

Application of reused material concept in the *rusunawa* planning

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ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received January 04, 2020 Received in revised form June 13, 2020 Accepted September 15, 2020 Available online April 01, 2021</p> <p><i>Keywords:</i> Slums Reused shipping containers Rental flats</p> <p>*Corresponding author: Yohanes Basuki Dwisusanto Architecture Study Program, Faculty of Engineering, Universitas Katolik Parahyangan, Indonesia Email: jbase@unpar.ac.id ORCID: https://orcid.org/0000-0003-2686-5048</p>	<p><i>The need for adequate and affordable housing drives the government to implement the rusunawa (low-cost housing) development program in various regions. Furthermore, the government promotes utilization of different replacement materials to optimize the cost and duration of rusunawa development, including reused shipping container. This research discusses the feasibility study of reused shipping containers as substitute material in the design planning of the Rusunawa prototype unit construction. It is a qualitative research that uses case study and statistical data-sets through literature review, precedent study analysis and field surveys. The results provided the standard guideline for designing Rusunawa units made from reused shipping containers and prototype typology units based on the occupant's type.</i></p>

Introduction

Slums and unsuitable settlements continue to grow in Indonesians (Mahagarmitha 2018). Various development programs are continuously promoted and developed to accommodate people's needs, especially Low-Income Communities (MBR). One of the most outstanding development programs is the construction of low-cost building or *rusunawa* (Pemerintah Pusat RI 2011). However, the procurement of *rusunawa* does not necessarily solve the problem of housing needs suitable for living. The Minister of PUPR in the 2018 Property Expo stated that the problems surrounding the development of *rusunawa* in Indonesia are centred on the development of unit and layout designs, structuring building mass, and regulations and development financing. According to the Minister of Public Works

Regulation Number 05/PRT/M/2007, the technical requirements in the design of *rusunawa* should meet the building layout standarda, as well as the building reliability with the following planning criteria (Menteri Pekerjaan Umum Republik Indonesia 2007).

Building requirements

These include requirements for location and intensity (GSB/KDB/KLB, etc.), architecture (appearance/facade, interior design, circulation, parking, etc.), and environmental impact requirements.

Building reliability requirements

Include safety (structure and fire), health (ventilation, lighting, sanitation, etc.), comfort (space, air, visual, vibration and noise), and convenience (accessibility).

This research initiates the design of *rusunawa* units by utilizing alternative materials, specifically reused shipping containers.

Method

This study discusses the feasibility of using reused shipping containers as alternative materials for *rusunawa* design units. It uses the literature study method and compares it with 2 case studies in the form of awakened residential and 1 building made of reused shipping containers. From the feasibility study, the basic guidelines/criteria for *rusunawa* planning are made from reused shipping containers.

Based on these standard guidelines, the design of unit typology is planned based on the type of occupant. Design analysis refers to the study of the Support-Infill System theory (Habraken, Boekholt, Thijssen, et al. 1976).

Reused shipping container

Containers are crates or boxes that meet technical requirements of the International Organization for Standardization (ISO) 668 as a means of transporting goods used in various modes, both land and sea (ISO 2013) (figure 1). Containers are considered effective because they can load various types of goods and save shipping costs (Levinson 2006).



Figure 1. Shipping container
Source: (Routley and Creative Director & Writer 2018)

Shipping containers are generally made of steel material (Cor-Ten Steel), have a tightly closed surface, and hinged doors (hinged doors) equipped with rubber gaskets and locking rods. Their structure is built from a steel frame. The walls are made of corrugated shaped stiffened panels consisting of steel, aluminium, fibre-reinforced polymer, or a combination of these three materials (figure 2).

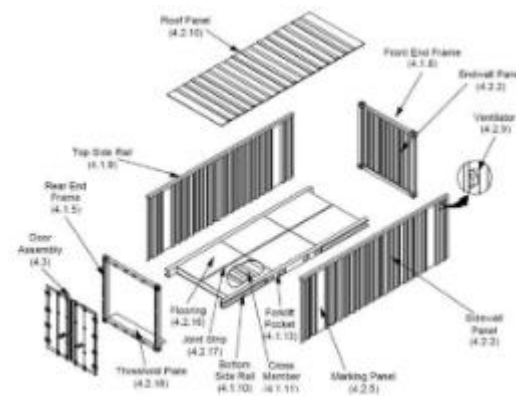


Figure 2. Forming elements of a shipping container
Source: (Manaadiar 2013)

According to Ismail (2015), there is a special type of container used to transport goods and can be safely converted into residential, particularly the Intermodel Steel Building Unit (ISBU) or more the High Cube Container (Ismail et al. 2017). This container is designed with insulation for inner space comfort, sound dampening and fire protection (Robinson and Swindells 2012).

Potential use of reused shipping container

Due to the development of residential building design in various countries, the utilization of reused shipping containers is quite significant. Similar to conventional materials, reused shipping containers also have advantages and disadvantages. Bender (2016) reported 4 potential uses of reused shipping containers as substitute materials, including adaptability, availability, sustainability, and efficiency (Bender 2016).

Adaptability

Adaptability includes strength, age (life span) and container durability.

1. Strength

Based on ISO standards, containers withstand loads up to 24 tons, or equivalent to a stack of 6 fully loaded units, without the support of additional structures (ISO 2013). This is because they are built from prefabricated steel structures with tested strength has been tested.

2. Age (life span)

The life span of the container usage depends on the type and load. Generally, containers are used for 10-15 years before they are sold or converted. After this duration, their condition decreases with a little rust, scratches, and some holes in the surface. According to Bender (2016), with periodic maintenance (Bender 2016), containers can last up to 50-60 years (Nunes 2009).

3. Durability

Containers are made of special technology steel known as Cor-Ten Steel. Furthermore, Steel is produced as weathering structure to withstand the weather and corrosion resistance. However, regular maintenance is needed to maximize the condition of the container's condition, including sand-blasting and repainting with iron paint.

Availability

According to World Shipping Council estimates, more than 30 million shipping containers operate throughout the world. However, more than 2 million container units were in the "retirement" period, abandoned in the depot area (Radwan 2015). These containers can be reused in different ways.

Sustainability

Sustainability is examined in 2 aspects, economics and ecology/environment.

1. Economy

The use of reused shipping containers may save *rusunawa* construction costs because they are relatively cheaper compared to conventional construction methods.

Based on the RAB *rusunawa*, Menanggal village, Gayungan, Surabaya built in 2016, the costs incurred for the construction were Rp. 35,836,025,000 (5 floor of rental flat with an area of 4,299.7 m²), or ± Rp 8,500,000 per m².

Shipping container price ranges from Rp. 15,000,000 to Rp. 30,000,000 per unit (depending on the size, type and age of the container). Compared to the construction price using conventional materials, the costs using reused shipping containers is Rp. 750,000 to Rp. 1,050,000 per m². Based on these rough estimates, reused shipping containers are far cheaper and more affordable.

Apart from cheaper unit prices, construction costs with reused shipping containers are more efficient because the construction duration is much faster with a relatively smaller number of workers (Madkour and El 2018). However, it is also important to consider the transportation cost to the construction site (Ismail et al. 2017).

2. Ecology/environment

The impact of reused shipping containers utilization on the environment, including the following.

- a. Reducing container waste (Pisinger 2002). Utilization of reused shipping containers can reduce 3500 kg of iron waste (Zberea 2016).
- b. Minimize construction waste (low waste construction).

Efficiency

Containers are modular prefabricated steel structures with a patent shape and size. This makes construction with container material easier. It does not require time and energy during construction using conventional methods (Madkour 2017).

Although it is relatively easy and fast to build, the modular form limits flexibility in designing residential units due to consideration of building utility and structures. There are several examples of shipping container module placement (figure 3).

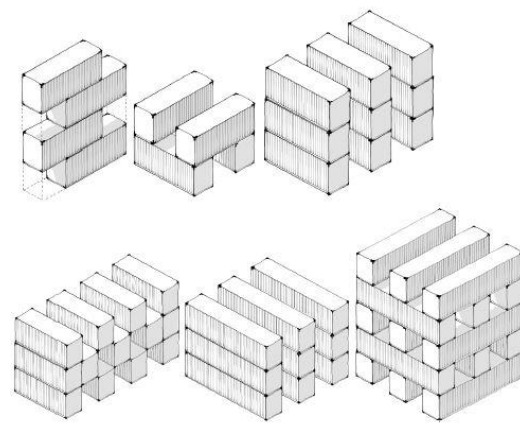


Figure 3. Shipping container configuration form
Source: (Botes 2013)

Based on the potential described earlier, there are several requirements for using reused shipping containers, especially for residential functions (related to *rusunawa* unit design criteria) (table 1).

Table 1. Criteria for the use of reused shipping container for *rusunawa* units

Building layout	
Location	Appropriate land use. Near the port/depot area.
Look/facade	Does not interfere with the visual environment (glare).
Environmental impact	Does not damage the protection/reserve area.
The building reliability	
Safety (structure)	Prefabricated steel structures withstand loads of up to 24 tons/6 piles of container units. The container age also affects the structure's safety. Used containers might last 50-60 years, with regular maintenance.
Safety (fire)	ISBU Container has a fire protection system with

	insulation on the interior walls and floors. However, fire protection systems are still needed, such as hydrants, sprinklers, etc.
Health (air)	Ventilation in containers is needed by modifying the unit and placing openings. Therefore, air exchange occurs. Artificial ventilation can also be used in the interior of container units, such as fans, air conditioners & exhaust fans.
Health (light)	The container is a waterproof closed steel box, hence needs modification to get natural lighting. The addition of artificial lighting is also needed, without disturbing the occupant's eyesight.
Health (sanitation)	Special pipelines need to be made for clean, dirty, rain waters because the container structure does not include utility lines.
Comfort (room)	Although the container shape is patent, an effective layout and furnace arrangement results in a comfortable living environment. The required area standard refers to the need for fresh air.
Comfort (air)	Containers generally smell certain chemical substances and may disturb the comfort of occupants. Ventilation Placement helps eliminate the odor. Furthermore, the use of exhaust fans facilitates air circulation in the unit.
Comfort (thermal and noisy)	Apart from relying on natural ventilation, additional insulation on walls and floors reduces heat and noise. Insulation that can be used includes polyurethane foam, rock wool, plywood, etc. (Prastiwi et al., 2015).

The following section compares how to apply criteria in [table 1](#) with the real condition of several study cases, consisting of 2 buildings with occupancy functions (pre-sedent study results) and 1 building with public functions (field survey results), built with reused material container shipping.

Case study 1 - Cité A Docks, Le Havre, France (precedent study)

Cité A Docks is a dormitory building consisting of 100 units covering 24 m² per unit, built from a combination of reused shipping containers of 20 Feet and 40 Feet arranged up to 4 floors ([Radwan 2015](#)) ([figure 4](#)).



Figure 4. A view of Cité A Docks, Le Havre, France
 Source: ([Cattani Architects 2010](#))

The problem raised in this project is the comfortable and affordable housing for students ([table 2](#)).

Table 2. Checklist of building reliability criteria on Cité A Docks

Building reliability criteria		
Safety (structure)	✓	Additional steel structures are used to support the container.
Safety (fire)	✓	Added 40 cm firewall insulation, including rubber coating between the container units.
Health (air)	✓	The width of the container is modified and placed openings for natural ventilation. No artificial ventilation was found, including air conditioners and exhaust fans inside the unit.
Health (light)	✓	The wide side of the container was modified, and glass openings were placed for natural lighting. Lights on the walls were placed on each container unit.
Health (sanitation)	✓	Though, unknown, it is assumed to be well designed.
Comfort (room)	✓	Based on the minimum area standard for residents of 1 person, an area of 14.4 m ² /unit is required. The unit area of 24 m ² meets the required minimum area standard.
Comfort (air)	✓	Achieved with the opening of each unit.

Building reliability criteria		
Comfort (thermal and noisy)	✓	Insulation installation helps muffle sound and noise.

Source: (Radwan 2015)

Case study 2 - Meath Court, Hope Gardens, Ealing (precedent study)

Meath Court is a low-cost housing building made of 20 Feet reused shipping containers, arranged in 4 floors. There are 60 residential units, consisting of 8 studio units, 20 1LDK units, and 32 2LDK units built for ± 288 homeless people. The construction of the Meath Court only took 24 weeks (figure 5).



Figure 5. Meath Court, London
Source: (Spinks 2019)

Table 3. Checklist of building reliability criteria at Meath Court

Building reliability criteria		
Safety (structure)	✓	There are no additional structures, though the container has rigid structures.
Safety (fire)	✓	Added 40 cm firewall insulation, including rubber coating between the container units.
Health (air)	✓	The width of the container is modified, and openings are placed for natural ventilation. Artificial ventilation is installed, including air conditioners and exhaust fans in each container unit.
Health (light)	✓	The wide side of the container was modified and glass opening placed for natural lighting. Lights were placed on the ceiling of each container unit.
Health (sanitation)	✓	Unknown, but assumed to be well designed.
Comfort (room)	✗	Based on the occupants' testimonies, the space in each unit is crowded. They often store goods in the corridor.
Comfort (air and thermal)	✗	Although there are openings and radiators installed in each unit, some residents claim to be stuffy, especially in summer.

Building reliability criteria		
Comfort (noisy)	-	Not known.

Case study 3 - Amin Library, Malang (field survey)

The Amin Library was built using 7 reused shipping containers of 20 and 40 Feet arranged up to 3 floors, with dental poly (ground floor) and library (floors 2-3) (figure 6).



Figure 6. Amin Library, Malang
Source: (Maya 2018)

Each container is given a different colour for different functions and activities (figure 7).

- Red container → Science and technology reading room, made of 2 containers 20 feet;
- Green container → Receiver room, made of 1 container 20 feet;
- Yellow container → Women's reading room, made of 40 feet containers;
- Blue container → General reading room, made of 3 containers 40 feet.

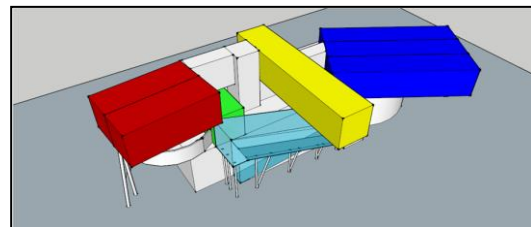


Figure 7. Colour for different functions and activities at Amin Library, Malang

Generally, all building structures consist of steel to facilitate construction. Access from the ground to the second floor uses steel structure and construction designed as a ramp. Also, there is access from the 2nd to the 3rd floor using stairs with steel construction (figure 8).

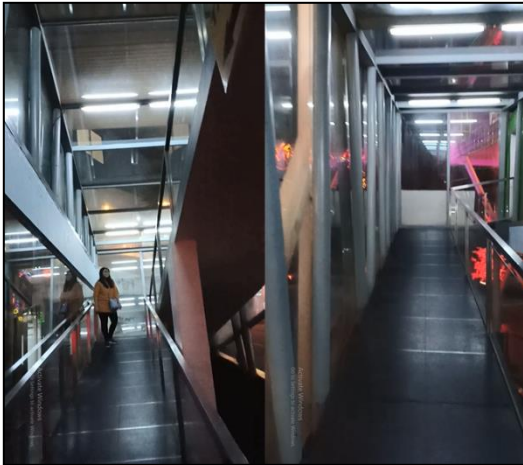


Figure 8. Amin, Batu, Malang Library access and circulation

Table 4. Checklist of building reliability criteria at Amin Library

Building reliability criteria		
Safety (structure)	✓	There are additional steel structures to strengthen the container structure.
Safety (fire)	✓	Added 10 cm plywood insulation on the interior wall.
Health (air)	✓	The sides of the container are modified, and openings are placed for natural ventilation. Artificial ventilation is installed, including air conditioners and exhaust fans in each container unit.
Health (light)	✓	The wide side of the container was modified, and glass openings were placed for natural lighting. Lights are placed on the ceiling in each container unit.
Health (sanitation)	✓	Though unknown, it is assumed to be well designed.
Comfort (room)	✓	The placement of furniture and circulation arrangements is quite good. Therefore, there is no collision when 2 people pass each other.
Comfort (air and thermal)	✗	Although exhaust and AC are installed in each unit, the room feels stuffy and smells of chemicals when the artificial ventilation is turned off.
Comfort (noisy)	✓	The design of container units is arranged for to sound does not penetrate between spaces.

In conclusion, the technical criteria of residential units' design are made from reused shipping containers, technical guidelines synthesis results, precedent studies and field surveys.

Table 5. Technical criteria for *rusunawa* residential unit design made from reused shipping container

Criteria	Description
Safety (structure)	May use additional structures or not since both are safe.
Safety (fire)	Need to add insulation to the interior walls and floors of each unit, and the installation of fire protection systems, such as hydrants, sprinklers, etc..
Health (air)	Natural ventilation is possible by modifying container units and placing openings for active air exchange.
Health (light)	Natural lighting is attained by modifying the unit, and placing openings for sunlight can enter the housing unit.
Health (sanitation)	The container structure needs to be modified to create utility pipelines.
Comfort (room)	It is necessary to consider the minimum standard area needed based on the type of occupant, and therefore an effective layout unit and furniture components can be designed.
Comfort (air)	In certain location and climate conditions, additional artificial ventilation is needed as air conditioners and exhaust fans.
Comfort (light)	Artificial lighting is needed as a light at night or dark.
Comfort (thermal, noisy, vibrate)	Insulation should be installed on interior walls and container floors to reduce external heat.

Several other requirements related to the physical condition of the reused shipping container to be used as residential *Rusunawa* (Woods 2015), include:

1. Containers must be waterproof, no gaps emitting light or air, no holes in the floor or roof of containers used, the hinges installed be in good condition.
2. Used containers should be free of chemical toxins (Baur et al. 2015).
3. The container should be free of moss. If found moss, maintenance needs to be carried out in the form of spraying a solution containing salt or a similar compound that is not harmful to health.
4. Where possible, used containers are free from corrosion. However, if there is corrosion, it needs maintenance by sand-blasting or by repainting.

From the precedent study, the types of residential units and reused shipping container units used include the following.

1. Studio type → Cité A Docks (1 unit of 40 feet – 24 m²; Meath Court (1 unit of 20 feet)

2. Type 1 Living, Dining, Kitchen (LDK) → Meath Court (2 units of 20 feet)
3. Type 2 Living, Dining, Kitchen (LDK) → Meath Court (2 units of 20 Feet)

Result and discussion

Rusunawa design prototype with reused shipping container

Based on the technical criteria in [table 5](#), a prototype layout unit and *rusunawa* mass is designed with reused shipping containers. Therefore, it is necessary to examine the needs of space based on the type of *rusunawa* occupants.

Occupant type and *rusunawa* space requirement

Referring to this research problem, the mass design and layout of the flat units are currently ineffective and inefficient. They do not accommodate the development needs of occupants ([Estaji 2017](#)). Therefore, it is vital to examine the occupant's types and the effective space requirements needed. The occupant's types are divided into the following.

1. Single (1-2 inhabitants);
2. Young family without children (2 inhabitants);
3. Family with 1 child (3 inhabitants);
4. Families with 2 children (4 inhabitants).

The following [table 6](#), [table 7](#), and [table 8](#) shows the broad requirements for each type of flat occupant, according to the minimum area standard and fresh air requirements. This is followed by data on space requirements, along with the dimensions of the space that needs to be accommodated in *rusunawa* units made from reused shipping containers.

Table 6. Minimum floor area based on flats occupants' type

Occupants type	L. Min (m ²)	L. Msx (m ²)
Single (adult)	9.60	14.40
Young family	19.20	28.80
Family +1 child	24.00	36.00
Family +2 children	28.80	43.20

Table 7. Data needs for space

Room name	User	Activity
Living room	Occupants	Socialize
	Guest	
Family room	Occupants	Relax
		Eat
		Work
Bedroom	Occupants	Rest

Room name	User	Activity
		Relax
Service room	Occupants	Toilet
		Dry in the sun
Utility room	Officer	Maintenance
Corridor	Every one	Circulation
		Socialize

Source: ([Hartinisari 2018](#))

Table 8. Dimension of unit space in flats

Room name	Lengthy (m)	Wide (m)	Total (m ²)
Living room	3.00	2.00	6.00
Family room			
Bedroom	2.00	2.60	5.20
Kitchen	3.10	1.60	4.96
Toilet	2.00	1.80	3.60
Dry area	0.87	2.00	1.75
Utility	0.60	0.60	0.36
Corridor	-	1.60	-

Source: ([Sanjaya and Tobing 2019](#))

The entire data needs to be examined further to obtain an effective layout of the unit layouts to suit the needs of each occupant. Therefore, the design analysis is conducted based on the Open Building Principles ([Habraken, Boekholt, Thyssen, et al. 1976](#)).

Design analysis with Open Building Principles

According to Habraken, to obtain an effective layout order, it is necessary to understand the 2 main components underlying the Open Building Principles, including, support and infill components. The support component in this study was represented by a reused HC Shipping Container unit, measuring 20 and 40 feet. The infill component is represented by constructional components, such as walls, floors, ceilings, corridors, and furniture.

There are 4 stages of analysis for producing an effective unit layout based on the needs of each occupant type.

1. Zone and margin analysis
2. Sector analysis
3. Basic analysis
4. Sub-variation analysis

Zone and margin analysis

Zone and margin analysis is carried out to determine the composition of functions in a single unit of residence and to the relationship between functions and effective quantities. It involves dividing activities into 3 spatial categories, namely: general/public (zone α), special/private (zone β), and service (zone γ) ([table 9](#)). Margins are areas between zones, such as corridors and

utilities. The following is the division of space based on zone and margin characteristics.

Table 9. Spatial distribution based on zone and margin characteristics

Room name	Zone α	Zone β	Zone γ	Margin
Living room	●			
Family room	●			
Bedroom		●		
Toilet		●		
Kitchen			●	
Hallway				●
Utility				●
Public Area				●
Corridor				●

Sector analysis

Sector analysis determines the possibility of unit typology formed from 20 feet container units according to the space requirements of each occupant type. Synchronization between the analysis results of precedents, occupant types and spatial data needs, concluded 3 types of *rusunawa* units with 20 feet containers (table 10).

Table 10. Typology of residential units based on sector analysis results



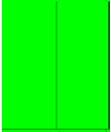
Type unit	Inhabitant total	Unit typology
Studio 1 unit of 20 feet container	1 Inhabitant	
1 LDK 1½ units of a 20 feet container	1 – 2 Inhabitant	
2 LDK 2 units of 20 feet container	2 – 4 Inhabitant	




Table 12. Residential unit variations based on sector analysis results

	Studio type	Type 1 Living, Dining, Kitchen (LDK)	Type 2 Living, Dining, Kitchen (LDK)
Large	14.88 m ²	22.25 m ²	29.64 m ²
Infill components	Construction: – Gypsum wall	Construction: – Gypsum wall	Construction: – Gypsum wall






Basic variation analysis

Basic variation analysis indicates variations or combinations of functions accommodated by each sector (table 11).

Table 11. Basic variations of functions placement in each unit

Type unit	Inhabitant total	Unit typology
Studio 1 unit of 20 feet container	1 Inhabitant	
1 LDK 1½ units of a 20 feet container	1 – 2 Inhabitant	
2 LDK 2 units of 20 feet container	2 – 4 Inhabitant	

Color and space function description

-  → Living room/family room
-  → Bedroom; bathroom
-  → Kitchen/pantry
-  → Hallway
-  → Corridor and public areas

Sub-variation analysis

The final analysis stage, sub-variations analysis, is the stage of placing infill components, in the form of constructional and furniture elements into each function in each unit type (table 12).

	<ul style="list-style-type: none"> - Insulation - foam + plywood - Partition - Window <p>Utilities:</p> <ul style="list-style-type: none"> - Shaft plumbing - Closet - Shower <p>Furniture:</p> <ul style="list-style-type: none"> - Sofa - Sofa bed (1x2 m) + Wardrobe build-in Pantry table 	<ul style="list-style-type: none"> - Insulation - foam + plywood - Partition - Window <p>Utilities:</p> <ul style="list-style-type: none"> - Shaft plumbing - Closet - Shower <p>Furniture:</p> <ul style="list-style-type: none"> - Sofa - Bed (1.2x2 m) - Wardrobe (0.5x1.2 m) Pantry table 	<ul style="list-style-type: none"> - Insulation - foam + plywood - Partition - Window <p>Utilities:</p> <ul style="list-style-type: none"> - Shaft plumbing - Closet - Shower <p>Furniture:</p> <ul style="list-style-type: none"> - Sofa - Sofa bed (1x2 m) + Wardrobe build-in - Bed (1.2x2 m) - Wardrobe (0.5x1.2 m) Pantry table
Sub variations			

Concepts of building units and mass

Based on the flats Development Guidelines, *Rusunawa* is built from 5 floors, with the ground floor being a commercial area and the 4 floors above as dwellings.

In the *rusunawa* design made from reused shipping containers, the concept adopted is an independent flat, where occupants generate their income through empowerment, such as urban farming. The following is the prototype layout and the number of container units needed (figure 9).

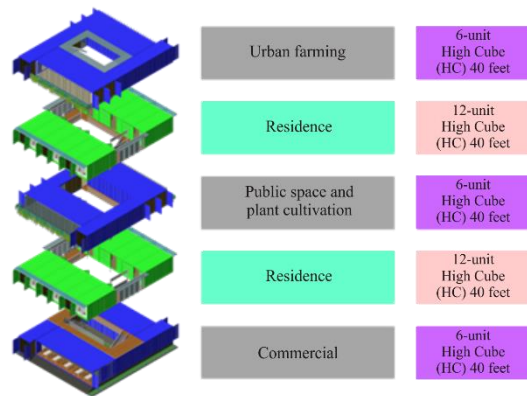
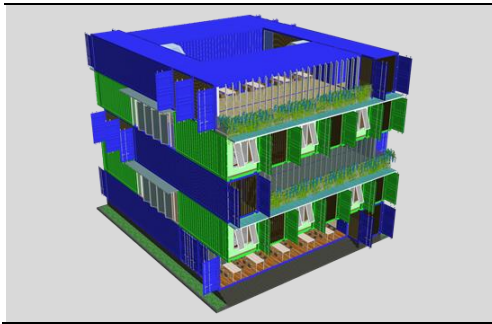


Figure 9. The prototype of *rusunawa* mass layout

The following is the prototype result of *rusunawa* mass based on unit type (table 13).

Table 13. *Rusunawa* mass prototype by unit type

Studio type	
Type 1 Living, Dining, Kitchen (LDK)	
Type 2 Living, Dining, Kitchen (LDK)	



Conclusion

Reflecting on several case studies, Indonesia needs to utilize reused shipping containers as dwellings. However, there is a need for further study on the construction site, particularly the transportation of container units and costs, as well as the climatic conditions in the location. The reused shipping container should be used as a technically suitable dwelling, though it should be adapted to environmental conditions.

Future studies should also focus on the social aspects of people living in residential units made from reused shipping containers.

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