (43.5%). This was the largest contributor to urban population growth in Indonesia [4].

Traditionally, Indonesian people live in a community or village based on agricultural activities. They developed a culture known as *gotong royong*, which can be translated to "share the burden together" or "cooperative labor" [5]. The culture of community labor is mainly related to agricultural works such as rice harvesting; however, this type of cooperation also exists in housing construction [5]. For example, in one rural village in Yogyakarta Special Region, a brick house was built in only 17 days with 293 person-days of labor around the year 1973 [5]. The custom of community labor for housing construction is not exclusive to Java but can also be found in the Bugis [6] and Bajo [7] cultures in Sulawesi and other cultures around Indonesia as well.

The practice of building houses with resources from inside the community (labor and financial) is called self-help housing (*perumahan swadaya*) [8]. This type of housing is categorized as informal housing. The term "informal" refers to the characteristic of housing which does not abide to certain requirements but is designed and constructed based on financial capacity and the demand of the owner [9]. Informal housing is built in rural areas (village) where the community connection is still strong. In urban areas, there is also informal housing, known as *kampong* [8].

The other type of housing, which is called formal housing, is built by the government or private institution, with a selected set of standards in accordance with relevant legislation [9]. This type of housing dating back to the colonial era when the Dutch East Indies colonial government-built houses for Europeans and state employee [10]. After the independence, the Indonesian government together with property developers provide housing for the increasing population. In general, types of housing are stated by Law 1/2011 on Housing and Settlement as follows. (see Table 1).

Table 1. Type of housing based on Law 1/2011 [11].

Housing Type	Purpose	Provider
Commercial housing	For-profit housing	Private developers
Self-help housing	For self or community dwelling	Individual or community with assistance from the government
Public housing	For low-income citizens	Government, state enterprise, or private developers
Special housing	For special purposes	Government
State housing	For supporting state employees in duty	Government

Another classification of housing is provided in the Indonesian National Standard (*Standard Nasional Indonesia*—SNI) on procedures for planning residential neighborhoods in urban areas. This standard establishes dwelling classification on architectural configurations and affordability.(see Table 2).

Table 2. Classification of housing based on SNI 03-1733-2004 [12].

Classification of Dwelling	Based on Architectural Configuration	Based on Affordability		
		Type	Market Target	Ownership
Single-family housing	Detached house Coupled house Rowhouse	N/A	N/A	owned or rented
Multifamily housing (apartment)	Low-, middle-, or high-rise apartment	Rented simple vertical housing	Low-income citizens	Rented
		Owned simple vertical housing	Middle-income citizens	owned or rented
		Luxury vertical housing	High-income citizens	owned or rented

Law 1/2011 stated that public housings (*rumah umum*) are constructed for low-income citizens [11]. The term "low-income citizens" (*masyarakat berpenghasilan rendah*—MBR) is defined as citizens who have limited affordability and therefore need government assistance in owning a home [13]. This socioeconomic group is generally not considered to be living in poverty, as they can fulfill their basic daily needs; however, they cannot afford to own housing.

The standard of low-income is dynamically changed based on several factors, including the region and socio-economic conditions. The current regulation set the maximum monthly income for low-income residents is IDR 6 million for single individuals and IDR 8 million for families (about USD 400 and USD 534, respectively) [14]. For provinces in Papua Island, the limit is at IDR 7.5 million (USD 500) and IDR 10 million (USD 667) [14]. These values are higher compared to the provincial minimum wages, in which the highest is IDR 4.9 million in Jakarta Special Capital Region and the lowest is IDR 1.9 million in Yogyakarta Special Region [15].

Government-provided public housing comes in the form of *rumah sederhana*, literally translated as "simple housing". The term "simple" is related to the low cost, as well as simple design and architecture [16]. Sometimes the term *rumah sederhana sehat* (healthy simple housing) is used to emphasize the health quality in the dwelling. Simple housings are built either as detached (landed) or vertical (apartment). Detached housing needs extensive land and is therefore only possible in rural areas. On the other hand, vertical housing is preferred in urban and suburban areas.

Vertical housing is defined as a multistory building which is divided into multiple units, in which each unit can be owned or rented privately and is equipped with common areas inside the premises [17]. Vertical housing can be divided into four categories, namely public vertical housing, special vertical housing, and commercial vertical housing. The purpose of these types is similar to regular housing, as shown in Table 2.

This paper discusses the current housing situation (Section 2) and addresses the challenges and solutions provided by the government. Section 3 explains livable housing and its performance criteria in Indonesian context, followed by reality of living in simple vertical housing (Section 4). Section 5 analyzes the issue of simple housing in terms of three factors (affordability, livability, and sustainability) and establishes the link between those aspects. Section 6 discusses what is lacking in the current design paradigm for achieving the improved livability of simple housing, followed by the proposed design solution in Section 7. Lastly, a summary of this paper and what shortcomings should be improved is discussed in Section 8.

2. Current Housing Situation

2.1. Housing Challenges

Population growth, as well as urbanization, increases the needs of housing. The combination of these two factors is happening across Indonesia. As a result, land price in the urban area is soaring to the point that it is becoming unaffordable for most of the population. This also contributes to national housing backlog, in which the growth of available housing cannot keep pace with the growth of housing demand. The housing backlog is defined as the number of households that do not own a house. (see Figure 3). People who do not own housing can live in official housing which is reserved for a small number of government employees, as well as members of the military and police forces. Ordinary people can live in someone else's house (relatives or friends) without paying (rent-free). If they cannot do that, these people end up living in slum areas or squatters.

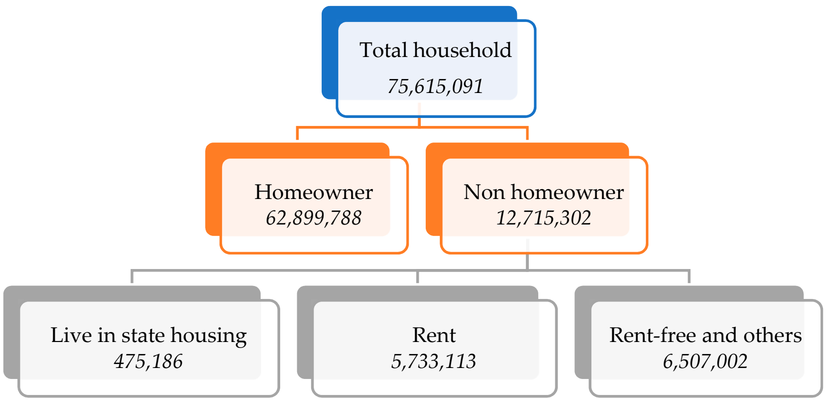

Figure 3. Housing backlog in Indonesia [18].

The future of housing in Indonesia will be more challenging, as the population is getting larger, and the price of housing keeps going up. Meanwhile, the new households, which comprise young adults and new families, are struggling to own housing because the growth of wages is not compatible with the growth of housing price. According to the 2019 survey by the Ministry of Public Works and Public Housing, 81 million of the population from the millennial generation did not have their own home [19]. More than 63% of the respondents cited financial constraints as a major hurdle to owning a home. (see Figure 4).

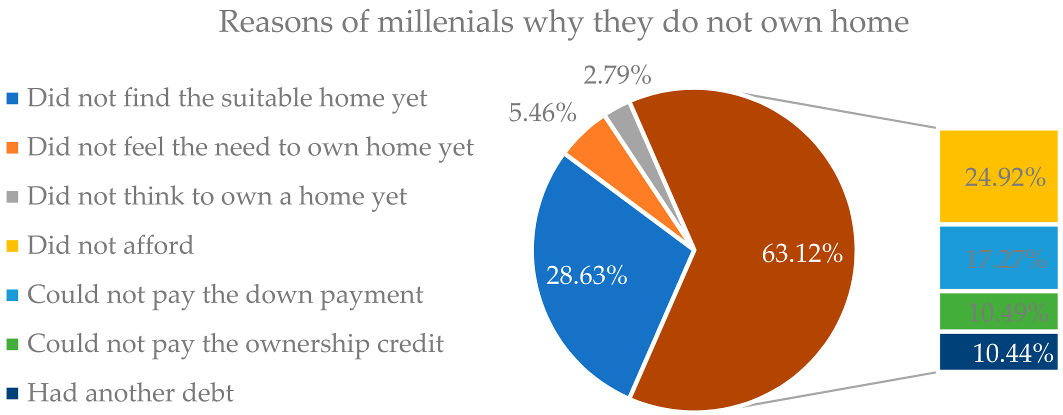

Figure 4. Reasons of Indonesian millennials do not own a home [19].

2.2. Government Housing Program

The most recent measure to overcome housing problems is the One Million House Program, which started in 2015 [20]. The program was created to accelerate housing provision and aims to provide at least one million units of housing each year. To overcome budget constraints, a collaboration was created between housing stakeholders, which are the government (national and regional), private sector (developer), and members of the public. (see Figure 5).

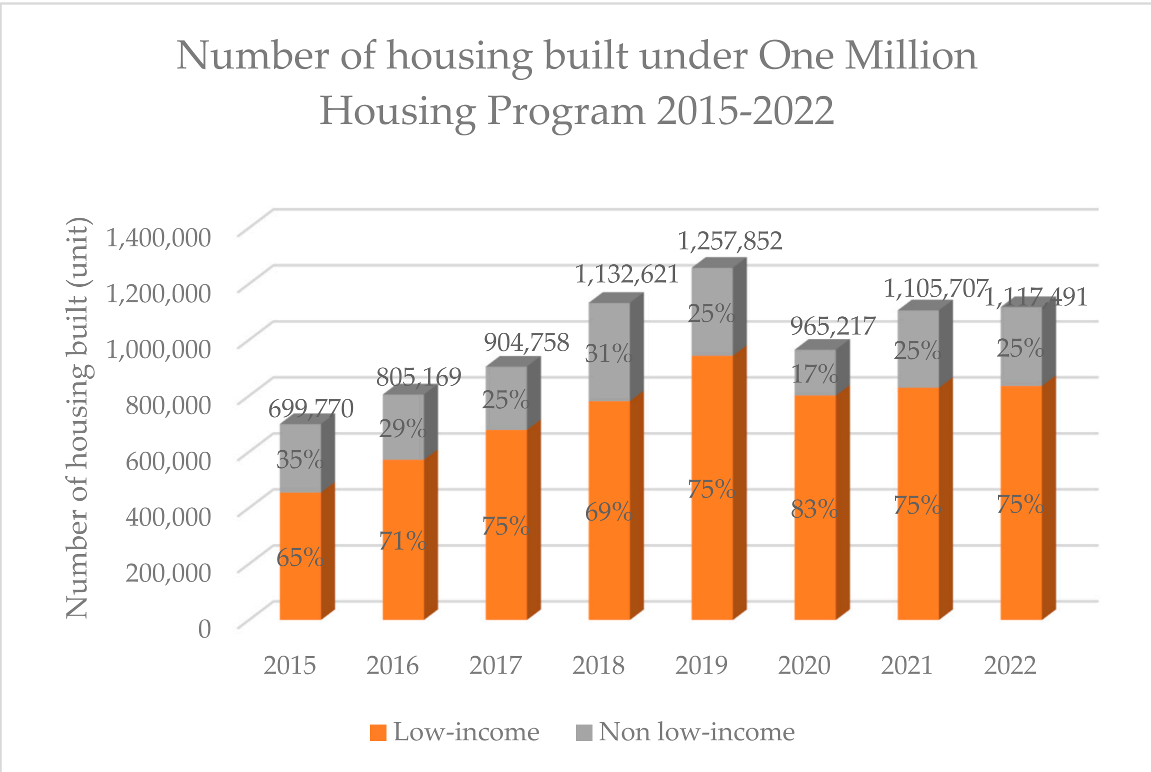

Figure 5. Number of housing units built under the One Million Housing Program [21].

Housing provided by this program can either be landed (detached) housing or vertical housing (apartment). Landed housing is usually built in rural or suburban areas where there is sufficient land. This type of housing is built by private developers based on government standards of simple housing. Meanwhile, vertical housing is built either by the government or large developers, and some of them are state enterprises. In this program, most of the constructed housing (about 70 to 80%) is simple housing, which is intended for low-income residents, whereas the others are commercial housing.

3. Livable Housing Performance Criteria

Housing should be suitable to be lived in, or, in other words, livable. The term *rumah layak huni* (RLH), which is literally translated as "livable house", is an important factor in the Indonesian housing paradigm [22]. The opposite of this term is *rumah tidak layak huni* (RTLH), which is essentially any housing that cannot fulfill the requirements to be considered as livable housing.

The English term "livability", a noun form of livable, has been used in built environment context since the 1950s [23]. In practice, there is no fixed framework on what parameters can be used to measure livability. Usually, livability is used in the built environment context for cities and neighborhood, and this scope is acknowledged by various institution and organizations, such as AARP [24], United States Housing and Urban Development (HUD) [25], New York City [26], and City of San Francisco [27]. Several academic institutions also use these terms to cover neighborhoods and communities [23].

Compared to the general definition of livability, which covers the broader scope of neighborhood, communities, or even cities, the definition of housing livability is not widely available. The Indonesian definition of livable housing (RLH) is a house which fulfills the criteria for habitation, such as safety, living area, and health [11]. In other region, for example, Australia, livable house is defined as a dwelling suitable for elderly living [28]. Meanwhile, the City of Boulder in the USA also has a requirement for livable housing, with emphasis on room and storage areas, as well as kitchen and appliance requirements [29].

Several research studies have been conducted on the topic of housing livability in Indonesia. As the definition of both the international term "livability" and local term "*rumah layak huni*" is broad, researchers have their own set of parameters for defining and evaluating housing livability. (see Table 3).

Table 3. Research related to housing livability in Indonesia.

Authors	Location	Main Research Keyword	Parameters	Key Points
Paramitha, Soemarno, and Silas (2012) [30]	Sidoarjo, East Java	Livability	• Infrastructure and facilities	Only focused on infrastructure, utilities, and facilities.
Ariyanti (2018) [31]	Kediri, East Java	Livability	• Flat amenities • Access to public facilities • Physical aspects of the dwelling • Economics • Social Interactions • Economics	The parameters were formulated based on expert judgement from academician, provincial housing official, and local officials.
Setiadi (2015) [32]	Kemayoran, Jakarta	Housing satisfaction	• Affordable rent • Quality of management • Building quality • Facilities • Social capital and quality of location	Affordable rent has the strongest correlation, and it is perceived by the residents as satisfying. Meanwhile, unit size and density are not satisfying for the occupants.

Table 3. *Cont.*

Authors	Location	Main Research Keyword	Parameters	Key Points
Muchlis and Kusuma (2016) [33]	(no information)	Housing comfort	• Visual comfort • Thermal comfort • Spatial comfort • Environmental comfort	Main determinants of housing livability are thermal comfort with energy efficiency, appropriate architectural design for visual comfort, healthy environment, and availability of open space.
Wiryanti and Rudiarto (2015) [34]	Semarang, Central Java	*Rumah Layak Huni*	• Space adequacy • Unit condition • Housing management • Ease of access • Tenure security • Social and community	The housing cannot satisfy the *layak huni* categories because of space inadequacy, low building quality, and low tenure security.
Febrina and Suwandono (2022) [35]	Klender, Jakarta	*Rumah Layak Huni*	• Physical condition • Basic utilities • Social facilities • Housing management	Physical condition includes space adequacy and overall building qualities. Basic utilities cover water, electricity, gas, and sewage. Social facilities consist of education, commerce, health, religious, and public affair facilities.
Harahap (2021) [36]	Bandar Lampung	*Rumah Layak Huni*	• Space adequacy • Comfort and health requirements • Building physical condition • Utilities • Safety and security	Combining between *layak huni* requirements and slum parameters i.e., housing that can be considered as slum.

3.1. *Affordability*

The simplicity of simple housing is intended to create affordable housing. The design emphasis is not on the luxury of the material but on the ability to enable both technical and social function. The design should also aim to shorten construction time, as well as minimize operational and maintenance costs.

Affordability is one of the most important factors in determining low-income residents' satisfaction with the performance of simple vertical housing [32]. Housing affordability is defined as the ability of households to purchase homes at a certain price level [37]. There are four metrics that are used to measure housing affordability: income affordability, repayment affordability, residual income affordability, and housing transportation affordability. Among these metrics, income affordability is the simplest. (see Table 4).

Table 4. Metrics to measure housing affordability [37].

Metrics	Definition
Income affordability	Based on ratio between housing sale price and household income
Repayment affordability	Ability of a household to make a repayment within an instalment term.
Residual income affordability	The ratio between amount of household income left after domestic expenses with total income
Housing transportation affordability	The ratio between transportation expense and household income

The simplest calculation for the affordability index is using income affordability as follows [18].

$$AI = \frac{MP}{12 \times MI} \quad (1)$$

where AI = affordability index, MP= housing median price, and MI = monthly household median income.

The equation shows that the affordability index determines how much is the median housing price compared to the annual median income. For rented homes, the affordability index will be the relationship between monthly rent and monthly income. Housing can be considered affordable if the affordability index (AI) value is equal to or less than 3 [18].

In addition, the government also regularly updated the maximum threshold for the owned simple-housing unit price and price per area based on provinces. The most recent update was made in 2022, and the regulation stated that the maximum area for simple housing is 36 m^2 [38]. For rented simple housing, the monthly rental rate is heavily subsidized by local government and varies between regions. (see Table 5).

Table 5. Maximum price per area for owned simple vertical unit housing in various provinces [38].

No.	Province	Maximum Price per Area (m^2)	
		IDR	USD
1	Aceh	Rp 8,500,000	$ 566.67
2	North Sumatera	Rp 7,800,000	$ 520.00
3	West Sumatera	Rp 8,800,000	$ 586.67
4	Riau	Rp 9,500,000	$ 633.33
5	Jambi	Rp 8,800,000	$ 586.67
6	South Sumatera	Rp 8,700,000	$ 580.00
7	Bengkulu	Rp 8,000,000	$ 533.33
8	Lampung	Rp 8,000,000	$ 533.33
9	Bangka Belitung Islands	Rp 8,900,000	$ 593.33
10	Riau Islands	Rp 10,000,000	$ 666.67
11	Jakarta Metropolitan Area		
	City of West Jakarta	Rp 8,900,000	$ 593.33
	City of South Jakarta	Rp 9,200,000	$ 613.33
	City of East Jakarta	Rp 8,800,000	$ 586.67
	City of North Jakarta	Rp 9,600,000	$ 640.00
	City of Bogor	Rp 8,600,000	$ 573.33
	City of Depok	Rp 8,500,000	$ 566.67
	City of Tangerang	Rp 8,400,000	$ 560.00
	City of Bekasi	Rp 8,400,000	$ 560.00
12	West Java	Rp 7,300,000	$ 486.67
13	Central Java	Rp 7,200,000	$ 480.00
14	Banten	Rp 7,600,000	$ 506.67
15	East Java	Rp 7,900,000	$ 526.67

Table 5. *Cont.*

No.	Province	Maximum Price per Area (m^2)			
		IDR		USD	
16	Yogyakarta Special Region	Rp	7,300,000	$	486.67
17	Bali	Rp	8,300,000	$	553.33
18	West Nusa Tenggara	Rp	7,400,000	$	493.33
19	East Nusa Tenggara	Rp	8,600,000	$	573.33
20	West Kalimantan	Rp	9,700,000	$	646.67
21	Central Kalimantan	Rp	9,400,000	$	626.67
22	South Kalimantan	Rp	9,000,000	$	600.00
23	East Kalimantan	Rp	9,900,000	$	660.00
24	North Kalimantan	Rp	9,800,000	$	653.33
25	North Sulawesi	Rp	7,800,000	$	520.00
26	Central Sulawesi	Rp	6,900,000	$	460.00
27	South Sulawesi	Rp	7,300,000	$	486.67
28	Southeast Sulawesi	Rp	8,200,000	$	546.67
29	Gorontalo	Rp	8,300,000	$	553.33
30	West Sulawesi	Rp	8,700,000	$	580.00
31	Maluku	Rp	7,600,000	$	506.67
32	North Maluku	Rp	9,600,000	$	640.00
33	Papua	Rp	15,700,000	$	1046.67
34	West Papua	Rp	10,700,000	$	713.33

3.2. Livability

The government requires livable housing (*rumah layak huni*) that satisfies the safety, health, and living area requirements [17]. Each of the requirements is addressed by different government agencies. The safety requirements are regulated by the Ministry of Public Works and Public Housing and encompass structural standards (include earthquake resistance), fire safety, and lightning and electrical safety [39]. Housing health requirements are regulated by the Ministry of Health, and living area specifications are based on the Indonesian National Standards.

The most recent housing health regulation was released in 2011 and covers physical, chemical, and biological requirements. (see Tables 6–8).

Table 6. Housing indoor air physical requirements [40].

No.	Parameter	Unit	Requirement
1	Temperature	°C	18–30
2	Illuminance	Lux	≥60
3	Relative humidity	%	40–60
4	Ventilation rate (air velocity)	m/s	0.15–0.25
5	$PM_{2.5}$	$\mu g/m^3$	≤35 in 24 h
6	PM_{10}	$\mu g/m^3$	≤70 in 24 h

Table 7. Housing indoor air chemical requirements [40].

No.	Parameter	Unit	Max. Level	Remarks
1	SO_2	ppm	0.1	in 24 h
2	NO_2	ppm	0.04	in 24 h
3	CO	ppm	9.00	in 8 h
4	CO_2	ppm	1000	in 8 h

Table 7. *Cont.*

No.	Parameter	Unit	Max. Level	Remarks
5	Lead (Pb)	μg/m^3	1.5	in 15 min
6	Asbestos	fiber/mL	5	fiber length 5 μm
7	Formaldehyde	ppm	3	in 30 min
8	Volatile organic compound	ppm	3	in 8 h
9	Environmental tobacco smoke	μg/m^3	35	in 24 h

Table 8. Housing indoor air biological requirements [40].

No.	Parameter	Unit	Maximum Level
1	Mold	CFU/m^3	0
2	Pathogenic bacteria	CFU/m^3	0
3	Other germs	CFU/m^3	700

There is a different way of determining the living area between simple landed and simple vertical housing. In standard landed housing, the living area for each person is related to the fresh air requirements and ceiling height [12].

$$\text{Area per person} = \frac{\text{Fresh air requirements}}{\text{Ceiling height}} \tag{2}$$

The fresh air requirement for adults is between 16 and 24 m^3/person/h, and for children, it is between 8 and 12 m^3/person/h [12]. The living area is 150% of total area needed for all the occupants [41].

Meanwhile, for simple vertical housing, the SNI states that each unit has a living area between 18 and 36 m^2 [41]. The maximum value was obtained under the assumption that there are four persons in each unit (9 m^2 of living area per person) [41].

3.3. Sustainability

The most recent and most comprehensive regulation to date (2023) about sustainable building in Indonesia is Green Building Regulation (*Peraturan Bangunan Gedung Hijau*—commonly abbreviated as BGH), which was released by the Ministry of Public Works and Public Housing in 2021 [42]. This regulation covers all types of buildings; however, only large commercial and institutional buildings with a floor area of more than 50,000 m^2 are required to satisfy this regulation. Nevertheless, new residential buildings and smaller commercial, as well as institutional, buildings are encouraged to satisfy the regulatory requirements.

The BGH regulation covers the planning, construction, operation, and demolition phase of the building life cycle. In general, criteria set by this regulation are related to site management, energy efficiency, water management, material usage, and waste management. There are also administration requirements, including green building document, supply chain, green management, and post-occupancy evaluation. (see Table 9).

Table 9. Parameters used in BGH regulation [41].

Site Management	
Building orientation	Building mass is parallel with east–west axis; therefore, the long sides of the building face north and south, with a maximum deviance of 15°. If the long sides of the building face east and west, façade engineering should be performed.
Green area	• Minimum albedo is 0.3. • Stormwater should be stored. • Minimum vegetation coverage is 20% of site area.
Parking and pedestrian	• Parking area $\leq$ 20% of gross floor area. • Availability of pedestrian paths and bike parking. • Availability of electric vehicle charging station.
Energy Efficiency	
Building envelope	Max. Overall Thermal Transfer Value (OTTV) = 35 W/m^2. Max. Roof Thermal Transfer Value (RTTV) = 35 W/m^2. Maximum Window to Wall Ratio (WWR) value = 30%.
Ventilation	Passive or mechanical ventilation. Conform with SNI 6390:2020 on ventilation design or the latest edition.
Air conditioning	Temperature setpoint value at 25 °C $\pm$ 1 °C. Space relative humidity value at 60% $\pm$ 10%.
Lighting	Conform with SNI 6197:2020 or the latest edition. One light switch for a space with less than 30 m^2 of area. Installation of occupancy sensor or lighting control system. Daylit zones are separated from electrically lit zones. Daylit zones are equipped with illuminance sensor.
Vertical transportation	Traffic estimation based on SNI 03-6573-2001 or the latest edition. Elevator equipped with VVVF system. Escalator equipped with slow motion or occupancy detector.
Electrical system	Electrical circuit zoning and grouping with individual meter. Submeter for load more than 100 kVA. Buildings with centralized air conditioning must install Building Management Systems. Planning for renewable energy utilization.
Water Efficiency	
Water sources	From city water, nearby bodies of water (with permission), rainwater, or recycled water.
Water usage	Water metering and water balance analysis.
Water fixture	Minimum 25% of installed water fixtures are water efficient.
Indoor Air Quality	
Smoking prohibition	Commitment from management to establish a smoking-free building.
CO and CO_2	Ventilation designed based on SNI 03-6572-2001 or the latest edition. Each space with a crowding potential must equipped with CO_2 sensor and mechanical ventilation which operates automatically to keep CO_2 concentration below 1000 ppm. Closed parking area with minimum opening must equipped with CO sensor and alarm, as well as automatic mechanical ventilation to keep CO concentration below 25 ppm.
Refrigerant	Refrigerant should have zero Ozone Depletion Potential (ODP) and Global Warming Potential (GWP) value less than 700.

Table 9. *Cont.*

Eco-Friendly Material	
Hazardous material control	Material must not contain dangerous adhesive and coating.
Eco-labelling	Concrete raw material sourced from local area with maximum distance of 1000 km. Cement and paint are produced by ISO 14001 certified plant. Wall coverings material sourced from local area with maximum distance of 1000 km. Recycled material accounts for at least 50% of total material budget. Utilization of material with minimum 40% domestic component.
Waste Management	
Implementation of waste management system	Waste sorting. In situ recycling facility.
Wastewater treatment	Treatment of wastewater before releasing to the city sewer system.
Water recycling	Utilization of recycled water for cooling tower and flushing.

4. Living in Simple Vertical Housing

Simple vertical housing is designed to be as affordable as possible. There are standards and regulations which must be followed; however, in practice, several prescribed parameters cannot be satisfied, especially regarding livability.

4.1. Affordability

Affordability is one of the key performance indicators of simple housing, reflected by the limited amenities offered in the dwelling to make the price as low as possible [16]. Aside from that, the government also provides subsidies and discounts to ensure that the price is affordable [16]. In practice, the unit price of simple housing, particularly housing built under the One Million Housing Program, can be 40 to 50% lower with government subsidies [18].

Based on 2021 data, the overall affordability index of subsidized housing in Indonesia for the years 2019, 2020, and 2021 were 2.18, 2.37, and 2.18, respectively [18]. There was a spike in the affordability index in 2020 mainly because of the lower income during COVID-19 pandemic. As the index values of these indexes are below 3, subsidized simple housing can be considered affordable [18].

The rented simple housing is exclusively built by the government and intended for citizens living in poverty or relocated slum dwellers. Residents pay relatively low prices compared to the rates of rent in regular landed housing. The rental rate is the most important factor considered by the prospective occupants. The rates are set by the local (sub-provincial) government where the housing is located. The monthly rate can be less than IDR 150,000 or USD 10, depending on the geographical location, as well as the position in the building. For example, the lowest rental rate for simple housing managed by the municipal government of Surabaya is IDR 39,000 or less than USD 3.00 [43].

Meanwhile, owned simple vertical housing is built by developers, either state enterprises or private companies. The listed price is between IDR 150 and 170 million across Indonesia, with the exception in Papua provinces, where the price is set at IDR 219 million [18]. This is well below the prices of small commercial housing, which is between IDR 200 and 300 million, except in Papua provinces (more than IDR 400 million) [18].

4.2. Livability

Simple housing is built with basic amenities to conserve construction, as well as maintenance budget. The living area is the most visible characteristic of a simple housing. Traditionally, the government has formulated an affordable super-simple house (*rumah sangat sederhana*—RSS) which has an area between 18 and 27 m^2 and satisfies the standard of healthy housing. In 2011, the government set the minimum area of housing to be built at

36 m^2, commonly called Type 36 [11]. The 36 m^2 size is based on assumptions that each person needs 9 m^2 of living space and that each household comprises four persons. Recent research stated that the ideal living space of a simple house is between 32 to 36 m^2 [44].

There was a legal challenge on the minimum living area based on reality that dwellings with living area less than 36 m^2 is more affordable for low-income citizens. One of the judges did not agree with the argument and stated that the most important thing is to keep the Type 36 housing affordable rather than shrink the housing size to maintain affordability [45]. In the end, the plaintiffs won, and smaller housing kept being constructed.

With such a small living area, residents need to make adjustments and adaptations. Limited space forces the occupants to use one room for a variety of purposes. They use the living room for sleeping, children playing area, ironing, watching TV, or even receiving guests. As a result, there is no distinction between public and private areas. Also, they use the bathroom/toilet for washing their clothes [46].

Small areas also present an overcrowding problem for bigger families. If the children already reach puberty age, this becomes another issue, as it is not possible for the child to sleep in the same room with his/her parents [47]. There is also a health risk since inadequate ventilation and close contact between family members increase the occurrence of acute respiratory infection [48].

In terms of facilities, simple housing is provided with water and electricity. However, the electricity capacity is limited, which is 450 VA for Type 21 and 900 VA for Type 36 [49]. If the residents want to add more appliances, such as an air conditioner or washing machine, they have to increase power capacity to at least 1300 VA [49]. This is problematic, as on one side, simple housing encourages simple living with minimum facilities; however, residents' needs and expectations cannot be satisfied by those existing facilities anymore. As a result, new electrical installation can be risky and dangerous, as it is not integrated to the building utilities [49].

Unavailability of air-conditioning systems means that the thermal comfort and ventilation of simple housing relied solely in passive systems. Units are prone to overheating and uncomfortable conditions in daytime. This problem has been identified by measurements in units located in Yogyakarta [50], Malang [51], Bandung [52], and Surabaya [53].

In addition, there are no elevators for apartments with less than eight floors, which can affect the accessibility of the building. Units for disabled residents are usually provided on the first floor (ground floor) for easy access. However, the elderly must walk up if their residence is not located on the first floor. In several buildings, there were no ramps and railings, nor standard furniture which suited the needs of elderly residents [54].

The material used in simple housing also has a significant impact on livability. Deteriorating buildings can degrade livability of the housing either from the safety or aesthetic viewpoints. Unfortunately, this occurs in several vertical simple housing, particularly the older ones. Examples of damage are cracks in joists [55], broken stairs [56], peeled-out paint [56], and window and roof deterioration [57].

The material selection of simple housing is performed based on technical specification either prescribed by the Ministry of Public Works and Public Housing or the Indonesian National Standard. In practice, however, the material performance varies between buildings. There are factors that affect the performance of architectural elements (roof, wall, floor, and utilities), which are (1) material quality, (2) finishing quality, and (3) maintenance quality [57]. Tropical environments (heat, sunlight, and moisture) and heavy usage can wear out these materials. Combined with inappropriate maintenance and slow management response [55], the lifetime of architectural elements can be much shorter than that of the building itself [57]. (see Figure 6).

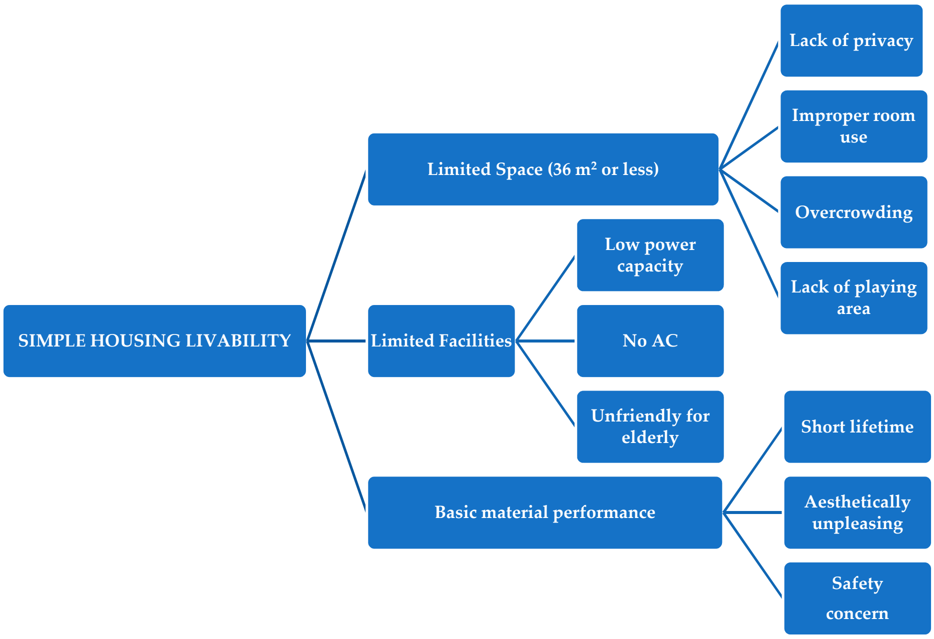

Figure 6. Living conditions in simple housing.

4.3. Sustainability

One of the most important aspects of sustainability is energy consumption. Throughout the lifetime of a building, there are two types of energy consumption: (1) operational energy and (2) embodied energy. Operational energy is energy consumed when a building is in operation, such as for lighting, air-conditioning, and appliances. Meanwhile embodied energy is the amount of energy required to extract, process, transport, install, and demolish a certain material. This type of energy is then considered for every mass unit of the material—hence its name, "embodied". Operational carbon and embodied carbon are similar terms from the perspective of CO_2 emission.

Indonesia, as with other countries, is still heavily dependent on fossil fuel. In 2022, more than 84% of Indonesia's energy came from fossil fuels in the forms of coal (40.71%), oil (30.16%), or gas (13.38%) [58]. In terms of electricity generation, the situation is similar. Coal still dominates the energy mix (67.21%), followed by gas (15.96%). Oil (2.73%) is used as diesel fuel in remote islands. In total, fossil fuels account for about 85% of electricity generation [59], meaning that any electricity usage will account for CO_2 emission released at the power plant. In 2021, the emission intensity from electricity generation was 0.892 metric ton of CO_2 per MWh. (see Figures 7 and 8).

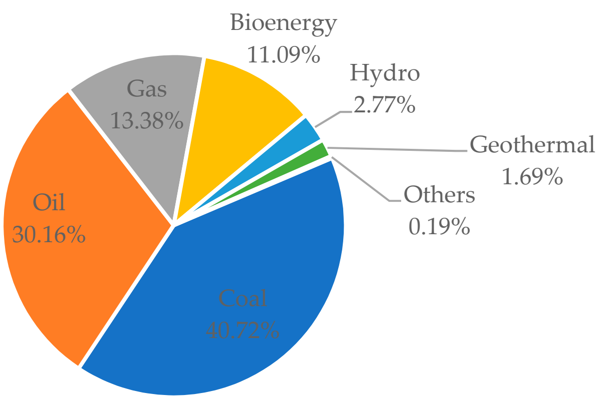

Figure 7. Indonesia primary energy supply [58].

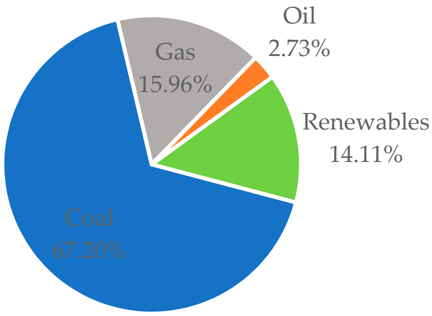

Figure 8. Indonesia electricity generation sources [59].

In 2022, the energy consumption of the household sector reached 144.47 million BOE, or equivalent to about 881.27 million GJ [58]. Electricity dominated energy supply (49.39% of total energy) and liquified petroleum gas (LPG), which accounts for 48.45% of the total. LPG comes in a cylinder and is widely used as the main fuel for cooking, which contributes a large share of the energy mix.

The household electricity consumption in 2022 was 116,095.41 GWh, and the overall installed capacity is 80,423.31 MVA [60]. The number of household customers is about 78.3 million [60]; therefore, the average installed capacity of each household is 1027 VA, the and electricity consumption per household is 1482 kWh. For comparison, the US's average household electricity consumption is at 10,720 kWh.

The typical energy consumption of simple housing is low compared to other types of housing because of the limited power capacity. As already mentioned in the previous subsection, power capacity in simple housing is either 450 VA or 900 VA [49]. Combined with the tight budget, only basic appliances are available. Table 9 shows the penetration rate of select appliances. Appliances other than the washing machine and AC have a penetration rate of more than 50%, thus signifying the necessity of having those appliances. (see Table 10).

Table 10. Penetration rate for select appliances in households with low power capacity [61].

No.	Appliances	Penetration Rate		
		450 VA (Subsidized)	**900 VA (Subsidized)**	**900 VA (Regular)**
1	Lighting	100%	100%	100%
2	TV	91%	93%	95%
3	Cellphone	75%	75%	82%
4	Iron	55%	67%	80%
5	Rice cooker	61%	71%	75%
6	Refrigerator	51%	64%	79%
7	Electric fan	56%	62%	70%
8	Washing machine	14%	23%	38%
9	AC	0%	2%	5%

With limited power capacity and basic appliances, the average monthly consumption of a 450 VA household is 45 kWh, and for a 900 VA household, it is 104 kWh. The annual consumption will be 540 kWh and 1248 kWh, respectively. In comparison, the annual US average household electricity consumption is 10,565 kWh [62].

Based on 2019 data, 450 VA and 900 VA customers totaled more than 55 million with annual electricity consumption of almost 64 TWh [61]. This accounts for more than 26% of national electricity consumption, which is 245.5 TWh [63]. In the long term, energy consumption will certainly grow significantly as the government builds more than a million housing units annually. In addition, the power capacity of 450 VA is being upgraded to 900 VA, and any new installation starts at 900 VA. Existing occupants can upgrade their power capacity to meet additional demand. Therefore, addressing energy efficiency on simple vertical housing is important.

Material usage also plays an important role in determining sustainability. Simple houses had the lowest embodied energy and embodied carbon compared to medium and luxurious houses [64]. In terms of location, the embodied energy and carbon values of housing in the capital area of Jakarta are lower than to those of Bandung. Simple housing uses relatively cheap material; however, frequent material replacement throughout the lifetime of the building can increase embodied energy. Aside from the embodied energy and carbon, which are indirect environmental impact, material can also directly impact the surrounding environment. Direct environmental impacts occurred in the extraction, installation, and demolition of the material.

5. Analysis of Current Situation

The main factors of Indonesian housing problems are affordability, livability, and sustainability. Those factors, as shown by Figure 9, are related to each other. The affordability problem stems from the widening gap between housing prices and income, particularly those of low-income citizens. The government alleviates this problem by providing simple housing with a basic design and basic amenities to minimize the construction and maintenance costs. This type of housing, however, still has some drawbacks in terms of livability, as the space and facilities are limited. In addition, simple housing does not incorporate sustainable design.

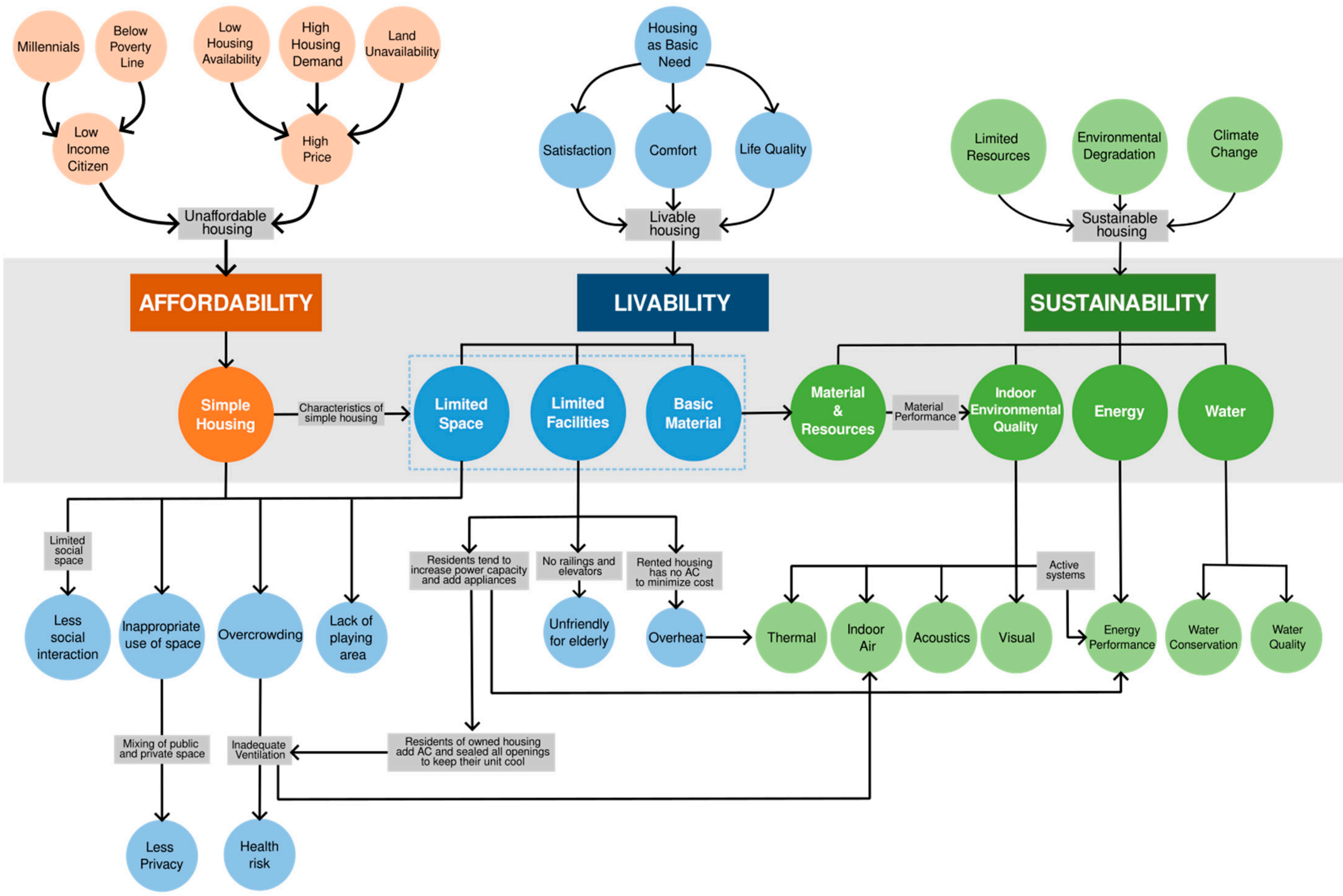

Figure 9. Identification of the problems and their relationship to each other.

Regulation states that simple housing has 36 m^2 of living area for a family of four, based on the assumption that each person needs 9 m^2 of living space. In practice, however, smaller units are occupied by four or more family members. As a result, occupants must adapt in such a condition by using the available bedroom for as many family members as possible. This will cause a lack of privacy and overcrowding. In turn, overcrowding will increase the prevalence of respiratory disease. Limited space also causes a lack of proper space for social activities and playing.

Power capacity in simple housing is limited to either 450 or 900 VA, which limits appliance usage. The relatively low power capacity highlights the issue of energy poverty on the low-income citizens in Indonesia. Large appliances such as washing machine and air conditioning are rarely found in the unit. Although the units are designed with passive cooling in mind, absence of air conditioning creates a thermally uncomfortable environment when outside condition is very hot and humid. Household which can afford more appliances will increase power capacity, however the installation of those appliances will not satisfy electrical safety standards.

In terms of materials, simple housing uses commonly available materials in order to reduce cost. The small size and limited energy consumption give simple housing less embodied energy and embodied carbon compared to other housing types. However, cheaper quality materials tend to need a greater replacement cycle, and this will increase embodied energy and carbon in the long term. Material performance will also affect indoor environment quality. Different materials will give different thermal performances, thus affecting thermal comfort, as well as energy consumption, for housing with active systems. In addition, materials can emit pollutants such as asbestos or volatile organic compounds (VOCs).

6. Improvement of Housing Livability

Section 5 and Figure 9 are related to the characteristics and the design of the simple housing itself, which lacks space and facilities and is incompatible with occupants' need, as well as the local climate. One can simply add space and required facilities to improve livability. However, there are significant constraints that will obstruct those initiatives.

First, as discussed in Section 3, the simple housing maximum size is set as 36 m^2 by law. Any housing that exceeds this number cannot be considered as simple housing; therefore, any government incentives cannot apply to them. Previous challenges to amend this number were dismissed by the Constitutional Court. Therefore, the improvement of housing livability cannot change the maximum area.

Second, the limited facilities available in simple housing is part of the effort to minimize construction and maintenance cost. Any additional facilities will increase the cost, and there is a risk of the simple housing becoming unaffordable. As discussed in Section 3, rented simple housing is built and managed by the government; meanwhile, owned simple housing is generally built by the private sector. If the government is willing to subsidize this type of housing, additional facilities will not be an issue. However, this is unlikely to be realized, as the government focuses on providing more housing rather than adding facilities.

Because of these constraints, any change to one part of the design will change the performance of the other. For example, if designers want to improve the privacy or accessibility of the unit, the existing room layout may need to be reconfigured. Changes to the room layout will have some effects on the building performance, such as thermal or visual comfort. This modification will also change the amount and type of material needed, which in turn affects the construction and maintenance cost, as well as the environmental impact. There is a possibility that this material adjustment impacts the building performance.

Existing research is usually focused on studying one of the three factors. Some of the research went further to propose an improvement within that one factor. However, the intertwined connection between affordability, livability, and sustainability requires a holistic paradigm to make sure that the optimization of every aspect can be achieved. Current approaches that focus on just one instead of three factors are not sufficient. Therefore, a new design approach is proposed.

7. Proposed Design Solution

A novel design approach is proposed, which consists of two stages: qualitative and quantitative stages. The qualitative stage mainly involves studying the livability aspects of simple housing. Unlike affordability and sustainability, which both have standards and quantifications, the concept of livability is not standardized. Therefore, a study about simple housing livability is required, and the judgement as to whether a design is livable or not will be dependent on a set of qualitative values formulated by the designers.

The qualitative stage starts with qualitatively evaluating affordability and livability aspects of the base case scenario, which is an existing apartment building. If the base case cannot satisfy one of the checklist criteria, a modification will be proposed through the option search. Otherwise, if the base case passes the affordability and livability check, the second stage (quantitative stage) will be initiated.

The second stage starts with an intermediate case step. In this step, a human behavior model will be developed based on the physical and geometric characteristics of the apartment building. The model then will be incorporated into integrated performance modeling step. The result then undergoes a performance check again. If the design satisfies all the parameters, it will be proposed as the new design. Otherwise, the process will go back to the option search and start over with Stage I again.

There are four main components of the flowchart. The first is the performance check, which is already established based on government regulation. In the qualitative check, the design will undergo the affordability threshold and livability check, whereas in the quantitative check, both criteria will be reevaluated plus the sustainability evaluation. The lists of the standard values are available in Table 5 for affordability, Tables 6–8 for livability, and Table 9 for sustainability. The second component is the option search component, in which a more detailed study should consider local climate, local socio-cultural condition, technological level, and cost. The third is the human behavior component, which is the response to changes in indoor and outdoor environment, as well as movement inside the building. The movement will be simulated using agent-based modeling. Lastly, the integrated performance modeling will incorporate various building performance simulations such as energy simulation, CFD, and daylighting simulation, as well as the human behavior model. (see Figure 10).

The output of the model is the proposed optimum configuration of the relationship between the three performance criteria (affordability, livability, and sustainability) with building design and environment. To achieve the optimum solution, the model must run multiple times; therefore, autonomous operation, as well as an optimization algorithm, will be needed. Furthermore, a regression model will also be required to establish the correlation between variables, so that the model can be used as a reference tool for designers and architects.

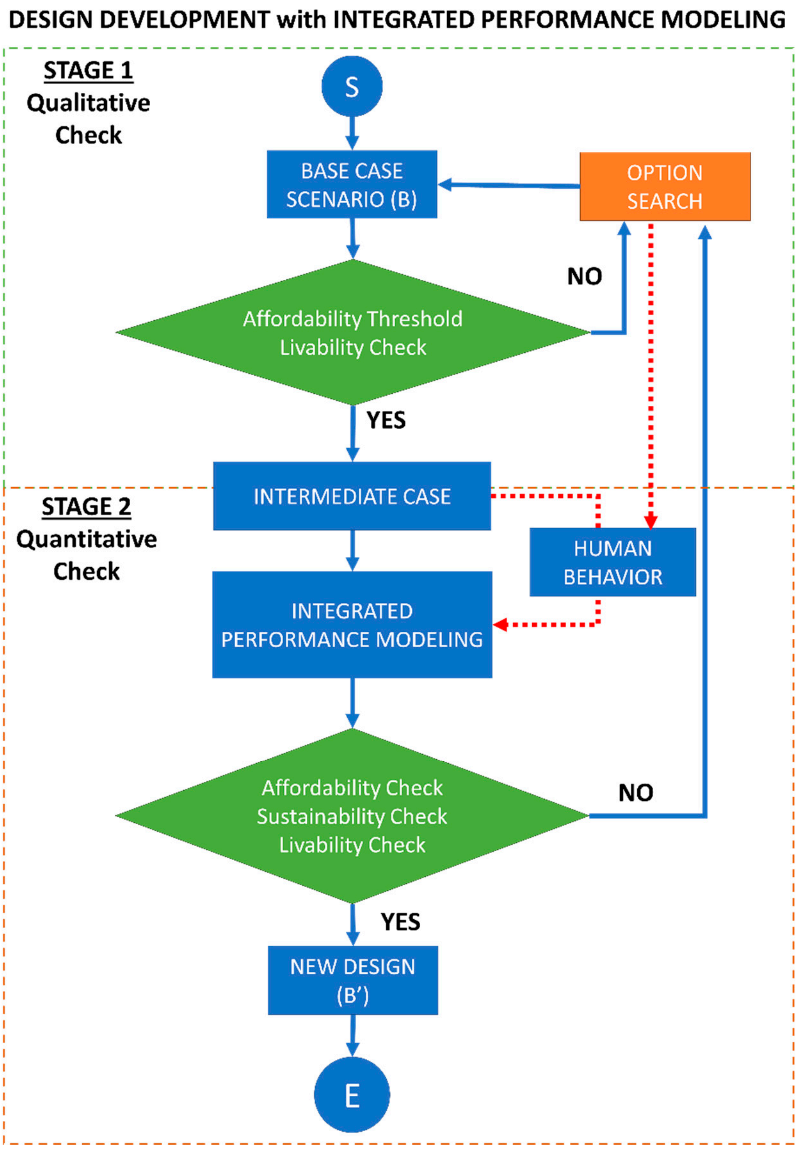

Figure 10. Research flowchart.

8. Conclusions and Future Works

Population growth, as well as urbanization, increases the need for housing. The combination of these two factors is happening across Indonesia. The supply of housing cannot meet the demand, therefore causing a housing backlog. There are at least 12.7 million households without their own housing, with the majority coming from the millennial generation. These people cannot afford to own housing because the price is too high. To overcome this problem, the government launched the One Million Housing Program, with emphasis on simple housing.

Simple housing refers to the minimalist nature of the housing to minimize cost and maintain affordability. The main characteristics of simple housing are limited space, limited facilities, and the use of basic materials. The regulation stated that any housing must be livable, which means the fulfilment of safety, health, and living area requirements. In addition, the government also prescribes a set of parameters related to sustainability.

It is found that the performance of the existing simple housing cannot satisfy some of the requirements. This is mainly related to livability criteria such as space adequacy, privacy, facilities, and indoor environmental comfort. The problems came from either inherently limited housing design, occupant requirements, or local climates. Therefore, a new design is proposed to achieve livable housing in Indonesian context.

The proposed design solution is trying to integrate all three factors simultaneously in a design process. As the livability factor is not yet standardized, the value of variables in this factor will vary depending on how the designer defines what livability is. More research and study are needed to further quantify the livability variables. In addition, the integrated performance modeling imposes additional constraints onto the subjective design and thus might produce no solution for an overall optimal design, which requires an interactive compromising of design goals and conditions—an organic collaboration among user, stakeholder, architect, and engineer.

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