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Designing Commercial Vertical Housing with the Implementation of Modular and Prefabricated Architecture

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ABSTRACT

Residence or housing is one of the basic needs of humans. Each individual has different housing needs based on their social, economic, and cultural aspects. This diversity requires housing design solutions with various design variations that can meet the residents' needs. Vertical housing has become one answer to fulfilling housing needs, but the quality of life in vertical housing is often considered worse compared to conventional housing. Currently, the constructed vertical housing buildings lack high spatial flexibility, as they typically have fixed forms and limited living space that restricts the flexibility for occupants. Commercial vertical housing with the application of modular architecture and prefabrication is one approach that can provide a solution to dynamic living needs quickly and responsively to the environmental typology, while also providing open spaces for residents to enhance their quality of life.

Keyword: Vertical Housing, Modular, Prefabrication

ABSTRAK

Tempat tinggal atau hunian merupakan salah satu kebutuhan pokok manusia, setiap manusia memiliki kebutuhan tinggal yang berbeda-beda sesuai dengan aspek sosial, ekonomi, dan budaya masing-masing individu. . Keberagaman ini membutuhkan solusi desain hunian dengan beragam variasi desain yang dapat memenuhi kebutuhan penduduk. Rumah susun menjadi salah satu jawaban untuk memenuhi kebutuhan hunian, tetapi kualitas hidup pada rumah susun dinilai lebih buruk dibandingkan dengan hunian umumya. Saat ini rumah susun yang dibangun tidak memiliki fleksibilitas ruang yang tinggi dimana umumnya rumah susun saat ini memiliki bentuk dan luas hunian yang tidak dapat diubah sehingga membatasi fleksibilitas ruang penghuni. Rumah susun komersial dengan penerapan arsitektur modular dan prefabrikasi merupakan salah satu pendekatan yang dapat memberikan solusi terhadap kebutuhan tinggal yang dinamis dengan cepat dan responsif terhadap tipologi lingkungan serta menyediakan ruang terbuka bagi penghuni untuk meningkatkan kualitas hidupnya.

Kata kunci: Rumah Susun, Modular, Prefabrikasi

1. Introduction

Housing is one of the basic human needs, each human being has different housing needs according to the social, economic, and cultural aspects of each individual (Andoni & Kusuma, 2016). The diversity of each aspect provides a unique dynamic where each individual has diverse housing needs in terms of shape and area. This diversity requires residential design solutions with various designs that can meet the population's needs.

Vertical housing is one of the answers to meet housing needs, but the quality of life in flats is considered worse than in general housing (Gibson et al., 2011). Due to the lack of flexibility in the space provided, a family continues to grow as time goes by. A family starts with a father and mother and then has children. The dynamic development of a family requires high spatial flexibility. Other things that cause the quality of life in vertical housing to be poor are the lack of green open space and social isolation (Barros et al., 2019). Sufficient green

space is also important to sustain a well-built environment(Ulinata, 2020). Currently, the vertical housing that is built does not have high spatial flexibility, as most of the current housing units have an unchangeable shape and living area, which limits the flexibility of the residents' space. The absence of sufficient terraces or balconies for residents to enjoy the outdoor space is also one of the shortcomings in the design of current vertical housing.

Commercial vertical housing with the implementation of modular and prefabricated architecture is one of the approaches that can provide solutions to dynamic living needs quickly and responsive to environmental typologies and provide open space for residents to improve their quality of life. With the modular and prefabricated architecture approach, the varied needs of thqe community can be met and adapted to the needs of each individual and, due to the characteristics of modular and prefabricated architecture, the construction time is relatively shorter so the housing needs can be met quickly and cheaper than conventional development. Through the modular and prefabricated approach, the design of commercial vertical housing can be made more flexible to create better green open spaces to improve the quality of life.

How to provide a housing design that can adapt to the diversity of occupant needs and design a configuration and module variation that can be adapted to the surrounding environment.The objective of this thesis entitled Designing Commercial Vertical Housing with the Implementation of Modular and Prefabricated Architecture is to provide flexible and fast residential design results to meet dynamic and diverse housing needs and produce residential design results that respond to the shape and contours of the environment. The scope of discussion is emphasized on the planning and design aspects related to the discipline of architecture to design a commercial vertical housing with the application of modular and prefabricated architecture. Matters outside the scope of architecture will be discussed in outline as long as they are related to the planning and design of flats, prefabricated architecture, and modular architecture.

2. Method

The method used in this research is qualitative descriptive method where theoretical and literature studies are taken from books, articles, journals, the internet, etc. The data collection method used are literature study and observation. Literature studies are taken from sources in the form of books related to commercial flats and residential design with modular and prefabricated methods. Direct observations were made of the conditions on the land chosen as the location of the design site.

3. Findings and Discussion

Vertical Housing

In the history of architecture, the initial design form of architecture originated from residential buildings. Initially, residential buildings were characterized as temporary, nomadic, and semi-nomadic. The temporary, nomadic, and semi-nomadic nature emerged because in the early history of humanity, there was a tendency for people to lead a migratory or nomadic lifestyle. The nomadic nature changed when the first cities emerged, leading to the transition from the construction of temporary residential buildings to permanent structures (Forster, 2009).

In the 20th century, industrial development entered Indonesia, bringing about social and cultural changes as the agrarian society transitioned into an industrial one. This transformation led to changes in the way of life in Indonesian society (Sabaruddin, 2018). The demand for labor increased, leading to urban population growth, resulting in an increased need for housing. To address this housing demand, vertical residences, commonly known as apartment buildings or high-rise housing, became structures that could provide living facilities.

In Indonesia, regulations specifically regarding vertical housing such as apartments and condominiums cannot be found. However, the legal basis for vertical housing can be found in Undang-undang Republik Indonesia Nomor 20 Tahun 2011 Tentang Rumah Susun (Undang-Undang Republik Indonesia, 2011).

Module and Prefabrication Design Analysis

The concept of prefabrication originated from the global colonization efforts undertaken by the English. The British arriving in a certain area needed buildings for resting and preparation. Because they were not familiar with the materials available in the occupied area and the need for buildings was urgent, components of these buildings were produced in England and transported by ship to the occupied location (Smith & Timberlake, 2010). The technique of prefabrication continued to evolve from the World War era until after the war ended,

during a period when the demand for housing increased rapidly. This surge in the need for residential housing was a result of soldiers returning home as the war concluded. Due to the increased demand for residential homes, there was a requirement for housing that could be constructed quickly. In the architectural approach to prefabrication, six technical principles can serve as guidelines when designing a prefabricated building. These principles are system, material, method, product, class, and grid (Smith & Timberlake, 2010).

Modular architecture has a direct relationship with the method of prefabrication in architecture. This is because the highest level of prefabrication in architecture is the module, which is used as a modular architectural system (Smith & Timberlake, 2010). Therefore, modular architecture is inherently connected to prefabrication in architecture and cannot be separated from it. In general, modular units do not have specific dimensions but rather their dimensions are determined by the limitations of the transportation available. However, there are recommended size limits to maximize the efficiency of module construction. The maximum width of a module is typically between 4 to 5 meters, the maximum length ranges from 16 to 18 meters, and the maximum height is around 3.66 meters. As for the structural material used in modules, those with a wooden structure are recommended to have a maximum height of 3 floors, modules with a metal structure can have a height ranging from 5 to 12 floors, and modules with a concrete structure can have a height ranging from 12 to over 20 floors. Each module can be arranged according to spatial requirements. There are three main combinations of module arrangements, namely, non-adjacent, semi-adjacent, and fully adjacent (Garrison James & Tweedie Aaron, 2008).

In the design of commercial vertical housing with the implementation of prefabricated and modular architecture, it can be concluded the type of each criterion is used.

Table 1. Building Design Conclusion

Criteria	Description	Reasons
Prefabricated Elements	The prefabricated elements used in this design are prefabricated modules	Module elements are the highest prefabricated elements allowing for more efficient construction time and relatively lower costs.
Prefabricated Materials	The materials used in prefabrication are divided into two, structural materials and panel materials (Crosbie, 2008). The structural materials used in the design are metal in the form of HSS steel and mild steel. The panel material used in the design varies from wood, and metal to concrete.	High-speed steel (HSS) is a steel that has high strength, lightweight, and fire resistance that is suitable for use as a structural material (McMorrough, 2018). Light steel is a steel that has high strength and lightweight, making it suitable as a structural material for module buildings.
Module Specifications	The module used in this building design is a module with a net area of 3 meters x 3 meters and a height of 3 meters. The modules in the design are built to a maximum height of 6 floors.	The module dimensions were determined to be 3 meters x 3 meters x 3 meters by considering the ease of transporting the modules from the factory to the land. The dimension of 3 meters x 3 meters is a safe dimension in the transportation process and the area of 3 meters x 3 meters is sufficient as a residential activity

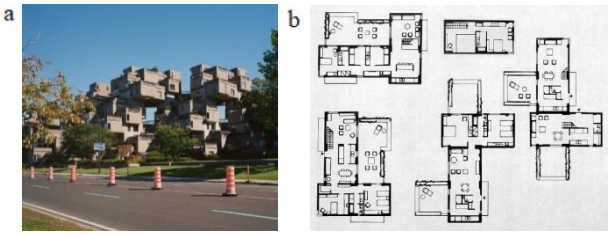
		(Panero & Zelink, 1979). The module building is designed with a maximum height of 6 floors because the material used in the design is metal steel(Neufert, 2002).
Module Structures	The module structure is divided into 2 parts: the main structure with a local foundation and the module and panel structure.	The main structure is an independent structure built first on the land that serves as a module support structure. The module structure is a 3-meter x 3-meter x 3-meter structure that will be the main column and main beam of a module. This module structure will then be paired with a panel structure that acts as a wall and partition.
Module Utilites	In the design of the residential module, there is 1 module dedicated as a shaft module that functions as a shaft for the entire module building system. On the ground floor of the module, there is an additional module so that the residential module is elevated.	The shaft module contains toilets and kitchens so that each residential floor gets a building system. Additional modules serve as a pathway for the building system as a whole
Fire Protection Module	There are two types of fire protection in the design, namely material protection in modules and fire protection equipment in the form of smoke alarms and Hydrant Tower.	Material protection in the module includes the use of GWB to protect the module from fire so that the fire does not spread to adjacent modules. Intumescent and mineral wool layers serve as protection for the main structure from fire. Protection tools in the form of smoke alarms are placed in the shaft module, especially in the kitchen, and hydrant towers are placed in each residential module.

Source: Analysis Result, 2023

Comparative Studies

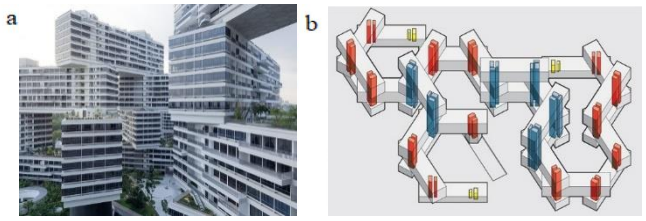
Comparative studies conducted in this research include Habitat 67, which is a prefabricated and modular residence designed by architect Moshe Safdie. This building is Safdie's experiment to look for residential

possibilities that use modular and prefabricated methods to reduce construction costs and make it possible to create a new residential typology that can integrate the quality of life of suburban housing into high-rise housing (Safdie, 1967). The prefabricated module has a size of 11.58 x 5.18 meters with the modules having a height of 3 metres. The modules are made of concrete that is molded in a factory and then brought to the site. The prefabricated modules are then arranged according to a predetermined design. This design allows each residence to have a roof garden, consistent airflow, and maximum natural daylight, a quality of life that is difficult to achieve with vertical housing.



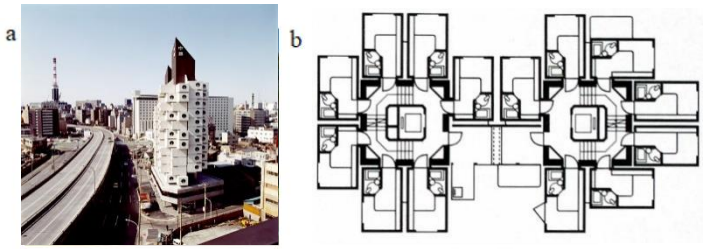
Picture 1. (a) Habitat 67; (b) Habitat 67 Prefabricated Module
Source: archdaily.com, 2023

The second comparative study is The Interlace, a residential apartment designed by Ole Scheeren and OMA (Office for Metropolitan Architecture). The Interlace tries to change the standard typology of socially isolated vertical apartments into a residence that is interconnected and forms a communal area that is integrated with the environment. To meet the space and service needs of each floor each module needs to be adjusted. At each apartment module meeting, there is a service shaft that facilitates the needs of each module. Due to this, the configuration of each floor in the module varies. In The Interlace 50 different floor plans are customised to meet the residential and service needs of the building. Each dwelling in the module has semi-private and private spaces. Within each dwelling, there is a living area, kitchen, dining room, toilet, and bedroom.



Picture 2. (a) The Interlace; (b) The Interlace Service Shaft Module
Source: archdaily.com, 2023

The third comparative study is Nakagin Capsule Tower, the first capsule building designed to accommodate the housing needs of out-of-town and in-town entrepreneurs. The building is located in the centre of Tokyo, Japan, and was built by architect Kisho Kurokawa. The building consists of 140 capsules that are stacked and rotated around a 14-story high central core. The central core is made of concrete and serves as a centre for attaching the capsule modules with 4 high-pressure bolts. The capsule modules have a size of 4 x 2.5 metres and the size of the capsules can be increased by combining capsules that are attached.

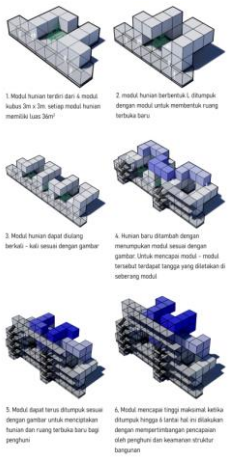


Picture 3. (a) Nakagin Capsule Tower; (b) Module Construction
Source: archdaily.com, 2023

Module Mass

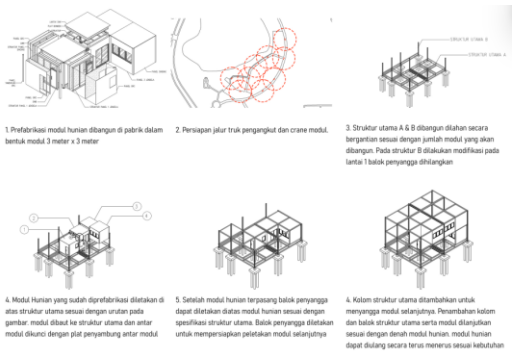
The residential module consists of 4 3-meter x 3-meter cube modules with a height of 3 meters (Chiara & Callender, 1987). The modules are placed in an L-shape to create an outdoor area that can be enjoyed by

residents. The residential modules are then stacked to create new spaces for residents who need them or for new residents who want to stay. With this L-shaped configuration, a new open space is naturally formed that can be used by residents. This module can be repeated horizontally according to space requirements. Each residential module is connected by a corridor that can bend and turn to follow the shape of the land. The residential modules are again stacked on top of the existing modules. To reach the residential module, there is a staircase module placed across the module with a distance between the staircase modules every 12 meters. Modules continue to be stacked with the same principle until they create new spaces and green open spaces for residents. The modules reach their maximum height when the residential modules are stacked up to 6 floors. This is done by considering the achievements of residents and the safety of the building structure.



Picture 4. Mass Development
Source: Analysis Result, 2023

The installation process begins with the prefabrication of each module in the factory in the form of 3 meter x 3 meter modules. In the process of transporting the residential modules, a truck transport path needs to be prepared in the land where the modules will be placed and the truck crane must be able to reach the location where the residential modules will be built from the prepared path. Before the modules are placed the main structure where the modules will be placed needs to be made first in the land. After the main structure has been built, the residential modules can be placed one by one in the sequence, and the modules that are connected are connected with connecting plates between modules. After the residential modules are installed, support beams can be installed on top of the modules according to the specifications of the main structure. These support beams are prepared for the laying of the next residential module. If there are new residential modules to be placed, the main structure columns can be added and the process of attaching the residential modules to the main structure can be repeated.



Picture 5. Installation of Residential Modules
Source: Analysis Result, 2023

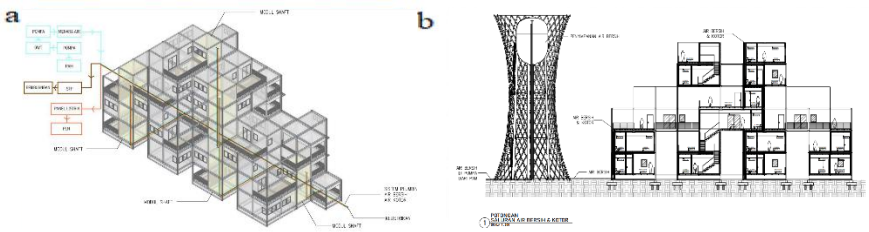
Land and Building System

In the design of Jakarta Garden City, East Cakung, East Jakarta, the residential area is divided into three parts to provide a way for truck cranes to carry and place residential modules. The eastern part of the land that is directly adjacent to the main road is used as a commercial area. This is done as a buffer for the residential area from the main road and facilitates access to the commercial area. Car and motorbike parking areas are placed

in the north and south of the land. The management module is placed in the southwest of the land adjacent to the Asya Marketing Gallery.

Picture 6. Site Plan
Source: Analysis Result, 2023

The clean water circulation of the building starts from the PAM water source which is pumped to the GWT (ground water tank) then the water is pumped to the water tower located in each residential module. From the water tower, it is continued to the residential module through the shaft module. The circulation of dirty water starts from the dirty water waste generated from each residential module directed to the STP (Sewage Treatment Plan) and then forwarded to the sewer. In the residential module, clean water, dirty water, and electricity piping channels are placed in an additional module on the ground floor. Clean water piping, dirty water, and electricity are forwarded to the shaft module.



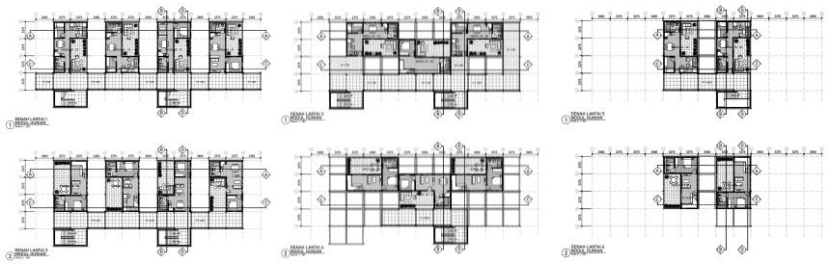
Picture 7. (a) Building Systems in Residential Modules; (b) Water tower and water line cutouts
Source: Analysis Result, 2023

4. Conclusion

Commercial Flats with the Application of Modular and Prefabricated Architecture is a building designed to answer the dynamic needs of human space by providing opportunities for residents to add space by adding residential modules. The design of this building also answers the problem of the poor quality of life in flats by providing open space on each floor for each occupant to create a unique communal space and generate a sense of building a community. This design also tries to respond to the differences in the shape of each land so that this building design is universal and can be used in various types of land.

Picture 9. Building Exterior
Source: Personal Data, 2023

Picture 10. Communal Area
Source: Personal Data, 2023



Picture 11. Residential Unit Plan
Source: Personal Data, 2023

Picture 12. Interior of Residential Module
Source: Personal Data, 2023

Picture 13. Module in Contoured Land
Source: Personal Data, 2023

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