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Spatial Evaluation Based on The Volume of Space Utilization in Low-Income Public Housing

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Abstract
The need for storage space at home has increased following the Covid-19 pandemic, yet in the design process of residential space, storing space is often neglected. Some scholars warned that cramped and crowded spaces potentially affect the residents' physical and mental health. This study proposes an analysis of residential space based on space utilization volume, which is divided into three parts: domestic space, storing space, and dead space. This research was conducted in the Rusun Dakota, a low-cost apartment building in Jakarta, Indonesia. We use a mix of qualitative and quantitative observation methods, 3D modeling, and space utilization volume calculations. We found that: 1) an average of half of the space volume is used for domestic space; 2) less than 20% is used for storing space, and 3) more than a third of the space volume is dead space. The latter potent to be utilized as storing space, although we do not recommend using the whole dead space. The finding unfolds opportunities for further research to find the optimal proportion for storing space.
Keywords: Storage Space; Space Utilization; Interior Design; Public Housing; Jakarta.

1. Introduction

The Covid-19 pandemic has forced most people to stay at homes. Most countries were unprepared to face the impact of this sudden and large-scale pandemic (Djalante et al., 2020). This situation called for special attention to multi-story housing (Tokazhanov et al., 2020) since cases often occur in crowded environments (Costa & Peixoto, 2020). During a pandemic, a house is no longer just a place to live (Tokazhanov et al., 2020). It becomes an essential place to accommodate the increasing activities at home (Dietz et al., 2020). However, most houses are not ready for this change (Tokazhanov et al., 2020).

Kunzmann (2020) argues that people often become frugal after a pandemic and choose to store essential items for the next crisis. Moreover, the "Stay at Home" policy increases the activity in the house and raises the need for storing space. However, this aspect has received less attention in the residential space design process (Marco et al., 2020). Inadequate storing space scatters the items in the house (Krieger & Higgins, 2002). A crowded space can also affect its occupants' physical and mental health (Shah et al., 2018; Tokazhanov et al., 2020).

Previous studies discussed how the residents use space in the house (Ellisa, 2016; Özsoy & Gökmen, 2017; Saputra et al., 2019). The lack of storing space in the house drives the residents to store their items outside (Devina et al., 2019; Ellisa, 2016; Mizanni & Ellisa, 2018). However, lack studies focus on how much space the residents use to store and place their items.

This paper seeks to explore how much space the residents use to store their items. We aim to determine the proportion of storing space, living or activities space, and the remaining space. Previous studies have analyzed space utilization based on the area of a room (Foye, 2017; Özsoy & Gökmen, 2017; Von Castell et al., 2014). We propose a spatial analysis using the volume of a room since space is used horizontally and vertically—for example, using a wall shelf to keep some items. Therefore, we try to see the proportion of space usage by residents based on the volume of the room. Data collection was carried out before the Covid-19 pandemic occurred.

2. Literature Review

In December 2019, an unknown outbreak hit a seafood market in Wuhan, Hubei Province, China (Liu et al., 2020). This outbreak came to be known as the coronavirus disease 2019 or Covid-19 (WHO, 2020). This disease can be transmitted from human to human through close contact (Li et al., 2020). Research has shown that cities with higher densities can spread outbreaks faster than cities with lower densities (Rader et al., 2020). The increasing number of deaths due to this virus has caused many countries to implement social distancing policies and lockdowns (Yuki et al., 2020).

Indonesia is one of the victims of the Covid-19 pandemic. On March 2, 2020, the government announced two confirmed cases of the Covid-19 virus (Djalante et al., 2020). As of April 29, 2021, Indonesia has reported cumulative numbers of 1,662,868 positive cases, with 1,517,432 recovered and 45,334 deaths (Ministry of Health of the Republic

of Indonesia, 2021). The government has taken various steps to tackle the pandemic, one of which is Large-Scale Social Restrictions (*Pembatasan Sosial Berskala Besar* or PSBB) (Djalante et al., 2020). The government closed office buildings, schools, universities, places of worship, entertainment venues, and places that could potentially gather crowds. People are forced to spend more time at home. Therefore, residential buildings are essential to support community activities, in addition to health centers and grocery stores (Dietz et al., 2020).

The pandemic has the most impact on marginalized people (Gupte & Mitlin, 2020). Dense environments and inadequate infrastructure hindered the health protocols implementation, such as quarantine and social distancing (Datta, 2020; Gupte & Mitlin, 2020; Jones & Grigsby-Toussaint, 2020). They are optimizing a house for work, items storage, and isolation work well in a house with ample space (Clair, 2020). However, it is not something everyone can afford, especially for those who live in an apartment. The apartment unit model has been arranged by the designer so that the residents have to deal with limited space. Most multi-story buildings are not ready to protect their residents because the building has a limited capacity to prevent the spread of the virus (Tokazhanov et al., 2020).

The housing issue is a recurring problem in developing countries (Ghasemi & Ozay, 2018), including Indonesia. Low-cost apartment building – or *Rumah Susun Sewa* or *rusunawa* – is a model of public housing that the Indonesian government has intensively promoted as an alternative for the urban poor (Kustowartojo et al., 2005). However, when the need for space increases, the standard size of a housing area is reduced (Hand et al., 2007). Indonesia has reduced the standard minimum size of a housing area since 1942 when the government set the minimum area for public housing at 36 m2 (Susanto et al., 2020). However, this standard has decreased to 15 m2. Susanto further argued that this size failed to meet the needs of residents and is only driven by profits for the construction sector (Susanto et al., 2020).

The Commission for Architecture and the Built Environment (CABE, 2009) reports that living in a small house is difficult. One of the reasons is due to a lack of storing space. During a pandemic, people will become frugal and save essential items for the crisis (Kunzmann, 2020). The government also advises people not to shop often (Clair, 2020). Driven by the desire to stock goods, people shop in large quantities to meet their needs during a certain period and trigger the increasing need for storing space. However, the storage space is often ignored in the residential design process (Marco et al., 2020).

The residents' tendency to store or collect items affects the design of the residential space (Marco et al., 2020). Items are acquired by finding, buying, making, or receiving gifts (Smith & Ekerdt, 2011, p. 377). Items are becoming tools to support activities and provide a feeling of pleasure and comfort (Smith & Ekerdt, 2011). Acquiring more items is also a factor for expanding their homes (Hand et al., 2007). They need more space to accommodate the items, such as new electronics or furniture (Hand et al., 2007).

Items drive the residents' behavior and affect the physical configuration of the house (Hand et al., 2007). Someone's belongings reflect the lifestyle and the identity of the owners (Hetherington, 2004) and indicate how they can design and arrange the objects in their house (Jacobs & Malpas, 2013). A house filled with items requires sufficient space for storing their items (Hand et al., 2007). A neat and clean space can create a warm atmosphere and positive emotions for the residents (Pickens et al., 2018).

However, owning many items potent to raise burden (Smith & Ekerdt, 2011) since too many items generate clutter. Clutter is a condition where space is filled with randomly placed items that can create chaos (Roster et al., 2016). Rees (Rees et al., 2018, p. 331) founded that excessive clutter led to mental illness and caused negative emotions in children, such as frustration, sadness, hatred, shame, and guilt. Cluttered spaces disrupt residents from carrying out everyday activities such as cooking, cleaning, and others (Frost et al., 2012).

Marco et al. (2020) divided the characteristics of items into 1) value, 2) time, and 3) visibility. Value associates with how valuable an item according to the owner of the external parties. In this case, the activity and identity of the owner affect his/her value of an item. When an item is useful for a particular activity, it brings satisfaction. For example, in daily activities, the primary function of the scissors is cutting the paper, yet scissors bring fun when they use to cut ribbons at an event inauguration. An item would change into a precious one, depending on the internal or external identity. The former relates to the owner's sentiment towards the item, such as a gift from a loved one. The latter relates to how the owners express themselves to others, such as wearing expensive watches to represent self-esteem.

The time as the second characteristic of items is associated with the ownership of items, of which their cycles depend on the residents' lifestyle. The duration of ownership and placement of items are dynamic and prone to change at any time. Technological developments affect the type of items since advanced gadgets, and electrical appliances would save more time. However, long last items occupied the space and generated problems when the existing space is limited. Marco et al. (2020) found that over time, storing space decreases even though dependence on electrical appliances increases.

The last characteristic of items is visibility or whether an item is displayed or not by the owner. The reason to display an item depends on the value the residents want to expose. For example, those who want to show up their success will display their belongings in places that are easy for others to see. The visibility of an item also depended on the functional aspect indicated by the frequency of usages. Items that are frequently used are positioned where they are easily accessible or visible—for example, a broom placed behind a door or in an easily accessible corner of the house.

3. Research Methods

This research was conducted in the *Rumah Susun* (*Rusun*) Dakota Kemayoran, a low-cost apartment building in Central Jakarta, Indonesia. Kemayoran is a sub-district that is used to be an airport area. On July 8th, 1940, the Dutch government opened Kemayoran as a commercial airport under KNILM (*Koninklijke Nederlands Indische Luchtvaart Maatschappy*). In March 1942, it was transformed into a Dutch military center during World War II. When Japan occupied Indonesia, Kemayoran was turned into a Japanese military center. After independence, the Indonesian government turned this area back into a commercial airport area. Over time, flight services at Kemayoran Airport increased rapidly, even though a second airport, Halim Perdana Kusuma, had been opened. Due to increasing capacity and concerns over the airport's location, the government built a new commercial airport called Soekarno-Hatta Airport, far from the city. After that, Kemayoran Airport was no longer in operation. In 1988-1994, the central government established the Kemayoran Complex Development Implementation Board (DP3KK) to regulate the development of the Kemayoran area. In 1992, a governmental organization called Perum Perumnas started developing Rusun Dakota in the former airport area. (Ellisa and Sari, 2013).

Figure 1. One of Rusun Kemayoran building (Authors')

Rusun Dakota Kemayoran is built on 30 hectares consisting of 11 building blocks, each of which consists of 5 floors (Setiadi, 2015). Each building is equipped with a commercial unit and common facilities on the ground floor. This apartment has three types of sizes, namely Type 18, Type 21, and Type 36. Type 18 consists of living space without a service area (kitchen and bathroom). In return, there is a communal kitchen and bathroom on each floor. For this research, we skipped Type 18 and only observed Type 21 and Type 36 as typical units with the living space and service area provided as the bare space to support the domestic activities. By focusing on Type 21 and Type 36, it will be easier to observe spatial usage patterns in the residential space of low-cost vertical housing.

We randomly selected fifteen (15) living units as our research objects: 1) eight Type 21 units and 2) seven Type 36 units. Type 21 consists of a multipurpose room (flexibly utilized as a living room, office, or bedroom), a kitchen, a bathroom, and a balcony. Type 36 consists of a living room, two bedrooms, a bathroom, a kitchen, and a balcony.

This research used a mixed method of qualitative and quantitative methods. We took several visits to all units to collect data through field observations and interviews with the residents. We took a photograph and took accurate measurements of the space and all the items placed in the apartment units to get the quantitative data. The detailed observations focused on how residents utilize the space and use the items combined with the data measurement to produce three-dimensional modeling.

We use computer software, such as AutoCAD and SketchUp, to model the conditions of the observed apartment unit. The 3D models include the spatial arrangement and the position of the residents' items. Afterward, we defined the space utilization by drawing a mass surrounding the space or items in the unit. The masses are divided into three

groups based on the space utilization category (Table 1): 1) domestic space; 2) storing space; 3) and dead space. Domestic space is routinely accessed and used by the residents for daily activities. They are living room, bedroom, kitchen, dining room, and bathroom. Storing space is space for possession. Marco et al. (2020) state that space for possession is a place to store residents' items collected and gathered within a certain period. Most of these items have no standard regarding where to put them. Items that fall into this category are clothes, decorations, photos, and others. In other words, storing space is used to place and store items. Marco et al. (2020) do not include furniture as material possessions in their articles because they assume that the furniture layout is included in the standard design. In this paper, we include furniture for possessions because the residents replace furniture according to their will without following the standard layout derived by the building manager. Space for possession does not always have to be furniture such as shelves, cupboards, or cabinets. The surface of objects (such as tables, top of the cupboard, the floor) is included in the possession space. Finally, dead space is neither domestic nor storing space, such as a space between two furniture or inaccessible spaces. We did not include walls or room partitions for calculating the volume and using descriptive statistics to determine the proportion of space utilization by residents.

Table 1. Space Utilization Category

Category	Definition	Spatial Justification
Domestic space (blue)	The area that can be accessed by an individual or family members for daily activities	Living space, bedrooms, kitchen, dining room, bathroom
Storing space (orange)	Area for storing/keeping the items to support daily life	Furniture, furniture surface, storage room to keep the residents' items
Dead space (green)	The area beside domestic space and storing space	Space in-between or inaccessible space, such as space higher than the average height

4. Discussion

Due to the page limitation, we took one example from Type 21 and Type 36 as representations. We used units 21A and 36A to explain how the residents use the space. Figure 2 shows the residential layout plan.

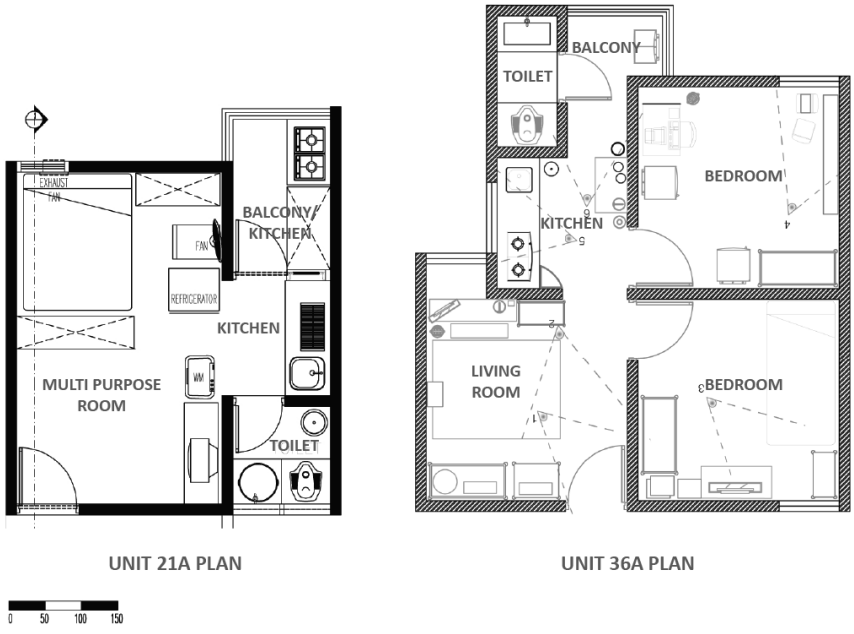

Figure 2. The plan of unit 21A and 36 A (Redrawn by Authors)

Unit 21A has five (5) residents. In the multipurpose room, a wardrobe divided the space into the living room and bedroom. There was no table or chair; all activities are *lesehan* or carry out on the floor to gain a spacious ambiance. The living room has more storage space, such as cupboards and cabinets. The residents have various electronic devices in this place, such as fans, air conditioners, washing machines, refrigerators, irons, televisions, laptops, and rice cookers. The owners put many items at the top of the cupboard, the washing machine, and the refrigerator. In the bedroom, the owner put a mattress on the floor. Therefore, the bedroom did not have space below for extra storage as in typical bed.

The residents never cook in the kitchen and return; they utilized the kitchen for washing the dishes and keeping small kitchen utensils. The available storing space in the kitchen included a cabinet under the kitchen isle and a

hanging shelf to place kitchen utensils. The smaller pans were hanging on the kitchen wall. As there was no cooking activity in the kitchen, interestingly, the cooking was done on the balcony, the area which was intended for hanging laundries. A stove is placed on the table next to the balcony wall. A large dish rack and big utensils (such as pots, buckets, large pans) can be found here. As the balcony transformed into the kitchen, washing the cloth was done in the bathroom. A wooden rod stretches across the bathroom to dry the clothes. The residents also used any available space in the bathroom wall to hang several pans.

Since Unit 21A has limited storing space, the residents had to adapt by storing their items on the balcony. Putting a large number of items in the kitchen hindered the air circulation in the living unit. The residents placed the stove on the balcony to prevent the smoke being trapped in the living unit. Lacking the storing space in the kitchen, the residents anticipated putting kitchen utensils in any available space, such as in the balcony and bathroom.

Unit 36A has four (4) residents. The living room has no tables or chairs, and in return, the owner spread the carpet. This space has several storage spaces, such as cupboards and cabinets. The residents stored items on top of the cupboard or cabinet. The main bedroom consists of a double bed, wardrobe, and TV cabinet. The wardrobe was strong enough to hold large and heavy items such as rice flasks and pots. The secondary bedroom has no bed but a mattress propped against the wall. The mattress will be laid on the floor just in case the residents need to use it. This room has a work desk, wardrobe, and refrigerator. Interestingly, the chair is used to put a basket of clean clothes so that the chair can transform into a temporary place to put things when necessary.

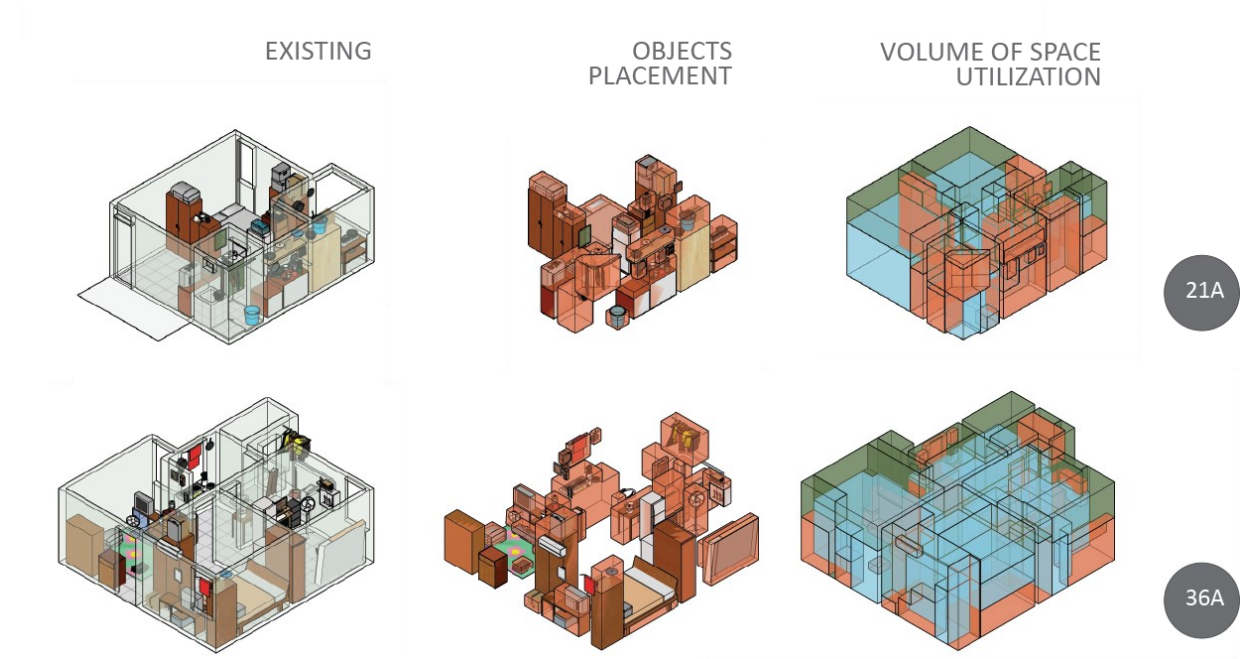

Figure 3. Object arrangement and space utilization in units 21A and 36A (Developed by The Author)

The owner stored utensils in the lower cabinet in the kitchen. The kitchen did not have a top-shelf like unit 21A, so the residents preferred to hang pots and pans on the wall. The upper surface of the kitchen isle was used to place utensils and food ingredients. The balcony has a washing machine, several buckets, and cleaning tools. An iron rod to hang the laundry put at the top of the balcony. The space utilization in unit 36A was still following its original function. The residents receive the guests, hold family activities, or iron the clothes in the living room. Figure 3 shows the arrangement of objects and the occupants' space utilization in units 21A and 36A.

We mapped the spatial usage based on the volume of space. Figure 4 shows the usage ratio based on the formulation of the space utilization category: 1) blue indicates the domestic area; 2) orange indicates storing space, and 3) green indicates dead space.

In type 21A, residents used 23.25 m3 or equivalent to 45.92% of the total volume of space for domestic space. In type 36A, residents used 35.56 m3 or 42.56% of the total space volume for domestic space. The residents use the domestic area the most. Therefore, it is the most extensive space in the unit. The residents of type 36A use 53% more domestic space than residents of 21A because type 36A has a larger domestic area. However, proportionally, the residents lived in Unit 21A use a little more domestic space.

Unit 21A used 10.82 m3 (21.37%) for storing space, and Unit 36A used 15.52 m3 (18.57%). In terms of volume, Unit 36A used 43% more storing space than 21A. However, in terms of the proportion of space, Unit 21A used more space

to store items than Unit 36A. It can be seen how residents of Unit 21A put more effort into increasing their storage space. Figure 4 and figure 5 show that the storage space arrangement in unit 21A was denser than unit 36A.

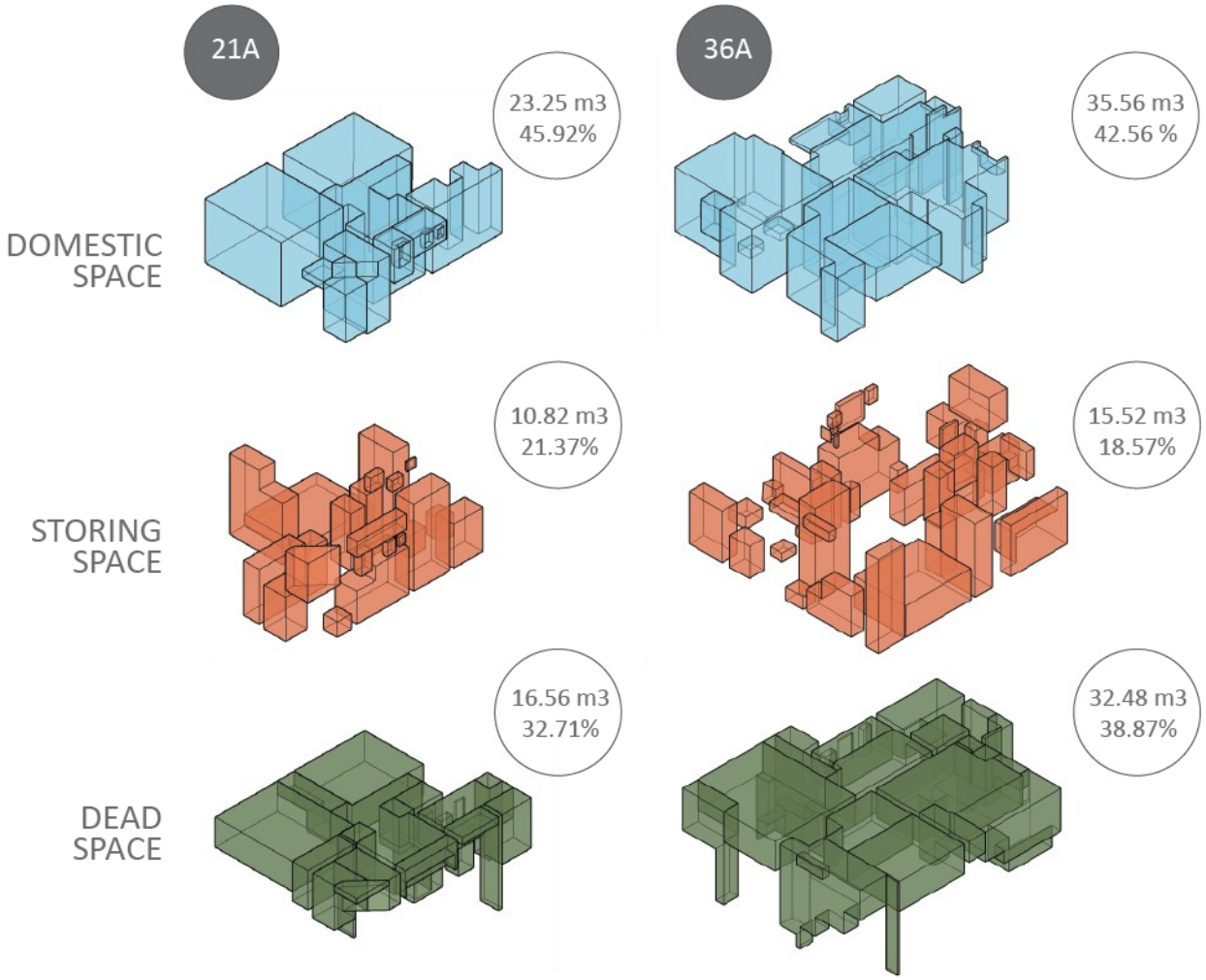

Figure 4. Space utilization ratio by category (Developed by The Author)

Unit 36A has 32.48 m3 (38.87%) dead space, or twice as much as Unit 21A with 16.56 m3 (32.71%) death space. Figure 4 and figure 5 show the proportion of dead space comparing to the other spaces. Most dead spaces were above 1,7 meters or more than the Indonesian average height. Figure 5 shows that there was still much space that the residents of Unit 36A did not utilize. It is because the Unit 36A unit used a lot of low cabinets. Therefore, Unit 36A has more dead space.

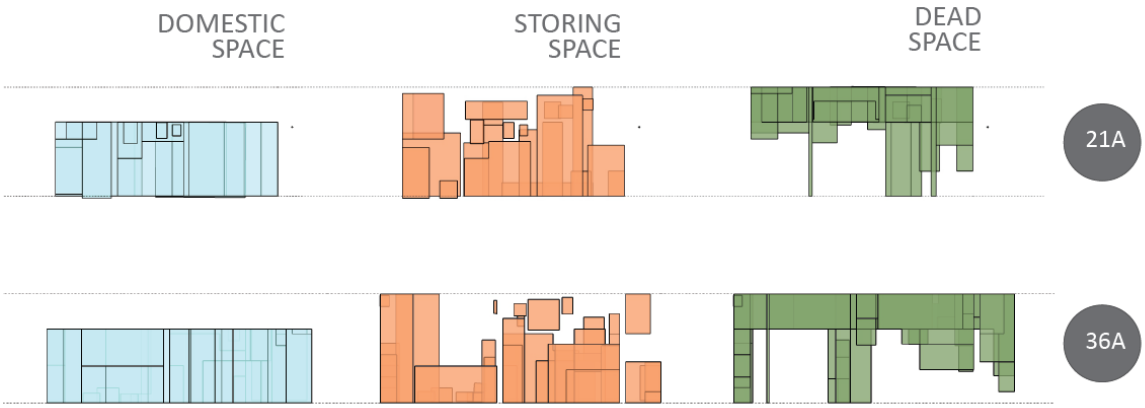

Figure 5. Side view of space utilization volume grouping (Developed by The Author)

Table 2 shows the total calculation of space utilization volume in Type 21 units. Different sizes of the apartment units affected the different amounts of volume. The average size of the room volume is 50.26 m3. The residents use 26 m3 or more than half the volume of the room as domestic space. For storing space, the average residents use 8.63 m3 or about 17.11% of the total volume of space. Meanwhile, dead space average volume is 15.62 m3, or 31.09% of the total space volume.

Table 2. Volume and percentage of space utilization in Type 21 (Developed by The Author)

Code	Occupant (s)	Volume (m3)				Percentage (%)		
		Domestic Area	Storing Space	Dead Space	Total	Domestic Area	Storing Space	Dead Space
21A	5	23.25	10.82	16.56	50.63	45.92%	21.37%	32.71%
21B	2	26.53	10.29	14.22	51.04	51.98%	20.16%	27.86%
21C	5	25.39	9.42	15.74	50.55	50.23%	18.64%	31.14%
21D	1	22.38	10.92	17.62	50.92	43.95%	21.45%	34.60%
21E	5	27.7	7.83	15.54	51.07	54.24%	15.33%	30.43%
21F	1	26.5	5.12	14.97	46.59	56.88%	10.99%	32.13%
21G	4	28.18	7.75	14.96	50.89	55.37%	15.23%	29.40%
21H	5	28.08	6.92	15.35	50.35	55.77%	13.74%	30.49%
Mean		**26.00**	**8.63**	**15.62**	**50.26**	**51.79%**	**17.11%**	**31.09%**

Table 3 shows the total volume calculation of space utilization in Type 36 units. The average volume of space in Unit 36 is 81.05 m3. Similar to Unit 21, different sizes of the apartment units affected the different amount of space volume. Table 3 shows that the average residents use 13.5 m3 or 16.67% of the total volume of the room for storing space. In this type, the average domestic space used is less than half of the total space volume, 49.52%. Meanwhile, the dead space in type 36 is more extensive, which is 27.37 m3 (33.81%).

As mentioned earlier, the space utilization in Type 36 was more significant than Type 21 in terms of volume because Type 36 had a larger area compared to Type 21. We tried to compare the proportion of space utilization by residents. Domestic space dominates in both types compared to other categories because daily activities require more space. In terms of volume, the average Type 36 uses 55% more domestic space than Type 21. However, proportionally, Type 21 uses domestic space, 51.79% of the total room volume, compared to type 36 at 49.52%. Meanwhile, the volume of storing space in Type 36 was 56% greater than Type 21. However, the proportion of storing space usage in Type 21 was slightly more significant (17.11%). The proportion of domestic space utilization and storing space is more significant in Type 21 because the residents try to use the limited space. It also explains that the dead space in Type 21 was lower compared to Type 36.

Table 3. Volume and percentage of space utilization in Type 36 (Developed by The Author)

Code	Occupant (s)	Volume (m3)				Percentage (%)		
		Domestic Area	Storing Space	Dead Space	Total	Domestic Area	Storing Space	Dead Space
36A	4	35.56	15.52	32.48	83.56	42.56%	18.57%	38.87%
36B	2	45.41	11.63	26.46	83.49	54.38%	13.93%	31.69%
36C	3	45.23	9.80	24.33	79.37	56.99%	12.35%	30.66%
36D	5	44.25	10.42	23.23	77.89	56.80%	13.38%	29.82%
36E	4	38.10	12.80	32.58	83.48	45.64%	15.33%	39.03%
36F	2	44.71	10.52	25.04	80.27	55.70%	13.11%	31.19%
36G	5	44.30	17.47	21.96	83.73	52.91%	20.86%	26.23%
Mean		**40.18**	**13.50**	**27.37**	**81.05**	**49.52%**	**16.67%**	**33.81%**

The study revealed that the number of people living in the flat did not affect the storage space size. Unit 21D had the most considerable storing space even though a single resident occupied the unit. Unit 21 D had many furniture and storage areas such as shelves, cupboards, and cabinets. Storing space in Unit 21D was almost the same as Unit 21A that has five residents. Unit 21D and 21F had one resident, but the volume of storing space utilization differed

significantly. Unit 21F only used 5.12 m3 (10.99%) of storing space, while Unit 21D used twice compared to Unit 21F. Unit 21D used storing space more than 21A, 21C, 21E, and 21H which has five (5) residents.

Figure 6. Existing conditions of apartment units (Authors')

Unit 36G has the most considerable storing space, up to 20.86%, since five residents occupy this unit. However, Unit 36D only used 13.38% of the total volume of the room as storing space, even though this unit also had five residents. However, residents of Unit 36D used domestic space than the 36G unit. It showed that space utilization depends on the residents' needs and lifestyle (Marco et al., 2020).

The amount of storing space did not always determine the arrangement of items in the units. Unit 21A was the most disorganized even though it had almost the same amount of storing space. Unit 21D unit looked more organized and more spacious than the Unit 21A. It was also apparent in Unit 21C. Five people occupy Units 21A and Unit 21C, but Unit 21C looked more spacious and organized. By observing the kitchen placement, the difference between Unit 21A and Unit 21G was noticeable. The storing space for Unit 21G was only 15.23%, while Unit 21A was 21.37%. However, Unit 21G installed the top cabinet that was attached to the ceiling. This cabinet added more storing space for kitchen utensils. In addition, some cabinets were equipped with doors, giving them a clean look. Unit 21A only used open shelves that have no door. This shelf had a limited capacity so that many objects cannot be stored. The objects on the shelves were not neatly arranged so that they looked chaotic.

Unit 36G had the most considerable storing space (20.86%), while Unit 36D had the most minor (13.38%) storing space. There were five residents in Unit 36G. However, the arrangement of items in Unit 36G looked quite neat and created a clean impression. Unit 36D had a pile of items in several corners of the room that created clutters. It was quite contrast to the Unit 36A and Unit 36B. The storing space for these two units was quite different (18.57% and 13.93%). However, the item placement on Unit 36B looked tidier, while Unit 36A seemed a little messy. It reveals that arranging items does not depend on storing space and the number of residents. The item placement is very dependent on the residents (Marco et al., 2020; Smith & Ekerdt, 2011).

5. Conclusion

The lack of space is a recurring problem in a densely populated housing area. People find it difficult to live in small houses, and one of the reasons is a lack of storing space (CABE, 2009). The recent pandemic has increased the need for storing space. The issue of storing space usage is problematic because it depends on the characteristics of the residents (Marco et al., 2020). However, by understanding how the residents use their living space, we can reveal how much space they can use at best.

The residents adapt and expand their storing space by placing items on the floor, which means that they simply maximize the utilization of the horizontal surface. They also use the wall for shelves or hanging items. Therefore, it is important to understand the use of space by volume, not by spatial area.

We found that more than a third of the room was dead space that was inaccessible to the residents and was risky to become the place for pests and germs to grow (Krieger & Higgins, 2002). It was clear that when appropriately used, dead space potent to become storing space and offer a solution to answer the issue of space scarcity. However, we do not recommend using the entire dead space because a room still requires air circulation. This study opens further research to find the right proportion to use dead space to solve the shortage of storing space in a low-cost apartment building.

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Conflict of Interests

The authors declare no conflict of interest.

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