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Affordable Modular Housing for College Students Emphasizing Habitability

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Abstract

This research investigated key concepts of temporary residence and analyzed characteristics of modular architecture. Based on the results of the critical review, this research proposed an analytic framework emphasizing habitability to identify the potential of modular architecture as affordable housing for college students. The framework is composed of three dimensions: habitability, sustainability and affordability. Compared to the existing studies on modular architecture, habitability is more heavily emphasized and a new term, 'affordability', is included in the proposed framework. Through the case studies, the residential environment of four dormitories was analyzed using the proposed framework with a focus on comfortable and healthy living. The results suggest that ensuring habitability is essential for residents' comfortable and healthy living; however, it would increase construction and maintenance costs. Social interrelationship among residents could be encouraged through various community facilities and activities, strengthening the residents' ties to the community. The proposed framework would contribute to the development of affordable housing for students, guided by the essential dimensions to be considered for the application of modular housing.

Keywords: modular housing; affordable housing; habitability; sustainability; flexibility

1. Introduction

With the transition to the information technology age, our Korean society has been restructured, which has influenced family life styles and their organization, leading to various types of families. One of the newly emerging types is the single-person household, composed of one resident (Yu *et al.* 2005). Accordingly, the demand for affordable housing that ensures accessibility to adequate housing for single-person households has increased. In particular, there could be a high demand for affordable and temporary housing for college students who live away from home temporarily in cities (Shi *et al.* 2005). The public sector has made efforts to provide affordable dormitories for college students, temporary homes for residents in redevelopment districts, and a reasonable standard of housing for low-income migrant workers. The proposed housing types are prefabricated housing, smaller-scale urban-type housing and modular housing, which are assumed to save construction time and money.

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In addition to housing affordability, the demand for flexible space has also greatly increased (Warouw *et al.* 2010). Space flexibility might be associated with the adaptability to adjust to changes in space requirements, including mobility and transformation of the space in terms of colors, lighting, textures, etc. (Kronenburg 2002; Tanaka *et al.* 2003). The concept of affordable and flexible modular housing has recently been frequently applied in the provision of dormitories for college students. The strength of modular housing is that it is a pre-cast structure that can be easily assembled, and is thus movable to other areas when needed. However, the efforts that have been applied to modular housing have mainly focused on the development of hardware aspects of the architecture, rather than residents' living quality and experience (Gu 2007; Na 2007; Siegal 2007). It is generally believed that the physical condition of modular architecture is poor, and thus residents' comfort and standard of living in architecture would be decreased.

This research aims to propose a potential housing type for dormitories to support students' healthy living. Primarily, our interest is in the potential of modular architecture for affordable housing, emphasizing students' living experience. This research was prompted by the question of what aspects of the residential conditions should be given more consideration for enhancing residents' living. Critical concepts and

characteristics associated with temporary residences were first identified, and then an analytical framework for analyzing the characteristics and application of contemporary modular architecture as flexible space utilization was provided. Based on the classification of the spatial characteristics of modular architecture, four dormitories used by college students were selected as modular housing cases. Based on the case studies, this research will suggest a promising direction for affordable housing for college students that will offer reasonable rent and healthy living conditions.

2. Related Works

Research that deals with temporary housing and modular architecture was analyzed in terms of key concepts and space construction. In addition, research into the residential environment quality was reviewed with a focus on habitability and living experience.

2.1 Temporary Residence and Space Construction

Temporary living in a residence means living there for a limited specific period, so the residence is assumed to be movable to other places after the specific period (Siegal 2007; Iwasa *et al.* 2012). Temporary residence in a space can be associated with flexibility, where interactions among residents, spaces and activities can be provided on a temporary basis. Kim and Song (Kim and Song 2012) defined temporary residences in terms of two aspects: primitive space that can be constructed for any context any time as needed, emphasizing mobility and flexibility; and fluid space that emphasizes transitory and instantaneous concepts. Modern temporary housing reflects open spaces performing complex functions for multiple purposes, producing new lifestyles in residential environments (Felix *et al.* 2013). The characteristics of space construction reflecting temporary housing were identified largely in terms of two types.

- The *transporting* type is a movable and transportable structure that can easily be constructed to be a residential space for a short time, based on residents' needs. The main features of this type are the lightness of the structures or materials for transportation, and ease of assembly or disassembly.
- The *transforming* type is a space with an instant transforming function to accommodate residents' daily activity programs and usage. This type emphasizes variability of the space, which can be adjustable to residents' needs without much effort. For example, by utilizing furniture, partitions or sliding walls, spaces can be extended and reorganized.

2.2 Modular Architecture and Space Construction

From the 1990s, containers have been used as temporary living space for workers on construction sites, and more recently have been introduced as an effective modular building material for residential spaces. Freight containers have great strength, durability and reusability. However, the metal of containers can conduct heat efficiently, so the temperature of the indoor environment can be changed rapidly (Kim 2011). The most distinguishing feature is the modular element, which means they can be moved to any area and assembled into any scale of space. Many people have proposed modular architecture as an alternative to conventional living spaces by emphasizing its potential for economic and efficient features (Slawik *et al.* 2010). Throughout the world, many modular units and containers have been developed for use as hotels, dormitories and housing. By utilizing the potential of modular architecture, the developers have added many ideas for modular housing in addition to the related research (Slawik *et al.* 2010; Kronenburg, 2002). The characteristics of modular architecture were identified in terms of space construction and unit composition as follows:

- The deploy-ability enables the extension or reduction of the space according to a situated context.
- The modularity represents the standard modular element that can be easily stacked up or combined.
- The weight of the modular is light, enabling ease of mobility and deployment.
- The interoperability allows it to be reconstructed or moved easily because of the simplicity of structure.
- The structure of the unit composition can be divided into five types: a single unit, a linear stacked structure, a stacked structure with various directions, a variable structure combined with a conventional building, and a variable structure extended from a single unit.

2.3 Residential Environment Quality

The overall assessment of human experience has been commonly expressed by the term 'quality of life' (QOL), representing either how well human needs are met or the extent to which people perceive satisfaction in various domains (Costanza *et al.* 2007). In the housing domain, authors are specifically interested in residential environment quality with a focus on habitability and living experience. Bonaiuto *et al.* (Bonaiuto *et al.* 1999; Bonaiuto *et al.* 2006) proposed a set of indicators that measured how people perceive the quality of their residential environment. They emphasized the importance of neighborhood attachment for the perceived residential environment quality. To improve the residential environment quality, Xianyu *et al.* developed a residential environment evaluation system and models focusing on residential attributes, residential satisfaction, residential preferences and residential selection factors (Xianyu *et al.* 2007). In general, two assessment methods are utilized for measuring the residential environment

quality. One is to use quantifiable indicators to reflect the extent to which human needs are met. The other is a subjective method including self-reported levels of happiness, fulfillment, and the like. The quantifiable indicators related to the physical condition of the dwelling, internally and externally, with the essential components being the adequacy of a house to live in and its energy and resource efficiency. Residential satisfaction is one of the most subjective factors associated with residential environment quality. Many researchers have worked on the assessment of residential satisfaction (Mohit *et al.* 2010; Ibem and Aduwo 2013; Tao *et al.* 2014).

3. Research Methodology

To identify factors necessary for planning modular housing for college students, a FGI (focus group interview) and field study were conducted with 17 college students who live alone in a one-box shaped unit in Korea. The survey was conducted in November and December, 2013. The one-box shaped unit is not prefabricated modular housing. Through the analyses of the current status of housing, authors attempted to ascertain what types of factors should be considered as essential elements when designing modular housing for college students. An analytic framework was developed based on the result of the investigation as well as critical reviews of previous studies on modular architecture and residential environment quality. To verify the proposed framework, case studies on modular housing was performed from March to July, 2014, through a field study and in-depth interview in four dormitories, where three of which are located in Germany and the other in Korea.

3.1 Result of FGI and Field Study

The responses to the interview and field study were analyzed in terms of physical conditions and satisfaction regarding the current housing, their demands of the housing and their preference of modular type. Housing habitability was raised as an issue by students. Students were not satisfied with their unit sizes. For example, they need a wider porch and more storage spaces for their units, and especially some space for a clotheshorse. They complained about the poor ventilation conditions of their environment. In general, the units contain just one room with a separate bathroom in each unit, where even the kitchen is a part of their one living space. It is difficult for students to have sufficient windows, so little air circulation occurs in the units. Furthermore, they were not happy about dry air in the environment that might be caused by the poor condition of the ventilation. It seemed that they are uneasy about their safety, especially regarding burglary. They argued that there should be secure systems or door locks for the entrance to the buildings in addition to that of each unit. They highlighted either inadequate heating sources and/or difficulties in heating their houses due to other issues such as lack of insulation or holes in the building structure, including floors, roofs, walls and windows. Other issues reported by participants related to the need for other major repair work and to general maintenance and upkeep of properties.

3.2 An Analytical Framework of Modular Housing

Table 1. shows the analytical framework of modular housing developed from the reviews of previous studies and the results of the survey. From the four dimensions, nine categories and twenty-four elements, fifty-three question items were developed for analyzing modular housing. To visualize the evaluation effectively, 'Harvery Balls', simplifying the value as a pictogram, were used.

The dimension 'habitability' refers to the basic requirements of the residence, including the four categories of safety, health, comfort and sociality. Each category has elements to be considered to realize it. For example, the elements of the category 'safety' are fire safety, security and physical safety, while the category 'health' includes five elements – thermal, ventilation, noise, light and hygiene. The concept 'comfort' is associated with three factors – location/transportation, amenities and personal environment. The category 'sociality' reflects community senses by including two elements – social integration and community facility. The dimension 'sustainability' represents the degree of reusability, environmental friendliness and mobility of the spaces. Existing modular units can be reused and some parts also can be replaced with new ones easily when needed. In addition to the consideration of eco-friendly materials for the architecture, the appearance of the modular unit is one of the important elements for realizing sustainability. The category 'mobility' consists of two elements – 'lightweight material' and 'rapidity of installation'. Under the term 'affordability', two sub-concepts – economic feasibility and modularity/flexibility were included. The former is associated with the cost whereas the latter is related to the functional aspect of the building. To guarantee economic feasibility, the unit price, the construction cost and the maintenance cost need to be reduced. Modularity is the most essential feature of the architecture because it enables complex composition using simple shapes of modular units. Modular units can be stacked linearly or in various directions when built. They can be flexible, being folded or unfolded according to a purpose of the space. It is also expected to support economic feasibility by decreasing the cost of the building construction.

4. Case Studies

Authors analyzed four modular housings using the proposed framework, as shown in Table 2.

4.1 Four Modular Housings

1) Delft Spacebox

The Spacebox was introduced as modular housing for college students at Delft University. Over 1,000

Table 1. An Analytical Framework of Modular Housing

Dimension	Category	Environmental Indicator (EI)	EI Questions
Habitability	Safety	Fire safety	1. Does the modular housing meet the requirements for fire retardants?
			2. Is there a fire alarm system or a fireplug?
		Security	3. Is there a secure gate in the building that can control visitors' access in and out?
			4. Is there a door view/lock or CCTV in the building for surveillance?
		Physical safety	5. Are there non-slippery finishes and handrails in stairs, corridors and balconies for residents' safety?
			6. Is there sufficient lighting in the corridors for residents' safety?
			7. Are there any flaws in the structure of doors and windows that cause difficulties in opening them?
	Health	Thermal environment	8. Is the indoor temperature in winter suitable for living?
			9. Is the indoor temperature in summer suitable for living?
			10. Is the indoor humidity in winter suitable for living?
		Ventilation	11. Is the natural ventilation sufficient?
			12. Is there equipment for indoor ventilation?
			13. Is there any treatment to prevent units from leaking water or dewfall?
		Noise	14. Is the noise level caused by the next-door unit acceptable?
			15. Is the noise level of footsteps between building floors acceptable?
			16. Is the shaking caused by external noise (i.e. people's movement in corridors, opening and closing of doors, cars' movement) acceptable?
		Light	17. Is the natural lighting sufficient in the daytime?
		Hygiene	18. Is professional maintenance performed for buildings and units?
			19. Is the hygiene of public spaces in buildings suitable for living?
			20. Are the finishing materials efficient for cleaning and maintenance?
	Comfort	Location/ Transportation	21. Is it convenient for them to attend colleges from their residency?
			22. Is there good access to public transport around their residency?
		Amenities	23. Is the Internet service available in units?
			24. Are there convenient facilities such as retail stores, libraries, bike storage and laundry rooms in buildings?
			25. Is there good access to neighboring facilities such as clinics and pharmacies?
		Personal Environment	26. Is the size of the unit sufficient for living?
			27. Is the height of the unit sufficient for living?
			28. Is the furniture convenient for living?
			29. Is there enough storage space in the unit?
			30. Is the size of the bathroom in the unit sufficient?
	Sociality	Social Integration	31. Is there a community organization in buildings?
			32. Are there various community activities provided?
			33. Is the circulation planned to encourage students to meet each other easily along the circulation?
		Community Facilities	34. Are there enough public spaces such as lounges and cafeterias?
			35. Is there an outdoor space for students' outdoor activities?
Sustainability	Reusability	Reuse of existing modules	36. Are existing modules reusable for modular housing?
			37. Are existing modules usable for other purposes?
		Interoperability of parts	38. Can old or broken modules be replaced with new ones?
	Environment friendliness	Materials	39. Are materials used for the modules environment-friendly?
			40. Are environment-friendly methods used to supply heating, boiling and electricity?
		Appearance (color, etc.)	41. Do the appearance, color and finishes of buildings look good with the surrounding environment?
			42. Are the indoor finishes and colors beautiful?
	Mobility	Lightweight material	43. Is the material of the modules lightweight?
		Rapidity of installation	44. Is it easy to assemble and dissemble the modules?
			45 Could modular housing be moved by cranes and built in a shorter time?
Affordability	Economic feasibility	Prefabricated	46. Can modular housing be mass-produced in factories?
		Construction cost	47. Can the construction cost for modular housing be reduced by a shorter construction time?
		Maintenance cost	48. Is the maintenance cost of a unit reasonable?
			49. Is there a way provided to reduce the maintenance cost?
	Modularity/ Flexibility	Deploy-ability	50. Are there various plan types?
			51. Are modules stackable vertically and horizontally?
		Transformation	52. Is each module modifiable or transformable?
			53. Can the composition methods of modules be varied for construction?

Spaceboxes have been constructed as dormitories for students across several districts of Holland. The Spacebox is located in a small city, Delft, 60 km from Amsterdam.

Fig.1. Indoor and Outdoor Environment – Spacebox

2) Amsterdam Keetwonen

Keetwonen is a dormitory of six building blocks made of containers. All containers were rented and SSF, a department of housing corporation De Key, does the facility management of the Keetwonen. Keetwonen is supposed to be moved to another site and reconstructed every five years.

Fig.2. Indoor and Outdoor Environment – Keetwonen

3) Berlin Eba51

The idea of comfortable housing with a low cost prompted the construction of Eba51.

Fig.3. Indoor and Outdoor Environment – Eba51

Eba51 is a student dormitory consisting of 400 modules of differently colored groups of shipping containers. The in-between zone is a place for meeting that serves as a common balcony as well.

4) Seoul Gongreung Hope Housing

The Hope housing is a public dormitory located in Gongreung, Seoul. The dormitory is composed of modules from the second floor to the fourth floor and a concrete structure on the first floor. Common living spaces such as a laundry room, a dining room and a book cafeteria are located on the first floor.

Fig.4. Indoor and Outdoor Environment – Hope Housing

4.2 The Analysis of the Four Modular Housings

The Spacebox solution at Delft University of Technology has strength in sustainability, but is weak in affordability due to the lack of variability of each unit's plan. In terms of habitability, it demonstrates many problems. For example, privacy and crime prevention are vulnerable points, and no community facilities are provided. Further, the units are small and storage space is insufficient. Through the in-depth interviews, it was found that students complain about stuffy units and insufficient storage space, which causes their residence to become untidy easily. Some students intend to move out because of the lack of community facilities. As no additional labor costs are incurred for construction, due to the prefabricated nature of manufacture, economic feasibility is good.

By utilizing the strength of the containers, Keetwonen provides good habitability in terms of safety and sociality among residents. Through the narrow, but long containers, the problem of the small size of the units is solved. Above all, the interior space can be divided into two sections according to residents' needs. Through the in-depth interviews, it was found that students feel a little uncomfortable with the narrow width of the container. However, they are satisfied with the separate kitchen and convenient community facilities in the dormitory. The weakness of the original cargo container was reinforced with fireproof and insulation structures. In general, Keetwonen rates well in the three dimensions of the framework, demonstrating the potential of sustainable and flexible planning.

Eba21 shows strength in habitability. By adopting multiple walls, insulation, noise prevention and natural ventilation, it demonstrates high values in 'health'. Different plan types are developed for one to three

Table 2. An Analysis of Four Modular Housings using the Framework

Dimension	Category	Environmental Indicator (EI)		Spacebox	Keetwonen	Eba51	Gongreung	Total
Habitability	Safety	Fire safety	fire retardants	●	●	●	●	●
			fire alarm system	◔	●	●	●	◕
		Security	a secure gate	○	●	●	●	◕
			surveillance system	◔	●	●	●	◕
		Physical safety	non-slippery finishes, handrails	◑	◑	◕	◕	◕
			lighting in the corridors	○	◑	◑	◑	◕
			flaws in doors and windows	◕	◕	●	◕	◕
	Health	Thermal environment	indoor temperature in winter	◕	◕	◕	◕	◕
			indoor temperature in summer	◑	◑	◑	◔	◑
			indoor humidity in winter	◑	◑	◑	◔	◑
		Ventilation	natural ventilation	○	●	●	○	◑
			equipment for indoor ventilation	◔	◔	◔	◑	◔
			leaking water prevention	◑	◑	◑	◑	◑
		Noise	noise level from next door	◔	◔	◑	◑	◑
			noise level between building floors	○	◔	◑	◔	◔
			shaking caused by external noise	○	◑	◕	◔	◑
		Light	natural lighting	◔	◑	◕	◕	◑
		Hygiene	professional maintenance	◔	◕	◕	◑	◕
			hygiene of public spaces	◔	◔	◕	◑	◑
			finishing materials for maintenance	◑	◑	◑	◑	◑
	Comfort	Location/ Transportation	convenient to attend colleges	●	◕	◑	◕	◕
			good access to public transport	●	●	●	●	●
		Amenities	the Internet service	◕	●	●	●	●
			convenient facilities	◔	●	◕	◑	◕
			good access to neighboring facilities	◔	●	◔	◕	◑
		Personal Environment	the size of the unit	◔	●	●	◔	◑
			the height of the unit	◑	◑	◑	◑	◑
			the furniture	◔	◔	◑	◔	◔
			storage space	○	◑	◑	◑	◑
			the size of the bathroom	○	◕	●	◑	◑
	Sociality	Social Integration	community organization	◔	◕	◕	◑	◑
			community activities	○	●	●	○	◑
			circulation to encourage meetings	○	●	●	◑	◕
		Community Facilities	public spaces	○	●	●	◔	◑
			an outdoor space	◑	●	●	○	◕
Sustainability	Reusability	Reuse of modules	reusable modules	●	●	●	●	●
			modules usable for other purposes	●	●	◑	◑	◕
		Interoperability of parts	modules can be replaced with new ones	●	●	◑	◔	◑
	Environment friendliness	Materials	modules environment-friendly	◑	●	●	◑	◕
			environment-friendly methods	●	●	●	●	●
		Appearance (color, etc.)	the appearance of buildings	◕	●	●	◕	●
			the indoor finishes and colors	◔	◑	●	●	◕
	Mobility	Lightweight material	the material of the modules	◑	◑	◑	◑	◑
		Rapidity of installation	easy to assemble and dissemble	●	●	◕	◕	●
			can be moved and built in a shorter time	●	●	◕	◕	◕
Affordability	Economic feasibility	Prefabricated	mass production	●	●	○	○	◑
		Construction cost	construction cost	●	●	◔	◔	◕
		Maintenance cost	maintenance cost	●	●	◑	◕	◕
			a way to reduce cost	◑	●	◑	◔	◑
	Modularity/ flexibility	Deploy-ability	various plan types	○	●	●	○	◑
			stackable vertically and horizontally	●	●	◑	◑	◕
		Transformation	modifiable or transformable	○	●	●	○	◕
			varied composition method	●	●	●	◑	◕

*Harvery Balls ○ ◔ ◑ ◕ ● represent 'very poor', 'poor', 'average', 'good', 'very good' respectively.

persons, where built-in furniture and sufficient storage spaces are provided. Buildings are connected through stairs, corridors and bridges, allowing residents' to have frequent encounters. Further, social interaction among residents occurs in community facilities such as a barbeque booth, a small garden and a gym. Emphasizing sustainability, it has an environment-friendly appearance with reused containers in addition to the adoption of biogas for heating. However, in terms of economic feasibility, mass production is not implemented, causing high construction costs. Through the in-depth interviews, it was found that students feel the high maintenance cost is a burden although they are satisfied with the habitability of the housing.

Gongreung housing was constructed in a shorter time by adopting modular architecture. It has strength in terms of environment friendliness and the maintenance cost. However, in terms of health, problems exist such as a lack of noise protection, uniform plan types and little natural ventilation. The size of the unit is small and the storage space is insufficient for two people. Through the in-depth interviews, it was found that students complain about the shared bathroom and the noise from external cars, especially the high shaking level caused by cars. Gongreung housing ensures affordability for students; however, it might cause problems in habitability, especially concerning noise and personal environment.

5. Conclusion and Discussion

This research proposed a framework to identify the potential of modular architecture for affordable housing. The framework is composed of three dimensions, namely habitability, sustainability and affordability. Habitability is heavily emphasized in the proposed framework to guarantee a reasonable standard of living. Previous studies on modular architecture applied to residences have concentrated on the size of the space with a focus on the economic feasibility. However, affordability should not be confined to the economic aspect, but include also the positive functional aspect of the housing, modularity, to provide a reasonable quality of living conditions.

To validate the proposed framework, authors selected four dormitories, and then analyzed the residential conditions using the proposed framework. There are several 'habitability' and 'affordability' issues to be considered for healthy living as follows.

Regarding safety, all dormitories exhibit good conditions except the Spacebox. However, weaknesses exist in health in all dormitories in terms of thermal environment, ventilation, noise and hygiene. To solve the problems, insulation, noise prevention, and cross ventilation are needed for modular architecture. By constructing balconies at the end of long and narrow modules, effective cross ventilation occurred in Keetwonen and Eba51. Problems existed with the hygiene of public spaces in all four dormitories. A maintenance service or finishing materials that promoted efficient cleaning should be implemented.

Regarding comfort, all dormitories are located in a convenient area with good access to public transport and convenient facilities. However, students complained about the size and height of units, storage spaces and built-in furniture. To support their comfortable living within a unit, varied types of plans with different sizes, and built-in furniture customized to students' lifestyles should be developed.

Regarding sociality, it was found that differences exist in students' satisfaction about their residency according to the availability of community facilities or activities in dormitories. Students in the Spacebox do not have a strong attachment to their communities because no community facilities are provided, while students in Gongreung housing also exhibit weak social integration because of lack of community activities. On the other hand, students in Keetwonen and Eba51 have a strong attachment to their communities with satisfaction about their living conditions. Social interrelationship among residents could be encouraged through various community facilities, strengthening the residents' feelings of belonging to the community. In addition, residents' encounters would be enhanced, leading to social interaction, through circulation via corridors.

Above all, ensuring habitability is essential for residents' comfortable and healthy living; however, it would increase construction and maintenance costs. For example, Eba51 ensures habitability; however, it demonstrates problems in economic feasibility because the high construction cost increases the maintenance cost accordingly. On the other hand, the economic feasibility of Gongreung housing is good; however, there are problems with habitability such as high noise and shaking. To ensure habitability teamed with good economic feasibility, the development of modular housing should be supported by public sectors such as government and municipal district. In addition, more sustainable systems that utilize various pieces of idle land efficiently or relocate modular units to another site easily should be developed. Further, emphasizing energy savings, centralized heating systems, economic hot water systems, maintenance cost aid and finishing materials that are easy to maintain could be provided to relieve the residents' financial burden in their living.

Through the case studies, authors see the potential of modular architecture for affordable housing, especially for college students. It is expected that we could construct affordable housing with sustainability and flexibility by utilizing the strengths of modular architecture, i.e. modularity, prefabrication, reusability, durability and low construction cost, etc. For example, we could build dormitories using affordable modular units on an available area of a campus and move it to other available areas when needed. As long as the availability is confirmed for at least five years, we

can start to construct dormitories for students without being concerned about the long-term availability of the land. The flexibility of modular architecture allows us to extend or reduce the scale of the entire dormitory facility, to suit any situation. There has been little research dealing with critical concepts and frameworks for research on modular architecture. The proposed framework would contribute to the development of customized and affordable housing for students, guided by the essential dimensions to be considered for the application of modular housing. Further detailed factors that can be applied to the modular housing will be explored, and more case studies will be discussed in future studies.

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References

1) Bonaiuto, M., Aiello, A., Perugini, M., Bonnes, M. and Ercolani, A. P. (1999). Multidimensional Perception of Residential Environment Qulity and Neighbourhood Attachement in the Urban Environment. Environmental Psychology **19**, pp.331-352.
2) Bonaiuto, M., F. Fornara and Bonnes, M. (2006). Perceived Residential Environment Qulity in Middle-and Low-extension Itlaian Cities. Revnue Euripeenne De Psychologie Appliquee **56**, pp.23-34.
3) Costanza, R., Fisher, B., Ali, S., Beer, C., Bond, L. and Bourmans, R. (2007). Quality of Life: An Approach Integrating Opportunities, Human Needs, and Subjective Well-Being. Ecological Economics **61**(267-276), pp.
4) Felix, D., Branco, J. M. and Feio, A. (2013). Temporary Housing After Disasters: A State of the Art Survey. Habitat International **40**, pp.136-141.
5) Gu, H. J. (2007). Design of Urban Playground with Container Boxes. Master, Kyunggi University.
6) Ibem, E. O. and Aduwo, E. B. (2013). Assessement of Residential Satisfaction in Public Housing in Ogun State, Nigeria. Habitat International **40**, pp.163-175.
7) Iwasa, A., Hasegawa, T., Shinkai, S., Shinozaki, M., Yasutake, A. and Kobayashi, K. (2012). A Practical Approach to Temporary Housing for Disaster Victims. Journal of Asian Architecture and Building Engineering **11**(1), pp.33-38.
8) Kim, M. K. (2011). The Characteristics of Space Construction for Container Architecture and Its Application. Journal of Human Ecology **15**(2), pp.177-185.
9) Kim, M. K. and Song, A. H. (2012). The Types and Characteristics of Space Construction in Temporary Small-sized Housing for Single-Person Household. Journal of Korean Housing Association **24**(1), pp.115-124.
10) Kronenburg, R. (2002). Living in Motion; Design and Architecture for Flexible Dwelling. Weil am Rhein Vitra Design Museum.
11) Mohit, M. A., Ibrahim, M. and Rashid, Y. R. (2010). Assessment of Residential Satisfaction in Newly Designed Public Low-Cost Housing in Kuala Lumpur, Malaysia. Habitat International **34**, pp.18-27.
12) Na, H. S. (2007). A Study on the Nomadic Characteristics of Modern Residential Space through Post Structuralism Speculation. Master, Konkuk University.
13) Shi, J., Ge, J. and Hokao, K. (2005). Campus Lifestyle and Its Relationship with Residential Environment Evaluation. Journal of Asian Architecture and Building Engineering **4**(2), pp.323-330.
14) Siegal, J. (2007). More Mobile, Portable Architecture for Today. New York, Princeton Architectural Press.
15) Slawik, H., Bergmann, J., Buchmeier, M. and Tinney, S. (2010). Container Atlas; A Practical Guide to Container Architecture, 2rd ed. Berlin, Gestalten.
16) Tanaka, M., Kikuchi, Y., Akazawa, A., Funo, S. and Kobayashi, M. (2003). Spatial Characteristics of Core Housing Units Brought by Residents' Extension Activities at Tung Song Hong Settlements in Thailand. Journal of Asian Architecture and Building Engineering **2**(2), pp.123-130.
17) Tao, L., Wong, F. K. W. and Hui, E. C. M. (2014). Residential Satisfaction of Migrant Workers in China: A Case Study of Shenzhen. Habitat International **42**, pp.193-202.
18) Warouw, F., Kobayashi, H. and Jung, J. (2010). A Study on the Open Building System for Multi-Storey Housing in Indonesia. Journal of Asian Architecture and Building Engineering **9**(2), pp.339-346.
19) Xianyu, L., Jian, G., Fei, C. and Hokao, K. (2007). Residential Environment Evaluation Model and Residential Preferences of the Changjiang Delta Region of China. Journal of Asian Architecture and Building Engineering **6**(2), pp.299-306.
20) Yu, J. R., Jeong, C. O. and Kim, Y. S. (2005). A Study on The Application of Smart Technology in Single Household Space. Proceedings of Conference of Architect Institute of Korea.