Form Flexibility Redesigning the Future of Housing

Author: Ar. Shivani Gaikwad
Assistant Professor
Department of Architecture
G. S Mandal's Marathwada Institute of Technology, Aurangabad, Maharashtra
Affiliated to Dr Babasaheb Ambedkar Technological University, Lonere, Raigad, Maharashtra.

***Abstract*:- The good interactive environment plays a key role in building new chords and nurture social interaction. The demands of modern world are constantly changing. The new needs, necessities and desires can be considered as the future goals. But these altering economies and changing family demographics have increased the complexity in meeting the spatial needs for existing housing. Shared use of space creates an opportunity for small events and spontaneous interaction. Thus, Real estate developers are designing mass housing with the features like shared rooftops spaces and other community spaces. Adaptability and flexibility play in all the experimental architectural projects. These visionary projects were created to bring together new technologies and possibilities in the buildings.**

But on the one hand, technical possibilities open up new horizons in architecture, while on the other, they give rise to new issues related to the disciplines of mathematics and geometry.

Flexibility in form has the ability to adapt over time, but formally and programmatically. Reversing alteration and unpredictable shift in the overall structure and function of the building is what flexible architecture deals with. It also guarantees diversity and complexity. The research investigates the implementation of flexible architecture. In the age of digital parametric non-standard architecture, mathematics and geometry represent the core of the architectural design process.

The main factor is user – oriented design. Parametric approach, which gives an idea to use parametric modelling and generative algorithm, can be used for modelling form. Adaptable practices should be made essential to meet the needs of changing communities, lifestyles and aesthetics.

The hypothesis has an aim to maximize the holistic lifestyle of a building and allow user adaptability over time. The main objective is to allow reconfiguration of building systems with growth and simple component exchange.

Key Words: Generative Algorithm, Form Flexibility, Reconfiguration, User oriented design.

INTRODUCTION

Our life in many aspects have changed after the invention of the computers, ever so often enhancing it. Even though we have all the knowledge at our fingertips somewhere, the real potential of these devices is yet to be explored.

Like all the other fields, architecture is a field which is benefited due to this computational revolution. We can call the era of Computer Aided Designs (CAD) as "Architecture 2.0". Productivity, quality of design and generating database for manufacturing can be considered as some of the benefited areas.

With the development of modelling software, we can say that we are moving towards the new phase in architecture which can be called as "Architecture 3.0".

For architecture 3.0 to come alive. It is necessary to evaluate energy modelling and sustainability aspect. If the present modelling software evaluates ten buildings at a time, architecture 3,0 should be capable of evolving thousands of buildings at a time.

Parametricism can be considered as the first step of the Architecture 3.0. This is the powerful tool that the architects have.

Parametricism can be confusing at times and cannot be capable to solve a contemporary problem, but it has a capability of creating a new architectonic style.

Further Evolution of Parametricism can be considered as Architecture 3.0. To have more efficiency in the designing it uses the computational tools.

Altering the edges concept moves even further. It creates an organism that responds to certain given inputs and creates itself. The role of the architect here changes from designing a building seeing given conditions to record those conditions in an algorithm and the system will generate it automatically.

With this process the aim of the project is to mimic the logical behaviour of the Tetris. In fact, one may not be able to recognize it in the final form, even though it could be possible to mimic natural form optimizations by introducing different parameters.

The project does not solve or attempt to solve any construction technological problem. But the project indeed introduces a revolutionary methodology to create the architecture of the future. Which will be economic, ecologic, sustainable, and will fulfil our needs even in highly complex dense urban environments.

1.1 THE PROBLEM

Today 50% of the human population lives in cities, and that portion is only increasing. Urbanization is an irreversible phenomenon. But are the cities prepared for this influx? Do they have the infrastructure to provide to housing, sanitation, education and healthcare services for all relocated population? As development increases urbanization is expected to rise as well in the future.

Cities if managed properly and make maximum use of its advantages has capability to lessen poverty rate and enhance liveability standards for the users.

But there is a desperate need for new urban models to tackle social, economic and environmental pressures in a sustainable way.

However, diversity in the cities means that a challenge in one city can mean something else for the other city.

[1] [Fig 1:] Traffic Congestion

There is no single set of solutions to suit every city and all its residents with their subjective views in quality of life. Local conditions should be taken into consideration to while proposing a solution. As an architect, we need to focus on the housing problem. Too often architecture has forgotten housing in favour of hyper expensive iconic buildings.

1.2 CURRENTLY PROPOSED SOLUTIONS

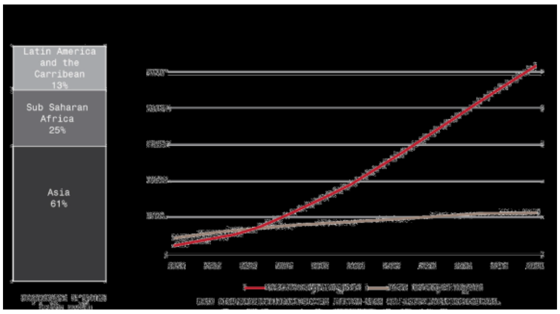
ization

[2] [Fig 3:] To meet the immediate demands

Government has continued to prioritize home ownership, they are providing tax incentives to developers, they are reducing the home loan rates for buyers. And while this is all step in a right direction, the supply is nowhere at the scale we need. There is a serious breakdown, where in on one hand we talk about the demand of houses and on the other hand the government states that there are about 6,50,000 houses left vacant. So somewhere, the demand is there but may be wrong products are being pushed to the market. One of the solutions could be that the project should be best suited to the current invertors of the real estate.

1.3 NEED OF THE PROJECT

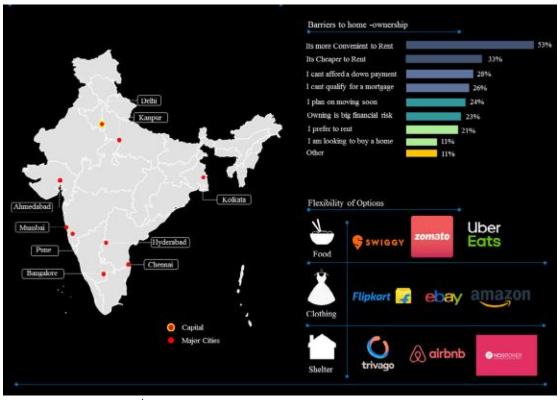
If the investors of the real estate are considered. The people born from 1981 to 1996 are called as Millennials, and by 2010 to 2011 the millennials became the investors of the real estate. If real estate and Millennials financial habits are considered, research says that majority of the Millennials prefer renting a house rather than owing a house.



[3] [Fig 4]: Projected rate of urban population growth in different regions of the world.

It is Convenient to rent rather than own, it is cheaper to rent, they can't afford the down payment, can't qualify for mortgage, plan on moving soon, owing is the financial risk; are some of the reasons for barriers of home ownership by the millennials.

The second reason is there is flexibility of options: The basic needs of food, clothing and shelter are replaced by Swiggy, ubereats, Zomato, flipkart, ebay, amazon, trivago, Airbnb and nobroker. Which gives millennials a lot of options.



[4] [Fig 5]: Flexibility of Options

2 UNDERSTANDING THE USER GROUP

Major change in Architecture was seen during post Industrial Revolution after the materials like steel, iron and glass were discovered. This led to large span structures and vertical architecture unlike before.

Due to technology and its advancement in Industrial work today we see loads of skyscrapers. Digitalization and technology being at its peak will have its impact on architectural industry.

The Indian Millennials feel that owing a house and paying monthly EMI's is a very impractical approach, and hence they believe in renting. Due to which this generation is also known as "Generation rent". It is an era where everything can be

rented, from houses to furniture. Which eventually benefit the users to invest their money in profitable areas.
Currently, five generations make up our society. Depending on the specific workplace, the workflow includes four to five generations.
GenZ : Born 2000 and later.
Millennials: Born 1980-1999
Generation X: Born 1965-1979
Baby boomers: Born 1946 and before.
Every generation has its own needs and demands for housing. The current focus is on the Millennials who are the largest population in the world and the iGen who are nothing but the followers of the Millennials.

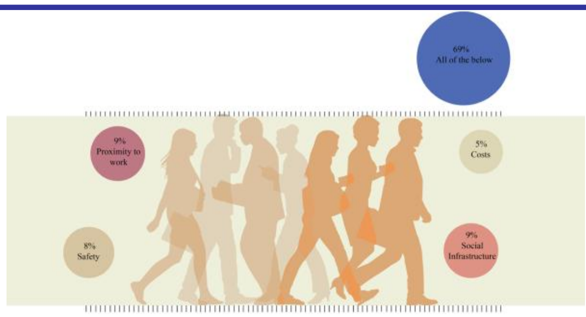
2.1 WHO ARE THE MILLENNIALS

The Millennials are the one which covers the maximum population of our country. They are the one who are into the earning and spending years which makes them the prime workers of our economy.
Millennials are the one who have witnessed the revolution in the field of technology along with destruction through economy and globalization.
Their behavioural patterns are different than that of GenX. They have been slower to marry and move out of their own and have shown different attitudes to ownership that have helped spawn what is being called a “sharing economy”.
As stated earlier, this is generation which has witnessed the revolution in technological field, which makes them digital locals. Their curiosity is what leads them to develop their shopping habits.
They have easy access to discount vouchers, product and user reviews along with comparison analysis.

Finally, they have dedicated to wellness, evoking time and money to exercising and eating right. Their active lifestyle influences trends in everything from food, drink to fashion. These developments are the one which will affect the economy.

2.2 FACTORS CONSIDERED BY MILLENNIALS WHILE CHOOSING A HOUSE

Millennials update their social media and share their busy life on a daily basis, but in their busy city are they satisfied to share time, passion and life?
Do the Millennials share too much? and are losing their boundaries? But when it comes to housing. What are the factors that are considered by the millennials while choosing a house? According to a research paper, there are certain factors considered by the millennials while choosing a house. Like; 5% considers costs, 9% social infrastructure, 8% safety and 9% Proximity to work while there are 69% of the millennials who prefer all of these.



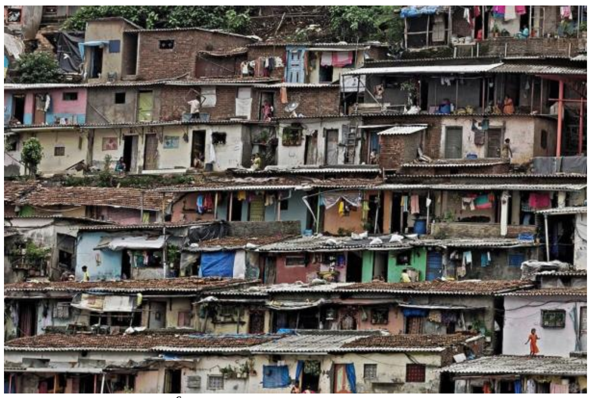
[5] [Fig 6] Factors while choosing a house

There are many types of Millennials, but the types of millennials that will be catered in the project are: Individuals, Digital Nomads, Students, freelancers, Single mothers and professionals.
A survey was done, by asking some questions to the millennials so as to analyse the need of the new investors with respect to housing.
The questions asked were:
Would you like to prefer a co-living space?
Would you prefer housing near your workplace?
What size unit would you prefer?
What will be the duration of stay?
What would you prefer to rent?
In a millennial housing what are your needs and preferences for food preferences?
The Survey report says that: About 50% of the Millennials would like a co-living space.
About 95% of the people want their house near their workplace. 60% prefer a Two-bedroom house for themselves. 44% of the Millennials will have a duration of stay of 1 to 4 years. 50% prefer renting an Apartment. and 75% of the Millennials would like to have their own kitchen so that they can cook their own food.

2.3 RESEARCH QUESTION

How can Reconfiguration lead to space variation so as to enhance the housing Typology?
Can Reconfiguration of houses fulfil the new demand of the millennial economy?

3. RECONFIGURATION – INDIAN SCENARIO


[6] [Fig 7]: Slums of Dharavi

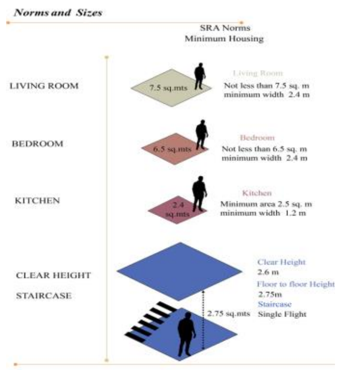
A self-organised urban system can be defined as the global pattern arising out of interactions between individual components, at various levels following certain simple rules of interaction.

Since the reaction of each individual component is slightly different, the resultant "whole" is always more than the sum of its constituent parts. While actual cities are heavily shaped by top-down forces, such as zoning laws and planning commissions, bottom-up forces play a critical role in city formation such as unplanned clusters.

The clustering of neighbourhoods based on similar trades, religion or for sharing resources is a result of an interaction amongst individual components which shapes the global order of a city.

Around 97% of the structures in Dharavi are self-built, consisting of temporary and semi-permanent huts which house residential, work and retail spaces.

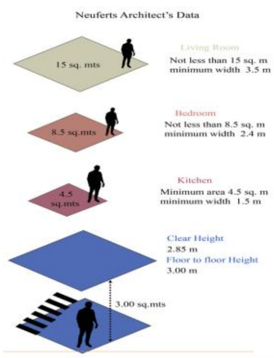
The remaining structures are either public or institutional buildings, such as schools, religious buildings, community halls, and public toilets, or apartment blocks intended for the relocation of slum-dwellers. There are three residential typologies in the Dharavi, the apartment block, the chawl and the self-built hut. The most recent one to be introduced is the apartment block. The Dharavi Community is very close-knit, structured mostly around family ties and work types. The smallest community unit are small families, comprising one to two generations, and generally not exceeding 8 people living under the same roof.



[7] [Fig 8] Norms and Sizes

3.1 NEUFERTS ARCHITECTS DATA

The book provides information about the requirements needed during the initial phase of designing. It deals with ergonomics, anthropometry and other building and interior layouts.



[Fig 9] Neuferts Data

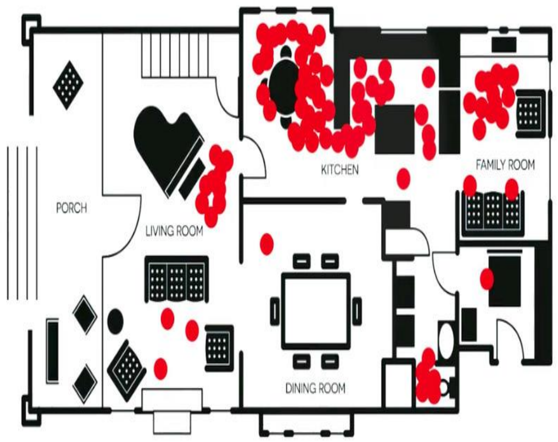
3.2 SCAN SAMPLING OBSERVATIONS

[8] Source: Life-At-Home-in-the-Twenty-First-Century-1-1024x543

Each red dot on the plan represents the location of a parent or child in the family11 household as observed every 10 minutes over the course of two weekday afternoon and evenings. Here, we overlay the aggregate set of our person-cantered observations-thereby collapsing a span of eight hours- into a single map (map depicts the downstairs of this two - storey house).

The patterns that emerge are striking fully two thirds (68 percent) of the family's use of space on weekdays is concentrated in two rooms, with the kitchen (48 percent) emerging as the single most intensively used space. Activities in the family room (20 percent) typically involve the TV or the computer. Upstairs bedrooms account for (18 percent) of observations, and the remaining home spaces are used even less (range 1-6 percent). Very intensive use of kitchen spaces is not just confined to India. Time dairy data collected from 500 families in eight American cities reveal that working families throughout the US are spending more time in kitchens than other places at home.

This recent study by the University of Chicago Centre lends strong support to our findings. Parents and children in family of 11 spend time in the kitchen in collectively different ways. Eating, of course, is one of the more popular activities for everyone. All of the meals transpire at the kitchen table rather than at the much larger and nearby dining room table. The parents spend much of their time in the kitchen preparing meals and washing dishes, whereas the children spend as much time on the kitchen table doing homework as they eat. These data make apparent that the family's kitchen as is true for nearly all families in the study- is an important place for communication and interactions now a days.

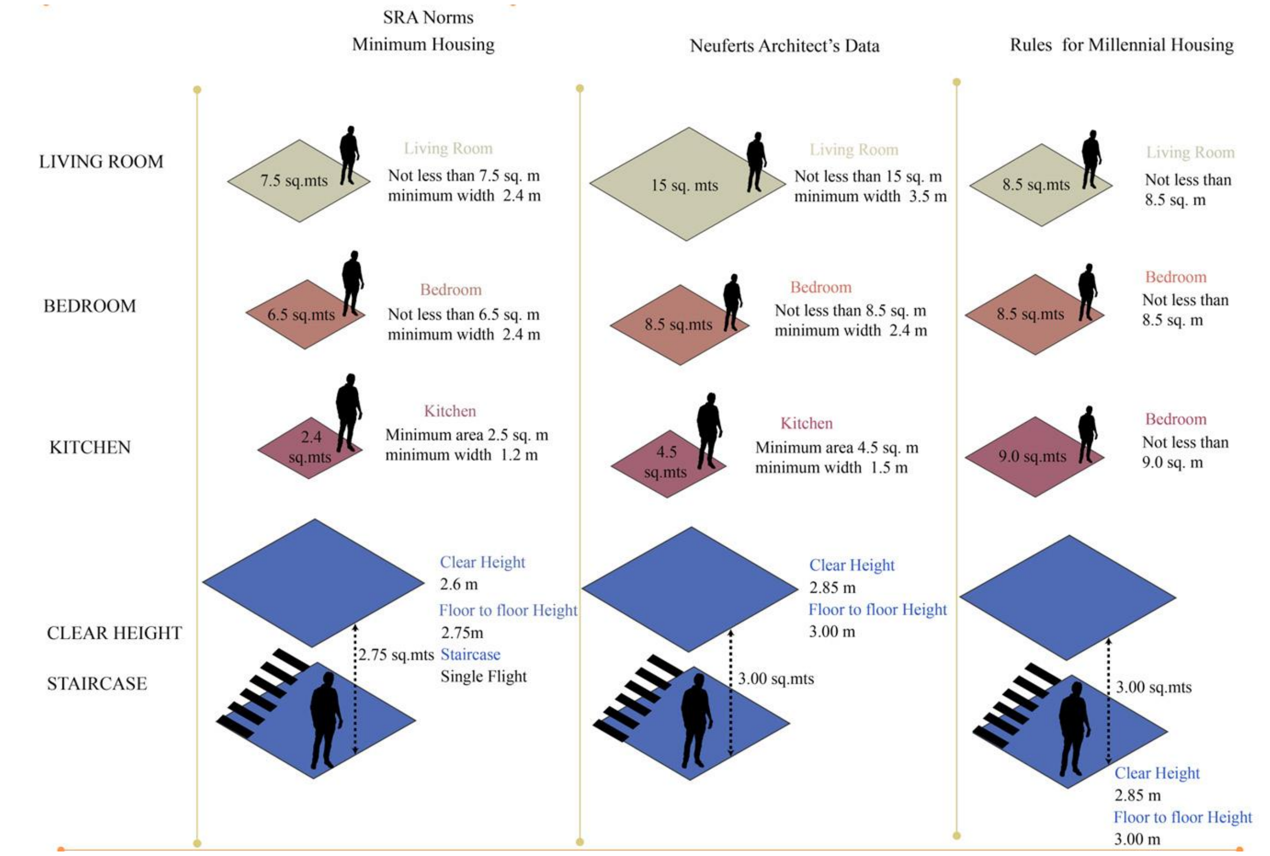


[Fig 10] Scan Sampling Results.

3.3 RULES FOR MILLENNIAL HOUSING

The scan sampling results makes it very much evident that kitchen and the family room which consist of the TV unit and the WiFi Router are the most used spaces by the family as well as single occupants.

If the SRA norms are considered the size of the kitchen is the smallest as compared to the other spaces. The Neuferts data also suggest that the size of the kitchen is the smallest among the other spaces. Thus, the research is criticizing the norms and new norms for millennial housing were proposed which are followed in the project. The new norms have doubled the size of the kitchen as compared to the sizes mentioned in the other two norms and standards.



[9] [Fig 11] Norms for Millennial Housing

4. DEVELOPMENT OF PRIMITIVES.

The research identifies five distinct primitives: Triangular, cubic, Pentagonal, Hexagonal, and Octagonal Prism. All the prisms have a height of 3 meters and the footprint of 9 sq. meters. 9 sq. meters is the smallest sleeping unit. Each prism was the tested for the number of connections possible so as to generate the combinational patterns.

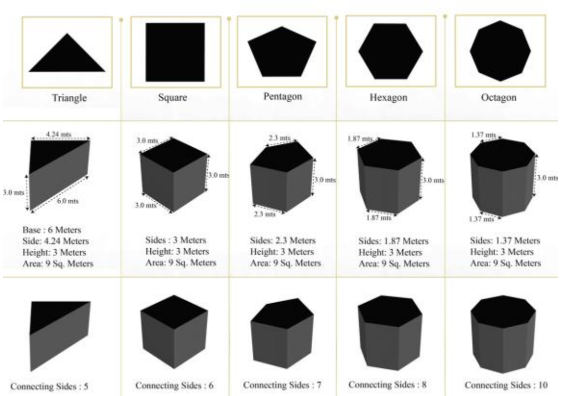


Fig 12: Development of Primitives

4.1 PROGRAM ANALYSIS

Each Prism s tested on its ability to hold a variety of functions. The prism then encloses the basic unit.

Each shape has been colour coded. The primitives placed outside the prism are the ones which are unable to get fitted in the area of 9 sq. mts. and are considered as errors.

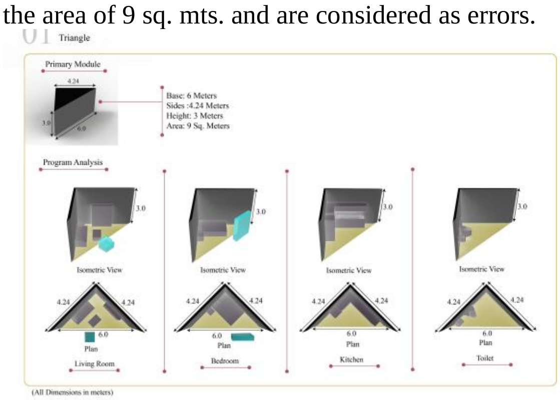


Fig 13: Program Analysis for all the selected primitives

4.2 COMBINATIONAL ANALYSIS

The primitives tried in all the prisms were then tested in a combination so as to check the connections as well as the number of combinational patterns formed.

It was observed that Triangles can grow and form a combination of up to 1BHK, 2BHK structure is not possible in a triangular prism as well as the prism has a number of errors in terms of accommodation of primitives.

Similarly, octagon cannot form a combination of 2BHK.

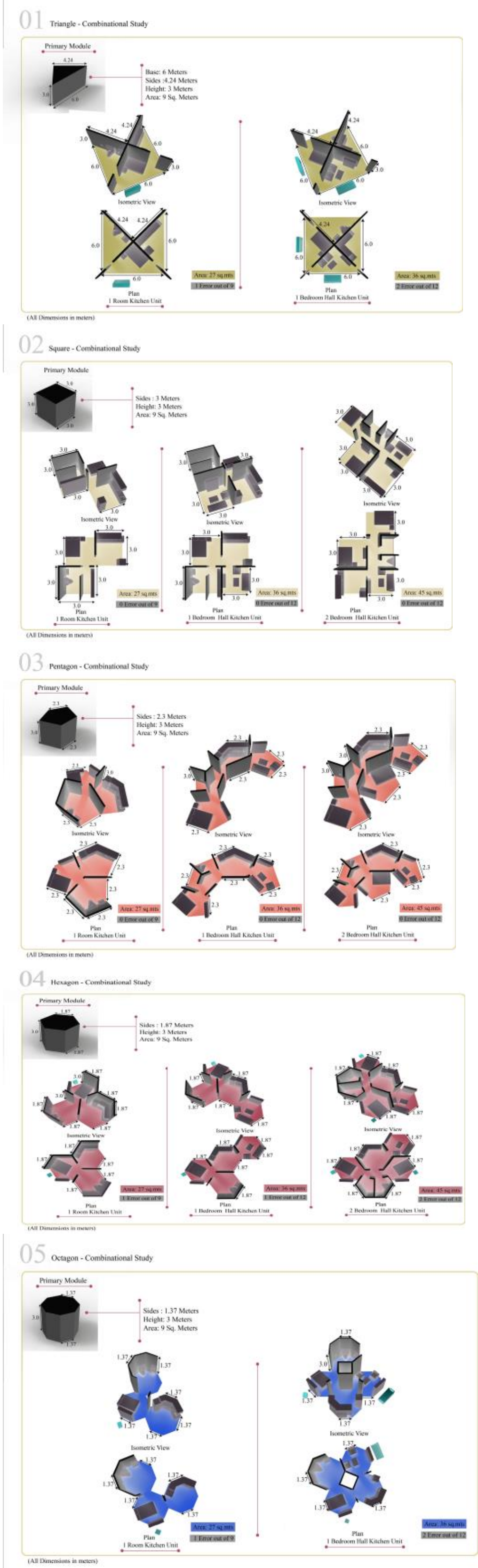


Fig 14: Combinational Analysis for all the primitives.

4.3 COMBINING THE GEOMETRIES- CONNECTIONS

The two prisms which does not have any errors in terms of accommodation of primitives are Square and Pentagon. These two prisms were then tested for the connections, and it was observed that easy and any type of connection is possible in terms of square. While when pentagon is tried for the testing of connections it was observed that due to the 108-degree angle, voids are formed between the units. One option was to treat these voids as cores, but then these spaces were very obvious, and no variation could be made in terms of the position of the cores, while in square the decision making of the positioning of the cores was possible. Hence Square was the prism which was selected for the further analysis.

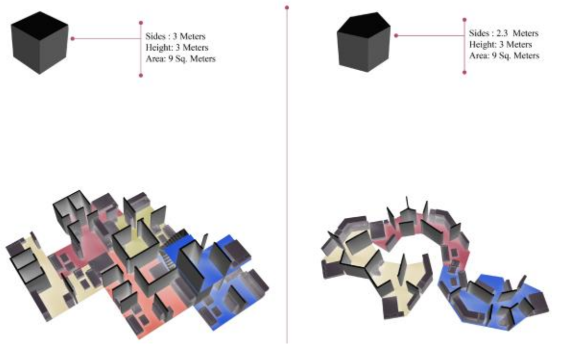


Fig 15: Combining the Geometries to check Connections.

4.4 SELECTING APPROPRIATE GEOMETRIES

As square was the prism that was selected for further analyses, Voxels were formed and then by varying the number of voxels different kind of combinations with different number of voxels was tested. so as to generate the catalogue of the spaces. which was then converted into plan, the voxels which could not be converted into plan were then rejected and only seventeen best voxels were designed for the catalogue.

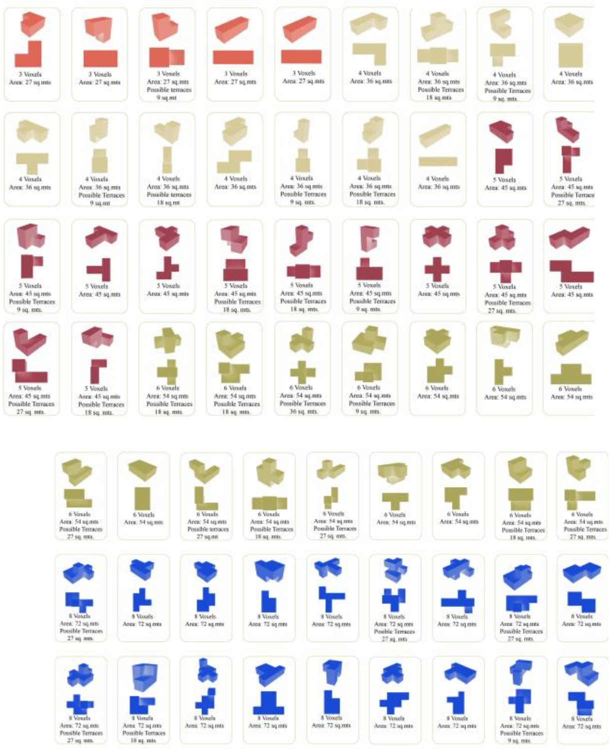


Fig 15: Selecting Appropriate Geometries using WASP

Selected 17 appropriate voxels were then converted into plan, as well as possible terrace areas were also identified.

Fig 16: The 17 selected appropriate voxels were converted into plans.

5.DEVELOPMENT OF SYSTEM

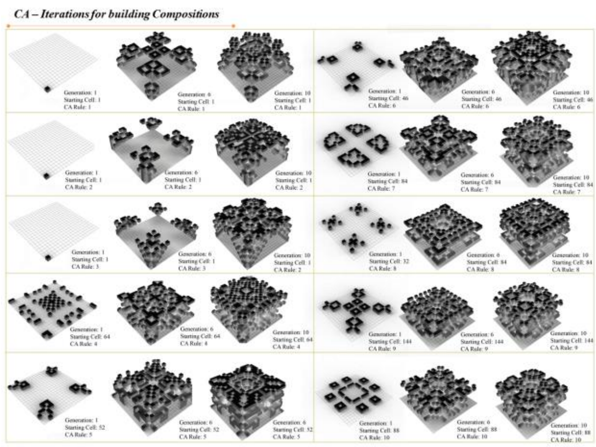


Fig 17: CA was used as the generative algorithm to develop a system with the help of voxels.

5.1 RULES FOR SELECTION OF ITERATION

Each Automata rule has some pros and some cons. One of the most influent factors for the choice is the density in the aggregation even though the structural coherence of the organism has to be considered. Structural coherence means that there should not exist any "unsupported cell". A first evaluation regarding the structural coherence has to be made virtually. Observing the aggregations, was decided to select or delete certain rules in the case those rules produced totally impossible aggregations in the reality. This was the first direct selection. The next step was to evaluate through the algorithm how many unsupported cells were generated and compare it to the total number of cells. Thus, the problem to solve was to avoid unsupported cells. Therefore, all the unsupported cells were deleted. This didn't create a noticeable reduction in density since generation number 10 doesn't generate too many unsupported cells. To detect the problematic cells the algorithm was set up to recognize the central point in each face, then was evaluated how many of these points have the same position in space. It is clear that low neighbour cells will have two coincident faces, therefore defining the centroid of this faces there will be two coincident points. Since unsupported cell does not have any incident face with the near cells.

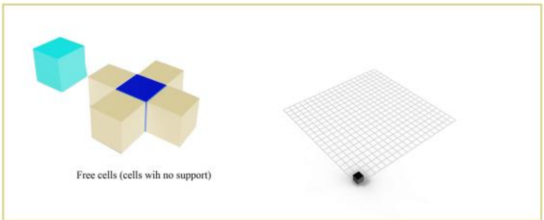


Fig 18: With the help of cellular automata, certain rules were set to select an iteration.

5.2 ANALYSIS OF CORE AREAS

What distinguish this new approach to architecture is the absence of a superstructure. This is the major problem for the building. Usually, buildings are design starting from the vertical communication. Vertical connections through floors are probably the most important aspect of the project. Usually, the vertical communication is designed first and then the rest of the building is designed around it. In this project this process is not possible since the aggregations are self-organized, and they don't assume any kind of vertical connections. It is obvious that it is impossible to make a vertical communication from cell to cell, therefore a different solution was adopted. The idea is to serve the maximum number of cells with the minimum number of cores.

There are two types of cores the one which is directly attached to the cells and the second which is attached through passages. Parameters were then extracted through the case studies so as to have the minimum and maximum areas. The minimum sizes of directly connected core area is 49 sq. mts. And the one connected through the passage is 103 sq. mts.

The maximum area of directly connected core area is 64 sq. mts and the one connected through the passage is 114 sq. mts.

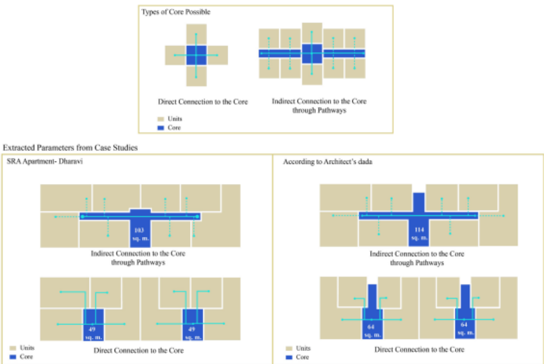


Fig 19: Analysis service core areas for the system.

5.3 FORMATION OF CORE AREAS

The core in the project measures about 6m x 9m having an area of 54 sq. mts. The core consists of a staircase, and two lifts. The connecting passage to the core can vary from minimum 1 voxel to maximum 8voxels i: e up to 24 meters. The passage need not be a straight passage it can vary in its shape, but the only condition is 8 voxels. And then the core area was placed and checked on the finalised CA iteration.

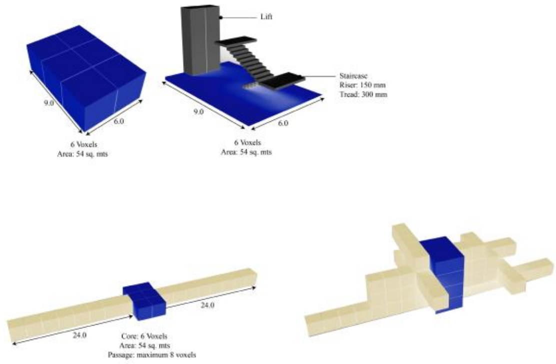
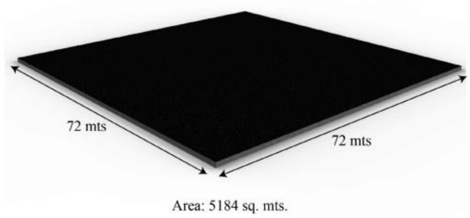
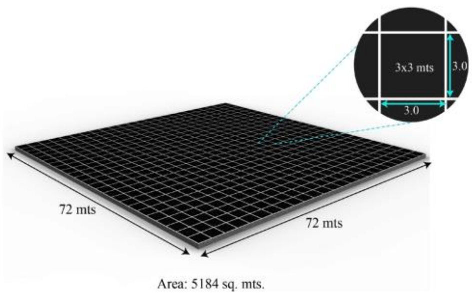


Fig 20: Core area Formation

5.4 GENERATION OF SYSTEM

The generated algorithm was then tested on the assumed boundary conditions. A 72 x 72 meters square was considered, as the boundary condition having an area of 5184 sq. meters. A 3m x 3m grid was then overlapped over the boundary condition. CA iterations were then used to generate green spaces on the ground. the rule is to have 20% green spaces on the ground. Which means 110 blocks of green spaces. Generation 21 gives the desired green area of 993 sq. mts. The selected CA Generation was then overlapped over the grid. And the first core unit is places. The placement of the core area is such that it is 6mts away from the boundary. This is because that is the maximum width of the modules. Similarly, all the other cores were placed in such a way that 8 voxels can be accommodated between two adjoining cores. and then, at the end the generated modules were then designed along the core area, eventually leading to a properly designed, well ventilated system.





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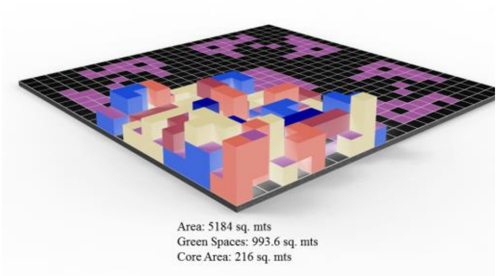

5.5 CELLS CONNECTIONS

After generating complexity, it was necessary to develop a strategy in order to connect the cells to the cores and moreover it was necessary to create a connection between cells to make different apartment solutions. The first thing to do was to organize the connections between the cells. The idea was to have four different apartments in sizes. The minimum area of the housing unit is 27 sq. mts and the maximum area is 72 sq. mts. Even though the apartment sizes varied, the shape of the modules also varied. This way the modules will be as various as possible and will accommodate different sized families with different range of prices. The logic for the association was to join a cell with at least one open face for proper light and ventilation. Once there will be no more neighbour cells the algorithm will connect the neighbouring cells with two open faces. This process will be repeated until all the cells will be connected and all the apartments will be created. The last problem to solve was to create a connection from the apartments to the cores. The algorithm was set up to search from the core. If the algorithm finds a cell centre, then the cell directly connects to the core, and the cell will be aligned to have the entrance towards the core. This process can go on only within a radius of 24 meters.

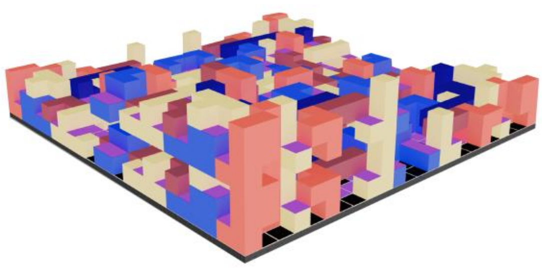

Fig 21: General formation using all the selected voxels.

6. DEMONSTRATION ON SITE

Tetra city needs to develop under difficult and various conditions. Therefore, the site for this project had to contain the most various urban fabrics. Magarpatta area in Pune is one of the best suited western city centres for this project. It has a grid plan development, but when we start to look at it in 3 dimensions it starts to appear more planned. Many typologies of buildings could be observed, there are malls, mid height office towers, low residential buildings, tens of empty or parking lots and different green areas. There is water body near the site. The main road is adjoining the site. The conditions are as various as possible. This way Tetra city can deal with different difficult conditions and evolve reacting to the surrounding environment. The project site has been chosen because it is adjoining the commercial area, can be in the close proximity to the neighbouring commercial and residential areas. The site is surrounded by high rise as well as low rise buildings and empty lots. This is a pilot project which aims to show the real potential of Tetra city. In future, all the vacant plots could be invaded by Tetra city and can grow theoretically infinitely. Of course, it will have to respect all the existing buildings and roads.

Fig 22: Site Surroundings.

6.1 SETUP

The first operation was to setup grid with 3m x 3 m cell size. This is the grid for the algorithm. The total size of the grid is 14 cells by 40 cells, which means that it is 41.46 meters x 120 meters. Unfortunately, the grid size couldn't be larger since the computational power available was not sufficient for larger scale organisms. The next step was to detect the centres of each cell. There were exactly 342 points inside the plots but one more step had to be done. The points around the cells of the plots were deleted, because there was necessary to create a walkway. It was made an offset from the boundary of 7 meters. This way the walkways will be least 3m large. The organism can't grow over the streets; therefore, a protection volume was set up along the walkways.

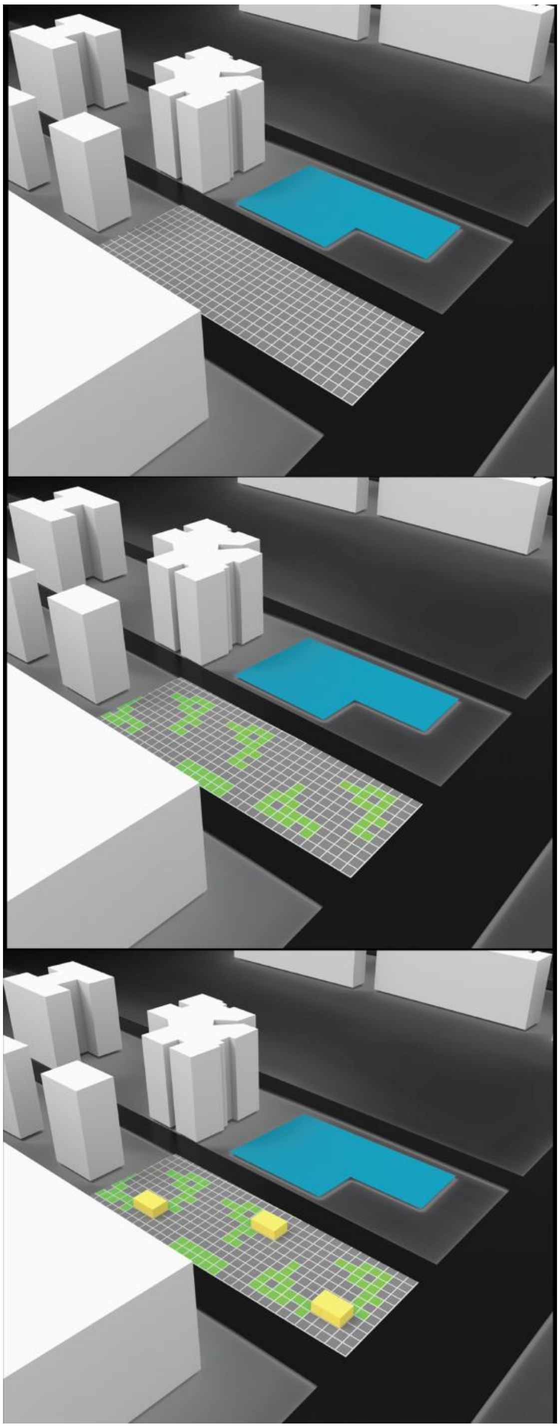

Fig 23: General formation using all the selected voxels on the selected site.

6.2 Final Output

So far, the process is linear and clear. As for the Cellular automata studies, the next step is to generate the final aggregation or final building if one prefers. All the parameters are already in the algorithm, the only difference is that this time the aggregations will be much larger and will start from the initial points in the plots. The final height of the organism will be six floors. Unfortunately, this is necessary to keep the number of cells relatively low to make it possible for the computer to compute the calculations. Even though, each generation in the evolutionary algorithm took from 35 seconds to 1 minute or more only to regenerate the aggregation. What interest in this thesis is not the best solution but, as a mentioned in the introduction, this research wants to demonstrate that a new process in architecture is possible. Therefore, one of the optimal organisms was chosen but surely not the best one.

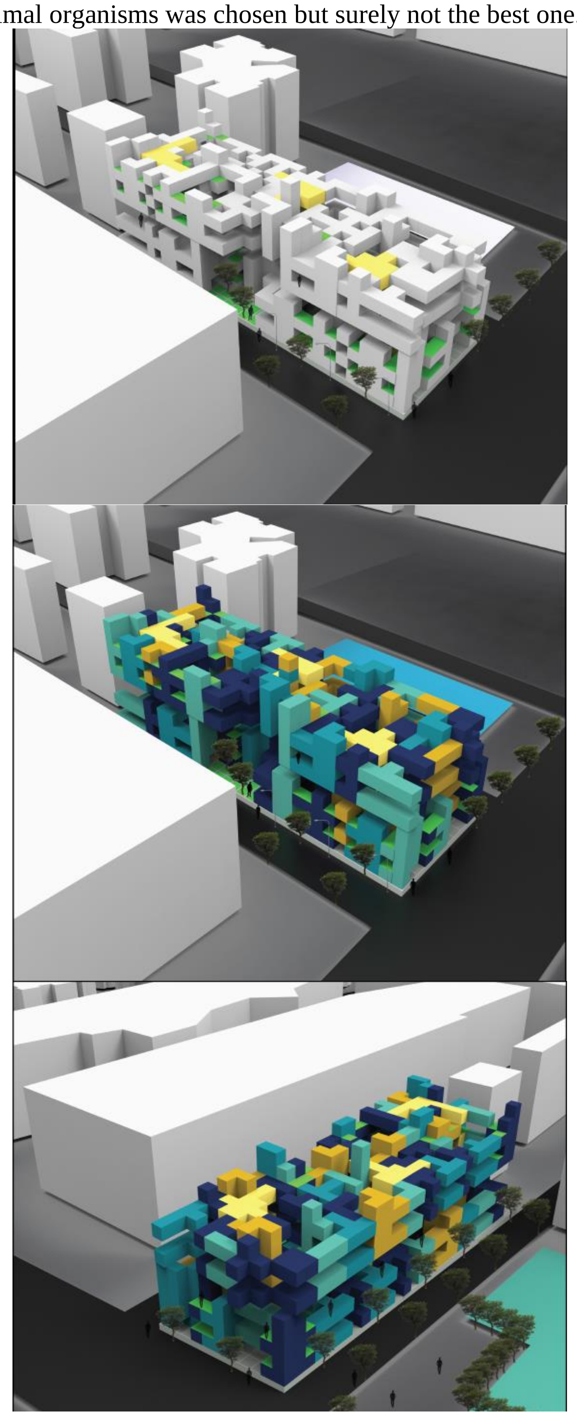

Fig 24: Overview of the voxels placed on site.

7. CONCLUSION

The proposal aims at the future, where the user will be able to purchase his house online. The house will be high quality manufactured building with high degree of design flexibility. Unconstrained building design will be combined with highly efficient industrialized products. The building will have the potential to exchange parts, components and even sub systems. Interchangeable aspects of the components, materials and systems will build in compatibility to the existing building.

This design typology is the future of sustainable design around the globe, and it also offers complexity of design solutions, notably cost effective and long-lasting architecture to cultural and economic needs.

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