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# Conceptual Design Study on a Multi-Story Building System as the Host Structure for Mobile Home Units

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## Abstract

A large percentage of the starting young working force or low-income segment of the US population cannot afford to purchase homes and must spend a considerable portion of their income on renting apartments. While mobile home or as currently referred to as manufactured home ownership could have been a temporary solution, the current housing market is not in favor of conventional mobile homes for various reasons. In order to make the idea of mobile home ownership attracting again, instead of mobile home parks, a new idea for placement of the units is needed. This paper builds on the concepts developed earlier for vertical mobile home placement. The methodology for this study is more conceptual design and comparison of strength and weaknesses of the options suggested for the proposed main concepts. Accordingly, this paper first reviews the path of developments from mobile homes on wheels to multi-story modular buildings and then contributes to a new concept for mobile homes where the unit can be plugged (*i.e.*, placed and secured) in a host multi-story structure, with the capability of being able to be removed at a later time. The contribution of the paper is mainly in developing ideas and requirements for conceptual design of the mobile home units, lifting systems, and the host building structure.

## Keywords

Residential Buildings, Mobile Homes, Modular Construction, Manufactured Homes, Housing Affordability, Multi-Story Buildings, Highrise Buildings

## 1. Introduction

The necessity for young or low-income workers to move from one town to another

is part of today's job dynamics. This early career challenge requires such population of workers to be renters, who reside in 34.7% of the rented homes [1]. Many renters also have to deal with high rental rates for extended periods and cannot afford purchase of their own homes, and this is a 50-year low issue, *i.e.*, the home ownership and rental market have reached an alarming state of unaffordability not seen since 1970's [2]. Accordingly, there is a need for a housing solution that simultaneously addresses affordability, mobility, and home ownership is evident.

This paper explores a new, inexpensive, movable housing option that could be introduced to the market to help such a workforce start home ownership [3]. While this may sound like the traditional mobile home (or as currently referred to as manufactured home), new concepts regarding where and how to place or securely position such mobile homes will be elaborated later in the paper. It should be noted that while the idea of mobile homes that once was popular (e.g., **Figure 1**) and can still be an option for some areas, unfortunately due to the stigma around such home ownership and the distance from mobile home parks (e.g., **Figure 2**) to city centers or metropolitan areas where most jobs are, such a solution is not generally realistic and practical any longer for large cities. Therefore, the demand for mobile home purchase and ownership has been reducing. The main idea of this paper is to contribute toward the concept of a multi-story structural system as a host structure that can house "removable" modular units to address this need, thus introducing a new generation of mobile home ownership [4]. These mobile units will be much like conventional modular units (**Figure 3**) used for multi-story modular construction (e.g., **Figure 4**) [5].

The units proposed in this study can be stand-alone mobile homes supported on the ground as conventional manufactured housing units as shown in **Figure 5** [6], or they can function mainly as intended in this conceptual design (**Figure 6**) [7]. Potential desirable attributes of such modular units include the following:

**Figure 1.** An example mobile home (Used with permission) (https://homenation.com/blog/cost-to-buy-a-mobile-home-in-michigan) [Site visited on 07/06/26].

**Figure 2.** An example of a dense mobile home park (Used with permission; Credit: Sydney Sanders with Braustin Homes: https://www.braustin.com/blog/how-to-find-the-right-mobile-home-park-to-live-in/) [Site visited 07/06/26].

**Figure 3.** Example of a modular unit for multi-story (Used with permission; Credit: Nancy Holliday: Holliday Development and Craig Webb) [Site visited on 07/06/26].

**Figure 4.** Example high-rise modular construction (Used with permission) https://s3da-design.com/steel-framed-modular-construction-for-high-rise-hotels-what-you-need-to-know/ [Site visited 06/20/26].

**Figure 5.** Proposed mobile home unit as a stand-alone ground support unit.

a) when the unit is not settled on the ground or plugged (securely positioned) in the host structure, it should be able to be towed, b) the unit should optionally have a compact economical design and preferably allow for utilization of recyclable materials, c) the unit should be durable and easily repairable if damaged, d) the unit should have retractable wheels and a custom interior design, and e) the architectural design of the unit should follow the principles of desirable indoor air and environmental quality for the occupants [8].

The idea that has been developed by Jellen and Memari [7] and is contributed to in this paper will allow an individual to purchase an affordable small home, which can be self-towed or trucked so that the homeowner can move the home where they need to relocate. The structural system of the multi-story host structure can be a steel or concrete frame system, which will have the capability of allowing the mobile home units to be plugged into the host structure or unplugged as appropriate (*i.e.*, secured in its position in the host structure, and then removed from the structure). The main design concepts for this proposed system consist of 1) the mobile home units, 2) the structural system of the host building, and 3) the mechanism to lift and plug/unplug the units. This paper first reviews the developments in mobile home industry from the original concept of a unit on wheels to multi-story modular construction made up of stacked modular units, to the focus of this paper, which is a new class of multi-story modular construction, where the modular units can be lifted and plugged in a host structure and later unplugged and removed when necessary. The emphasis here is then placed on development of the system concept to allow a unit to be lifted from the street level and plugged into the structures, as shown in **Figure 6**. A comprehensive background literature review was conducted and is briefly explained in the next section to provide a context for the path of mobile home development from early features to multi-story modular buildings to the concept presented in this paper. This includes review of relevant studies on the main conceptual design and construction

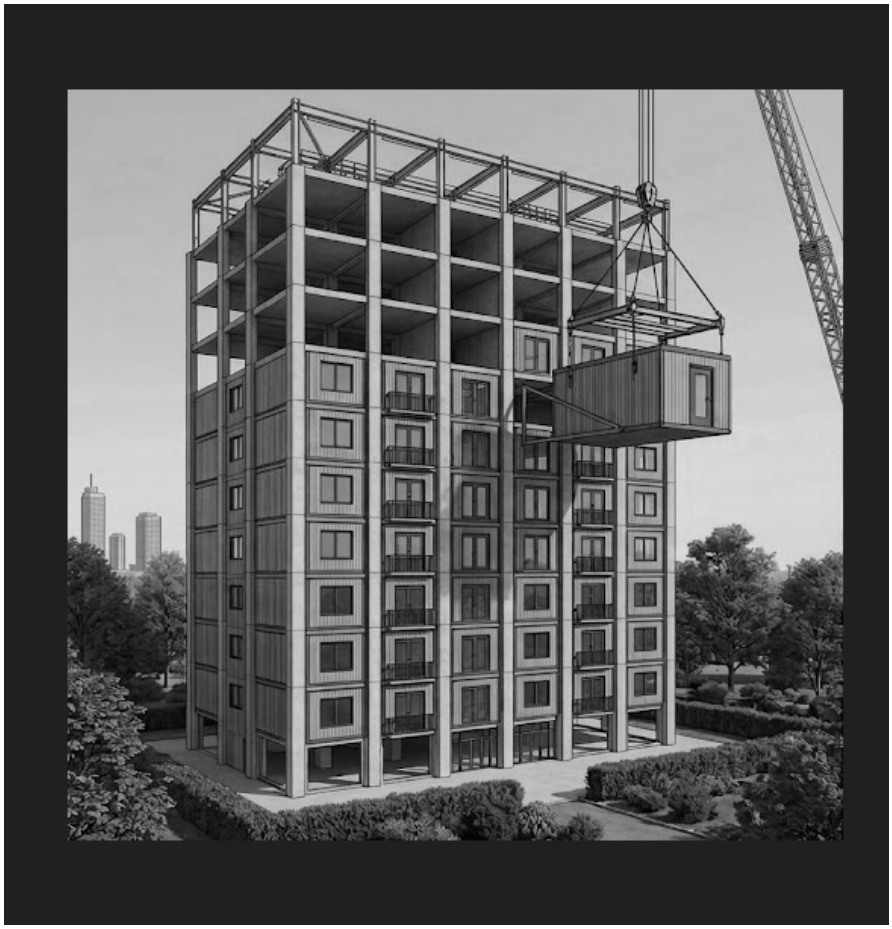


**Figure 6.** Proposed concept of a modular unit that can be lifted and plugged into a host structure (Sketch adapted from [7]).

systems developed for housing mobile home units in multi-story structures. Finally, the paper presents and discusses strengths and weaknesses of new concepts developed here for the mobile units, the lifting system to place a mobile unit in a host structure and the structural requirements for the host structure including some green design suggestions.

## 2. Brief Literature Review on History of Mobile Homes

"Travel trailers" of the 1920's were the predecessors of modern-day mobile homes [9]. The 1930s witnessed a rise in new designs and popularity of these manufactured units, with total sales of $55 million for about 100,000 units annually. During World War II and beyond, many made these trailers as home [10]. After the war, due to the popularity of these units, more advanced models were created and instead of trailer homes, they were called "mobile home". The peak of the popularity of these units is thought to be in the 1950s and 1960s, beyond which interests and thus the demand started to change.

According to Wallis [11], two factors influenced the rise and fall of interest in mobile homes. The factor that gave rise is the innovative creation of parks that

housed mobile homes. The factor that caused the decline in interest is the regulations imposed on such housing in the 1970s and 1980s. More specifically, the National Mobile Home Construction and Safety Act of 1976 required safer and better-quality mobile homes, and it changed the term from "mobile" homes to "manufactured" homes, which would need specialty equipment and a licensed installer to transport and set the unit in a lot [12]. Such a change that is associated with higher prices and better quality removed the stigma about mobile homes, as the units were now considered manufactured homes and were not actually mobile. These manufactured homes, however, did not have the advantage of affordability that was associated with traditional mobile homes. These and other challenges are reflected in a study by Wentling [13] who describes the story of mobile homes and the journey to be considered manufactured homes in the United States. The study investigated the challenges faced by manufactured housing as well as its potential to address the shortage of affordable housing.

Mobile homes gradually turned to permanent housing [11], and currently, these manufactured homes need to be located in a given lot without the ability to be mobile. One of the goals of the Housing Act of 1968 was to have these manufactured homes available for low-income households. "Operation Breakthrough" (May 1969) was intended to provide such a housing system for the target population, and in four years the United States government sponsored production of 25,000 mobile homes, which cost the government $72 million. During the same period, the mobile home industry built 2.5 million units. In effect, it became clear that the only unsubsidized and affordable housing system was factory-built housing, and this was the beginning of their acceptance as a form of permanent housing. Of course, this change was also associated with more regulations for this special type of housing. Because of the building code or other relevant standards for safety and quality, these homes were not as affordable as prior to the 1970s, but the occupants benefited from higher quality that meant safer and more durable homes.

One issue that perhaps impeded the popularity and high production of mobile homes is the challenge to create mobile home parks of better quality. A study by Shai and Eaton [14] discussed the background and context of mobile home communities in the United States. It focused on the fact that mobile homes are a common type of affordable housing, particularly for low-income segment of the population. The study showed, however, that mobile home parks are frequently situated on properties that are undergoing redevelopment or re-zoning, which may force the entire parks to relocate and/or some mobile homeowners to move to other locations. Moreover, mobile home parks frequently have fewer restrictions and safeguards than other types of housing developments, which might make tenants more susceptible to further relocation. The study's conclusion emphasized the significance of comprehending mobile home residents' experiences in the context of housing policy and planning.

The terminology related to mobile homes had to be revised in the 1980s because the public could not distinguish the differences between different products such

as manufactured vs mobile homes vs trailers. Today's manufactured homes are not mobile, except for their transport to their permanent location. The mobile home, on the other hand, was still truly mobile. Beginning in 1960s, the manufacturers started to produce the two basic types of factory-assembled homes: manufactured homes (formerly referred to as mobile homes) and modular homes (which are factory assembled in two or three parts for detached single family homes or as rectangular shaped units for multi-family buildings) [15]-[17]. Given this trend, out of the 27 top mobile home manufacturers, 10 of them also produced modular homes or recreation vehicles (RVs) by 1987. Despite the public's interest in owning mobile homes, the trend towards fewer parks being available and also more regulations being passed led to reduced number of these units to be found in parks, e.g., only 40% by 1987 (**Figure 7**). This resulted in a trend for mobile homeowners to also own their own land, since more parks were being taken away from their intended purpose of providing the land for these units.

**Figure 7.** An example of a less dense mobile home park (Used with permission; Credit: Sydney Sanders with Braustin Homes: https://www.braustin.com/blog/how-to-find-the-right-mobile-home-park-to-live-in/) [Site visited 07/06/26].

According to Wallis [11], from mid-1970s to mid-1980s, housing costs increased by approximately 34%, while the income for many declined. This forced the low-income families to spend more on housing. This era made middle-income households find the manufactured home option the practical solution. During this era, the low-income population still had to choose mobile homes as their only available option. But the numbers were on a decline, and to compare, one can consider the number of mobile homes shipped in from 1967 to 1976, that is 3,799,730, to 2,640,084 during a decade later, *i.e.*, 30.5% drop. Another statistic that shows how much more expensive site-built homes were compared to mobile homes is to consider that in 1977, 62% of site-built new homes would cost less than $50,000, but the percentage dropped to 18% in 1983. This convinced low-income households of the affordability of a manufactured home [11], as they realized the true mobile home was something of the past.

Based on reference [18] statistics, during 2025, the number of single-section manufactured homes (equivalent to the old mobile home category) produced based on HUD-code and shipped to the home buyer was about 45,000 units. This constitutes 4.4% of the total U.S. single family housing starts (1.013 million) in 2024. While this shows a relatively strong demand for such manufactured homes but the underlying fact for this demand is the affordability. According to reference [18], the price for such single-section or single-wide manufactured homes with a size between 600 to 1300 $ft^2$ varies between $60,000 to $100,000. When we compare the average of $80,000 for these manufactured homes with the average price of $525,000 for a typical 2300 $ft^2$ site-built home, we see that the manufactured homes cost about 15% of the site-built homes. However, the price of the manufactured home mentioned, does not include cost such as land, transportation to the site, foundation, site preparation, crane, installation, utility connections, septic/well, steps/decks, permits and landscaping. If we set aside the cost of the land (assuming the buyer already has the land), such costs can be over $40,000. And if we assume the lan can also add another $40,000, then to be able to live in a manufactured home, it could cost a total of about $160,000, which would be about 30% of a typical site-built home. Therefore, such additional costs may still be strong factors to force the potential home buyer to continue to be a renter. Nonetheless, the majority of the segment of the population that will opt to purchase such manufactured homes include young and first-time home buyers for whom the lowest cost is the path to homeownership, then lower income households, then the retirees who want to downsize, and finally the rural households and single adults or single income households reference [19]. Such information and data reinforces the need for a new model of manufactured home ownership that will effectively reduce the overall cost for the target population.

To summarize, one can now understand that the regulations and changing economy forced the highly affordable mobile homes to change to less affordable manufactured homes [20]. The need for affordable homes, however, is still around and must be dealt with [21]. Needless to say that despite the wish for home ownership, the low-income population sector cannot afford site-built homes or factory-built modular homes. Therefore, the idea of a multi-story mobile home seems to be quite relevant and valid as a new system to create affordable and truly mobile homes.

## 3. Review of Developments in Multi-Story Modular Building Construction

Development of multi-story modular buildings can be traced to the evolution of single-family modular homes, which are the modern generation of factory-made homes with roots in traditional mobile homes. While today, such modular homes are designed based on the same code as site-built homes, manufactured homes are built following HUD regulations and are set up on temporary or permanent foundations [22]. Considering the success of single-family modular construction, de-

velopers have also been successful in creating multi-story modular buildings by stacking pre-manufactured units that are shipped to the site (**Figure 8**). Given the widespread acceptance of this new type of modular construction, a parallel concept has been developed recently to stack the pre-manufactured units on top of an existing low-rise building in order to maximize the benefits of 2 - 3 story engineered buildings made of concrete or steel to host additional few lightweight stories to build apartment units in low-rise downtown areas of metropolitan areas [24] [25] (**Figure 9**). Such developments have paved the path toward the concept of removable units, which is the main subject of this paper. This section reviews representative literature in multistory modular construction, vertical expansion of existing buildings, and the new concept of remove-able units in high-rise modular construction.

**Figure 8.** Modular units being stacked on top of one another to form a high-rise building (Adapted from [23]).

**Figure 9.** Conceptual vertical expansion example: (left) preexisting structure; and (right) modular expansion on top (Adapted from [23]).

### 3.1. Multi-Story Stacked Modular Buildings

The process of constructing multi-story stacked modular buildings consists of building the modules by the manufacturers of such units, transporting them to the site, lifting and stacking them, as the units are tied together to create residential or commercial buildings. The unit dimensions can vary, but one option will be to consider a typical modular unit that has the following dimension ranges: 12 to 16 ft wide, 40 to 65 ft long, and 11 to 13 ft high. If we now consider an average size unit of 13 ft wide, 50 ft long, and 12 ft high, the weight can vary from 20,000 to 30,000 lb (or 9 to 13.6 metric tonnes). Such units are normally transported on trucks or trailers and are considered oversize load. At the job sites, usually these units are lifted using cranes. This method of construction is believed to cut the construction time by at least half compared to the conventional site-built option [26]. After each unit is positioned, it is anchored to the structure and stays there for the life of the building. **Figure 8** shows a conceptual example of such erection process. The innovative concept presented in this paper is a significant departure from the conventional practice of multi-story modular construction by allowing the plugged units to be removed and taken away from the building, thus allowing the units to be truly mobile.

### 3.2. Modular Buildings for Vertical Expansion of Existing Buildings

Besides new multi-story modular construction [4], renovation projects in congested urban areas provide another opportunity for use of modular units to vertically expand existing buildings. Renovation based on off-site construction and vertical expansion using modular units offers a unique opportunity to add a few lightweight stories on the roof of some qualified existing buildings [23] [24] (**Figure 9**). There are many challenges that present themselves when discussing the successful implementation of prefabricated elements, especially for a multistory modular system on top of existing commercial buildings. Several studies can be cited that have discussed projects related to vertical expansion concepts (e.g., [27] [28]). Process maps are needed to explain the engineering design process for this

type of construction. One aspect to address is a case study to show how the process map works and illustrate recognizable factors in the design stage. These aspects help better understand how the overall process of building multistory modular housing on top of existing buildings that have sufficient structural and foundation capacity for vertical expansion.

Jellen and Memari [7] presented a case study with the focus on building code assessment and structural engineering aspects of a hypothetical vertical expansion of an existing building. The design process includes preplanning, structural evaluation of the existing building, expansion conception, and expansion analysis. The preplanning phase involves determining appropriateness of the building considering constructability, safety, access, floor plan geometry, and incentive programs as a modular application evaluation. The structural evaluation of the preexisting building involves condition assessment of the building, including determination of any strong connection points for the future expansion. Then the expansion conception phase is considered, and at this stage the module type and manufacturer are studied/selected. This is followed by building-code analysis and transfer-mechanism planning. During the analysis phase, the concept is further reviewed to address any structural analysis and code review issues. With respect to modular construction and the manufacturer's role, the sequence of load application needs to be carefully considered. The study also used a commercial structural analysis package to analyze module design and weight placed on preexisting structures. In the modeling study, a wall-bearing system and a corner-bearing modular system were considered for comparison, which led to the identification of the wall-bearing module to be more suitable for one-story and two-story expansions considered.

It should be noted that modular construction should meet the International Building Code (IBC) (e.g., [29]) requirements. The IBC is used as a reference to ensure that building construction meets minimum safety and health standards. Compliance with the IBC is essential when employing modular construction methods to ensure that the building satisfies necessary safety and health standards. Also, front-end planning is the phase of a project's planning that occurs before construction begins. Effective front-end planning can aid in spotting potential problems and ensure that modular construction projects are effectively finished, on schedule, within budget, and in compliance with the IBC.

### 3.3. Hybrid Modular Buildings with Removable Modules

While the vertical expansion concept amounts to stacking modular units on top of an existing short building, just as in multi-story modular, where the units are stacked from the ground level, the next concept develops a structural system as the host to receive modular units to be plugged into the structure through the open bays (**Figure 10**). Referred to as the hybrid modular method, the approach involves conceptually separating fixed structural systems from movable living systems, where a fixed, traditionally built 3-dimensional frame structure houses movable modular living components [7] [30]. The basic idea for this new hybrid ap-

proach involves having a sustainable modular unit suitable to be plugged into and out of an existing standing structure. One key objective here is to demonstrate how a hybridized modular construction can be implemented with traditional construction technology.

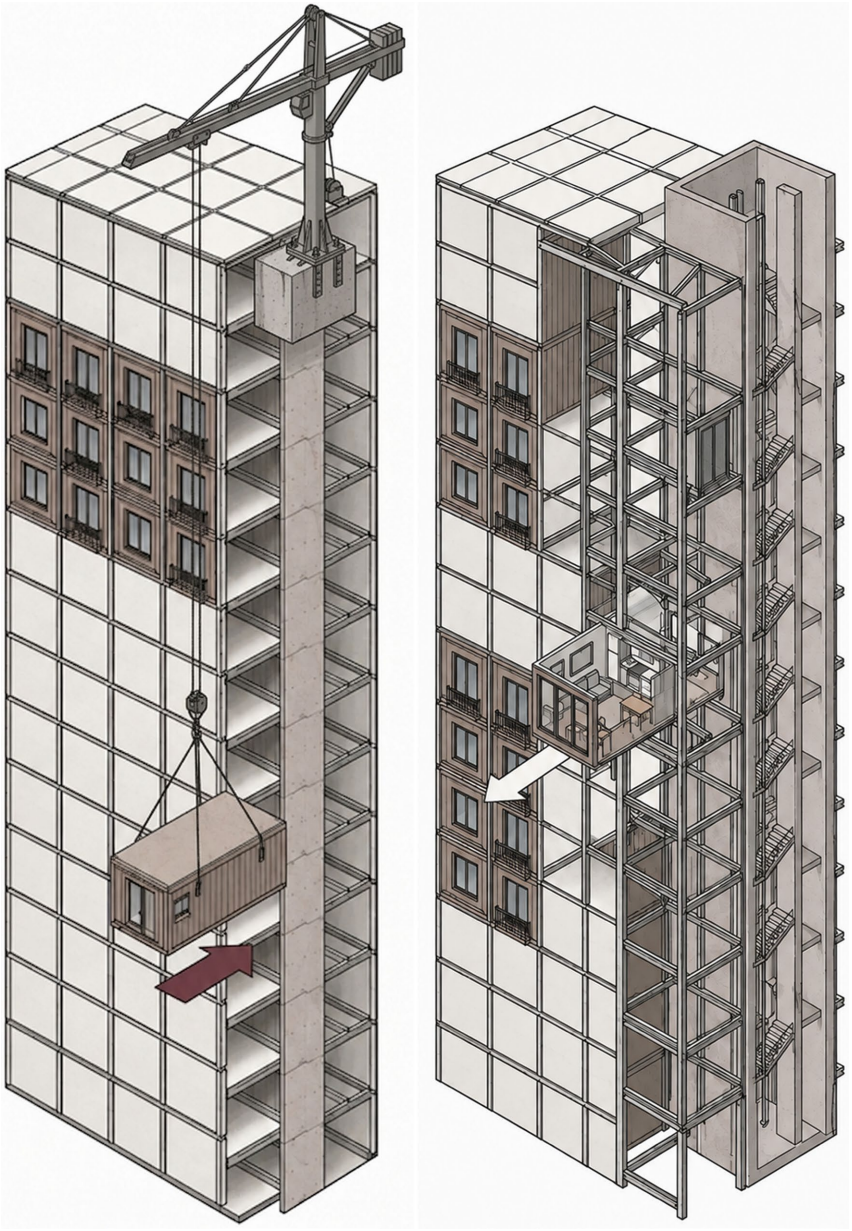


**Figure 10.** Concepts indicating inserting a living module in a core-supported system and a living module being removed from a frame-supporting system (Adapted from [30]).

The permanent host structure and the changeable living modules, each having their own functions that serve their own purposes, constitute the two main components of design of multi-story mobile structure. The host structure is designed to accommodate the distribution strategy and house the MEP (mechanical, electrical, and plumbing) systems. It can also provide common spaces and incorporate

local energy generation. The customizable living modules that fit together in different dimensions with doorways to adjust for differing living scenarios on the other hand accommodate whatever the occupants need for living in the unit. According to Di Pasquale *et al.* [30], depending on the degree of space they add to the host structure, two types of hybrid modular buildings can be considered. One type extends the host structure, which includes open spaces for the living modules. The other type reduces the dimensions of the host structure, *i.e.*, makes it compact, and only allows essential core structure.

With respect to the structural systems for modular construction, there are three main forms, the first being a conventional stacked multi-story modular construction where the self-supporting structural system consists of the modules stacked forming the complete structure. The next type is a core-supporting system including a staircase where the modules are surrounded by a reinforced concrete or steel core, which resists the lateral loads (e.g., wind or earthquake effects) and provides stability. The living modules are connected directly to the core, but since they are still stacked, they transfer gravity loads to the foundations. Also, since they are fixed in place, it is not possible to randomly interchange living modules [30]. The last structural system suggested in the literature consists of a frame supporting system, where steel beams, girders, and columns forming a three-dimensional frame system transfer vertical and horizontal loads down to the foundation. This option allows units to be placed or removed in random order without violating structural stability. This system can be considered a desirable option for the general concept of mobility, *i.e.*, mobile homes. Nonetheless, a combination of the core-supporting and frame supporting systems seems to be the most advantageous. This option provides a strong core structure, while still allowing the modules freedom to be plugged and unplugged. This last option will allow the modules to be responsible for carrying the live loads they are subjected to and their own dead loads. This mixed configuration also allows the host to have unoccupied spaces with no consequences to the stability of the whole structure itself.

To sum up the literature review, it is clear that there is room for more innovations to improve design and construction of the units that exist in the form of traditional mobile home, the manufactured/factory made homes, and the modular home segments of the housing industry. The traditional mobile home units have been successful in bringing about a housing type that has been comfortable and affordable with less constraints. Now integrating the concepts of multi-story modular and mobile home units has helped introduction of the pluggable modular multi-story building.

## 4. Development of Complementary Concepts for the Lifting System, Living Units, and the Host Structure

In this section, new concepts are introduced related to the lifting system, the mobile units and the host structure. More detailed discussions on the requirements for such systems and desirable characteristics are presented in Section 5.

### 4.1. Lifting System Mechanism

In this sub = section lift system options are explored and evaluated. One of the concepts for lifting a modular unit and placing it in the designated space is to borrow an idea from the mechanism used in multi-story parking structure where cars are hydraulically lifted and placed in certain spots, as shown in **Figure 11** (e.g., [31]-[33]).

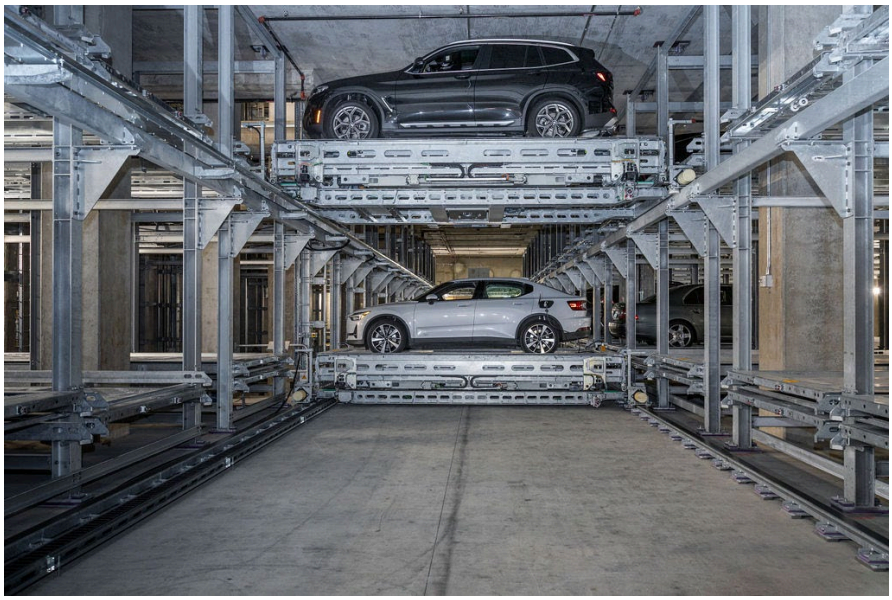


**Figure 11.** Hydraulic car lift parking systems: (Used with permission: Credit: Harding APS: https://www.hardingaps.com/parking-blog/semi-vs-fully-automated-parking-whats-the-difference-blmfd) [Site visited 07/06/26].

As one option, this lift system idea for parking structures can be considered for lifting modular (MOD) units as well, where once the unit has arrived at the building site, a roof-mount crane or a ground supported crane will pick the unit up and place it on the disk-shaped elevator. The hydraulic elevator would then lift the unit to the designated floor and rotate until the unit is aligned with the proper opening in the structure (e.g., **Figure 12**). The unit will then be pushed into the pre-existing host structure space and will be locked in place. While this idea would need to be a streamlined process, it may not be the most practical lift system option because parking garages have heavy daily traffic coming in and out. Furthermore, unlike a parking garage, a mobile home unit will not be leaving frequently, and it will be plugged in for months or years. Of course, while an automated system would prove useful, it may not be cost effective, and it will likely be very expensive and time consuming to customize a fully autonomous system for such a large-scale job.

A second option for lifting the units would be to use a crane on the ground or even mounted on the roof, as used on high-rise construction sites (e.g., **Figure 13**). This option is a more practical and affordable system compared to an auto parking elevator option. The crane option, however, would need the building to

**Figure 12.** Automated car lift parking systems: (Used with permission) (https://blog.getmyparking.com/2017/08/30/an-overview-of-automated-parking-system-and-its-types/) [Site visited 07/06/26].

**Figure 13.** Roof mount crane to lift modular units in highrise modular construction (Used with permission. Credit for the image: Britlift, Apex Drone Photography, and Outpost Management: https://britlift.com/lifting-modular-homes/) [Site visited 06/21/26].

be customized to mount a permanent large crane on the roof. Of course, even a ground-mounted crane would impose challenges to plug the units after it is lifted, because such units need to be inserted from outside of the structure into their designated spaces, and it would thus require large portions of the exterior (enve-

lope) walls to have the ability to be open at the time of unit insertion for proper installation. Accordingly, a 3-dimensional wall-framing system may be too complex and expensive for a multi-story host structure with a crane on the roof or ground mounted crane. From another perspective, the wall structure must accommodate structural members for wind girts, sag rods, and cross bracing to handle wind loading. Design of a building with multiple garage door-like openings exposed from outside may not be architecturally and aesthetically pleasing, in particular with the further issue of having an exposed crane (in case of ground mount crane) permanently outside the window of the units.

While lifting the modular unit via crane is certainly a possible option, it also introduces multiple challenges. There is an existing mechanism that is already exercised in buildings to move large items to upper stories, and that is a large freight elevator (**Figure 14**), which can be built as part of the structure or attached to the host structure to lift the modular units. With such an option, one would employ large tractors or forklifts to slide the units in and out of the elevators when a unit gets to its proper floor. In such a scenario, these freight or service elevators would be different from the elevators used regularly by the public/residents. The idea of creating hydraulic freight elevators located on the end sides of the building would allow for more "premium" space for additional units or common spaces inside the building. Significantly different from the crane concept, with the freight elevator idea, the units will be moved into and out of the building from inside so the structural system of the exterior walls of the host structure will no longer present a design challenge. Much like a normal hotel, the lower floors can act as common areas, while the upper floors are used for living space modules. Design of such freight elevators will follow the standards for freight elevator design and would need to be custom designed. For example, the freight class would need to be at least C1, which permits a forklift and a large load to travel on the elevator. It would also need to have front and rear doors, which would allow the unit to be

**Figure 14.** Example large freight elevator (Used with permission) (https://www.elevators.com/freight-elevator-classes/) [Site visited 06/21/26].

placed and offloaded at the proper floor level. The capacity should be at least 20,000 pounds with a cab size of 12'-0" × 14'-0" × 22'-0" [34].

### 4.2. Modular Unit

Some basic requirements for the mobile units are discussed in this section. The modular units should be designed to encourage mobility, while also having the ability to "plug in" to preexisting structures. Because the basic idea for such designs requires the units to be mobile, this means that the housing unit should be able to be plugged into a host structure and then unplugged and transported to a new host structure as desired. As over 60% of the rental units are occupied by young adults [35], such modular units would provide the mobility needed by such a population sector and of course would satisfy the desirable homeownership simultaneously. An example of the life cycle for such a mobile home is shown in **Figure 15**.

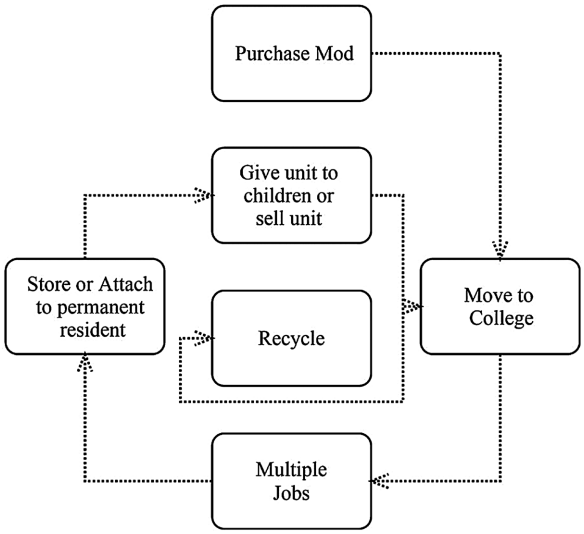



**Figure 15.** Life cycle of a unit (Adapted from [7]).

Just like the conventional modular units for multi-story buildings (**Figure 3** and **Figure 4**), a rectangular shape would be the best option. With respect to the dimensions for these units, a ceiling height of 10 - 12 ft, a width of 10 ft, and a length of roughly 20 ft would be appropriate. Needless to say, such dimensions need to be consistent with the dimensions of the units for the host structure. The structural frame of the unit will accommodate for utility connections when it is plugged into the host building. A panel box on the side of the unit will provide safe connections to the host [36]. The mobile units should be manufactured with long life cycle and with easily removable components to allow for more efficient repair jobs as well as making the deconstruction easier for recycling. As is common for recycling/reusing such units, a lightweight frame/cladding is desirable. Furthermore, the modular unit can also be designed to be placed on a chassis for towing, or it could optionally have retractable wheels for easier movement capabilities.

### 4.3. The Host Structure

This section discusses and evaluates the early concepts for a host structure that can house mobile units, as well as some proposed requirements for consistency with the suggested lifting systems. The host structure is expected to be located in high density urban areas, where 55% of the world's current population lives and is expected to increase to 68% by 2050 [37]. Design and layout of the building can vary depending on many factors. Two potential layouts are discussed here, including their strengths and weaknesses. The first layout has a cylindrical shape with a structural core built around a central freight elevator. The suggested height is limited to roughly twelve stories, and the framing system is considered structural steel that will be designed for the applicable live and dead loads, besides wind and seismic lateral loads. The building will have a custom hydraulic freight elevator, while a forklift would be used to move the units from the elevator and into the bays on the floor where the unit will be housed. Given that for this circular floor plan concept the elevator shaft used for the units will be in the center of the building, a loading bay must be designed on one of the lower levels of the building. The negative side of this concept is the concern for noise levels during unloading and placement operations. The concept also calls for multiple passenger elevators to be located within the building as well as commercial and public space on the lower levels. The bays that will house the units would be placed side by side near the exterior walls for efficient use of the space. **Figure 16** shows a visual representation of an early concept for a vertical trailer park [38] (Kohlstedt, 2020), which can be adopted and modified for the host structure.


**Figure 16.** A schematic illustration of vertical trailer park portrays a cylindrical shaped structure for mobile home units (empty black colors indicate parking spaces) (Adapted from [38]). (https://99percentinvisible.org/article/mobile-home-skyscrapers-elusive-dream-vertical-urban-trailer-parks/) [Site visited on 06/21/26].

This study suggests a rectangular-shaped floor layout for the host structure with two large freight elevator shafts attached to the short sides of the building. These elevators connect to pathways outside for ease of loading and offloading for minimal disturbance. The modular units could be directly transported to the elevator and lifted to the proper floor. Just like the previous concept, the host structure would have roughly twelve stories with a wide hallway that runs parallel to the long side of the building. The wide hallway will allow forklifts to operate within the space to slide the units into the proper bays. The rectangular shape of the host building allows the mobile units to easily be plugged and also provide square footage efficiency. As in the circular floor plan concept, multiple passenger elevators would be available within the building as well as public and commercial space on the lower levels.

Another new idea for the host structure is that the roof of the host structure can house solar panels for local energy generation, or function as a green roof per architectural design preference. The design of the steel framing system will follow conventional structural design and would include beams, girders, and columns supported on appropriate foundation. The live load for design of the structural frame should consider the movement of the units during vertical/horizontal transport and plugging/unplugging operations. To be consistent with the trend for sustainable design, the host structure should be designed as a green building that will allow cost-saving and energy efficiency. Accordingly, one way to do this is by achieving Leadership in Energy and Environmental Design (LEED) certification, through which a globally recognized rating can be assigned to the system, and which would be a measure of the facility's overall sustainability achievement. According to the U.S. Green Building Council, 61% of corporate leaders believe that sustainability leads to market differentiation and improved financial performance [39]. Accordingly, paired with the health and environmental benefits, this makes obtaining a LEED certification worthwhile for this type of project.

## 5. Further Evaluation of the Proposed Lift System, Mobile Units, and the Host Structure Options

This section provides further details into the proposed concepts for the lift system, the mobile units, and the host structure itself, including some desirable green design concepts for the units and the host structure.

### 5.1. Evaluation of the Proposed Lift System

Three main lift options of roof cranes, freight elevators, and an automated parking system discussed conceptually in the previous section are compared in this section. An automated parking garage-like concept could prove too costly and impractical for the purpose of the host structure, as unlike the parking building where cars move in and out in a parking garage all day, every day, the modular units will not have frequent movements. The permanent crane option (based on roof or on the ground) is affordable in the long run but poses design challenges

and is aesthetically undesirable. Therefore, a common freight elevator seems more reasonable than the other two options. However, design of a large elevator poses certain design challenges and concerns that need to be eased. Based on the earlier discussion, a class C1 elevator that would allow a forklift and its payload load to travel together would seem to be the best option here. Such an elevator will not be designed to rotate. Therefore, the design would require front and rear doors to have opening capability for onloading and offloading. The elevator capacity can be a standard of 20,000 pounds with a cab size of 12'-0" × 14'-0" × 22'-0" [34]. A forklift can directly place the unit onto the elevator and take it off easily to place into the proper bay. Two identical elevators will be needed to make the building symmetrical to avoid congestion when one elevator is already in use. The design of the elevator shafts will be such that they will not impose gravity and lateral loads on the host structure and will therefore have their own independent structural system and supported on their own foundation but will be adjacent to the host building with short bridge access to its hallway. **Figure 17** shows a conceptual example of a large freight elevator with a modular unit inside. The custom-sized elevator shaft with two-door opening will have to be designed and built to resist all applicable structural loads, which will then satisfy all safety concerns.

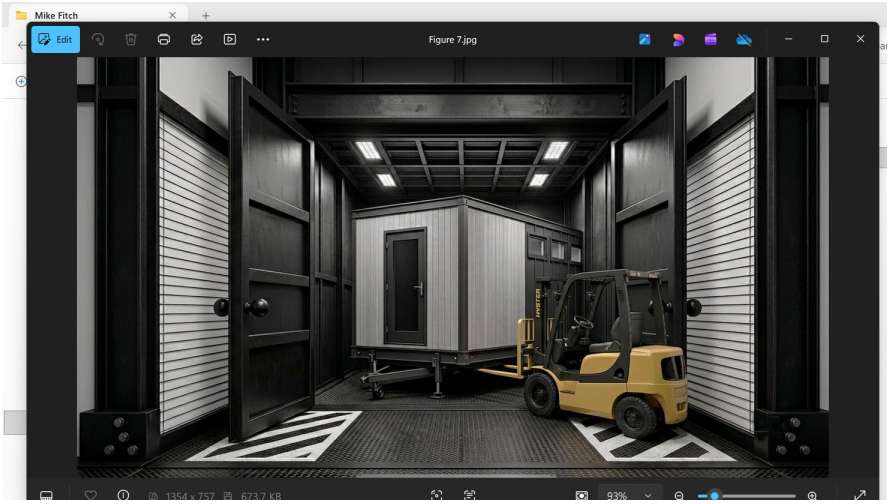



**Figure 17.** A schematic illustration of relative size of a hydraulic freight elevator (Adapted from [40]).

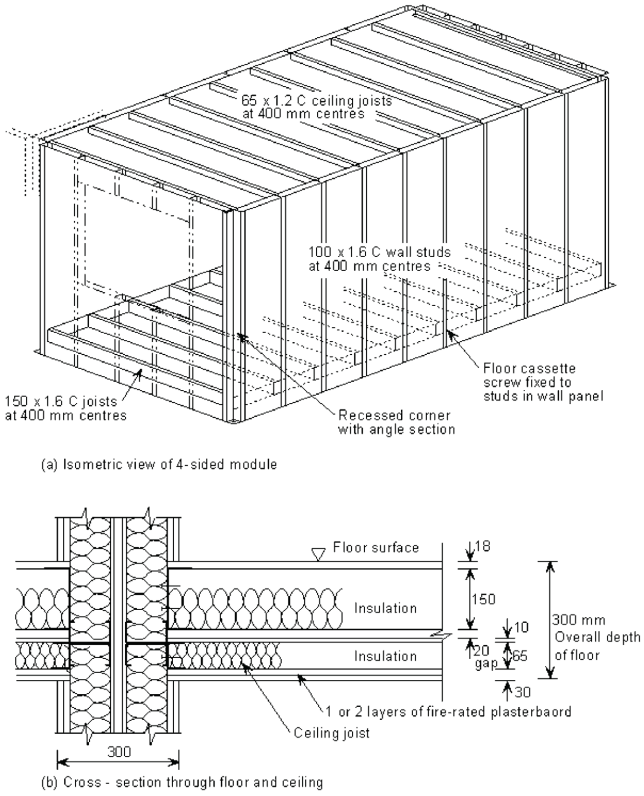
## 5.2. Requirements for Design of Mobile Units

As in conventional manufactured housing units, the modular units for this proposed concept are expected to provide quality housing while being affordable and allow mobility. The form of the host building with units installed is envisioned to be of the form of multi-story apartment complexes, where each modular unit will include standard amenities. As discussed earlier, these units will be responsible to carry their own live and dead loads (assuming the unit is supported at the four bottom corners) and will rely on the host structural framework to support the entire unit gravity loads. **Figure 18** shows photos of typical light gauge steel units.

The conventional shaped/formed modules will have rectangular sides and top and bottom with an entrance on one of the short sides. The six panels consisting of a floor cassette, four wall panels, and a ceiling panel are attached by properly designed fasteners. The ceiling joists are likely lightweight steel C sections, which can also be used for the wall sections to transfer vertical loads. A conceptual configuration of the unit and the way it is lifted at the factory is shown in Figure 19, where the C sections are expected to be designed and sized to support multiple units stacked on top of one another.

While the units shown in Figure 18 and Figure 19 are intended for stacking of the modules in conventional multi-story modular buildings, the units proposed here are somewhat different in design of the members/joists/posts in the sense that the members for the subject units do not carry any gravity loads from other units since the units are not stacked; rather, they are plugged into the host structure. Accordingly, the most cost-effective C section members can be designed keeping in mind that the only load being supported is the unit's own self weight. The walls will be insulated and will have layers of fire-resistant plasterboard to

Figure 18. Typical light gauge modular units (Used with permission) (https://ccssteelframing.com/modular-building/) [Site visited 06/21/26].



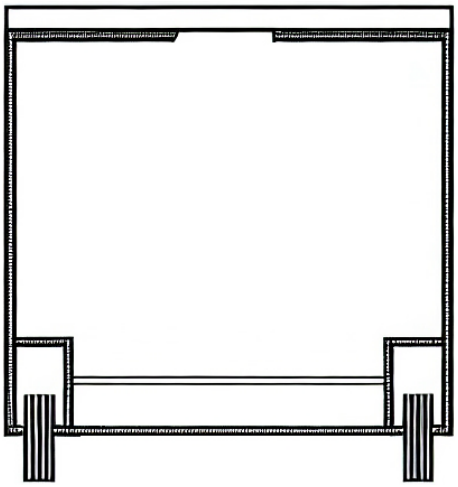

(a)

(b)

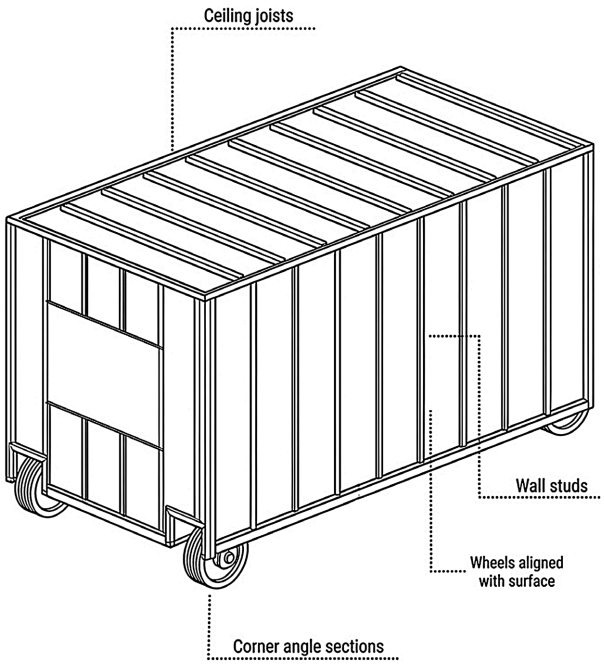
**Figure 19.** Isometric and cross-section view of a typical 4-sided module and the way it is lifted at the factory (Used with permission). (https://www.steelconstruction.info/Modular_construction#Dimensional_planning) [Site visited on 06/21/26]. (a) Isometric and cross section view of a light gauge module; (b) Lifting of a unit at the factory.

ensure structural integrity and to stop the spread of flames across the building [41]. It should also be noted that these units can be sold directly from the manufacturer to a new home buyer, where the price for an unfurnished unit with the size if 10 ft × 20 ft could vary significantly from $14,000 to $80,000, depending on the amenities, quality, and manufacturer (https://comstruc.com/modular-buildings-cost/).

With respect to the unit's mobility, there is an important difference between the subject units for the purpose of the proposed concept and those for conventional stacked construction for modular housing. These units need to have retractable wheels, shown conceptually in **Figure 20**. A built-in hydraulic system



(a)




(b)

**Figure 20.** Conceptual section view of a unit with retractable wheels detailing the wheel housing space with wheels extended out (Adapted from [7]). (a) End view; (b) Perspective View.

would be utilized to lower or raise wheels at the base of the unit. A retractable hitch on the unit could come out so it could be towed as needed. With such wheels, perhaps there is no longer a need for an independent trailering system. Once the unit is placed in a location to be sitting for extended period, the wheels can retract to level out the unit and prevent it from moving. Of course, another function of the wheels envisioned is when the unit needs to be "plugged in", and that is when the wheels can be used to roll the unit into the bays. The forklift will act as a guide to shift the unit around rather than lifting it up.

Finally, since this unit is not designed to be used in a conventional multi-story modular building where the units are stacked, the roof of the unit for this concept is available to offer additional features such as recessed cavities in the roof and perhaps the unit's roof can be equipped with solar panels or skylights, in particular for conditions when the unit would be used a s a stand-alone module supported on the ground (**Figure 5**). This feature would be more appealing to those who intend to really travel outdoors with the unit instead of plugging it in for long periods of time.

### 5.3. Structural System Requirements and Green Design Considerations for the Host Structure

The rectangular layout as opposed to a circular one is further discussed to evaluate feasibility. The 12-story structure will have four passenger elevators with their structural shafts acting to provide additional lateral resistance. Two passenger elevators are to be placed next to each other on either side of the facility with a stairwell beside each set. It is envisioned that the first floor will act as a main lobby with additional spaces for activities like swimming, laundry, and gym. This will be more of a shared public space for homeowners. The second floor is thought to function as a commercial space with rooms for offices, food services, and storage/maintenance. The upper ten floors will house the units. The structural system allows bays to remain open until new units come in. For the case study example shown in **Figure 21**, each floor will have 10 bays on each side of the longer side of the building for a total of 20 units per floor. Ceiling heights in the host structure can be up to 14 feet high to allow for forklifts and units to move around. **Figure 22** shows the conceptual elevation sections for the host structure that illustrates the column spacing, floor heights, and unit placement.

As far as the structural system of the host structure is concerned, its form is relatively simple because of the rectangular plan of the units. It is expected that for a site with reasonable soil bearing capacity, a concrete mat foundation will be used to support the loading from the columns and walls, but of course, other systems such as footing or pile system are also feasible. The mat foundation option, however, will help prevent/minimize differential settlement at column lines to avoid any relative deformation of the frame structure that may impact the units being plugged in or removed across the building. As mentioned, the matt foundation is just an example since the type of foundation to use will depend on

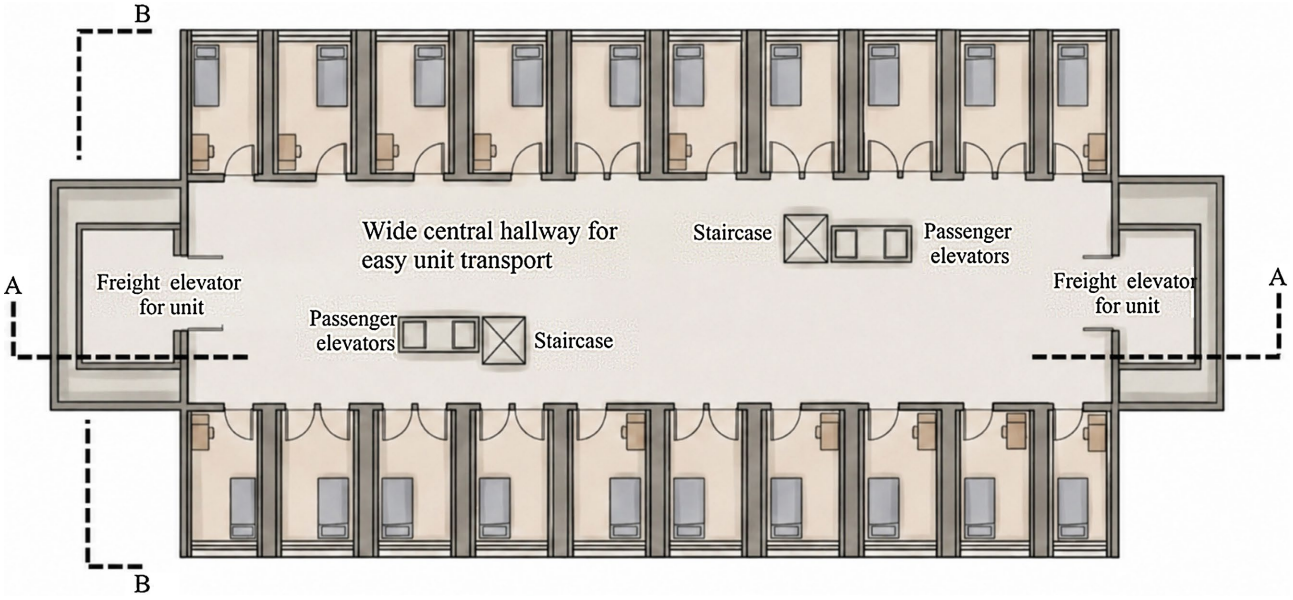
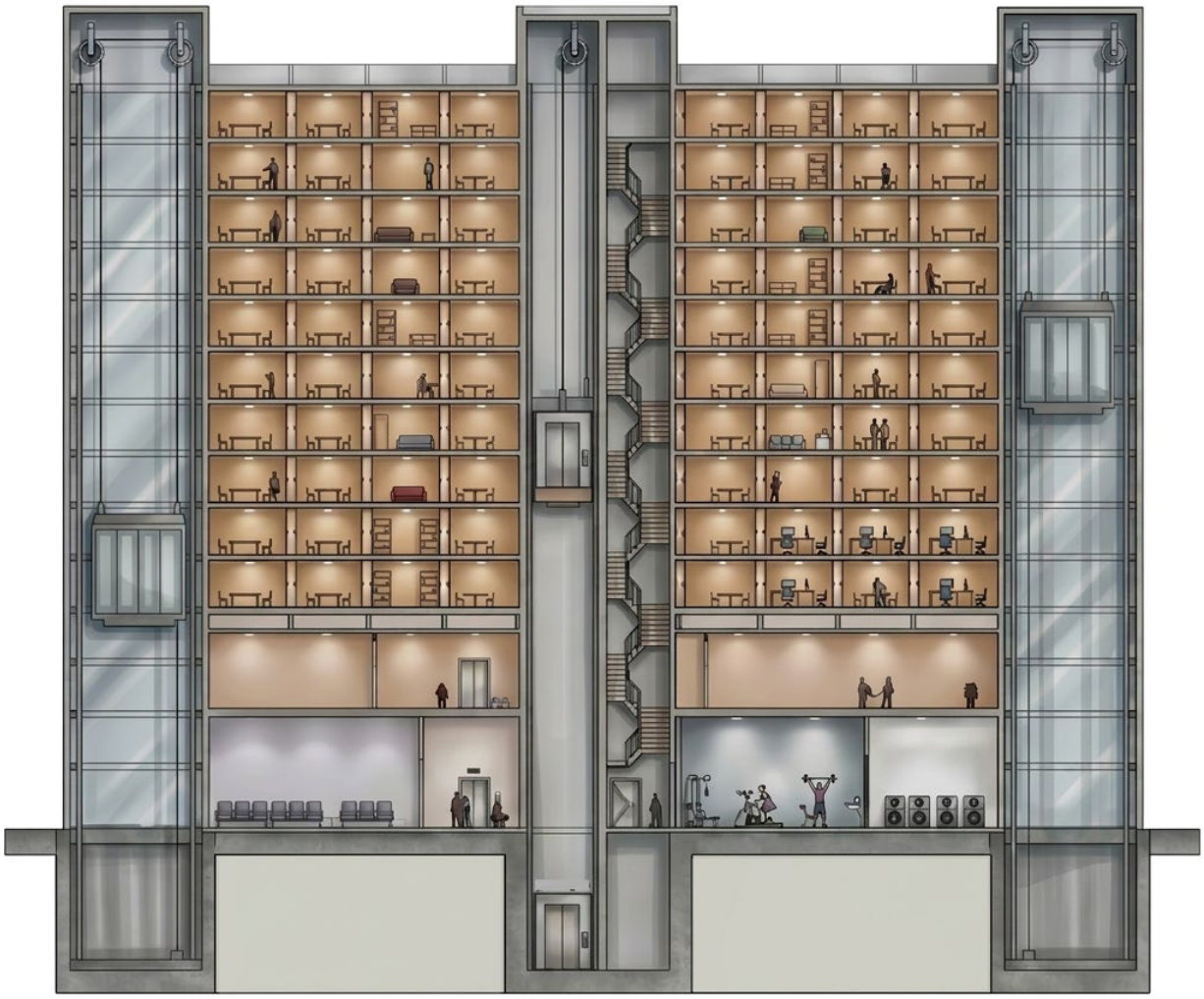
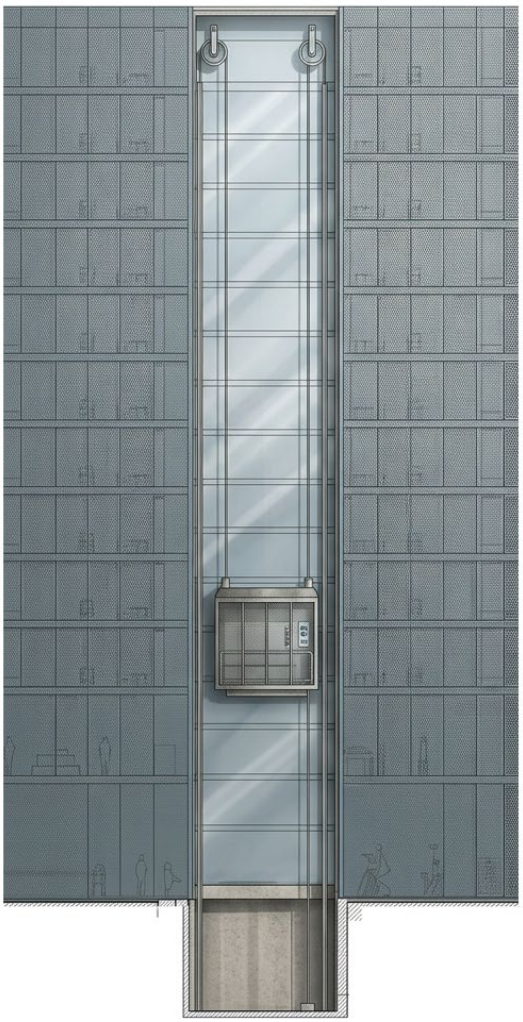



**Figure 21.** Conceptual floor plan for floors 3-12 in host structure.



(a)



(b)

**Figure 22.** Elevation drawing of host structure excluding elevators for unit transportation. (a) Long direction Section A-A; (b) Short direction Section B-B.

location and soil conditions. Much of the structure will utilize strong steel framing members that will be designed to safely transfer the design loads based on the building code requirements. The load path follows a path beginning with the loading applied to the beams and then transferred to the columns, which will then reach the foundation. The exterior frame lines and perhaps some interior ones will be strengthened with cross bracing, wind girts, and sag rods, as necessary for lateral load resistance.

The roof framing plan must account for the loading produced by the optional solar panels, garden, and HVAC system as well. The host structure roof mounted solar panels will be the preferred choice here to make the building more energy self-sufficient. The floor framing plan will contain various sized steel beams and girders with some open bays that directly support the units once they are plugged in. The modular unit will be rolled into the bay and locked into place using vertical pins and rail stoppers. These structural connections are to be designed effectively

following the relevant standards and codes. The utility connection module is then attached after the unit is safely secured in place. The host structure and the unit must have compatible spaces available in proper locations to make these connections efficiently. This applies to all mechanical, electrical, and plumbing connections. The wheels under the unit can then be raised so that the unit can rest its weight onto the steel framing system directly. The same process in reverse would then take place when a unit is to be removed from the host structure, that is, the wheels would be lowered, and a forklift would assist in moving the unit to the elevator shaft.

As mentioned earlier, obtaining the highest LEED certification for the multi-story host structure is one of the design goals so the structure can be sustainable and stand out. A study by Pan and Zhang [42] explored the sustainability of materials in modular construction and compared the environmental impacts or usage in urban development. LEED Credits are earned based on a variety of criteria and are based on a point system, so that the more points are assigned to the design, the higher the project is rated. The levels of certification include certified, silver, gold, and platinum. Reaching minimum gold rating is the desirable goal for this design concept. Exploring ways for how such a project can earn as many points as possible is key. Overall, such projects need to encourage resource and energy efficient technologies and practices. Credits must be identified and pursued specifically to be achieved. The main areas of focus to obtain as many points as possible will include energy and atmosphere, innovation, and indoor environmental quality. The solar arrays to be placed on the roof alongside other targeted performances should help achieve points within the energy and atmosphere category. Housing of environmentally friendly modular mobile home units within the host structure would hopefully assist in earning points within the innovation category. Utilizing low-emitting materials and allowing ventilation systems to filtrate air is key to obtain credits within the indoor environmental quality category. Collecting at least 60 points will award the gold certification status, which is globally recognized. This status signifies that the building is actively implementing sustainable strategies to provide economic, health, and environmental benefits. Achieving such LEED certification also requires proper planning for project management.

With respect to fire safety related to the freight elevator shafts, the hoist way shaft is envisioned to be constructed of concrete to reach the required fire-resistance rating and to be self-supporting. A pathway should be constructed that will lead the units directly to the enclosed loading bay areas. Once at the intended level, the units will be easily offloaded and unhitched so they can be guided directly into the freight elevators. Most materials envisioned to be used for this type of project would classify as conventional but are expected to be as much sustainable as possible.

## 6. Concluding Remarks

This paper presented some complementary ideas to contribute toward an earlier developed concept of a host structure to house mobile units, which revitalizes mo-

bility in housing by suggesting a new way to use mobile home units. While the proposed concepts pose many challenges for detailed design and actual implementation, at this conceptual stage, the focus has been on the mobile home unit, the structural system that houses it, and the lifting mechanism for vertical transportation. Each of these aspects is an important consideration for detailing toward better developing the viability for such a proposed solution. The mobile home unit can take on many shapes and sizes. A uniform rectangular prism was chosen here as the typical shape (as it is commonly available) so it could be easily transported and fit into its designated bay. While being compact, it also provides enough space for desired amenities and required utilities. Manufacturing such units is expected to be straightforward for modular unit manufacturers, given their successful track record in producing units for stackable modular building systems and can thus be done in a cost-efficient manner. This also drives the price down for the target young starting career homeowners, making it a more appealing housing option. The materials used to produce the unit can be as recyclable as possible to maintain environmental friendliness.

The steel framing with matt foundation host structure designed to house the mobile home units will be a distinctive construction project. The bays that the actual units rest on are designed as steel members that can support the varying loads present. The suggested example 12-story building can store 20 units per floor for a total of 200 units from floor 3 to 12 with the ability to place or remove them at any time of day. Needless to say, the more host structures built to house modular units around the country, the more effectively this concept can be implemented in practice.

The ability to transport the mobile home unit vertically to its resting position is one of the biggest challenges of this concept. Multiple options are available for this aspect of the design, but it seems that utilizing a freight elevator is the most logical choice, as it can stop at each floor level and can function smoothly with proper safety concerns. It is envisioned that two elevators can be available for simultaneous operation so that no congestion is expected to take place when units need to be placed or removed. As elaborated, an automated parking system concept would be too complex and expensive for the task at hand, while a crane system concept adds unnecessary hazards and aesthetic issues. Overall, with the integration of various concepts presented, the idea comes together to complete the desired outcome. In summary, the paper has suggested a new housing alternative that is affordable and appropriate for lower income segment of the population in metropolitan areas, in particular for young adults with a transient lifestyle. This allows the target population to own their home rather than rent, and this brings about an option to experience life from a new perspective by breaking through the binding chains and constraints for home ownership.

## Author Contributions

The contribution of each author is as follows:

1) Michale Fitch: Conceptualization, methodology, investigation, writing - original draft preparation, visualization.

2) Ali M. Memari: Conceptualization, validation, investigation, resources, data curation, writing - review and editing, supervision.

3) Shahryar Habibi: Validation, resources, data curation, writing - review and editing, visualization.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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