AFFORDABLE HOUSING

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1. Low Income Families

Issue in The U.S.

"The increase in inequality in income is a longtime trend, but the pressure on middle and low-income workers is going up rapidly. Especially if they live in an area where there are high housing and gas prices, like California."
Alice Rivlin.

Poverty Threshold

Low income families defined as families who have an income less than the poverty threshold. For example, a family of three who make $20,400 per year or less are considered low income (fig:1).

The poverty threshold determines what kind of benefits a low income family receives, such as the affordable care act, food stamps, and Medicare.

The main is that most low income families are working as 89% have at least one full time, full-year worker and about 25% of low income families facing a severe housing problem.
About 25% of American children live in a low-income family with at least one working parent, and about 40% of low income families have children that are younger than 18 years.[1]

Housing Issues For Low Income Families

Based on the American Housing Survey Data, low income-families are facing a severe housing problem due to the increase of rental cost across the entire nation. Rental housing prices increased due to the noticeable rise in land and construction costs. Thus resulting in low income families no longer being able to afford homes. The housing rental considers affordable when it about 30% or less of household income.[2]
The other reason for working families isn't able to afford rental housing is low hourly wages. Although in most cases the hourly rate falls under a yearly increase, it takes too long to reach the appropriate wage to afford housing. For example, an hourly rate of $9 takes about 11 years to increase to $14 which is only a 4%.

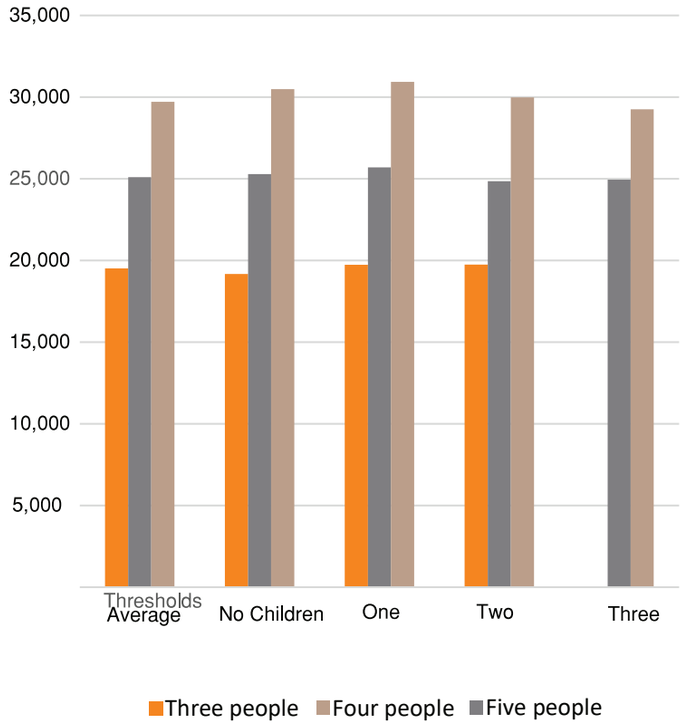


Fig (1): Poverty thresholds by Size of Family and Number of Children in the USA Year 2017 by United States Census Bureau

Family Structure

Another critical matters to consider are the different family types in the US, which are divided into four main types: type 1 being the single-parent family, type 2 being extended family, third is the childless family, and type 3 being the grandparent family, which has lately becoming in recent years. One other type of family structure, the nuclear is defined as the traditional family with parents and children. Yet due to the burden of life expenses, this once popular type of family structure is becoming less common while other types are growing in a noticeable way. The most popular examples of this are step-parents and Nuclear families who live with grandparents.

Figure 2, a study on low-income families with children, indicates that 59% of guardians work full time while 11% have no income.

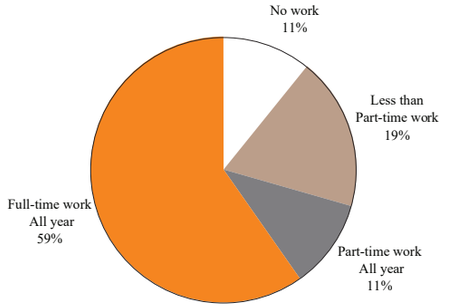


Fig (2): Work Effort of Low-Income Families with Children

Racial Disparities Among Low-income Families

When comparing the household income from 1967 to 2017 explain the relationship between the race and the income, has stayed relatively the same since 1967. Studying these racial disparities and when it comes to income, helps to see which ethnicity suffers most, and is in need most for affordable housing. This research also would helps to see which ethnic groups are most in need for more work opportunities, and more aggressive efforts to give them equal chances to climb the economic ladder (fig:3).[3]

When it comes to the low income families in the U.S., according to the Urban Institute survey a 42% are white, are white, Hispanic race represent

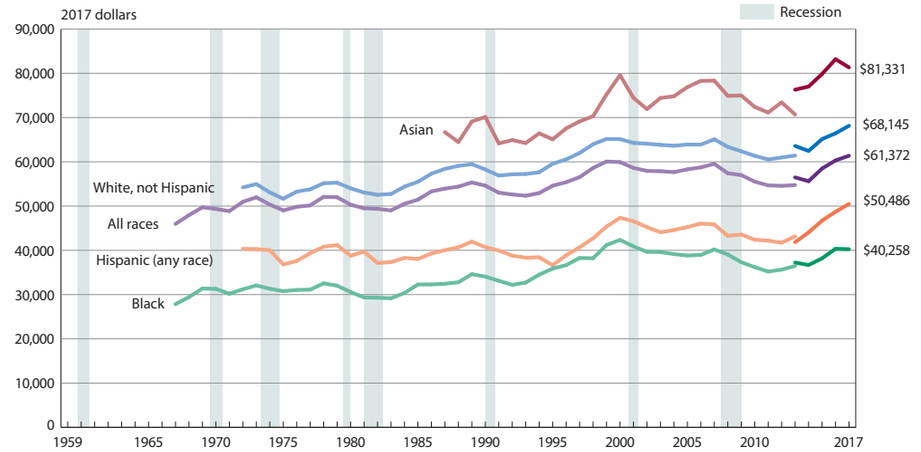


Fig (3): Real Median House Income by Race and Hispanic Origin: 1967 to 2017

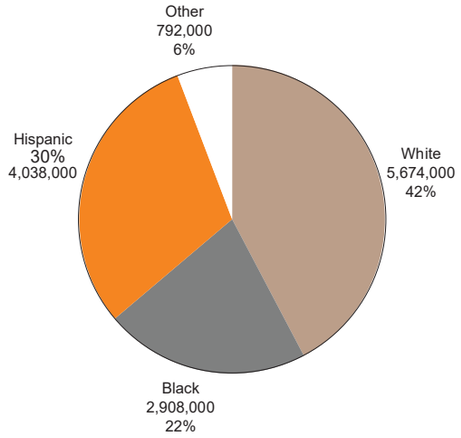


Fig (4): Low-Income Families by Race and Ethnicity

about 30%, African American represent about 22%, and all other races represent 6% (fig:4).

In fig:5, a visual representation of low-income families according to the race and family structure. With this information and having a better understanding of the low-income families in the area, this chart helps to determine what type of families is more in need of affordable housing in the area.

From the demographic map according to the household income of the U.S., the mid-south region reflects lower income, when the mid-north region has median household income. Zooming on Michigan State the project location, the southeastern region of the state shows the lowest household income, furthermore, Detroit City has the lowest household income in Wayne County (fig: 6-9).

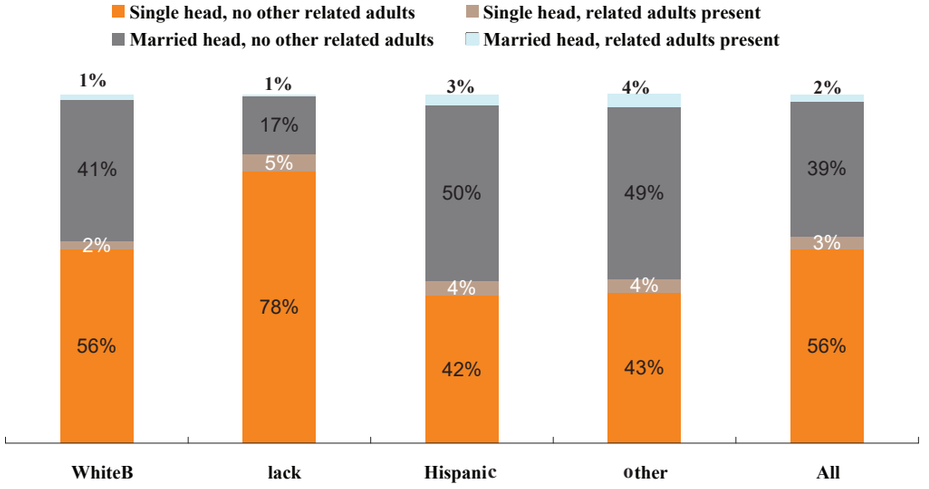


Fig (5): Distribution of Low-Income Families by Family Structure and Race/Ethnicity

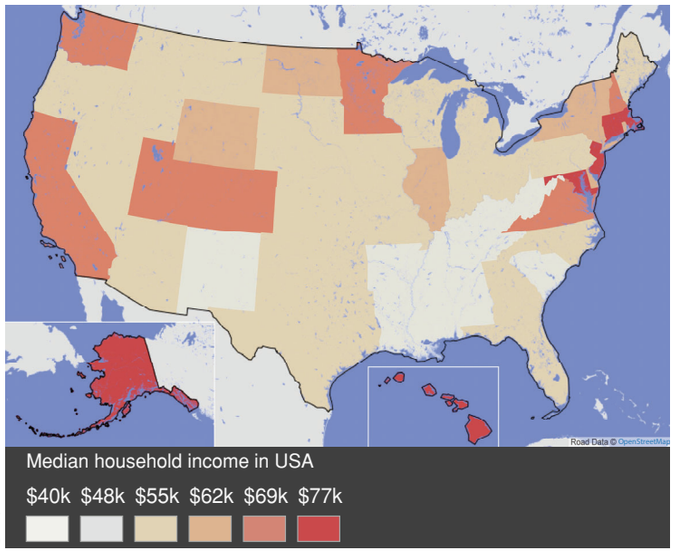


Fig (6): Demographic Income Map

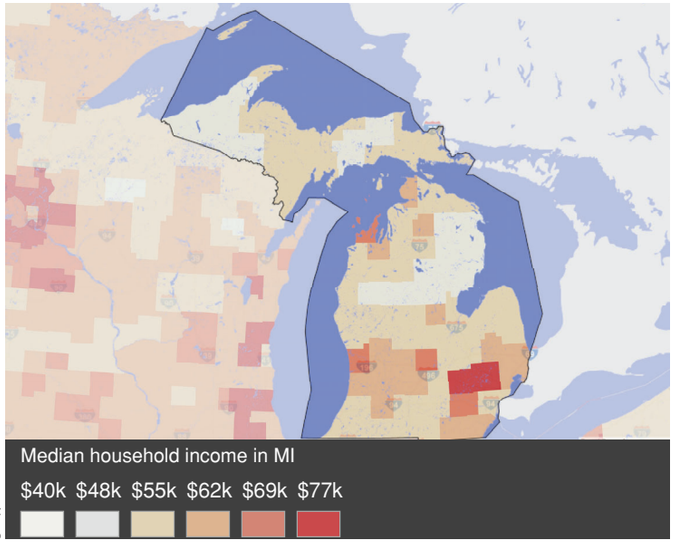


Fig (7): Demographic Income MI Map

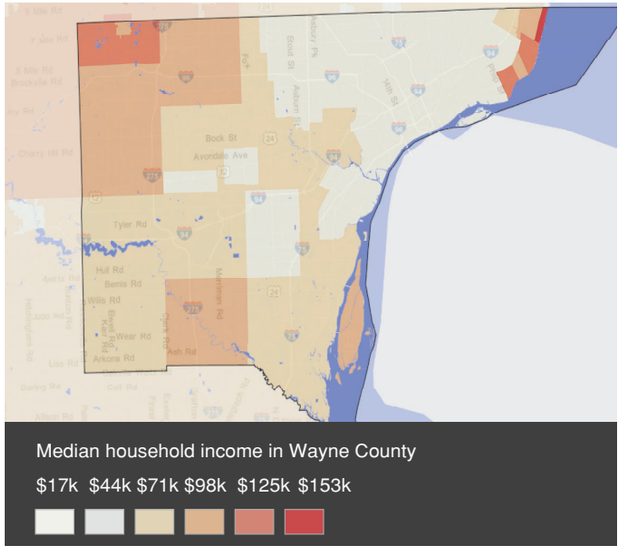


Fig (8): Demographic Income Map in Wayne County

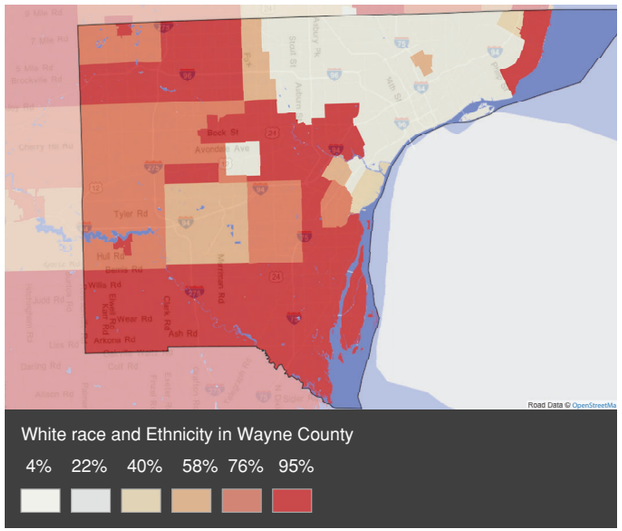


Fig (9): Demographic Race Map In MI State

Conclusion:

Based on the charts' analysis and studying the issue of low-income families in the U.S., specifically Detroit, Michigan, I was able to conclude that most low- income families are unable to afford a home, especially families with children. Detroit is one of the top cities in the U.S. that's in serious need for affordable housing as they hold the record for lowest average household income in the region. Most of the families in Detroit that are in need of housing are African American with a high percentage of them having children.

What Detroit needs most is affordable construction to be provided for low-income families and to encourage investors to want to invest in this type of project. Low-cost construction could also help reduce the overall cost of the monthly rental fees which will then help reduce the financial burden on renter families.

2. Precedent Studies
1. History of Affordable Housing

The history of affordable housing can be observed as early as the ancient civilizations. During those times the type of housing was typically a reflection of the society class, therefore the lower and working classes lived in more affordable housing compared to those in a higher or richer classes. Because of, this housing type inevitably there was an acceptable segregation in society. Low income families in ancient civilizations were excluded and separated by boundaries through fencing or distance in which they would be placed in communities far away from the upper classes.

For example in ancient Rome, social classes were divided primarily into two: the upper class who were known as Patricians and the lower class who were known as Plebeians. The way the houses were built reflects which type the class one belonged to, the insulae houses -meant for the lower class- are small units or apartments were typically two vertically stacked levels, the upper class, on the other hand, used to live in Domus, known as larger single-family houses which were well decorated to show the wealth of its owner.[4]

The insulae had shops on the first floor, and apartment units on the top, these units was relatively small and were attached to a drainage system that connected the entire city (fig: 10).

The insulae reflects some similar aspects to residential complexes in the, such as all units having indoor pluming systems, and a shared central yard in which every 6 to 8 apartment blocks grouped around.[5]

Just as in ancient Rome, Low class houses in ancient Egypt, also separated from the elite class houses. Egyptians built their working class houses by using affordable materials and minimal decor. Atypical, ancient Egyptian low class houses was a small single family units, with an interior yard and flat roof, which was used for families to lounge, sleep and eat on. It would also contain a closed room used for storage and napping through out the day.

Fig (10): Insulae, low income housing in ancient Rome

Fig (11): Mud brick houses in ancient Egypt

The houses were made out of mud brick from the Nile riverbank, mixed with wood chips and water. To support the door and window headers, they used wood. The closed room was usually furnished with woven the its material made out of mud and straw, this doubled as a heat source in the winter. The ladder that was used connect the flat roof with the ground level was made out of brick. Reed hung from the flat roof for shading canopies for shading. Reed was also used to cover the doors and the windows to protect the interior from the heat, dust and flies (fig:11).[6]
The room was connected to an interior courtyard, that was used to grow vegetables. Families would also keep chicken and goats who roamed the courtyard. [7] The working class houses in ancient Egypt, were carefully designed to fit the Egyptian family. to lower the cost of construction all materials were gathered from local sources and mostly were built by the owners themselves (fig: 12).The working class houses used to be surrounded by walls for safety, and separated from upper class houses. Generally speaking the houses in Egypt did not have a running water systems, instead residents or slaves would bring the water to the house, and bathrooms which were just a hall in the ground.

Lower class houses were built with one wall layer and up to three layers of brick walls in upper-class homes. In some cases, working class housing was temporarily attached to specific big projects, such as building the pyramids which took years to make it. This type of temporary homing had fair quality and were usually smaller and more compact than permanent housing. (fig: 13).

Fig (12): Low income family house in ancient Egypt

Fig (13): Mud and brick town remains

Housing classifications in ancient Egypt also created obvious segregation in society that which explains the distinction in building quality and construction techniques.

In ancient India, houses for low-income families were separated from the rest of other the classes by clustering the units in one enclosed community. Unlike ancient Rome and ancient Egypt, where houses were mainly built according to economic status in ancient India, in addition to the economic approach, also considered the religion. They considered the ancient Vaastu and Shaastra principles when building their houses which was typically described as a square house concept, centralized by an open yard with Agnihotra in the middle (fig:14).

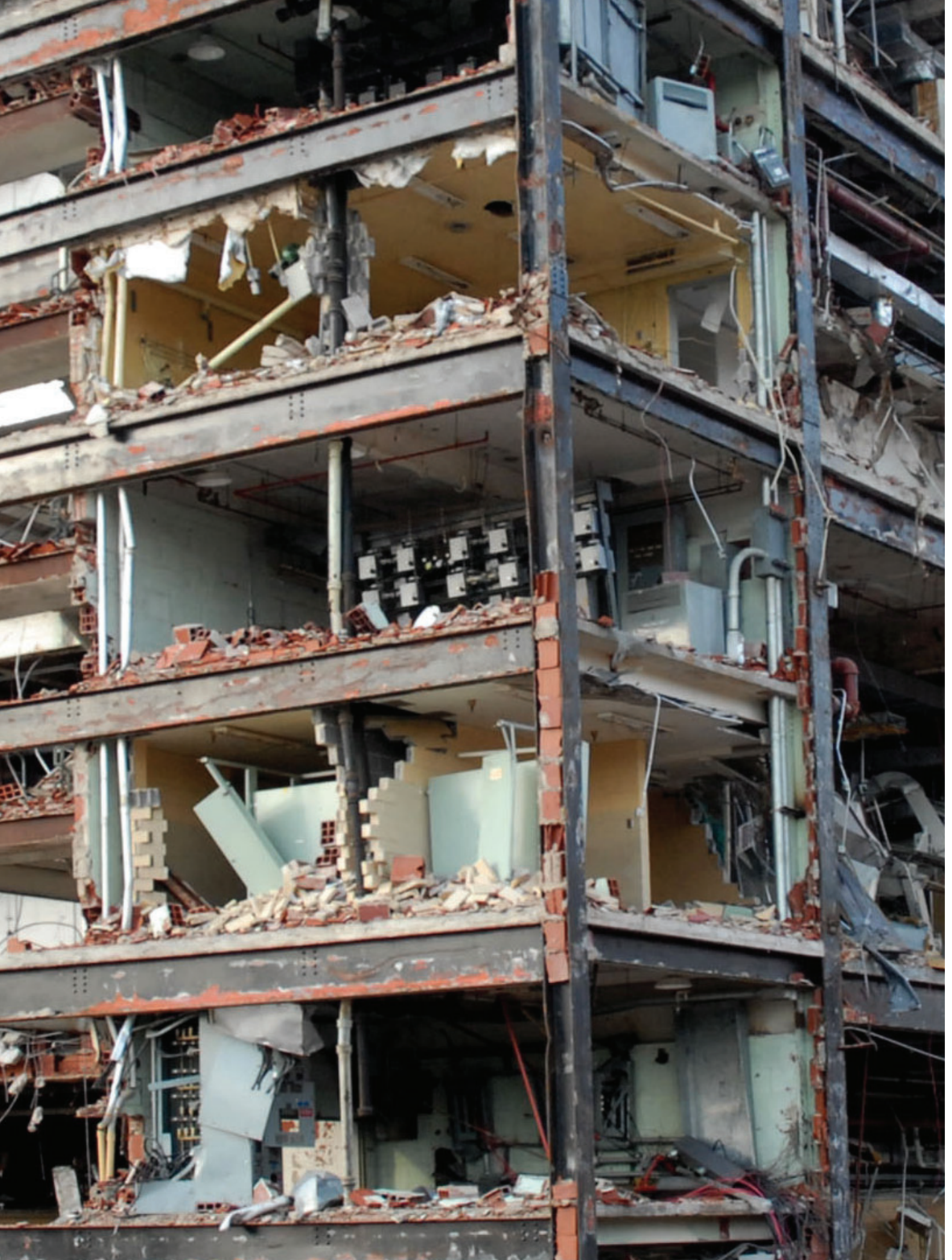
Ancient India, also had a sense of urbanism due to the fact that the whole city was built with a more holistic approach. Each low income housing cluster surrounded a middle common area; always taking into consideration the location of the trees building order for the housing was according to a social hierarchy.[8] Lower class housing in ancient India were built from a mix of mud and palm leaves. Houses were relatively simple, built with a consideration of security. Foundations and walls were made out of sun-dried bricks; building tools were used to ensure the right verticality of the walls. Houses typically had a flat roof with interior and exterior walls mostly covered by plaster.[9] Low

Fig (15): Housing in ancient India

Fig (14): Agnihotra, the fire of God

income family houses in ancient India had the advantage of covered sewer systems and mostly all communities were surrounding the river for water source and ease of living.

The city structure in ancient India had significant influence from religious principles, all design planning ideas were based on the sense of security and comfort within an urban setup. Similar to low-income family housing in ancient Egypt, houses in ancient India were built primarily using local materials which affected overall construction cost. The social classifications can be observed in the houses' size and height, as the higher class used to live in multi level houses, and the lower class lived in smaller and shorter units.



2.2 Unsuccessful Public Housing in the U.S.

As a response to the great depression during the 1930's, agencies launched programs to solve the housing issues for families who were unable to afford a home. These programs eventually made up a federal department of their own which became known as HUD (Housing and Urban Development). The programs within this department gradually grew and evolved based on various social and economic factors.[10]

In the mid 19th century, St. Louis suffered from low quality housing and substatial racial segregation dilemmas which effected the community as a whole. Due to the low quality housing in this particular area, along with the emphasis on providing assistance to families who were suffering from poor living conditions, the city of St. Louis proposed affordable housing in the form of high-rise apartments. The city hired architect Yamasaki to design these buildings in the lower north side of St. Louis to accomodate the low income families. Yamasaki proposed 57 acres worth of typical high-rise apartment buildings, each including 11 floors. These were refered to as Pruitt-Igoe public housing. Each building had a community space, laundry rooms and skip-stop elevators which were designed to skip specific levels to allow residents to use stairs and engage through the verticle neighborhood concept. (fig:15).[11]

Outside seating areas and playgrounds were implemented in this project alongside a reliable maintenance program, in 1957, the units grew to be more than 90% occupied with an equal percentage of occupants showing appreciation for all the city efforts to keep the buildings in good shape. Eventually, residents denuded said buildings and the maintenance upkeep began to falter due to finances. Gradually the premises grew vacant with the exception of those who were considerably very poor. The skip-stop elevators eventually stopped working all together.

The crime rate within these buildings grew to be some of the highest in the city until HUD decided it was better to evacuate the entire complex of all residents as opposed to fighting a losing battle. In 1971, authorities decided to demolish two of the buildings while attempting to keep the rest of the buildings in tact in hopes that things would turn around. Unfortunately this didn't work out the way the city and state hoped it would, therefore, they demolished all Pruitt-Igoe housing. (fig:16).

As exceptional as the idea of Pruitt-Igoe housing was during this time, it's most daring aspect was that it's architecture never took a class or race

Fig (16): Pruitt Igoe Public Housing in the City of St. Louis

Fig (17): Pruitt Igoe Public Housing Demolition

Fig (18): The Cabrini-Green In City Of Chicago

into consideration despite being located in a city with a previous history of social and racial issues. The true reasons behind this community's decline remain unclear, however, based on the data and evidence provided, it's easy to infer that the decline of this community was most likely the result of factors within social and racial status's.[12]

Another example of an unsuccessful public housing system is the Cabrini-Green project which was built between 1958 and 1962 to assist in ridding Chicago from its impoverished citizenship. Similar to St. Louis, Chicago faced racial factors that led to dedicating Cabrini-Green housing to poverty-stricken African American families.

As mentioned in the book "American Project: The Rise and Fall of a Modern Ghetto", the crime rates began to rise while residents from surrounding neighborhoods complained of an increase in drug and gang activity within the Cabrini-Green public housing. In addition, most of the residents within this housing system were unemployed and lived in deplorable conditions.[13]

Most of the residents of this public housing were unemployed, lived in a deplorable condition. The gang violence and drugs spelled within all the buildings to reveal another failure of public

Fig (19): The Cabrini-Green Project Demolition

accommodation. In 2000, the Chicago Housing Authority made the decision to demolish Cabrini-Green developments which was their approach to transferring all of the city's public housing to mixed-income units. The last building was demolished in 2011 bringing public housing to an end in the city. The demise of the Cabrini-Green project rid the city of low-income African American families, however, through this process, an isolated island of unemployed, low-income families developed while gaining disapprobation from surrounding neighborhoods. .[14]

Ann Arbor, Michigan is another city which decided to remove affordable apartment buildings, but for different reason than the previous two case studies. Their decisions were based on the lack of community space, the need for accessible homes and the goal to provide an increase in energy efficiency.[15]

This led to proposing new developments which would eventually accommodate more families. The city also placed precedence on considering an environmental approach within these new homes which reflects their goals to create healthy,

Fig (20): Buildings in the 3400 block of Platt Road, Ann Arbor

Fig (21): Building at 701 Henry St., Ann Arbor

Fig (22): Proposed new Affordable housing on Platt Road, Ann Arbor

Fig (23): Proposed New Development at 701 Henry St., Ann Arbor

Fig (24): Kippax Palace, Hopewell, VA

affordable communities and blend low-income families with the rest of the city.

When Ann Arbor Housing found demolition to be the only solution to the inefficient affordable housing, Kippax Place in Hopewell, VA developed a management system to help keep the building up. They then broke ground in 1973 as public housing by Hopewell Redevelopment and Housing Authority to cover the need for affordable homes in the area.

Due to the bad management and low funds, the building maintenance got effected and turned the building into almost an inhabitable status. The building was facing same fate like other public houses in the in the U.S. Broken windows, pipes HVAC was not working right and eventually elevators stopping, led to a complete evacuation to the building.

"Kippax … was losing about $90,000 a year when you look at the revenue that we get from that building and the overall expenses that it takes to run that building. We're losing about $90,000 a year." Steven Benham[16]
Fortunately, management proposed another idea to partnership with on of the community based housing company to turn the unit into completely privately owned and keep the rental rates low to fit low-income families and seniors budgets.

The management new vision was successful to

Fig (25): Kippax Palace, Hopewell, VA

fix the issues the building faced, they renovated the entire building, install new HVAC system for more efficient result and to lower resident energy bills. The units now come back to the market and available for low income families according to Hopewell HUD Rental Assistance In come Qualifications.
The Kippax Palace sets and example of failed public houses that became successful just by turning it to a private entity.

Now more affordable housing projects are privately owned, and get advantages of the available federal programs in order to keep the rental cost low.

Conclusion

With all of the factors involved with the public and affordable housing, there were legitimate reasons involved with it's failures. The first being the concentration on low-income families in one community such as the Pruitt-Igoe and Cabrini-Green buildings. The solution to this was to break up this housing style into smaller units and place them in a more strategic spot within the city. A smaller number of affordable units helped to facilitate blending their residents within the community which helped them grow financially and educationally. This also helped to limit the crime percentage due to the fact that maintaining a limited number of units is easier and more controllable compared to the bigger buildings where a small maintenance issue can be turned into something catastrophic and/or political.

Affordable housing should be designed according to the need of low-income families in the area,. For example, if the area needs affordable housing for seniors or disables, accessible approaches should be considered. If the city wants to build affordable housing for families, multi-option interior plans should be provided to accommodate all low-income family's, no matter their size. Some cities with environmental concerns such as Ann Harbor also have to consider eco-friendly units. Lastly, location is the last important aspect. Affordable houses should be located in an area where the city has plans to develop. Think about the area's future and the way individuals will receive the new wave of affordable housing.

2.3 Successful Public Housing in the U.S.

The efforts to make quality, affordable public housing following the second world war never ceased. Federal organizations such as HUD adjusted their policies and goals based off of economic changes and social factors. This made it clear that a good affordable housing design is one that considers various approaches in building a healthy living space for all.

My first precedent study is affordable housing in Albuquerque, New Mexico called The Beach. The project architect is Antoine Predock, the project purpose is to provide housing for veterans, low-income family and student in the area. The location of the project was carefully picked, it's close to the historic district where motels, cafes and restaurants are close by, it is also in between of Albuquerque County Golf Club and the Hispanic cruisers.

Interior design played an important role in this project as it directly reflected the peoples needs within the area by displaying various layouts: Studio units, one bedroom apartments and two bedroom apartments. Each layout was able to accommodate both families and individuals in any circumstance (fig:26).[17]

The exterior of what we now consider "complexes" has quite exceptional design which

Fig (26):The Beach complex different layouts.

Fig (27):The Beach complex colored facade

Fig (28):The Beach location advantage

takes the surrounding culture into consideration. Colorful facades and neon lights are often utilized to emphasise exterior elevation heights (fig: 27-29) As an architectural professional. Predock also considered the mountains in the background of the property, making sure they were able to compliment the project's location (fig:28). On top of responding to the people's essential needs, this complex also helped to enhance the sites and culture in this particular area. Currently, The

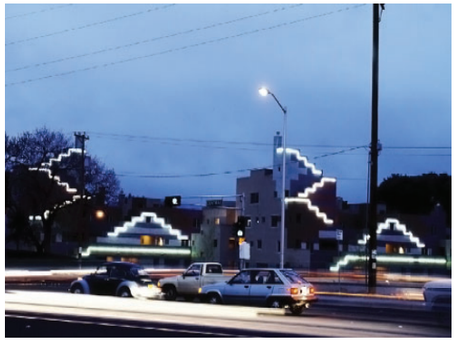


Fig (29):The Beach neon motif

Beach offers rentals from $500 to $1,000+ while continuing to stand solid on their plan to provide affordable housing for renters and equally great business for landlords alike.

The University Houses located in Philadelphia, PA. also display another successful example of affordable housing. Similar to The Beach complex, this architect also considered the surrounding cultural elements in his design.
It corresponds to the 1976 amendment to the National Housing Act. Congress stated a clear national policy calling for the elimination of sub-standard and other inadequate houses and the realization as soon as possible of the goal of a decent home and suitable living environment of every American family. This articulates the other American housing dream: that of lower income Families caught in the deepening spiral of urban poverty.

In an area close to downtown Philly, the location of the University Houses proposed to build a total of 70 units specifically for low-income families in the area (fig. 30). Friday Associates (the architect of this project) considered the Victorian motifs which were common in the area (fig. 31). The units were townhomes consisting of three floor buildings. The architect created an impressive entrance in the corner location which led to a courtyard with seating areas. This was done in order to create a social aspect within the space (fig. 32).

The factors that make this development successful are primarily, the location and project design which considers cultural aspect and blend low-income families in the community by placing the development close to the downtown. Also the architect was achieved a cost of $49/SF in 1983 which considered relatively affordable construction.

The last precedent study of the successful affordable housing is Modular Homes of Ladywell Leisure Centre, London, UK. The Lewisham Council found that there's a need for free temporary homes to solve the homeless

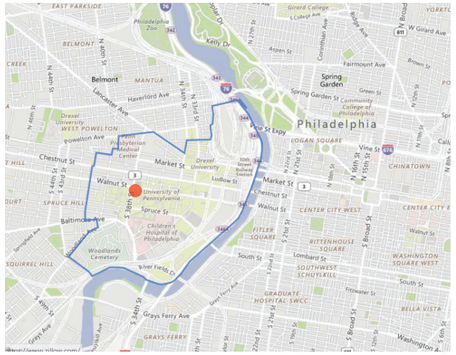


Fig (30):University City Townhouses Location

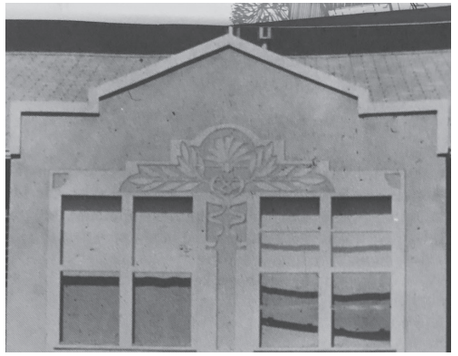


Fig (31):University City Townhouses Victorian Motifs

Fig (32):University City Townhouses Entrance

Fig (33):University City Townhouses

families problem in the area. Lewisham Council hired architect Rogers Stirk Harbour + Partners' to design these homes. The architect goal was to find a quick, appropriate, economical solution to built temporary units with minimum lose (fig:34). The architect proposed volumetric modular units to create moveable development in Ladywell Centre which had an old development that demolished in 2014. Responding to the high demand for affordable housing the volumetric units provide 24 homes and will remain on site for couple years, then the city will relocate it to another location as needed, since the system flexibility, the city can reduce the number of units or even sell to a different city or private entity.

The design goals are the use of standard size units and find ways to connect them together with a consideration of the exterior look of those units and the interior space function (fig:35).

As far as design, the goal for these units was to be able to use standard size units and find a way to connect them while also considering the exterior appeal as well as the internal functionality (fig. 35). This was accomplished through several aspects. On the first floor, retail shops were constructed to create an urban setting. The second, third and fourth floor were designed for living spaces which provide all necessary needs for families (2 bedrooms. a living space, kitchen, storage & bathroom) while each apartment combines 2 volumetric spaces (one for the 2 bedroom and the other for the common areas, fig. 36).

Fig (34):Ladywell Centre Volumetric Development

Fig (35):Ladywell Centre Volumetric Flexibility

Fig (36):Ladywell Centre Development layout

Conclusion

I can infer from the precedent studies of the successful affordable housing examples, that several factors effect the affordable housing, but I found the two factors would be design quality and construction cost. The design quality includes: liveability, adoptability, design that corresponds to the people needs and consider cultural and healthy community approaches. The construction cost which directly effect the units' rental cost, also consider the compacted units to use the land in more efficient way. Moving forward with those two principles, my research focused on the ways to make quality design with minimum possible cost constructions.

3. Design Quality and Cost Rules
1. Sketch Problem

Fig (37): Shipping containers sketch problem

The "Sketch Problem" aimed to experiment with utilizing different construction ideas within a full design sketch

Shipping containers

One of the most intriguing ideas I came across during my research was the use of shipping containers to design affordable housing. I then experimented within this system by designing a full collage of shipping container designs solely to see how people would respond (fig. 37)

Regular Construction and Community Inviting

The benefit of regular construction is that it has the flexibility to be able to provide commercial stores on the ground floor. This is meant to leave an open invitation to surrounding communities to come participate in social activities in hopes that they find the property intriguing enough to potential become a part of (fig. 38)

Fig (38): Regular construction of retail stores in ground floor and apartments in upper levels.

3.2 Design Quality and Cost Control Rules

Based on the previous studies, design goals were created to control the design quality. They were also utilized to create case studies and propose the final design.

Fundamental Design Goals

Fair Housing:

Which can be achieved by providing different layout sizes that fit all type of families, and individuals. Also, a fair housing considers the affordability. This goal primarily to ensure the equity between all low-income families.

Health and Livability:

Promote public health by making walking and biking attractive options and by encouraging community and other outdoor living areas that are appropriate to the place and the people who will use them. Also, create spaces to invite other people from surrounding communities to ennead with the new development residents.

Sustainability:

Encourages certain development patterns and building methods to make efficient use of the land, energy and all other resources. The goal is to build things that last and to be able to adapt to needs over time (such as environmental changes).

Physical Character:

When it comes to design, it's essential to use one that is flexible enough to accommodate any requirements. It's also equally important to be able to enhance all design characteristics in order to make them attractive and livable for every situation.

Housing and Other Human Needs:

Providing a mix of housing types to meet the needs of residents is a must. This is particularly important when it comes to residents with children or accessible housing needs.

Compact Development:

Use land efficiently by having new construction take a compact form, also consider low number of units from 70-200 unit max per conclusion of unsuccessful affordable housing.

Ways to Reduce the Construction Cost by OVE [18]

To control the cost, this list was created to address all the construction techniques that can be considered to reduce the construction cost. Based on OVE (optimum value engineering) research by NAHB to reduce home building costs by design.

Plumbing:

1- Consider the pluming in the design plan
2- All the pluming fixtures, lavatories, bathtubs, sinks and toilets and laundry should be clustered around same area.
3- Stack kitchen, bathrooms and laundry vertically to use single vent for all. Align walls of all the plumbing fixtures to avoid vertical paths.
4- No pipes on the exterior walls for insulation purposing.
5- Prefabricated pluming wall is possible if all the plumbing in same wall.

Heating & Cooling:

1. Always place in a central area for good air distribution.
2. Specifications for windows and doors should be carefully considered for heat loss and gain.
3. Focus on incorporating ducts into the design plan to avoid unnecessary horizontal ducts.
4. Consider all required space to run the ducts within the design.

Electrical:

1- Minimize number of switches, fixtures and outlets.
2- Switches are located close to the fixture to reduce the use of wiring.
3- Service panel should be placed closed to

kitchen or utility room to minimize the use of heavy wiring.

Stairway and Access Panels:

1- Straight runs are most cost effective.
2- Stairs should be parallel to floor joist, so one joist every 24" (efficient) can be used.. Should use modular for accuracy
3-stairs should not interrupt the structural beam or bearing wall.
4- Likewise the access panels to the attic.

Foundations:

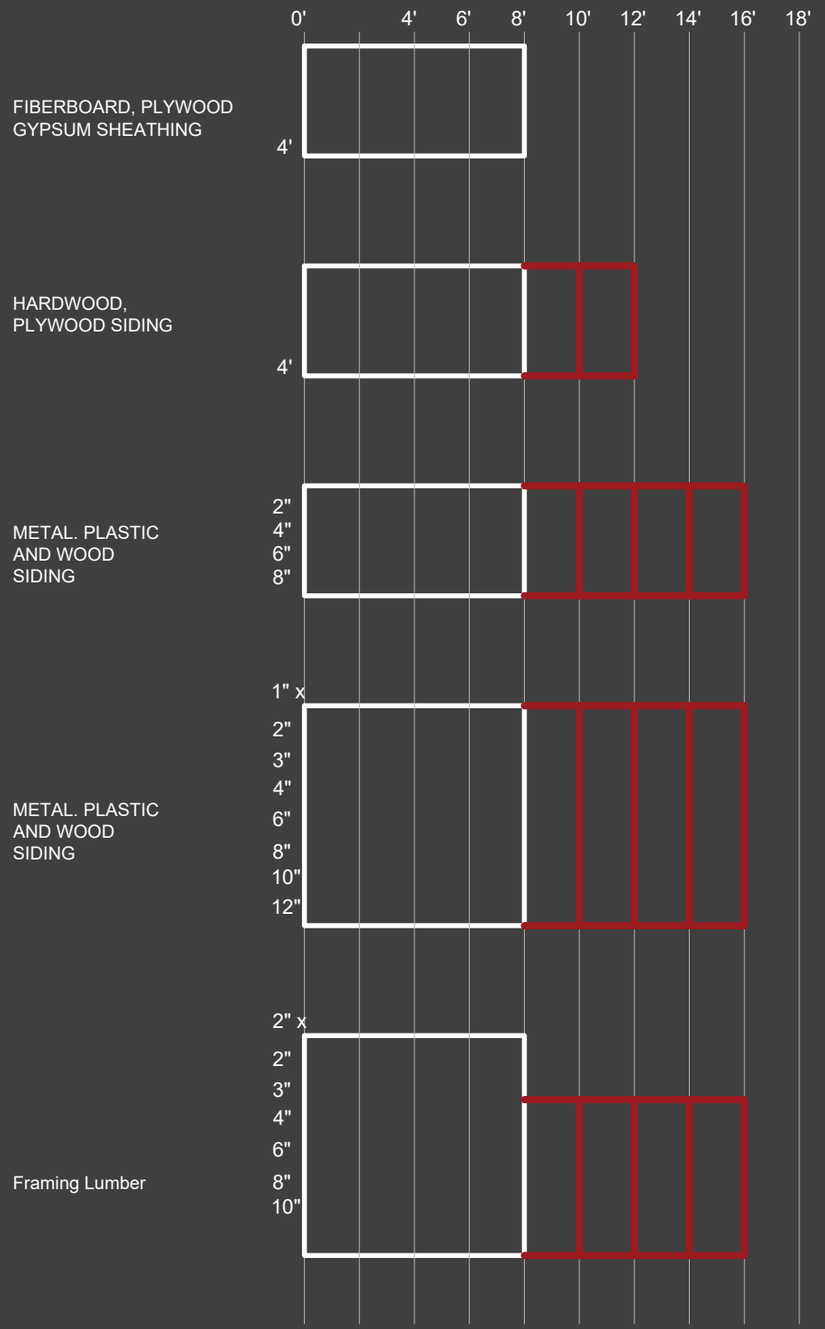
Concrete slab is optimum solution for cheaper foundation, the first floor joist space for maintenance

As a sub category from the design quality list, it's essential to determine the minimum interior space requirements to ensure the function of the spaces and the livability.
The minimum interior space dimensions were initially based off of finding the overall layout dimensions per unit.

In addition to the OVE design, material elements must also be considered to reduce the cost of construction. OVE research also includes the size of the materials which is crucial when discussing budget.

In the next few pages, my goal is to propose the use of interior space requirements for various room sizes and arrangements as well as listing material sizes which prove a 2' module is the optimum increment of space when including exterior walls.

Minimum Space Dimensions



Construction Material Sizes

3.3 Principle Analysis and Design Processing

Considering each guideline from design quality, OVE, minimum space requirements and material sizes, thinking about interior space during the design phase became a must. I also found that locations of mechanical rooms and plumbing fixtures designed according to the 2' module are crucial in determining the final design look in a highly functional space.

For example, I placed the mechanical room in the middle to use the HVAC system in the most efficient way, that will make all duct runs equally to all rooms. In addition to placing the mechanical room in the middle of the space, plumbing fixtures should be on an interior sharing wall with other unit to reduce the cost by using sharing pipes. By moving forward with this concept, the interior space will be shaped accordingly, which also effect the adjacent units, corridors and all building design.

On the other hand, initiating the design by placing both plumbing fixtures and mechanical room in on cluster on same wall of another mechanical and plumbing cluster from the apartment adjacent to it will give the advantage of mirroring the same plan in one row then mirror the whole row to create double loaded main corridor.
Because the centralized mechanical room is one of

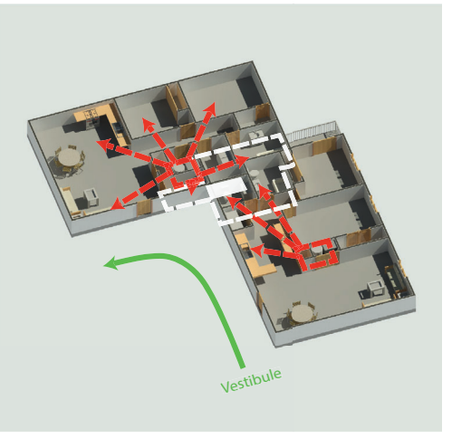


Fig (39): Mechanical room Center Placement

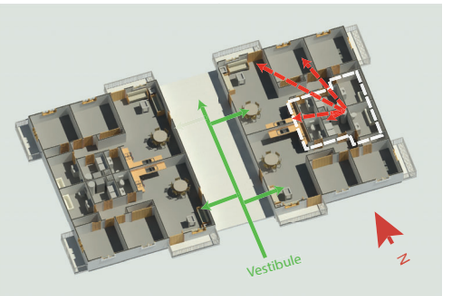


Fig (40): Cluster Mechanical Room and Pluming in one area

the most important aspects in a unit, it's essential to create the apartment buildings with adequate spacing arrangements just for this. All designs have used BIM to evaluate the functionality of the dimensions and corridors within the space. As pictured in fig. 41, you can see that at this point, we are now able to connect the other apartment units and create an entire complex.

The next step is to try and design on 2' modules in order to achieve modularity of the space. Based on previous analyses, placing the mechanical room in the center with the consideration of 2' increments and testing all stages in BIM to ensure functionality is a good place to start. Once that is accomplished, the goal is to then divide the space around the mechanical room into rooms which fit the minimum required dimensions within the unit (page 43). This is also done to the second unit which has less flexibility due to the length and shape of the shared walls. Once all is said and done, we now have connected units which form an entire complex. (fig:44).

Throughout this process, there are two adjustments in which I found to be essential in completing the building design: the first is shifting the mechanical room to get a better space (especially in the second and third units), the second is breaking the rule of having wet common walls in order to get better unit orientation.

After practicing a handful of these plans on a 2' module, I found that starting with the entirety of the building design could be a great place to start and could allow for the most optimum building orientation. With that being said, starting the building design from the exterior walls would ease the locations of the entrances and interior corridors.

The first step to creating a design which starts with exterior walls is to determine how many units are needed and the what the best orientation would be. From there, you then combine them in one outlined building with suggested dimensions

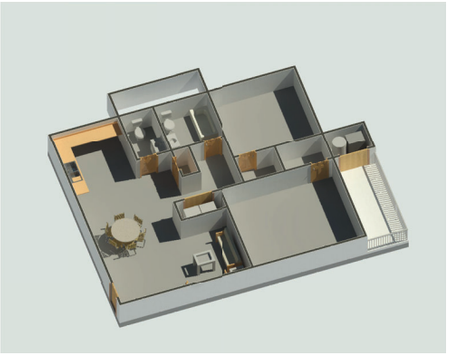


Fig (41): One Unit Design

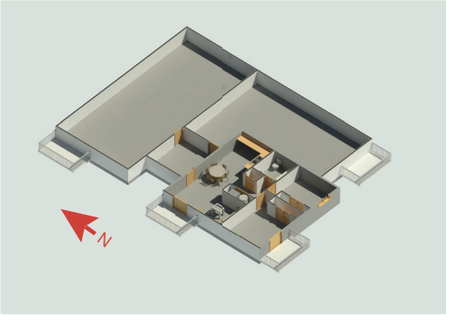


Fig (42): Whole Building

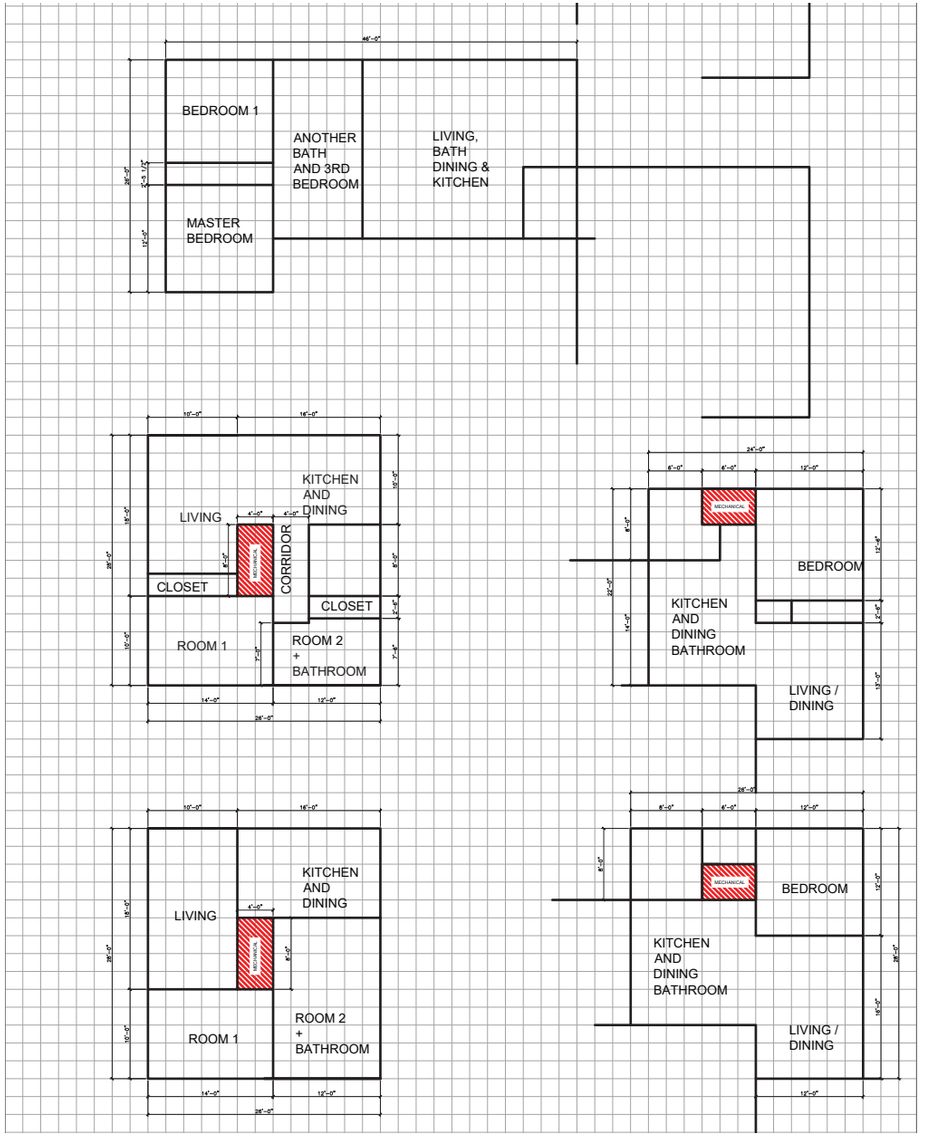


Fig (43): Design One Unit on 2' Module

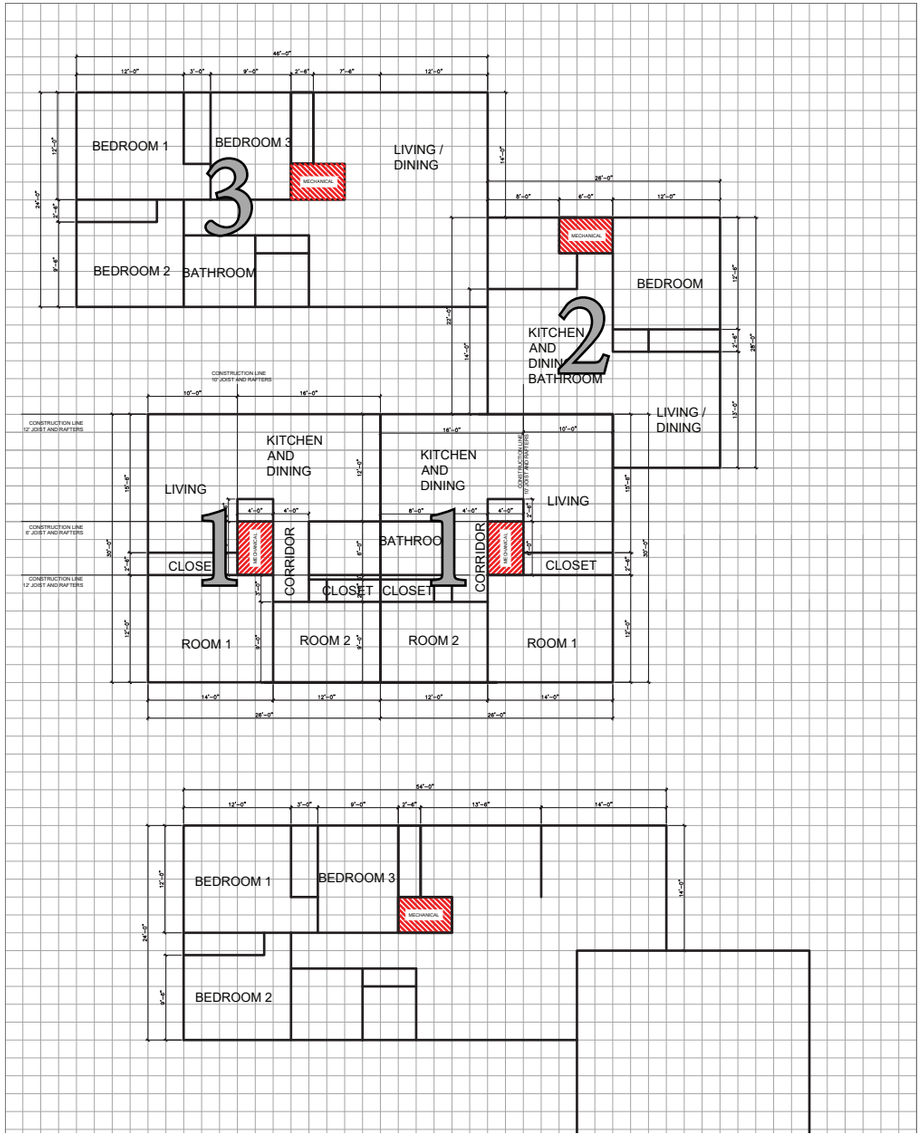


Fig (44): Design One Unit on 2' Module

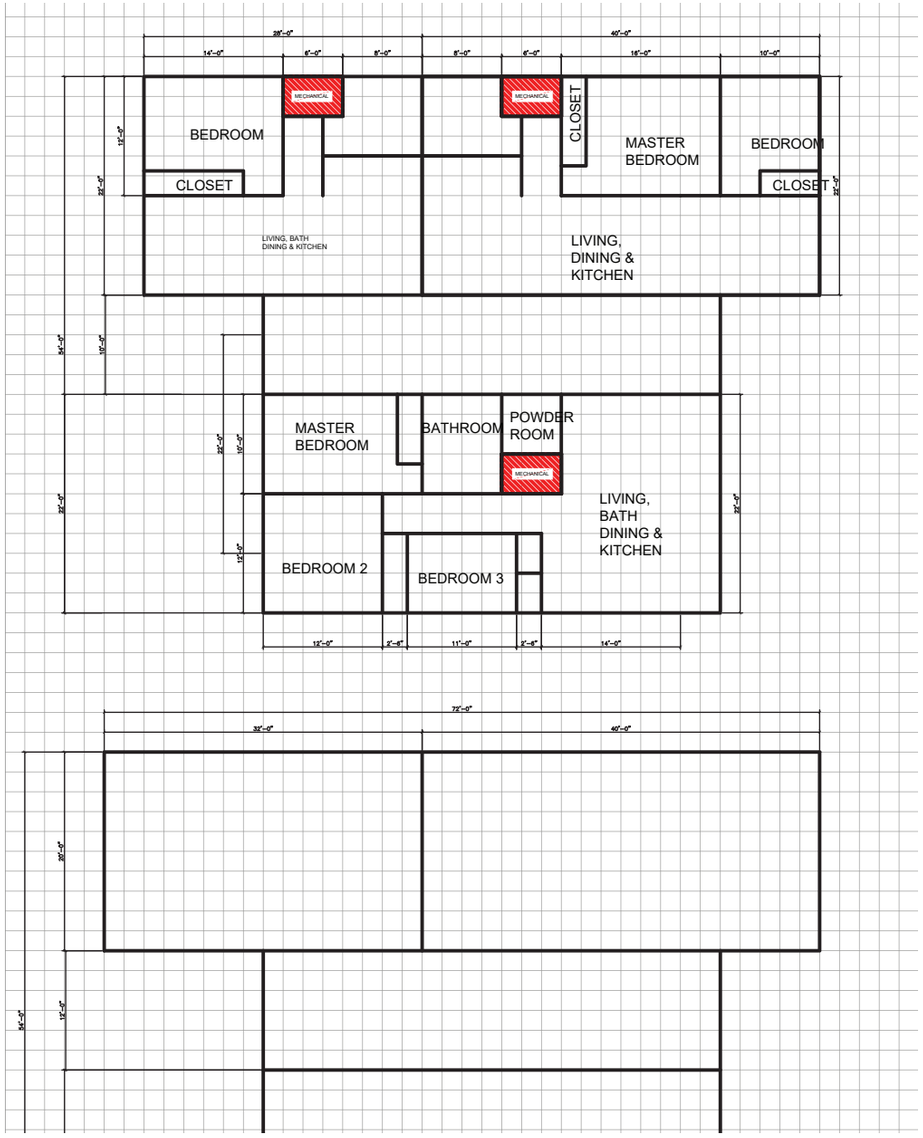


Fig (45): Design One Building on 2' Module

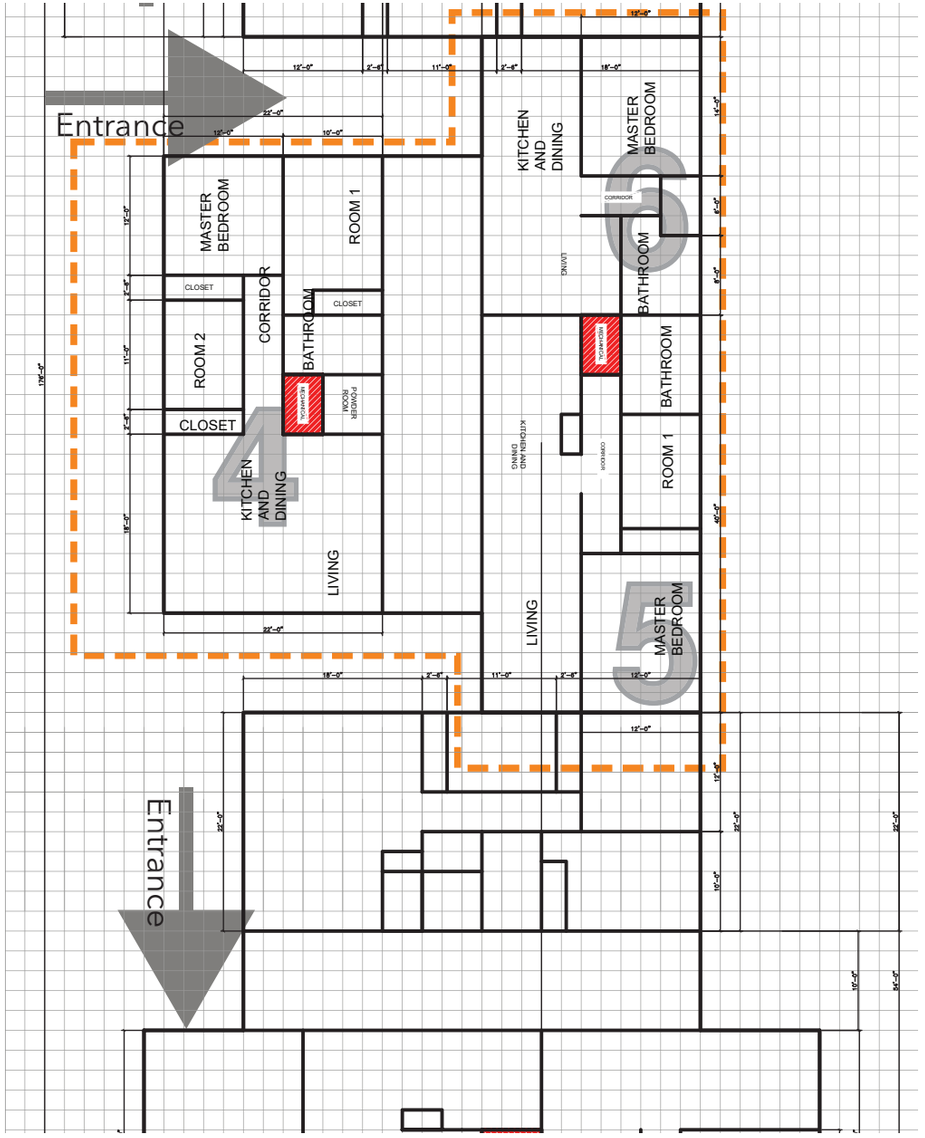


Fig (46): Design One Building on 2' Module

based off of the total dimensions in the first methodology (fig. 44 & 45)

Then take the outline that has been created and divide its interior spaces according to all design rules. After that, determine the entrances and corridors in the building. The next step is taking the building then connect it with similar units with consideration of the building orientation to create a bigger complex (fig: 46).

After that, furnish all layouts in BIM, also check the solar solstice & the sun path. Also, design corridors, entrances, exterior and interior stairs.

Building corridor should consider the movement circulations (with furniture) also consider accessibility from the street through the entrance and corridors then apartment doors. Other elements to be considers such as: entrance canopy, roof terrace option (if the roof is flat)

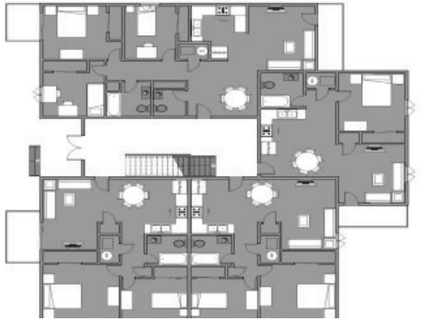


Fig (47): First floor Plan

	Number of rooms	Total Units
1 780 SF	2 Bedrooms 1 Bathroom	4 Units
2 644 SF	1 Bedrooms 1 Bathroom	1 Units
3 1100 SF	3 Bedrooms 1.5 Bathroom	1 Units
4 1015 SF	3 Bedrooms 1.5 Bathroom	2 Units
5 880 SF	2 Bedrooms 1 Bathroom	2 Units
6 615 SF	1 Bedrooms 1 Bathroom	2 Units

Fig (48): Total Units Schedule Analysis

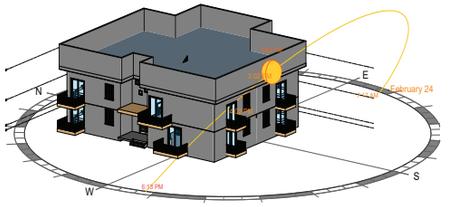


Fig (49):Winter Solar Solstice & Sun Path

Fig (50):Building Orientation

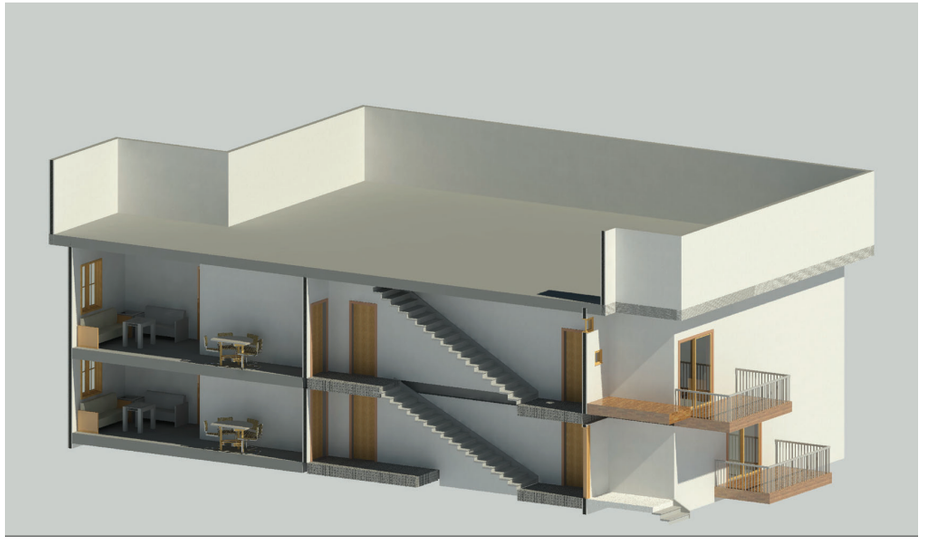


Fig (51):Section to Illustrate the Vertical Relation

and windows according to the orientation of the building. Fig: 48 is the first building and the complex total units and area size analysis to be used as a comparison tool with other proposed designs.

Precedent Evaluation

This phase aimed to study precedent of low-income developments by evaluation according to the design qualities and cost rules in pages 40-42. The main criteria of choosing the precedent study is to evaluate a project that is for low-income families or seniors, also considered the project that correspond to specific social reason.

The first example of this was Roosevelt's energy saving, low-income senior housing in Roosevelt, NJ. The architect for this project considered the use water heat storage and ventilation within the units. The same architect also considered single level homes for accessibility and outside spaces for neighbors to gather.

One of the major keys to make this development efficient is the building orientation, the building axis is along the east-west so the building heat gain is appropriate.[19] According to all these factors, the complex was successful to address matters like sustainability, the healthy community, and accessibility.

The second example is Acorn buildings in Oakland, CA which were built in 1969 for low to mid income families. The architect for this project considered various aspects to create this complex design as well as taking lessons learned from previous public housing fails into consideration (fig. 54).

In 1964, this particular design won a competition for large affordable housing. When it came to design and quality, it was a fan favorite. However, the complex faced technical failures due to the lack of gutters and elimination of overhang throughout the entire building. The rain began to cause damage to the buildings facades which led to water eventually seaping into the units. All residents evacuated the building besides those who weren't capable. Due to the vacancy, the crime rate increased.[20]

The design considered: the fair housing by providing different unit sizes, saving in plumping by stacking all fixtures vertically, the competency also the physical character of the buildings.

The final case study is Colton Palms in Colton, CA. which had 101 units for seniors. The architect for this project incorporated social elements such as gathering areas and a library. The designs consisted of unique physical characteristics for the residents. However, there was a missed opportunity to save in construction cost due to the odd triangulable layout. One other flaw is that the palm trees surrounding the complex isolated it from the rest of the community, so outsiders rarely engaged with the residents.

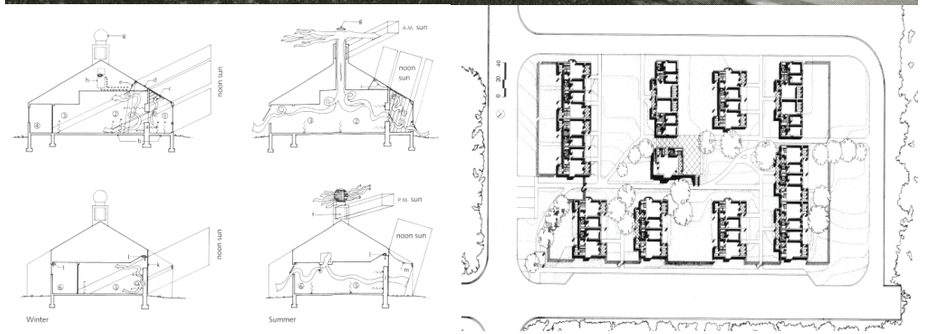


Fig (52):
Roosevelt's Energy saving low-income senior housing
Roosevelt, NJ

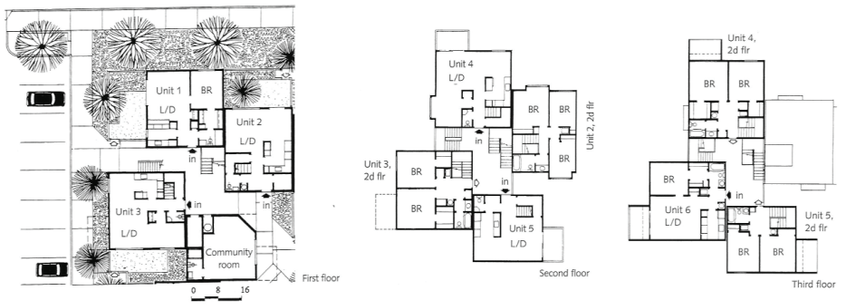


Fig (53):
Acorn buildings, Oakland CA
Built in 1969 for low to mid income families

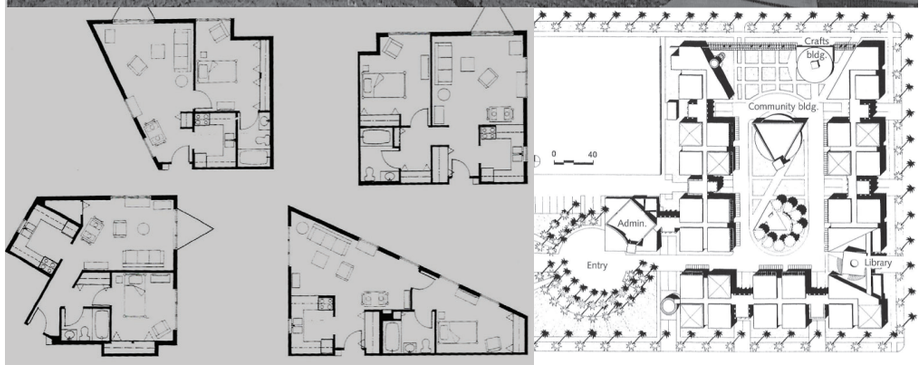


Fig (54):
Colton Palms, Colton California
101 Units for seniors

4. Design Phase
1. Construction System

The construction system plays a major role throughout the design phase and has a crucial effect on the construction site and final design. My research is mostly focused on comparing the most common construction methods starting with regular construction. This type of construction is typically accomplished by all material being delivered to the site followed by the construction crews framing out all of the buildings and then covering the interior and exterior walls with material. After these initial steps, mechanical, electrical and plumbing is then installed before finishing all surfaces.

The second system is the prefab construction which starting to rise lately due to the system affordability and time saving. The affordability of the prefab construction system comes from the elimination of most on site work, by dividing the building into pieces and manufacture it in a closed controlled area, then ship all pieces to the site and put it together. Also affordabilty comes from buying huge amount of materials and fixtures which gives the manufacture low price advantages.

The third system is the volumetric modular system which is similar to the prefab system but is also able to eliminate all of all the on site work by providing the full constructed units by dividing the entire space into one, two or three volumetric units and connect them on site to create an apartment. The on site work is more expensive due to the liability, construction managing and seasonal work, but working in a factory eliminate all those factors that effect the cost of construction.

The final system is shipping containers which appears to be growing in popularity and utilized everywhere, however, this system is quit opposite of it's reputation. Each shipping container's construction requires special insulation to isolate the steel from heat gain or loss. One other major issue is that noise easily travels through the steel and creates unpleasant living quarters. The shipping container system is built on four corner steel and must be stacked perfectly vertical in order to transfer. Advertising for the shipping containers claim this system to be sustainable, however the containers must actually be new in order to handle all loads. They also rust easily which limits their life span and durability causing them to need to be replaced more often than not.

From the comparison schedule above, the on site construction is a flexible way to be incorporated into any design. However, due to the on site labor work and required on site management,

	Quality			Cost					
	Physical Character	Human needs	Sustain-ability	On Site Labor Cost	Material cost	OVE Rules	Modularity	Construction Time	Cost / SF
 On Site Built Construction	Flexible to accommo-date any design or physical concerns	Can provide mix houses types of any size and accessibility requirements.	Can include sustainable aspects but it effects the overall cost	Maximized as all the system get installed on site. Plus site manage-ment and limited to the adulate sea-sons to do construction	Full market price material	Can be applied	Limited to the material module	It takes about 4 to 6 months (minimum) after choosing design	$137 is cheapest price founded. Actual price for current project is $160.
 Stick-Built Construction	Flexible to accommo-date any design or physical concerns. But might cause price increase	Can provide mix houses types of any size and accessibility requirements.	Can include sustainable aspects but it effects the overall cost	Less on-site labor cost due to the prefab method	Cheaper due to factory bulk purchas-ing of the materials	Can be applied	Limited to the material module	About 10-12 in factory and 10-12 on site Maximum 6 month total	Cost range from $100 up to $170 depends on the required finish
 Volumetric Modular construction	Inflexible to shape any design due to standard unit sizes. Project propose a solution.	Can provide mix houses types of any size and accessibility requirements.	Sustainable aspects included such as the ability to adapt more needs and units can be relocated	Lowest on site labor cost as the system pro-vided includ-ing all walls floor an the space	Cheaper due to factory bulk purchas-ing of the materials	Can be applied	In addition to the material modularity, it also provides volumetric module which safes time in construction and faster instal-lation	About 8-10 in Factory and 4-6 on-site Maximum 4 month total	Range $50 to $80 de-pends how costume is it

 Shipping Container Houses	Inflexible to shape any design due to standard unit sizes. Subjective physical character	Subjective due to the maximum interior height is 7'-6" A.F.F.	Unsustainable system as for liability the units must be new and by time units get rusted and will need to be replaced	Lowest on site labor cost as the system provided including all walls floor an the space	Cheaper due to factory bulk purchasing of the materials	Partially can be used as structure supporters will be steel and wood steel connections need special connectors, has odd sizes	In addition to the material modularity, it also provides volumetric module which safes time in construction and faster installation	About 4-10 weeks not including the period to manufacture the container itself	$90 average per SF including the metal unit up to $150 cost due to especial insulation and structure

Cost Sources:

Modular Home Network: http://www.modularhomesnetwork.com. Modular home	$50-$80	Modular homes
National Association of Home Builders: modular home is $76.80, according to the National Association of Home Builders.	$76.80	Modular homes
The average stick-built home costs $94.34 per square foot.	$94.34	Stick-Built
https://www.fixr.com/costs/build-apartment : $125 national average (should add 10% due to Detroit city additional cost)	$125	On site Built
Current project in Ann Arbor (Avalon Affordable housing): about $160 per SF.	$160	On site Built
https://offgridworld.com/10-prefab-shipping-container-homes-from-24k/ Cheapest is container homes $150 per SF.	$150	Stick-Built
https://metalbuildinghomes.org/prefab-shipping-container-home-builders/ Cheapest contaier homes	$90-120	S. Containers
https://www.thrillist.com/home/gorgeous-prefab-homes-and-cheapest-land-for-sale-in-every-state-for-building. for prefab houses up to $170 per SF	$170	S. Containers

also construction is usually seasonal depends on weather which add more cost to it and also it takes longest time to construct according to the comparison schedule. The regular construction could be sustainable as needed, however incorporating sustainability in the system will increase the cost of the construction. Material prices will be same as market price since the material will be purchased just for this job. The average cost per square footage according to all sources is the highest among other construction systems. The average cost per square footage is $137, but a current affordable housing in Ann Arbor, MI is $160 per square footage.

The prefab construction system has been an alternative solution to reduce the cost of the construction, and been used since a couple of decades now and proved its affordability. The cost reduction of the system depends on the elimination of big portion from the on site labor and manufactures get bigger discounts in material cost when they buy in bulk. Also, the ability to work anytime during the year due to the controlled area and cover working spaces that manufactures usually offer. The prefab construction system can be modified to used in any design, however in some cases, it gets complicated with custom designs, therefore most of the prefab system manufacturers tend to manufacture standard designs. The system also can adopt sustainability but that would increase the cost. The other important factor that make the system more affordable than regular construction is manufacturing period which is shorter.

The volumetric modular construction system is very sustainable due to the fact that it's mobile and allows for any future modifications. However, it is a bit more difficult to deal with since the system has limited space due to truck sizes. This is why, when utilizing this systems, it's best to make all construction decisions at the beginning.

The modular construction system has all of the same cost advantages as the prefab system, and then some. What makes this system stand out is it's ability to minimize working on site as well as it's material modularity which can be used in each volumetric box. This systems average cost per square footage is the lowest amongst all other systems. When compared to all other systems, the modular system is also the fastest construction method.
Another cost reduction factor in this system is the material modularity which is automatically considered in each volumetric box design.
The system average price is the lowest among other systems per all cost sources. Logically per all cost reduction factors that are embodied in the system, it is lowest cost per square footage.

The final construction type mentioned in the above chart is shipping containers. This system appears affordable at first glance, however it cost a ton to insulate the carriers especially in locations such as Michigan where the construction cost requires higher R value due to the cold.

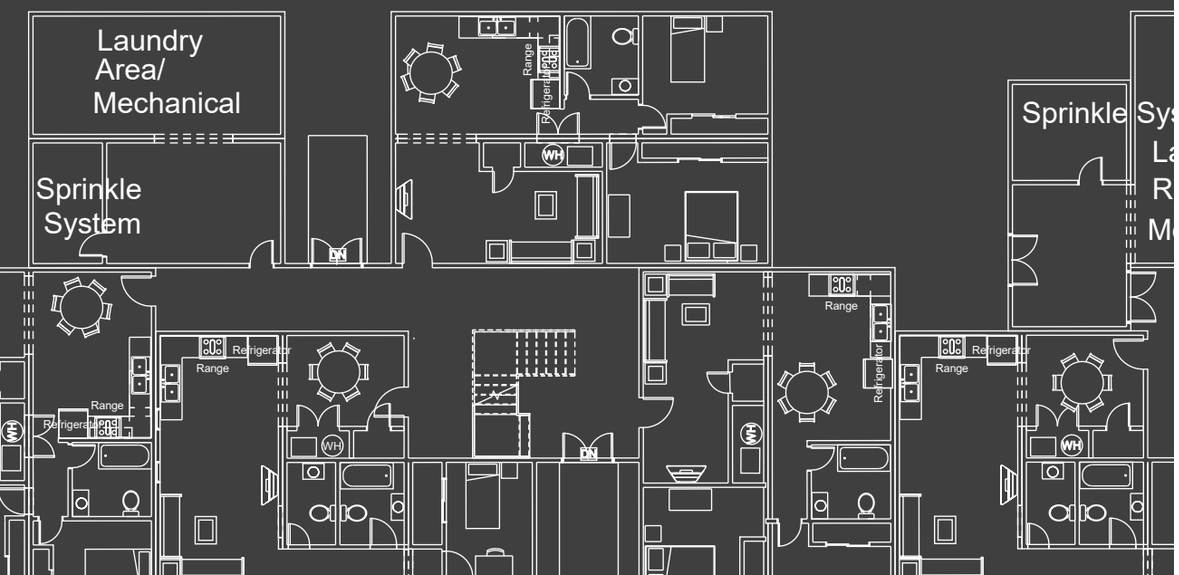
Another factor that makes shipping containers hard to deal with is the use of the metal structures which have proven to be difficult during the design and assembly processes. When building higher than one single level, the top row needs to be stacked perfectly on top to avoid more steel structure's being added to the lower units in order to carry the extra weight. The maximum interior height of the unit from floor to ceiling in 7' 6" which is considered low living quarters and can cause most to feel uncomfortable while inside. Because this system is manufactured according to special standards, all elements require special installation. Although this may be one of the quickest methods for construction, there are a ton of technical flaws which require extra attention.

And since this system manufactured according to special standards that aren't related to construction, all elements in the construction systems will required special way to install it, such as doors, windows and plumbing fixtures.

The price of the shipping container system is varied depends on the quality of the finishing, for example if the system exterior walls will be covered -which is a necessary in some states- that mean it will cost more than the uncovered system. The system cost range is $90 up to $150 per square footage.
Form the system comparison and analysis it can be inferred that the volumetric modular system would be the best system that balances between the cost and design quality.

The modular system been used here in the U.S. before as a way to reduce the construction cost, however, all the previous projects were custom units or luxurious town houses. The main factor the affordability lies on is standardize the space and make it more efficient.

Through all of this research, I've concluded that the volumetric modular system creates the best balance between cost and design quality. This system has been often used in the U.S. to reduce cost for custom units and luxurious town homes because it's affordability lies on standardization and making the space as efficient as possible.



4.2 System Analysis

After picking up the volumetric-modular construction system, in this phase, I analyze the system to evaluate it according to OVE ways to save in constructions. The reason I started with this step the design quality goals could be achieved by any system, except the accessibility which is required specific minimum spaces to be accomplished, and the sustainable approach that is related to type of construction. Also, accessibility will be evaluated in this chapter. All other design goals will be addressed in the building and site design phase in the last chapter of this book.

The truck that will carry the system units has a specific capacity, so the maximum size of each modular unit should be according to the maximum truck load which is 12' wide, 48' long and 14' height. Since those are the maximum so smaller unit should be considered, also 48' long truck is not drivable in some streets, so it's better to use 40' long trucks (fig:56).

The modular system gets delivered on site a whole entity; walls, ceiling, floors and finishes. . In addition to the system itself is sustainable, I propose the use of Dryvit as an exterior material to increase the R value of the walls which will reduce the use of energy (fig:57).

Cost Evaluation

The modular construction system can accommodate the OVE rule to place the mechanical room in the middle to get more optimum air distribution around the space (fig:58).

Pluming efficiency can be accomplished by stacking all the plumbing fixtures on one wet wall, which could be incorporated in the system in the manufacturing phase (fig: 59).

According to OVE, the most efficient foundation system is the slab foundation which can be utilized in this specific type of construction. This would be done by placing the first floor on the slab, leaving a space between the slab and first floor finish for the floor joist or trusses. This small space can be used to run mechanical and/or plumbing pipes through (fig. 60.)

The electrical design should be incorporated in the design phase in order to visually consider all required space it may need. This would also allow an opportunity to eliminate all unwanted outlets and switches.

Stairs should be placed parallel to the floor joist to eliminate the use of any additional structures which would carry the stair loads.

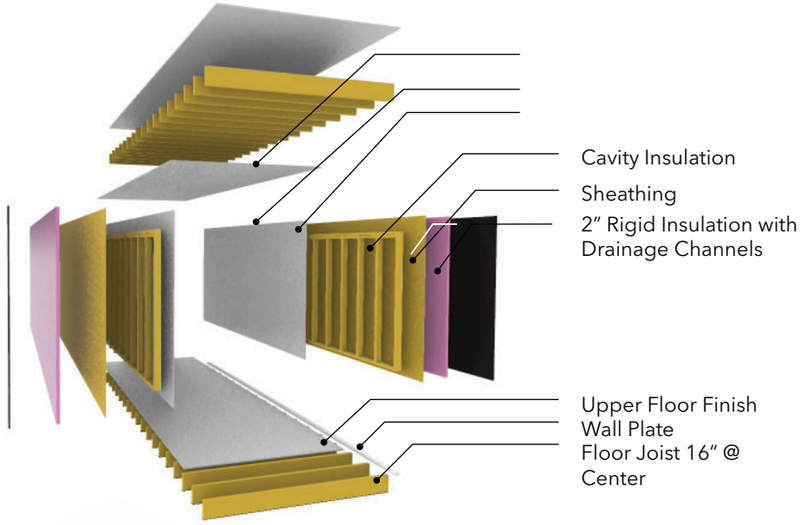


Fig (55): Modular System Details

Fig (56): Truck Size

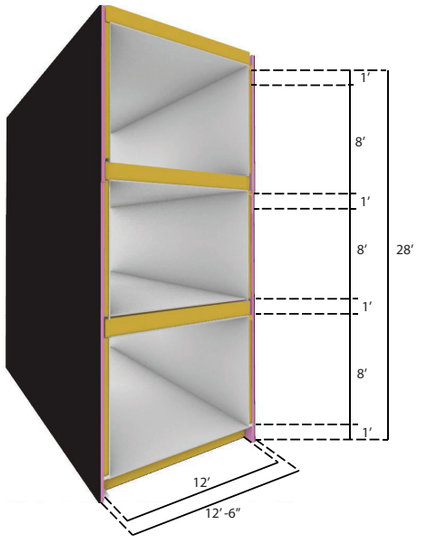


Fig (57): Typical 3 Level Dimensions

Advantages of Dryvit as exterior material:
- Ecology friendly and low maintenance required
- Can be repainted and no replacement is required
- Moderate cost
- Can be done in the factory
-Higher R value comparing to other materials (add 8-10 R value to normal installation)

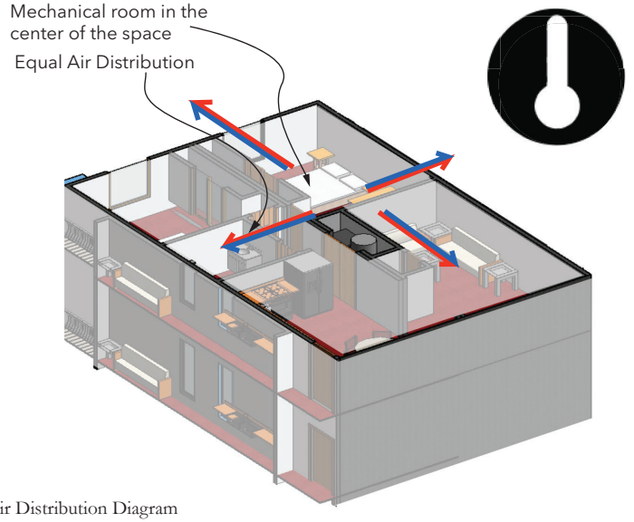


Fig (58): Air Distribution Diagram

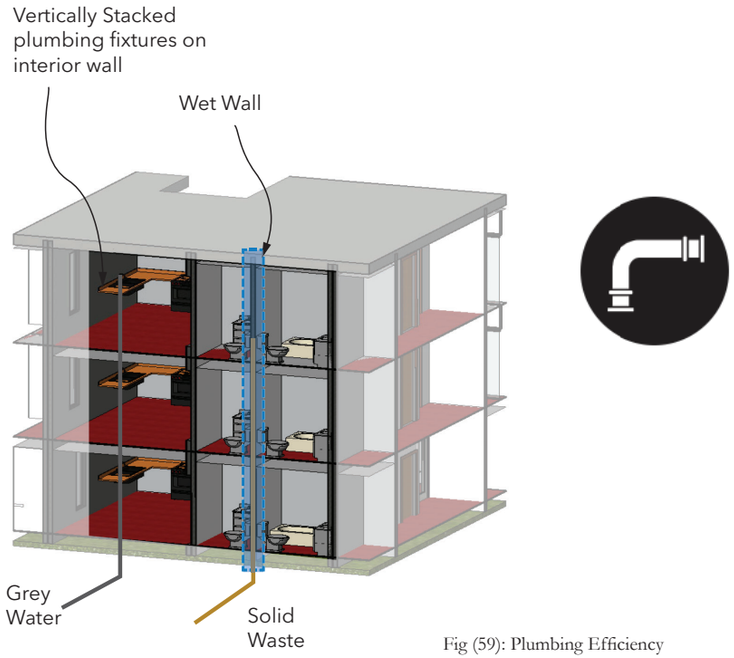


Fig (59): Plumbing Efficiency

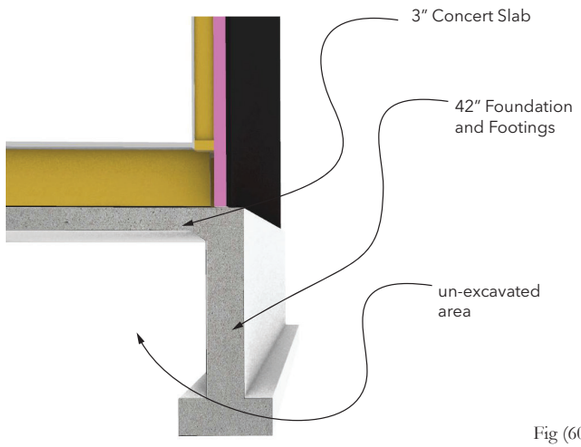


Fig (60): Foundation Efficiency

4.3 Complex Design

Moving forward the volumetric modular system, the initial design used this system in a symmetrical way by incorporating three units in three different sizes: 12'x12', 12'x24' and 12'x30'. This design combines these three boxes to accomplish the most appropriate layout within the plotted space in the floor plan.

As it is shown in figure: 61, the proposes complex design has 22 apartments, are connected by three corridors size 12' x 36' long. Each corridor serves three apartment, and the total height of the building is 28', lies on three floors. The design proposed 10 two bedroom apartments, 6 one bedroom apartments and 6 studio apartments.

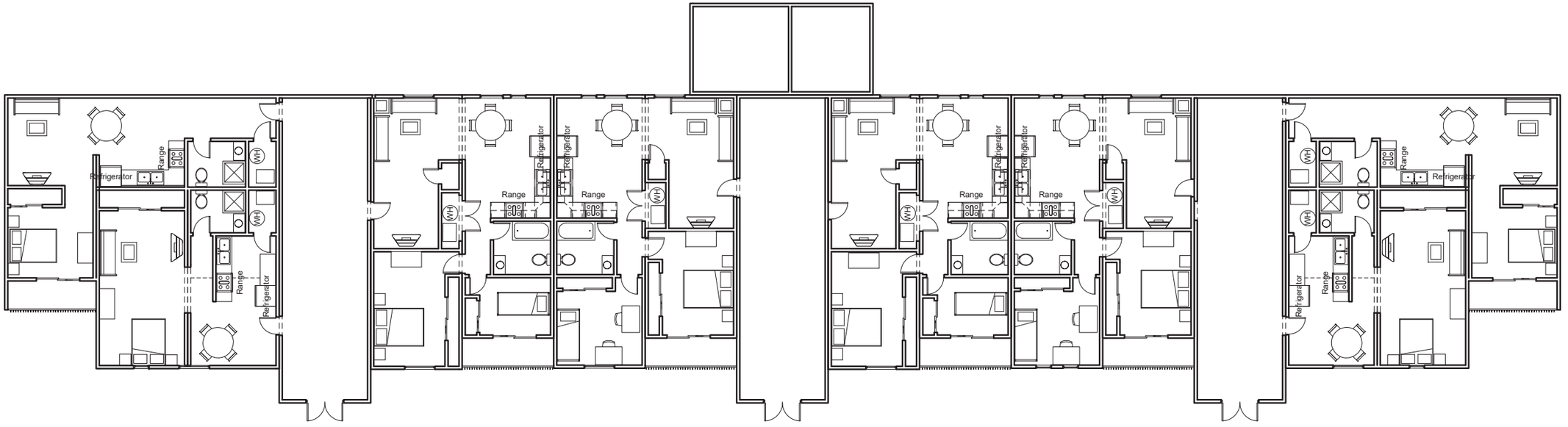
The middle top portion of the building has roof top terrace which creates interesting gathering spaces. The punctured in facades to emphasis the use of the modular system and the flat elevation facing north confronted by the backyard of the building.
The second proposed design in figure: 62 entirely build out of two modular box sizes: 12' x 24' and 12' x 36' units. Similar to the first proposed design, this building combines both box sizes to achieved the most adequate layout depends on how many bedrooms are required.
This particular design proposed a total of 36 apartments connected by three compact corridors per every four or five apartments. The flat roof was designed as an extensive rooftop terrace for residents to gather. This designs facade distracts from the idea of the use of modular units. The north facade has pockets which create interesting shaded seating areas.

This design proposed 9 three-bedroom apartments, 21 two-bedroom apartments and 6 studio apartments.

By comparing the two designs, it's easy to infer that the second design is more efficient in saving land and overall space. It also offers more quality seating areas in the backyard which are shaded. By toning down the look of modular patterns in the front facade, this could help positively effect people's opinions about the use of modular systems in affordable housing.

One other advantage found in the second design is the wider range of apartment sizes offered. This will allow for different family type and sizes to potential move in. For example, one individual has the option of occupying a studio while a family of four has the option between two to three-bedroom apartments.

Fig (61): First Proposed Plan and Axonometric rendering



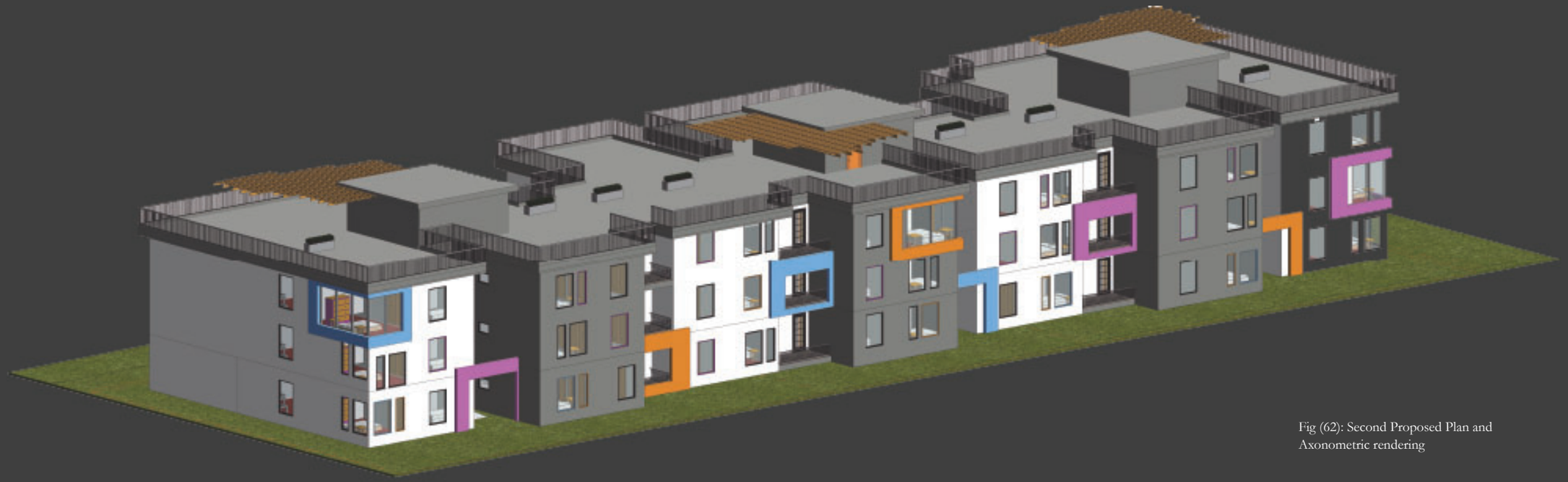
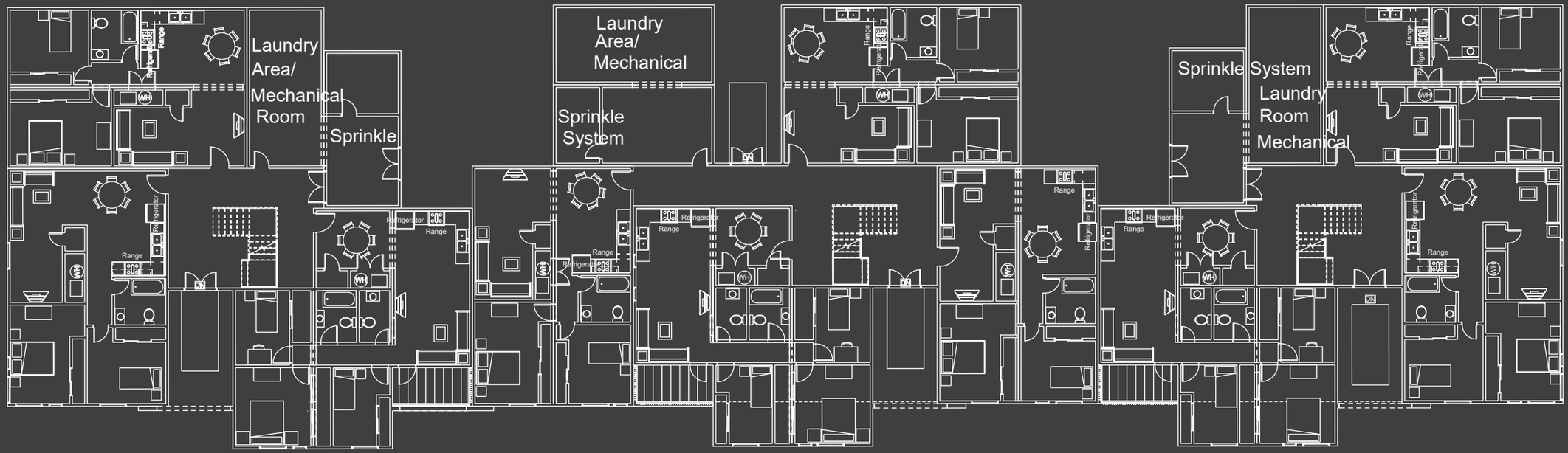


Fig (62): Second Proposed Plan and Axonometric rendering



The Building Design Analysis

According to the initial site design on page 82, the complex has three different building designs: (A), (B) and (C).

Building (A) has 6 two-bedroom apartments, 3 one-bedroom apartments, 3 three-bedroom apartments and 2 studio apartments. This building was designed to contain 5 modular boxes, size 12'x24', and 6 modular boxes, size 12'x36' per floor. This comes to a total of 198 boxes size 12'x'24' and 228 boxes size 12'x36' within the entire complex.

This design contains 21 1 bedroom/1 bath apartments at 720 SF, 26 studio apartments at 576 SF, 39 3 bedroom/2 baths at 1008 SF and 84 2 bedroom/1 bath at 864 SF. This brings the total to 170 mixed units within this complex.

The entire complex has 1 bedroom, 1 bathroom, area size 720 SF and total apartments is 21, studio apartment area size is 576 SF and total apartments is 26. Also, it has 3 bedroom, 2 bathrooms with area size 1008 SF and a total of 39 apartments, and 2 bedroom, 1 bathroom, area Size is 864 SF total units is 84 apartments. The total apartments in this complex is 170 mixed units.

The two bedroom apartments have two modular boxes size 12' x 36', the three bedroom apartments have two modular box size 12' x 24' plus one modular box size 12' x 36'. Also, the one bedroom apartments have one modular box size 12' x 36' and one modular box size 12' x 24', the studio apartments have two modular boxes size 12' x 24'.

The first floor in unit (A) has two 2 bedroom apartments, one 3 bedroom apartment, and one 1 bedroom apartment. The typical floor above the first floor, has two 2 bedroom apartments, one 3 bedroom apartment, one 1 bedroom apartment and one studio apartment.

This variety meant to fulfill all type of family needs. Although this complex design to accommodate low income families, according to the low income families issue study in the first chapter, it is expected to receive a handful of low income individuals that are looking for appropriate and affordable housing in Detroit, Michigan area.

The apartment building (A) has two entrances, typically one of them is faces a new proposed street, and other one faces a parking lot. The entrances will maintain smother circulation in and out the building. Buildings (B) & (C) also has two entrances, one on the main street and the other leads to the back of the building where there is a seating areas and backyards.

Each apartments in the complex has at least one balcony, all units are oriented in a way to minimize the number of windows that face the north, to reduce the heat loss from the windows when the wether is cold. Also, all apartment balcony primarily face east or west for better heating gain.

All apartments have the main door leads to the kitchen or dining table with consideration of

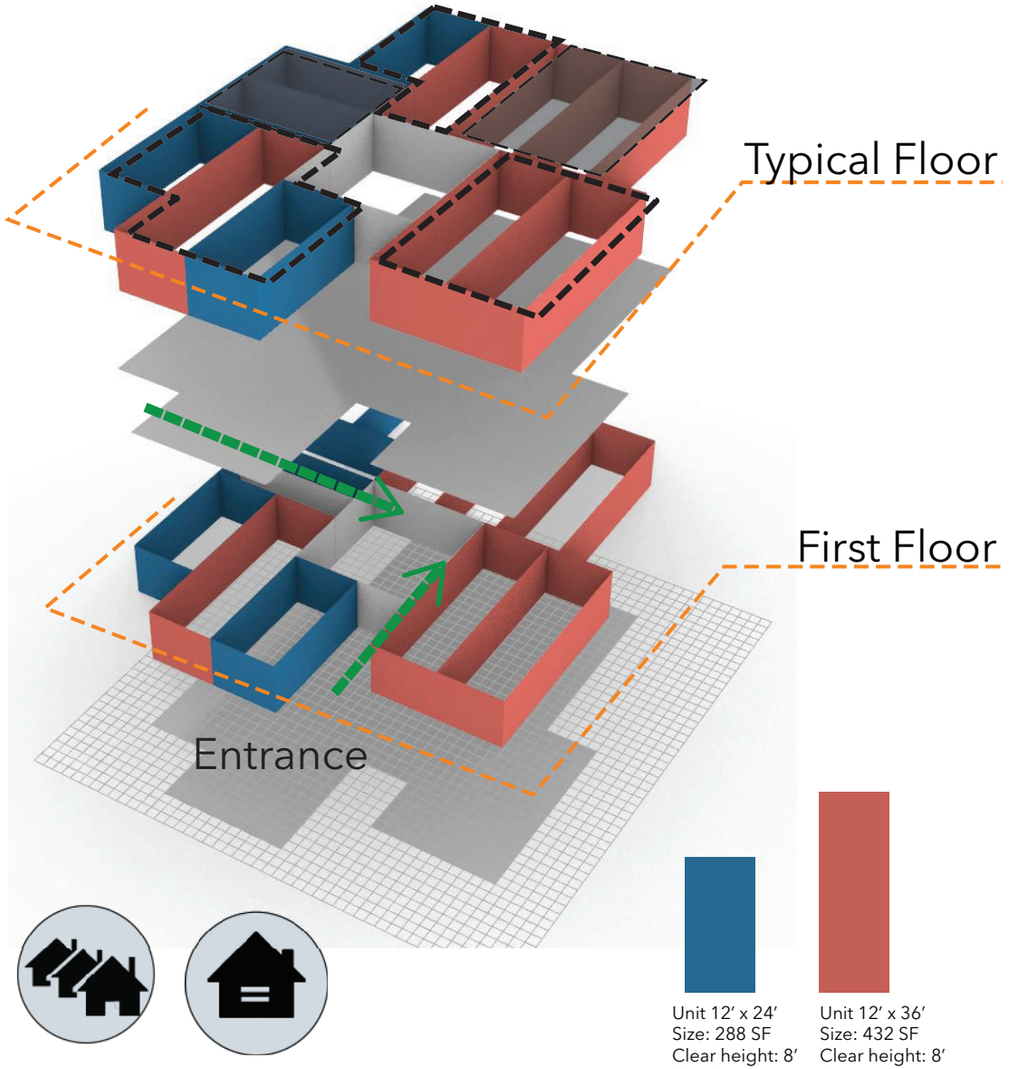


Fig (63): Building (A) analysis Diagram

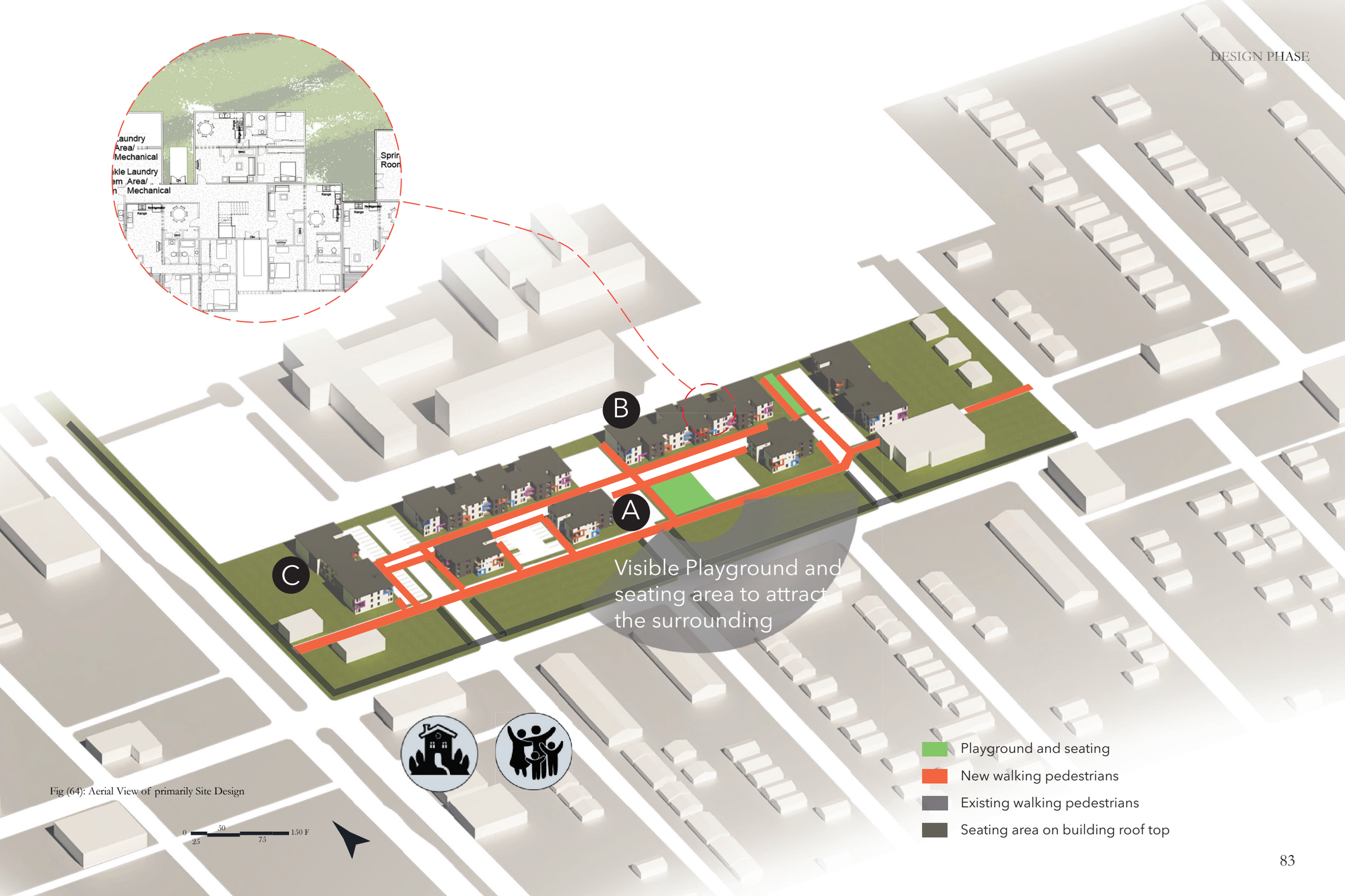
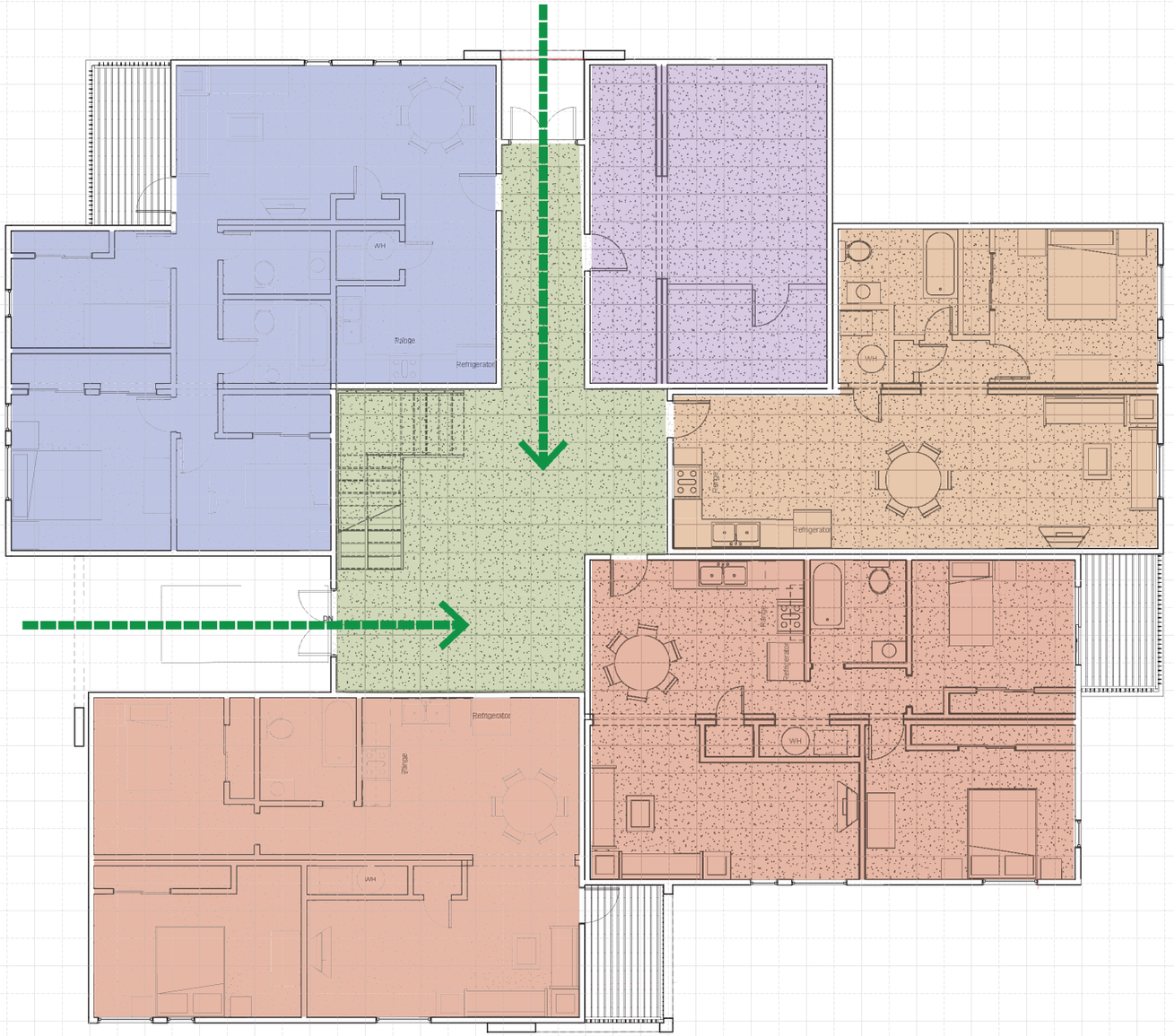


Fig (64): Aerial View of primarily Site Design



Total Units

170

3 Bedroom 2 Bath
Total Size: 1008 SF
Total units: 39

2 Bedroom 1 Bath
Total Size: 864 SF
Total units: 84

1 Bedroom 1 Bath
Total Size: 720 SF
Total units: 21

Studio Apartment
Total Size: 576 SF
Total units: 26

Fig (65): Building (A) Design Analysis

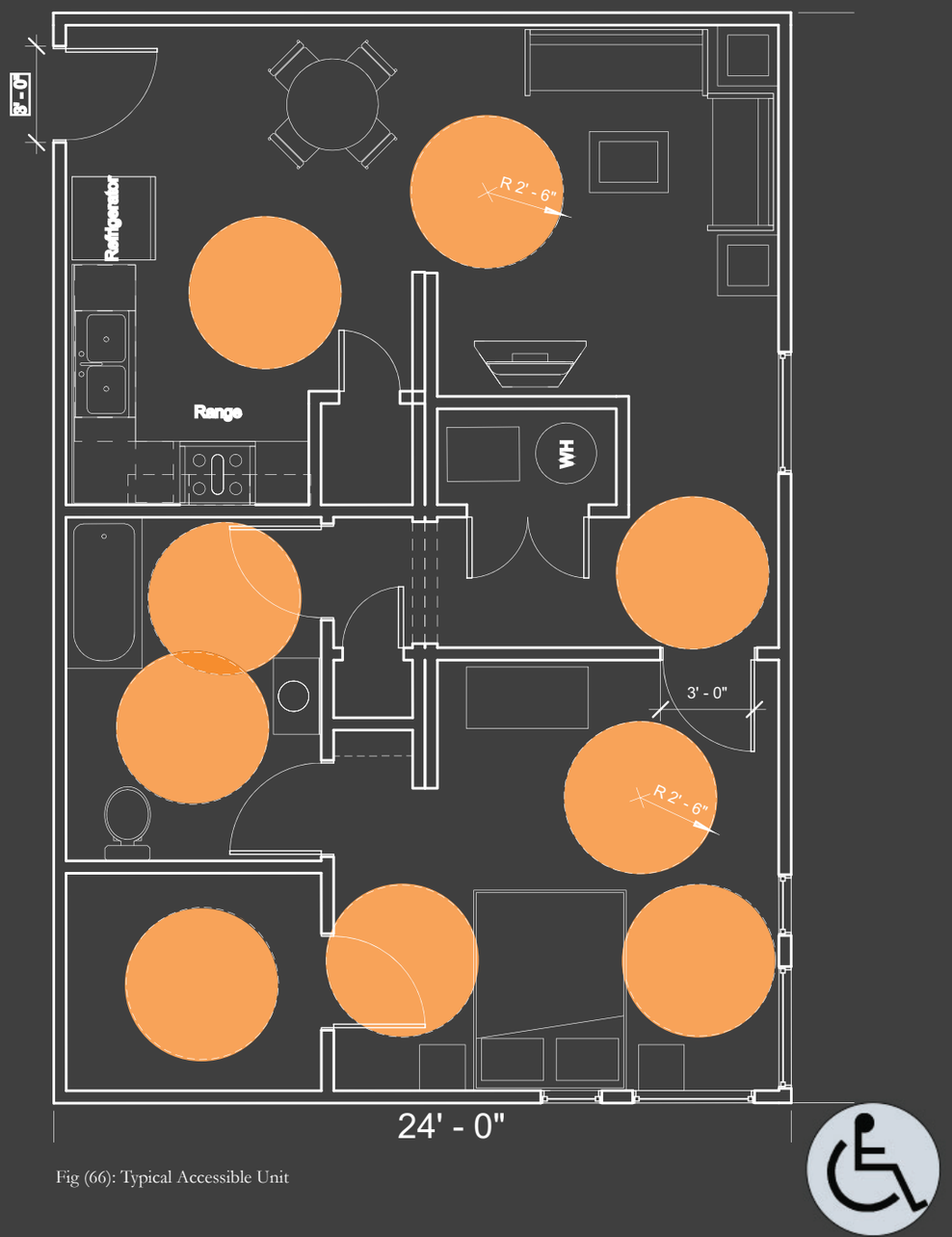


Fig (66): Typical Accessible Unit

Accessibility

Accessibility is important to consider during the design process. If the design and location fail to provide accessible homes, that would mean the entire concept is a bust.

Prior to designing accessible units using modular system, there are some rules need to be recognized: the ADA doesn't generally cover housing, Fair Housing and MI code require all ground floor units, and all units reachable by elevator, to meet certain standards - adaptable, but not fully accessible. MI code requires that 2% of units be fully accessible (not less than 1 if the site has at least 20 apartments). If there's federal funding, UFAS requires 5% of units be fully accessible.[21]

According to the regulations above, a total number of four full accessible units will be required
On a typical two bedroom apartment layout, placed the 60" diameter accessible circle, then modified the space and the doors to accommodate residents with disability. Due to the additional spaces that the accessible house requires, a two bedroom apartment turned into accessible one bedroom apartment.

The site design

In Detroit City the Department of Planing and Developing, there's a future plan to develope multiple locations in the city. The Department of Planing and Developing divides the city into three section: the east, the west and the central. The site is located on Livernois Ave. south the University of Detroit Mercy McNichols campus. The City has a plan to develop all the commercial stores along Livernois Ave. Also, the location is a cross street from the Fitzgerald area, which is a very stable neighborhood.

Another reason to choose the site, is being adjacent to a university which should give some advantages to the site: such as the feeling of safety and potential of commercial project growth.

The site has six vacant blocks of Purtian Ave., punctured with three dead-end streets. Across street the location has a three multifamily houses which make the this type of housing not strange in the location. Also, it is surrounded with a handful of bus stations which make public transportation reachable. There's an alley divides the site six blocks and a commercial corridor.

The first step was made in the site design was to create a new street connects the dead-end street for smother car traffic. Then emphasis the alley and connect it with Livernois avenue, the alley will be exclusively for biking and walking to ease the movement around the commercial corridor and within the new development.

In the middle south block, a play ground placed to invite other people from surrounding communities to come and engage with new development residents. The design proposes proper amount of parking lots to reduce the amount of using off street parking. The accessible parking spots connected by a ramp

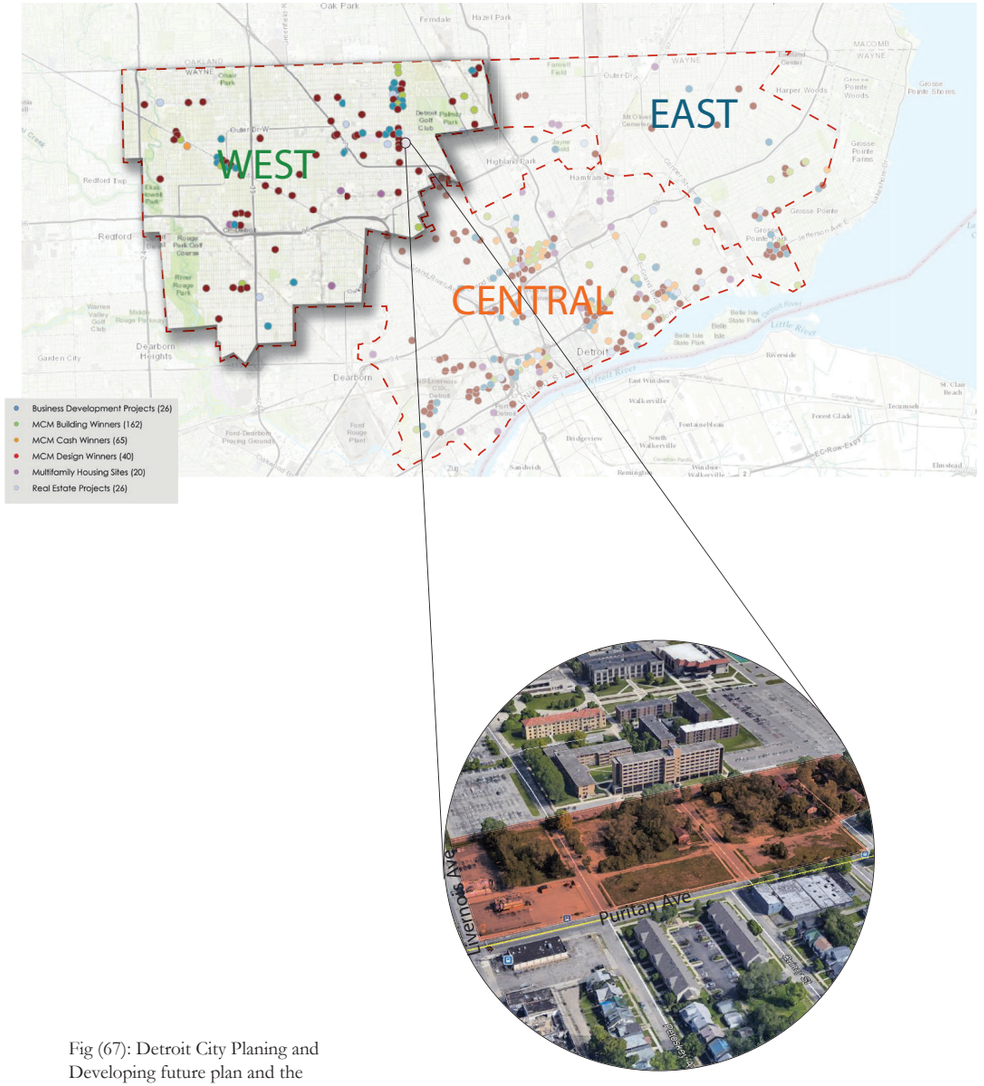
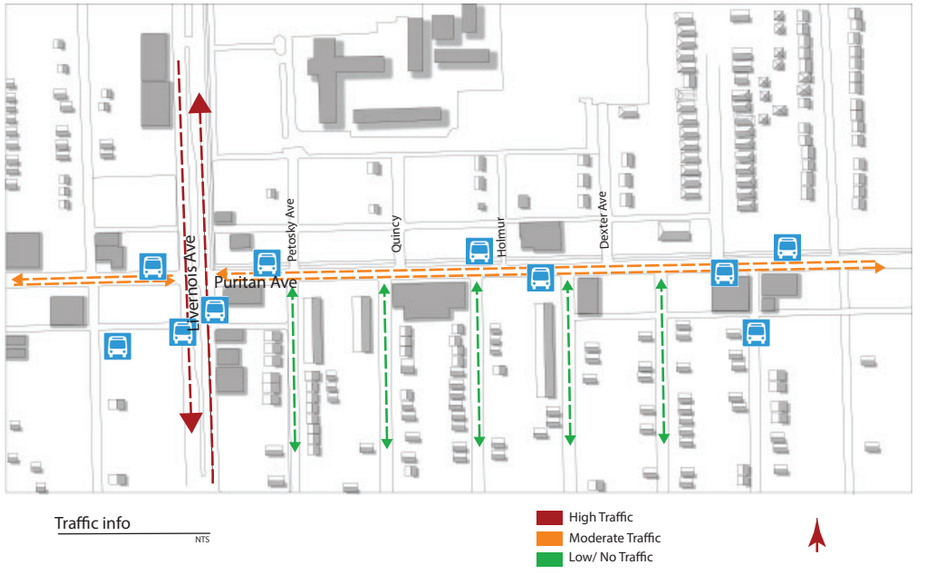


Fig (67): Detroit City Planing and Developing future plan and the site location south the University of Detroit Mercy.




Size:
12086
Size:
18115
Size:
16641
Size:
18074
Size:
16385
Size:
16669
Quincy St
Holmur St
Dexter Ave
Fairfield St
Stoepel St
Livernois Ave
toskey Ave
10 20 40 80 140'
N
100


University
of Detroit Mercy
Livernois Ave
Proposed Street
Play-
ground
Petpskey Ave
Proposed Walking Alley
Quincy Ave
Holmur St
Dexter Ave
Puritan Ave
0′ 20′ 60′ 120′ 200′


Petosky Ave.
0
10′
30′


Quincy Ave.
0
10′
30′


0
10′
30′
Holmur Street

Proposed New Street
East Corner

Proposed New Street
West Corner

Proposed New Pedastrian

Roof Top View

Design Quality Evaluation

In the cost evaluation in page 69, which proved the modular system affordability, the design quality represented in the design according to the goals' list in page 40 as follow: fair housing fulfilled by providing a variety of apartment sizes to accommodate all family types, with big focus on families with children. All residents have an equal access to all complex amenities, such as roof top terrace and common laundry rooms, also, using playground, seatings and all pedestrians.

The health and liveability promoted in the design by providing multiple pedestrians that connect all the streets in the new development with the main one on Livernois avenue, and proposing the biking alley that separates the commercial corridor and residential units. Also, the open view of the playground invites the other Community members to come and engage with the new development residents, to help low income families in the complex blend with their neighbors. Also, the providing different scales of outdoor areas such as the roof top terrace and backyards with are exclusive for the residents use, that in addition to seating benches that available for everyone to use.

The physical character presented in the system flexibility to accommodate the design, however since, the system i modular and has a specific dimensions, it must be considered in the design from the beginning, to incorporate the box dimensions in the space design. The good physical character of the whole development accomplished by completing all outdoor elements and how it complements the buildings' exteriors. Elements such as, trees benches and pedestrians.

The complex considers other human needs such as the accessibility, by providing accessible parking spots according to the code, and ramps that leads to a barrier free corridors and ability to provide accessible units. The design also considers a playground outdoor areas for children.

The design provides combated units that respect the use of the land, and optimum corridors that serve at least four units, which eliminates the unused spaces. Also, to ensure the best use of interior spaces, all the apartments furnished using building information modeling (BIM).

Conclusion

Everyone involved in the affordable housing world knows that this type of construction is actually expensive and not affordable in any sense of the word. Perhaps the use of the word "affordable" came from the subsidized programs from the government or non-profit organizations which help to lower the cost of rent. In recent years, the construction costs of affordable housing are more than the marker rate for the following reasons. Organizations that are funding affordable housing for social equity require the contractor to pay the on-site workers the union rate (even ones not in the union), they also often pick expensive designs to push away any negative perception of affordable housing from neighbors. Another factor is the mandatory sprinkling systems which are to be included in all affordable and public housing. Some inflexible local regulations like city zonings, require a specific type of multifamily housing such as town houses or minimizing the height of the buildings, which restricts the architect from proposing apartment buildings or other compact design solutions. Generally speaking, the governmental obstacles are big burdens and cause most developers to lean towards building private communities, which a low-income family cannot afford. This defeats the purpose of "affordable housing".

Most architects of affordable houses realize that they won't get affordable units for low income families without the government subsidizes, few architects working on alterative and creative solution to provide affordability through the design, and material selection, in some cases the final design of this type of affordable housing is architecturally better than regular market units.[22] The affordable housing design is more complected than regular private houses, as when the private owned houses' residents essentially concerns more about the quality of the interiors, and exterior quality is not fatal factor, the poor designed public and affordable houses face a rejection by their neighbors. Therefore, the design of the affordable housing projects must consider the aesthetic factor and how the development will fit within its surroundings.[23] All attempts to provide affordable units are mainly by some construction techniques using regular construction, such as material savings, standardize the construction to reduce the labor cost as possible. The prefab or stick built construction consider relatively affordable comparing to the regular on site construction, however, it is required special labor to connect the manufactured pieces on site.

The site design is also one of the difficulties that faces the affordable houses, the process of the site design and final approval takes too long and governmental obstacles usually slower the process which increase the cost of by paying city property taxes with no profits. Also, the critical factors to make the development blending with the surroundings cost great amount of money. Also, normally affordable

housing units count is fewer than commercial units on the same space.

Based on the analysis of the proposed design and system in this research, it is inferred that design using the volumetric modular system will significantly reduce the construction cost. The system incorporates all optimum value engineered ways to reduce construction cost, it also heavily depends on modularity and standard units which give the system cost reduction advantage over prefab construction. Another cost reduction factor is minimizing the on site labor.

The design using the modular system provides quality of living that satisfies the residents of the development and will appear architecturally pleasant to other communities. Also the system consider efficient by considering the use of energy, by providing construction material and techniques that reduce the energy consumption. Reducing the energy consumption, will help reduce the residents' monthly energy bills and which is a long term affordability.

Building the design based on the modular system provides a quality of living that has the ability to satisfy all future residents and surrounding communities by appearing architecturally pleasant. This system also considered as an efficient use of energy by providing construction materials and utilizing techniques that reduce energy consumption. Through these efforts, the residents' monthly energy bills will also be reduced and assist in creating long-term affordability.

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Endnotes

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