Generating High Density Residential Housing Apartments in the edge of City Den Haag Vliet/A4 Zone

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Introduction:

The structure of this design-research project is based on three major parts. Due to the fact of core of this project relating to the Randstad 2040, it was first necessary to get enough information in the regional, national and international scales. Included in the first part, an overview of the Randstad is a first step of design process. Continues with analysis of infrastructure, connectivity among cities, population growth and city expansion in that region, a design question will be defined; “To design high density housings as a demand for population growth and city expansion”. Choosing an appropriate location in Prince Clausplein is required to first create a master plan in that area. Then Site analysis relating to the environmental issues, spatial organization and existing situation would explore the design constraints and relating solutions as a demand for future. It then continues to briefly determine a required program and exploring certain way to deal with. The first part will be terminated by having a preliminary design in that context.

The second part is mostly related to the research process. Due to the inherent properties of high density housings in this large area, a research goal is based on looking for a way to create a tool being able to organize a vast number of housing units. Due to the technological development and the vision through future, a research question was defined as “How a high density residential housing form can be generated in a computer program by scripting algorithm based on a certain rules in order to commit to the programmatic functions”. A principle aim of this research is to crate a series of mass prototypes which could promise the initial architectural conditions.

The last part will look forward to the rest of architectural requirements. The third part as the most critical and intriguing process is going to consider the research outcomes in terms of architectural guidelines. The results of research part are a series of mass prototypes of units, while getting an idea about the organization and arrangement of housing is no longer a final decision of design process. However, those outcomes create a large number of patterns which would give an idea to the designers how to start their design processes. Considering architectural conditions in different types of housing such as studio, one bedroom and two bedrooms apartments captured a major part of third section. Besides the architectural rules, looking for appropriate structural and mechanical systems being well adapted to the context are the challenging part of this design process. At the end, the quality of the final outcome will be taken into account.
Summary:

The intervention is located on the 30000 m² land bordered to the east side of the Vliet River and serves as a transaction to the future residential development in Prince Clausplein. This area surrounded from three sides by existing residential units connecting to the A4 highway and commercial zone in the east side.

A Main public space structures the project. In this matter, public space weaves five unit wings together around the green park in the center. Street paths in the project express the relation between pedestrian, motorway, green and public facilities. However, parking lots are located in the ground level as well as behind each blocks to not obstacle the physical view.

Main entrance to the site is on the west side where there is a high pressure of transportation and a 18m north-south Vlietweg street also make a connection to the west side of the river. The green roof of public amenities on the west side creates a green continuity to the river and makes a transition between inside and outside.

This project reflects the idea of coexistence of uses and combination of different activities. The buildings present variable identity along the public space. Different Functions ranging from public to private create diversity while keeping the unity. In the north side blocks consists of houses business in the ground floor, offices in the first floor and residential units beginning from the third floor. The ground level is the public level, the area for social interact and urban connections. The first floor recovers the urban front through a continuous gallery of offices. The change in the organization of units begins from the 2nd floor to the upper ones announcing the change in the function. In contrast to the vertical organization of spaces in the north, blocks in the south are located separately to emphasize on the continuity of green spaces and their interaction to the main public space. Hereby, a coherent public space is created for different user groups.

A diverse housing apartment; studio, one bedroom and two bedrooms housing have been made different building forms while creating an integrity within a coherent shape and offering appropriate privacy and view. Accessing to each apartment requires passing through certain level of privacy. These spaces can be ranged from public to private from central yard to the housing unit. Besides that, generated by scripting an algorithm, a mass of housing units creates an environment with a series of diverse outdoor terraces in each wings. These terraces depending on the architectural functions in each level can be divided into public, semi-public and private ones belonging to each apartment.
Part 1

Design Process
1- An overview of the Randstad of Holland:

The Randstad area with approximately 4500 sq.km located in the west side of the Netherlands. This area bordered from Dordrecht and Rotterdam in the South via Den Haag and Leiden in the west to Amsterdam in the north and Utrecht and Amsfort in the east. This area which is conceptualized as a ring of towns and cities is separated by green spaces around called “Green Heart”. The region includes 12 cities and home for about 8 millions people. The largest cities are Amsterdam, Rotterdam, Den Haag and Utrecht. These cities which are called “Big 4” are the major part of country’s economic power.
Randstad as a county’s economic power region is a place for about 3000000 various jobs. The port of Rotterdam is the most important entry and departure for goods transported over sea and Schiphol airport located just south of Amsterdam is Europe’s forth largest airport in terms of passenger’s movement. A dense network of roads and railways connects the cities of the Randstad with each other and with other parts of the country and North West Europe.

Option for the future use of this area was drawn to the side of real metropolis in order to let the economic agents benefit from the associated agglomeration economies. To control further consumption of green space, national planning memorandum of 1966 introduced the strategy to concentrate growth in designated new towns and urban regions across the country. In the Randstad “new towns” and “growth centers” were designated at the outer edges related to these cities” Alkmaar, Hoorn, Purmerend, Lelystad, Almere, Houten, Hellevoetssluis, Spijkenisse.
In 1970, falling economic growth started to affect the socio-economic foundation of larger cities. By the end of the decade, industries confronted with the lack of ground in the face of increasing global competition. The national planning memorandum at that time published focusing attention to “urban renewal” stimulation economic growth in especially the peripheral regions of the country. As a result, of growth in the number of new towns played an important role to accommodating population growth in the Randstad area.

Growth in the national economy of the second half of the nineties had an influence on the economy of country’s urban cities especially northern half of the Randstad. Amsterdam and Utrecht developed into a highly dynamic service orientated economy and the ambition of Metropolitan of the Netherlands became more essential. It should be considered in such a powerful economical region that could compete with other seven Metropolitan projects in Europe including Basin Parisien in France, Central Belgium, and Greater Dublin in Austria, Northern Switzerland, South East England, Rhine Main and RhineRuhr in Germany. Inside the region, the main focus is to develop conditions relating to economic dynamics that abound in the Schiphol, Amsterdam and Utrecht zone and keep the green hearts for recreational aesthetic and ecological values.

1-1- Population Growth:

In 2008, the Netherlands had slightly 16.5 million inhabitants with 53% accumulated in the Randstad area. The most populous cities are Amsterdam with 740000, Rotterdam with 604819 inhabitants, Den Haag with 482000 and Utrecht with 300030 inhabitants. In compare to Amsterdam and Rotterdam, Den Haag is the densest city populated with 2500 inhabitants per sq. km. Amsterdam, Rotterdam and Utrecht ranked follow respectively.

The Randstad population increased from 7.4 million to 8.5 million between 1982-2002. The population distributed unequally around this region which can be investigated in 3 categories:

a) Traditional cities or main cities
b) Suburban
c) New towns located away from the traditional cities.
Population growth in traditional cities declined in 4 big cities. It can also be concluded that there is a direct relation between migration from these cities and unemployment until the second half of eighties. In the nineties, attentions were drawn to these areas and these traditional cities confronted with increase in population rate. While there was an unevenly population growth in the traditional cities, their surroundings show quite consistent growth since 1980. It can be considered as a result of their attraction and green areas where draw people's attention for a stable life.
1-2- Infrastructure and Transportation:

Shortly the Randstad can be defined by two words; accessibility and economic performance. Transport is an important sector in Dutch economy. This major function is concentrated in the Randstad Holland around the international seaport of Rotterdam and Amsterdam-Schiphol Airport. Compared with other main metropolitan areas in Europe, the Randstad economy relies heavily on its position as a node in international transport networks.

In the Randstad the major transportation dedicates to four major cities; Amsterdam, Rotterdam, Utrecht and Den Haag. Due to the Schiphol international airport near the Amsterdam, that region has got the dominant pressure through transportation. However, transportation in this region can be considered in different scale. In terms of global scale, Amsterdam due to its tourism attraction and existence of several business firms as well as international transportation has the higher number among other cities. Follow that Rotterdam, Utrecht and Den Haag have the 2nd to 4th ranks. But in contrast to global scale, national scale represents a different arrangement. Rotterdam which is the main port of supply transportation with relation to other countries outside of the Netherlands has the first rank beyond Amsterdam, Utrecht and Den Haag.
1-2-1- Public Transportation:
In the 20th century, the number of people using their private cars increased. Motorway traffic in the Randstad has increased to five, ten and on some roads even twenty times than the volumes forty years ago. At the same time, the cities have grown in size and are enveloping roads that originally lay beyond the urban edge. The cities of Rotterdam and Den Haag are gradually merging to form into one larger regional urban network. These new urban areas suffer from high levels of noise disturbance, air pollution and congestion. All this translates into an increase in traffic and a growth in the number of criss-cross relationships.

In the 1990s the regional public transport network in the South Wing of the Randstad consisted of the Metro/light rail, the Sprinter (rapid transit) and local train services. This network is supported by city and rural bus services and a tram system in the Rotterdam/Den Haag urban area. In 2010 several important additions and changes will be made within the overall network: TramPlus, the Metro, RandstadRail Rotterdam, RandstadRail, Den Haag Light Rail and Stedenbaan have been added to the transportation systems. Doubling the infrastructure will make it possible to separate the different train systems.

Mobility networks influence a variety of spatial characteristics, such as the size of cities and towns, the intensity of functions, the degree of mixed use and the decentralization of activities. These relations were determined using a set of indicators which describe the positions of the stations within the network and the characteristics of the surrounding areas that will be influenced by the network:

i. by public transport
ii. by car
iii. local housing and employment densities
iv. the degree of mixed use
1-3- Employment:

The Randstad stands out as the Netherlands most service-oriented region. Being the country’s most urbanized region, the Randstad was the first region in the Netherlands to undergo the transition from a predominantly industrial to a predominately post-industrial or service economy. In 2002 the Randstad covered 57% of total employments of the Netherlands which was approximately 3 million jobs. The big 4 cities are holding the highest number of jobs; i.e. Rotterdam 606000, Amsterdam 578000, Den Haag 416000 and Utrecht 391000. Den Haag has the highest employment density with 1300 jobs per sq.km. Typically employment density is high in the small cities and low in the bigger ones that generally contain large track of un-built land. Before the 1990, many of the traditional cities had experienced negligible or even negative employment growth, but after the nineties the total number of jobs grows 3 million in 2002. During these years, Randstad saw a rapid development in economy which was partly urban based. Many firms and activities proved to be sensitive to the agglomeration economies belonging to the urban realm, resulting in the positive employment growth of traditional cities.

1-3-1- Type of Activities:

Network Cities and the vision through metropolitan in 2040, the focus of the employment structure will be on the 8 business services sectors1 to be expanded: accountancy, advertising, banking, designs, logistics, insurance, management consultancy and Law. These are the main type of activities in the Randstad as a motor of the Netherlands economy. The total number of business sector in the Netherlands is 908000 jobs and 66% of them are in the Randstad compared to 57% in total employments.

The analysis of service business connection requires selecting a limited number of business service centers (cities), at the regional level (Randstad), the national level (the Netherlands) and the European at global scale. In terms of regional scale, four major cities in this area including Amsterdam, Rotterdam, Den Haag and Utrecht stand in the first rank. Amsterdam seems to be filled with most of the banking, accountancy, advertising and law firms which all relates to the need of nation’s capital. Rotterdam is favorable place for design consultancy and logistic service provider. About the quarter of the firms find it necessary to have an office in Utrecht and Den Haag.

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1 - These types of activities are known as Advanced Producer Services
At the global scale, foreign law firms, advertising companies and banking firms hardly venture out into different areas of the Randstad. In that scale Amsterdam and Rotterdam are in close competition for the status of “most connected cities”. Amsterdam emerges as the country internationally best connected city with Rotterdam at the certain distance and the strongest linkages between. And then Utrecht and Den Haag follow as a third and forth cities with the second linkage in between.
On the regional level proximity to the market is considered to be very important. Therefore, firms have offices in one of more cities in the Randstad, but also in other smaller cities. On the national level, other kinds of relationship with clients appear. Proximity to regional markets is less important. The relatively small scale of the Netherlands makes those national-oriented offices rather evenly distributed over the country. Rotterdam has even more national oriented offices than Amsterdam, although differences are very small. The other two large cities are also relatively well connected.

On the international level some real differences appear. Large APS firms generally favor Amsterdam to serve international operating clients. Amsterdam is best connected in intra firm networks with an international scope. Rotterdam and especially other large cities follow. Among the 8 activities which are the economic powers of the Netherlands advertising firms are clustering in the Amsterdam. Advertising companies are in close relation with media-companies, production companies and publishers. Rotterdam on the second place contains some advertising companies. The number of these firms as a result of global market is increasing and Amsterdam is going to be filled with them in the future.

Connectivity among different types of activities in 4 big cities

**Regional**
- Amsterdam
- Rotterdam
- Den Haag
- Utrecht

**National**
- Rotterdam
- Amsterdam
- Utrecht
- Den Haag

**European**
- Amsterdam
- Rotterdam
- Utrecht
- Den Haag

**Global**
- Amsterdam
- Rotterdam
- Utrecht
- Den Haag
1-3-2 Commuting:
Population growth and employment development are the most two important factors to
determine the daily committing pattern in the Netherlands. As a result of traveling which
based on the population rate and type of employments, we can consider the daily commuting
flow in the Randstad. During the past decades, commuting in the Netherlands increased. It
was not only because of working population increase, but also as a result of travel-to-work
distance. People intend to live and settle outside of traditional cities as explained earlier, and
tavel to work in these areas. Some regions are connected to each other much stronger than
others.

In the northern wing, most of the flows are being directed between Amsterdam and Schiphol
as two largest employment centers which clearly indicate the importance of schiphol airport.
The schiphol airport is not only important as a result of employment flow to Amsterdam, but
also as its fictional operation which connects other countries to the Netherlands.

In contrast, southern wing is dominated by a small number of balanced between big cities,
Rotterdam, Den Haag, Leiden, Zoetermeer and Dordrecht. This connection can be
considered as less hierarchical and more balanced commuting flows that northern wing.
With relation to the life and work, commuting can be divided into in-commuting and out-
commuting. Amsterdam has a maximum in-commuting traveler while Rotterdam is a
combination of life and work with commuting travelers. However, the international
accessibility of the main ports is endangered by the growth of car use in the Randstad. It is
expected that the number of cars will increase from about 5.1 million in 1989 to about 7.5
million in 2010.
1-5- Housing Demand:

On a map of Europe the Netherlands is a mere pinhead. Even so the country has a population of nearly 16 million people. Almost half of them live on one tenth of the country’s total area in cities such as Amsterdam, Rotterdam, Den Haag, Utrecht and in smaller towns, together forming an almost continuous urban belt: the Randstad. The Randstad can be regarded as one large metropolis.

A metropolis is an urban region that provides the widest choice of nearly everything such as houses, jobs, schools, leisure activities and essentially transportation. However, most people’s idea of a metropolis is dominated by skyscrapers. This is hardly surprising, but not true. Skyscrapers dominate central business districts, but the rest of a metropolitan area consists mainly of green suburbs, housings, business parks, universities, seaports and airports, landscape parks and, in the Randstad, a dozen historic city centers and an awful lot of water.

For the entire Randstad, it is estimated that between 2010 and 2030 there is a need for 360000 to 440000 new dwellings. The aim is to rely on 40 percent of these within existing urban areas. The rest will be built outside the existing urban areas, but these green field developments will be linked as much as possible to the cities and to existing traffic and transport services and facilities. The great challenge is also to find a balance between development needs and environmental concerns.

In order to fulfill the demand for housing in the Randstad, the New Towns were created alongside existing towns or around several villages. They attracted ‘neo-urban’ residents, who use different centers for shopping, employment and entertainment such as cinemas, green parks, and leisure centers and sports stadiums. They affect lifestyles, families, consumers, employees and workers in the New Towns and in the periphery. In the New Towns, as in most European suburbs, housing was designed for nuclear families. As the quality of public transport serves was average at best, this group became largely dependent on the private car and this had a direct impact on family structures. The New Towns generally did not provide leisure activities for children or kindergartens and crèches within walking distance, as in the old centers.

But in the industrialized world this situation is now changing due to the arrival of foreign migrants with large families and low incomes in need of decent housing, and the ageing of the population. ¹ The image and attractiveness of New towns has declined, and they are no longer considered to be the ‘best choice’ for those who want to live outside the congested urban

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¹ - Gaborit P. Reinventing the new town mindset, NovaTerra Connected Cities, December 2005
areas. People initially moved to the New Towns because of the quality of the environment and the lower land prices. Jobs have been created in the New Towns mainly because of their location close to large cities. They have attracted businesses by offering good infrastructure, tax incentives and facilities. Some towns have attracted more services and high-tech companies. New Towns have succeeded in providing a wide range of cultural and leisure activities, and in most cases residents are encouraged to participate in the social life of the town to raise the sense of community.

New locations for housing are situated as much as possible within the city boundaries or otherwise near the large cities. Vacant areas within the cities will be filled in as much as possible, which will lead to an increased building density. Adequate amenities will be necessary in each neighborhood in order to meet the demand for leisure activities. Amenities such as workshops, theaters, small-scale sport facilities taking up little space are located in the residential neighborhoods.

As mentioned earlier public transport is another key feature in new towns. In the one hand, network transportation should facilitate the relation between several activities in these towns. And in the other hand, the demand for transport between the new urban areas and the original town centers should be met. Mobility and transport have implications for all the other aspects of the New Towns: their economies, urban planning and governance.

In the south wing of the Randstad, there is a stronger emphasis on realizing new housing developments through transformation, revitalization and redevelopment, especially near
existing stations and infrastructure. Rotterdam and Den Haag have a particularly great interest in upgrading and expanding their housing stocks, as they really need to become more successful in tying middle and higher income households to their cities.

In Utrecht region finally the idea is to enlarge the housing stock with 32000 new dwellings between 2010 and 2030. The Utrecht region, through its centrality and attractive environments offers one of the most popular living environments of the Netherlands and demand for housing is correspondingly great.

About 44 percent of the Randstad area is urban area, with infrastructure taking up a considerable part of the space. This implies a high level of environmental pollution per square kilometer. Environmental problems are a major concern in long-term urban and planning schemes in the Randstad. Intensive motor traffic makes a substantial contribution to the environmental pollution. The important starting-points in transport policy are the reduction of environmental pollution through limiting the growth of car use and at the same time the improvement of international accessibility of the main ports in the Randstad.

The structure of the landscape is increasingly dominated by the process of urbanization, which comprises industrialization, expansion of cities and the attendant growth of infrastructure and recreation facilities. Adjacent cities are threatening to merge. Because of its central position the Green Heart is an ideal place for establishment of industries and housing areas. This means that the Green Heart is increasingly affected by these types of development.

The idea of master plan in the Randstad area should provide a great diversity in regional possibilities, both for households and for economic activities. The main centers will specialize in management functions, international activities, banks, research and development, cultural activities and high-level public administration. Their living environment will be improved through urban renewal, which entails improvement of housing stock, decongestion of older densely built-up areas, and expansion of green areas within the towns. Recreational facilities will be provided and improved in the immediate vicinity of the large urban centers and medium-sized towns selected for expansion.
2- Den Haag 2020:
Den Haag in the west side of the Netherlands has drawn an ambitious future vision in the world. It would be an attractive place for occupants, visitors, employees and companies. One of the major characters of this city is the combination of several activities offering living and working environment as well as suitable place for supplies, culture and recreation. Achieving these characteristics is in the close relationship with the strong quality of economics in the south wing of the Randstad. Different features of Den Haag can be considered as follow:

- A unique position to the sea
- A reflection of a justice and location of a legal activity
- A place for mixture of several cultural and social activities
- An appropriate monumental resident place
- An attractive place for visitors

Den Haag is already occupied with 480000 people and has a vision to accommodate a capacity of minimum 505000 occupants in 2020, respectively 37500 houses and 40000 new jobs. This development is only possible with the strong economical development in the future vision. This city is also committed for the engagement of the city edge and surrounding area of south wing with the green spaces, water supplies and infrastructure.
2-1- Current situation:

East side of Den Haag is globally shaped by the Vliet River and green spaces. This location is relatively characterized by vacuum and green spaces which in some location combined with some villa houses and industrial buildings. This district is defined by a region between Vliet River and A4 highway connecting Rotterdam and Amsterdam. So this part is on the territory of Den Haag which should be linked to the city in the future.

This location somehow separated with A12 highway connecting Utrecht and Den Haag. The importance of this road is in the international level which will connect two metropolitan areas in Europe; i.e. The RhineRuhr in the Germany to the Randstad in the Netherlands. The north part of this region includes a green sport area and some industrial blocks while in the south side, there is a big golf region and villa buildings. The area has a green character in substantial parts but has a poor influence in the integration of that to the quality of life. The importance of this region is its potential as an appropriate place regarding the expansion of residential spaces in the east side of Den Haag. In addition, east side of prince clauseplein is confronted with a strong ambition for the villa houses. Therefore, the importance of this region is so strategic in terms of right connection between city expansion, residential buildings, economic potentials, commercial functions and green spaces to the existing situation.
2-2- Development of master plan in the Vliet/A4 zone:

We are specifically focusing on the area between Vliet River and A4 highway. But in the upper view this location is an important junction in the regional, national and international scales. As mentioned in the first section, this junction is so importance once looking through the economical flow of the Randstad. In two different directions, movement and commercial activities resembles different feeling of space. Although fast speed in A4 highway and its edge reflects the speed of business activity, entrance to Den Haag city passes through A12 highway. Thus different kind of movement and its relationship to the type of activities in the highway edge should be considered in the master plan. At this time there are two train stations Voorburg in the west side of Vliet river and Ypenburg in the east side of A4. However Vliet band needs a right public transportation to connect upper part to the bottom part of A4 in order to make a combination between living and working environment.

In the general term, the idea of creating a new urban environment is based on commercial and living spaces which should be bridged appropriately. The A4 highway creates a commercial zone in the global scale from south to north and it connects France to Amsterdam. This area is confronted with the large number of international transportation and commercial activities. In the perpendicular direction, A12 highway continues from east to west and terminated in Den Haag city by the sea. Prince Cluseplein is an important junction in terms of global and regional scale particularly where it reaches Den Haag city.

The location between A4 highway and Vliet River can be considered by four major type of activities as well as environmental spaces; commercial and industrial, residential and recreational activities as well as green and water spaces. The golf area on the south side of A4 has a capability to link commercial and residential spaces. There is a demand for connection between upper part and bottom part on the vliet/A4 zone.
According to the existing situation and the analysis of the site with respect to the master plan of Den Haag 2020, there is a demand for well organization of city expansion. In the city edge we are confronting with the dispersing of population and their need for residential spaces. Besides that the outstanding environment around Vliet River would exert an additional positive effect in that regard. All in all, at first stage living spaces would be distributed around the Vliet zone which is more critical in terms of city expansion. The commercial activities would be put next to the highway edge to well reflect the future of business district in that region. In terms of environmental consideration, these activities, one in the city edge and one in the highway edge need to be linked by green spaces.
The area of the Vliet river edge will be accommodated with high and low density residential spaces. Companies and offices next to the highway with their accessibility criteria and visibility quality also play an important role. This living environment would challenge with less issues in compare to the central city with several activities, while neighboring areas have influences on that. The area of Vliet/A4 zone has a gross area of 340 ha. And with respect to the 80-88 houses per hectare in the city, this location with green and sport centers would have capacity for 50-55 houses per hectare. The south part of A12 in the Vliet/A4 zone with about 50 ha and upper part with about 35 ha have a capacity for 2750 and 2000 houses respectively. Shopping malls, cinema, fitness as well as recreational activities are needed for that location.
For companies and office buildings, accessibility and visibility to their surrounding are the major aspects. For the future of Den Haag, Prince Clausplein is considered for approximately 30 hectare offices and companies in such a way to be well connected with NS station of Ypenburg and Voorburg. In order to integrate commercial activities with green spaces, there is a possibility for these companies in the south and north side of the A12 in the Vliet/A4 zone to be designed in such a way that the business area and green spaces could be combined. Although Ypenburg area in the east side of Vliet/A4 zone is regionally separated from the city edge but it has an important role to attach that region to the city by infrastructure network. This location with critical accessibility and work flow is a suitable place for commercial zones. An appropriate infrastructure as well as good relation to the train station and car accessibility would also make it as a conceivable location for recreational activities. Swimming pools, saunas, sport centers, shopping malls integrating to the green spaces could make a commercial park and increase the quality of space. For instance, some kind of APS
activities such as ICT management firms could be combined with a management institution to not only draw the international attentions through business activity but also develop a business park to improve the quality of education.

The development of these areas can not be separated from the improvement of infrastructure. An important concern in that regard is to increase the use of public transportation and bicycles to reduce the traffic and negative environmental impacts. Although sounds effects and noise pollution are in the higher level around Prince Clausplein, but it is required to integrate a highway life time to the surrounding activities in such a way to meet the users environmental comfort. This important issue can be reached by integrating architectural and environmental approach. Considering green spaces such as trees as a sound barrier, appropriate building forms and heights as well as using right materials are the basic ways in order to meet environmental issues.
3- Design Process:

3-1- Design Question:
For city expansion and population growth new rules of urban development should be formulated. These principles should lead to the sustainable environment that city edges act as connectors between existing situation and future development.

> How a feasible residential complex as a demand for population growth and city expansion can be designed along the city edge and next to the highway in order to make a sustainable environment for the future development?

3-2- Design Challenges:
- How to create a public space in which people could gather and enjoy their life time besides their private activities
- How environment and green spaces can be associated in the program
- How working activities can be combined with living one
- How to create a place outside the city where people feel comfortable and safe
- How city edge can be considered in order to create a continuous city fabric
- How these residential blocks in Price Clauseplein can introduce the future of the Randstad

3-3- Design Constraints:
Design constraints in this special function and critical location can be considered from different points of view. Residential spaces in compare to other types of activities are unique. They should fulfill different ranges of human need. If people no longer feel comfortable in their houses, it will exert the negative influence in their lives. Therefore, building regulations, human environment and comfort principles are among issues that constraining this design.

- The type of housings and their costs should be compatible with users social level, otherwise, they do not feel satisfied to live there.
- Besides the limitation relating to a building and its function itself, a location and environment exert influences in the design processes. In one hand, city edge is mostly
known as a poor location due to its low quality and critical criteria in terms of urban context. Besides that, environmental issues of highway differential this location from other places in the cities.

- This location is affected by highway criteria, river and special environment which can be known as accessibility, environmental issues, visual attraction and urban context.
- This location is affected from one side by river, other sides by commercial buildings and current existing residential blocks.
- This location relates to the Vliet river and city boarder, and regardless the urban issues it promises to create a specific situation in terms of visual attraction.
- Although having good accessibility to the highway is one of the major advantages of Prince Clausplein, but several environmental issues would restrict the design process that should be taken into account.

3-4 Design Solutions:

- In order to integrate working activities to the human life, each block should be a combination of working and living activities.
- In order to make a continuous fabric connecting to the city, geographical typology and infrastructure can be considered as one way in order to reach the goal.
- In order to create a comfortable space, physical attraction of the region and environmental aspects of the location should properly taken into account.
- In order to facilitate the movement and transportation, different types of streets are required. The direct connection to the infrastructure by means of tram or bus and appropriate ways for private vehicles should be met. In addition, adequate space for cars parking should be included in the area.
- Besides car and public roads, separated routs for bicycles and walking paths in the location are necessary to be integrated with residential spaces.
- In order to meet the whole aspects of human life in the residential complex, various spaces in the range of public to private ones are required. In addition to the main public space of the complex, a certain number of open spaces belonging to certain number of domain should be provided for inhabitants.
- In order to create an environment that could well resemble the future of residential buildings, computer programs and algorithmic architecture are used in the initial stages of design process.
3-5- Design Location:

According to the investigation and site analysis, it can be concluded that several housing units are standing in the south side of Vliet river and A4 highway. Unlike the virgin area which there is an advantage to design from scratch, in this location there is a great challenge to deal with the existing situation. Therefore, as a design ambition it is required to consider the existing situation particularly the area accumulated with residential spaces and several other activities.

Existing situation in the A4/Vliet zone

The location is necessary to be selected in the area that could continuously connect the west and east side of vliet river in terms of residential spaces. As can be seen in the following picture, there is a left over green space that would be influential in the development of high density residential spaces. It should appropriately adapt to housing around it as well as make a continuous fabric to the city for the future use.
The location as an area around 30000 sq.m. and it is surrounded by housing units from three sides. The main access to the site is from westvlietweg continuing from north to south. It is also located in the area where there is a main local access to the other side of the river and den hag city.
4- Program Requirements:

This program is aimed to settle 103 inhabitants per hectare. Due to the future vision of population growth, the Randstad has to provide residential spaces with 53 Units per hectare. This program is going to create a living environment with 80% living spaces, 12% working spaces and 8% shopping malls. The ratio of covered area should not exceed than 20% of plot area. Residential apartments offer three types of building units; one, two and three bedroom apartments.

The main concept of this residential complex is to create an integrated environment between living, working activities and green spaces. Having sufficient space for public activities where people can gather and socialize with each other is a mainstream of this program. In order to meet the all aspects of the program, parking lots should be well combined to the all activities to provide enough spaces for 500 cars. The detailed for required spaces represented as follow:

**Lock Area:** 32500 m²

**Working Units:** Total: 5000 m²

**Housing Units:**
- **Quantity:** 100  **Area:** 25-30  **Total:** 2500 - 3000 m²
- **Quantity:** 200  **Area:** 55-60  **Total:** 10000 - 12000 m²
- **Quantity:** 200  **Area:** 100-110  **Total:** 20000 - 22000 m²

**Parking:** 5000 m²
- **Quantity:** 500  **Area:** 10 - 12  **Total:** 5000 - 7500 m²

**Public Facilities:** 4000 m²
- **Shopping mall**  **Total:** 2500 m²
- **Conference Hall & Library & Gymnasium**  **Total:** 1500 m²

**Green Spaces:** 6000 m²
In order to get a clear understanding about the program, the following illustration would express the physical appearance of the program.
5- Target Groups:

City centers have a poor environment for a living, but rather high quality for working activities which make them as suitable locations for middle income people. Two groups of people prefer to stay outside of the cities, low income and high income people, but their location differentiates from each other. Currently, Vliet/A4 zone is a place for middle and low income people who prefer to live around the city boarder and travel to their work in the city. However, a little further from the A4 highway, city suburbs draw an attraction of high income people. Due to the expansion of the cities, this interaction between different types of housing will be changed in the future.

There are several issues that would exert an influence on scattering a people in different area according to their income. These issues can be considered as amount of population per capita, accessibility, connectivity, type of activities around a location, environmental condition, land cost, segregation and so on.
The population is growing and Den Haag is expanding. It is aimed to be in a part of metropolitan city and Prince Clauseplein would have a significant role in that regard. Commercial activities will be accumulated around it where there already are residential spaces. Cities expand and lifestyle will be changed. It will be in the city instead of out of the city. This location would not be as a city boarder; however, due to the good accessibility, public transportation, physical attraction and etc, it would create an appropriate environment for high income people. Therefore, this location would have a critical characteristic in the future in terms of residential spaces.

Due to the ambition of this project, it should consider the lifestyle of the people in the 2040. In this area particularly in the general term, the Randstad metropolitan area, concentration is aimed to be more on the working activities. The target group would span a range of people with the age of between 25 to 40 years old. Families become smaller with less number of children. These kinds of nuclear families have one, two or three persons which intend to work during days while spending a short time together during evening and nights. They would spend most of their times out of the houses and enjoy a short period of time in there together. During weekends they prefer to be outside, having fun and communicate with others. In the architectural points of view, it means that houses would become much smaller and more flexible. There would be no longer a need for defining particular activities in the house. They would easily alternate their function according to the human needs.
6- High Density Housings:

During the years population growth rate has trend sharply upward. While the pace of population growth has accelerated, another fact remains constant; we always have the same amount of land. Therefore, we are taking up more space per capita than we used to.

As a result of car transportation cities expanded outward in a large increment in a dense fabric. Metropolitan areas use less land per capita to accommodate their fast growing populations. Areas that were originally built to a low density filled in at a faster rate than they expected outward\(^1\). Despite the fact that the large metropolitan areas sprawled, many downtowns grow denser. This can easily be seen in some metropolitan areas such as downtown Chicago Illinois or Seattle Washington. Demographic trend indicate an emerging market for urban location and city housing, due in part to an aging population and declining family size. This feature is emphasized more in some cities where confronts with the growth in the immigrant population.

\(^{1}\) Campoli, J. “Visualizing Density”; Lincoln Institute of Land Policy; 2007; P. 6
Depending on a land and population growth, high density housing can be designed in different pattern. Sprawl housings are detached from urbanized location and city down town. There are some disadvantages in terms of accessing to shops, schools, recreational facilities that would increase the necessity of private transportation. In particular way, arranging towns in such a compact pattern that facilitate the transportation and life activities can provide benefits. In terms of sewer, water, roads, electric and other infrastructure elements, compact form equals fewer pipes and poles and less asphalt and concrete per unit of housing.

**Density:**

*Number of Units per hectare = Number of units / Site Area (hectare)*

*Number of Dwellings per acre = Number of Dwellings / Site Area (acre)*
Transportation savings is one of the biggest benefit of concentrating people and jobs into smaller geographic area. Where homes are speared out, more energy must be expended to serve them; more gasoline to access them; more oil or natural gas to heat them and more electricity to cool them. Freestanding homes consume 88-95 percent more energy than houses of equal size that share a common wall. Combining energy use for travel, home and an individual’s portion of what is used for community infrastructure, the contrast in energy consumption between low density and high density housing is striking.

City dwelling use fewer energy resources and generate less pollution than suburban and rural neighbors. People drive less in places where densities are high, streets are interconnected and jobs are interspersed with housing. In addition to economy and environmental benefits, density offers the advantages of urban life namely the choices and options available whether people live and work in close proximity. At higher densities it is possible to offer more amenities like cultural events, medical services, shopping and dining options. Campoli clearly defines the term density and crowding:

“Density is often associated with crowding, but it is important to distinguish between the two. Density is a number of people in a given space while crowding is a subjective perception that that number is too high. Places can be very dense, but may not be perceived as over crowded if they are designed to comfortably accommodate many people.”

So, there must be a good balance between number of density and number of people that it would create a livable space. Living closer together is more appealing when the built environment is designed well and cared for. Dense urban neighborhood such as Chicago’s Oak Park, Seattle’s Capital Hill and Brooklyn’s park slope have been valued over time for their high quality of life. These places offer the benefits of density without negative aspects like overcrowding or monotony.

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1. et al, p. 9
Density goes hand in hand with alternative transportation. Higher concentration of people makes mass transit feasible, and transit is the most efficient way to larger number of people. Transportation can be divided as transit centers, bike lanes, sidewalks, ride sharing program and bus shelters and parking. An interconnected street network that serves both vehicles and pedestrians can make neighborhood life more community and convenient.
One of the most significant benefits of density is the potential to save open land from development. Like context and transportation, open space is a key issue in planning for density. Living closer together has some negative aspects such as less private space, fewer parking areas, and more noise, but good design can help overcome some of these drawbacks. Carefully placed and proportioned public space often compensate for the loss of large lots. Clearly defined private gardens can be more appealing outdoor spaces that large. The best dense neighborhood includes a lively mix of use, housing types of architectural styles and public spaces.

One of the great benefits of high density housing is that it brings people close enough together that they can interact without traveling far. The higher the density, the more people and activities there are. By locating a mix of uses and public spaces within an optimal walking distance from homes, arranging buildings to create well-proportioned outdoor spaces and designing streets to encourage human interaction.

Street trees, narrow roadways, wide sidewalks, prominent cross walks, bike lanes and bus shelters are some of the design elements of pedestrian. Such a system of open spaces and natural elements would reach into every neighborhood. The green spaces system should weave into the site, offering every resident a direct connection to nature and natural processes. Trees play an indispensable role. Green infrastructure offers many environmental benefits, but the main advantage is that it provides an element of tranquility to areas of high activity. It satisfies human need that is often denied in urban life.
6-1- Building Types:

Density is affected by three factors: house or unit size, building coverage versus open space and building type. Several residential building types have developed over the years to shelter people in low, medium and high density settings ranging from ranch houses to skyscrapers. Designing for density requires using a building type or types that best fit the context of the site and needs of the residents. The decision to use a specific type determines the density range of neighborhood.

There are several ways that unit blocks can be organized in a city context. As illustrated in the follow these housing units can be categorized in 6 main formats:

1. Single family: less than 12 units per acre;
2. Attached town house: 12 to 24 units per acre;
3. Stacked town house: 20 to 45 units per acre;
4. Low rise (2-4 stories high): 20 to 40 units per acre;
5. Mid rise (5-12 stories high): 50 to 100 units per acre;
6. High rise (taller than 10 stories): higher than 60 units per acre;

1 - Campoli J. MacLean A; “Visualizing Density”; Lincoln Institute of Land Policy; 2007; P.51
### Low rise - high density

- **Attached Houses**
  - Δ 75

- **Detached Houses**
  - Δ 50

- **Stacked houses to towers**
  - Δ 125

- **Existing Situation in Vlecb/A4 zone**
  - Δ 35

- **Vision in 2015**
  - Δ 56

<table>
<thead>
<tr>
<th>Single Detached</th>
<th>Semi Detached</th>
<th>joined Court</th>
<th>Duplex</th>
<th>Row House</th>
<th>Triplex</th>
<th>Quadruplex</th>
<th>Back to back semi-detached</th>
<th>Stacked row house (4 bay)</th>
<th>Stacked row house (2 bay)</th>
<th>Garden apartment</th>
<th>3 story walkup apartment</th>
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<th>Combined apartment &amp; row house</th>
<th>Skyscraper</th>
<th>High rise apartment</th>
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<td><img src="image16" alt="High rise apartment" /></td>
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6-2- Parking Lots:

Storing cars is a most challenging part of the high density housings. Where the space is at its premium for housings, a large number of spaces required to park cars would exert a significant influence in the design process. Space that is used for car parking and covered with asphalt can not be used as a green space or any other types of amenities. These spaces should have a proper relationship with other activities while not disturbing them. There are several ways to organize parking lots in high density housings.

1. Central Lot: buildings around the lot
2. Perimeter Lot: cars around the building
3. Pilot: cars on the ground floor beneath the housing 1st floor
4. Internal Structure: cars in the center of the block
5. Underground
Many residential streets are wider than necessary. They should be designed with the minimum pavement width that will support the area’s traffic volume, on-street parking needs and emergency; maintenance and service vehicles. A simple way to narrow a suburban residential street is to provide for one parking lane rather than two. In especially low traffic areas, sidewalks may be restricted to one side of street or, in certain situation, eliminated. Different type of parking lots in the street can be considered in a project. According to the above mentioned factors they can be divided as follow:

6-3- Street Patterns:

Streets connect the private to the public domain and also link different type of neighborhood. Street design contributes significantly to the quality and character of a community since appropriately designed streets create safe, quiet and healthy environment.

Current thinking of street pattern design appears to be divided between concern for the efficiencies of infrastructure and traffic, and a consideration of aesthetic. The perceived quality of a street depends on both physical and operational attributes. Street life, visual complexity, social status and population density are incidental attributes dependant on culture and history. On the other hand, safety, security, comfort and a sense of enclosure are functions of design.

Due to the different serving functions, streets have different types and sizes. They range from highway to pedestrian. The emergence and rapid popularization of automobile affected the street patterns and make all the urban periphery accessible. At the same time, it introduced many disadvantages: noise, environmental impacts and pedestrian safety. Automobiles require streets designed for speed and driving. Thus, different types of activities, facilities and transportation means express the clear meaning of hierarchy in the design context. For example, accessing to the inhabitation from highway needs a transition from high speed to low speed, car to pedestrian in order to create an appropriate environment between automobile and inhabitants.

Satisfaction surveys of suburban residents often mention walk ability. It implies comfort access to amenities such as recreational area, retail stores and work places. The presence of these amenities can be affected by a street pattern but clearly not determined by it alone.

Viewing nature whether it is in the form of parks, boulevards or treed avenues in an urban environment is a source of delight. Green space has been found to have social and psychological benefits. Green spaces provide visual relief and opportunity for relaxation. It also has environmental benefits: it cools the air, recycles carbon dioxide and retains rainwater. Due to these benefits it emerges as a key element of quality in a residential development.
The effect of roads on human activities is significant. They can be considered as a transition for a car around houses, or can be combined to the life activities around it. In general street is an area which is dominated by movement, and depending on its speed a variety of activates can be happened there.
First degree road is the one that car has a significant role in there. This type of road consists of several wide lanes in which cars can quickly pass. However, life and human activities are mostly happened in places with fewer cars. In contrast to that, third degrees are narrow with paved ground, speed is too low in there and automobile is integrated to the human activities. In these kinds of streets, people walk and children play in the street and bicycles can freely pass. In addition to these two types of streets, second degree can be considered as a one in between with a combination of several activities. However, its width is wider than third one and can accumulate larger number of cars.
Standard width for residential streets, with parking on both sides.

Allowing parking on only one side can further reduce the width of low-volume residential streets.

Grass and aggregate shoulder vary.
7- Site Analysis:

The intervention is located on the south side of A4/Vliet zone. This location with 30000 sq.m area is surrounded by several residential buildings in three sides, north, south and east. Although the location has a far distance from A4 highway but it should well access to the main transportation. As was developed in the master plan, residential zone in the east side of Vliet River is separated by green zone from commercial area in the west side of A4 highway. The main significance in this matter is a green barrier which protects the residential spaces from environmental pollution as well as creating a natural connection between different types of activates.
The main access to the site is provided by the west side; westvlietweg with 15m wide connects the north and south side of Vliet/A4 zone. This area is also connected to the city by crossing the Vliet river which creates an attractive physical appearance for the living environment. There are also different types of roads and streets with lesser width around the area which could facilitate the transportation in the south wing and through highway. Therefore, the main access to the area is from west side where there is a junction connecting both sides of river.
8- Concept & Architectural Organization:

The main approach through this design project is based on looking from top to bottom. In order to design properly according to the demand for future use, the process was first initiated by getting enough information regarding the Netherlands and the Randstad in the largest scale. There is a general master plan defined by government explaining the need and ambition for the Randstad in 2020 and this design project is no longer detached for that.

According to the information and spatial organization of the Randstad area, it was clearly observed that the Netherlands and particularly the Randstad is confronting with the large amount of population growth and the lack of housing units. As mentioned earlier there is a need to provide 53 housing units per hectare until 2020. In that matter it is first necessary to create an architectural master plan in the Prince Cluaseplein with relation to the proposed countries spatial planning.
In the architectural points of view, the design process in that area is based on investigating on site constraints; spatial and environmental and clarifying the appropriate solutions in that regard.

An important feature of this project is to create high density housings while making a relationship between working and living environment as well as public amenities. In order to meet this goal and promise to the programmatic functions, each building is defined into three zones. In that matter, there is a need to have an appropriate relationship between them in the horizontal and vertical direction. Public zone in the bottom includes commercial spaces such as working areas and offices while private zone on the top consist housing units which require more privacy than other types of spaces. Shopping level can be considered as such as space that would link offices in the bottom to the housing units on the top. Besides that shopping level is a continuous one in different blocks.
Residential spaces in compare to other types of activities are unique. They should fulfill different ranges of human needs. If people no longer feel comfortable in their houses, it will exert the negative influence in their other activates. The importance of human needs in high density housing becomes more significant. HDH in compare to other type of spaces confronts with more architectural issues. These features can be considered as type of housing, proper density, right accessibility, parking location and car organization and so forth.

Public spaces have a significant psychological effect on human needs. People tend to gather and communicate with each other. Especially in the residential spaces, inhabitants are apt to spend their time during weekend with their families. In that matter, development of the site is based on having a main public space where belong to the all inhabitants. This space should also create a green connection among all blocks and facilities. In the ground level, public space is combined with public amenities defined as program requirements. These spaces include library, conference hall as well as commercial offices. Around the public space streets would create the site pattern organization. This area would create a livable space where inhabitants could gather and communicate with each other. In addition to that, there are several spaces on the backside of each block which relatively separated from the central area. Besides the public spaces spread in the site, balconies are integrated into the residential zone in the upper level.
Dwellings are designed to acknowledge the different requirements for privacy and control the transition. In that matter, there is a hierarchy from public realm in the center to the private spaces. In the horizontal direction, considering hierarchy is determined by different types of transportation speed. In that regard, parking lots with less auto speed is placed on the backside of the building and in the front they are combined with other types of movement; walking and bicycle movement in such a pedestrian and bicycle path respectively. In the vertical direction, relationship among diverse spaces is considered in different ways. Although different zoning; public and private, are placed vertically on top of each other but private spaces should not suffer from the public activates. In the architectural points of view, this objective is reached by optimizing the place of circulation spaces as well as controlling a position of its entrance in each floor. However, there is a well-accessing from outside to the private zone while not disturbing the public spaces.
Achieving a suitable provision and satisfactory design of parking arrangement is an important factor with relation to its surrounding. Car movement in the site is aimed to be kept as its minimum rate and integrated with other types of transportation. Having green spaces and particularly trees in the site will significantly reduce air contaminates and control environmental condition inside the buildings as well. Therefore, in the design concept housing units on the upper level are somehow detached from transportation in the ground level. Parking lots are situated in the periphery area and the backside of building blocks. In addition to that, cars can also be located in the ground floor beneath each apartment.
A situation where cars are located in the ground level below the apartments

Site typology; different alternatives regarding site typology

More open spaces

More spaces around the building
Building stories should well respect to the local context and public or semi-public ones. Building blocks with 5-6 stories will usually have sufficient scale to provide good definition of the streets. Taller building with more stories up to 8-9 floors can also be justified when they help to achieve design objective being recognized as a landmark. However, building forms as a result of rule-based computer design would create a landmark in the Vliet/A4 zone. This approach not only indicates a vision of 2040 as a technological development, but also creates several alternatives meeting the architectural requirements.

This project is divided into two parts, design and research. The former part has a major ratio of process (70%) and the research part consists 30% of that. The research activity is aimed to reveal solutions of the research question:

*How a high density residential housing form can be generated in a computer program by scripting algorithm based on a certain rules in order to commit to the programmatic functions.*

It is aimed to find an architectural organization and building forms of housing units in the computer programming. In such a relation to the design process, research part is to be committed to the architectural guidelines defined in such a rules in a computer program. More information regarding the research process and its outcomes is presented in the research section.
Part 2
Research Process
Contents

1- Summary:
The aim of this research is to present a feature of cellular automata (CA) as a kind of computational methods generating architectural forms based on the certain rules. The study focuses on he defined grammar of shapes and rules to generate three-dimensional building forms. Applying this approach in the initial stage of design process could add a fresh perspective to architecture. In this research, architectural constraints, circulation spaces, light and certain number of density and housing types are the basis of principles for the form generation explorations.

2- Objective:
The demand for high density housing (HDH) as a result of population growth and city expansion is increasing. Although several high density housing projects are designed around the world but still there are several challenges which architects and designers deal with.

Due to the time constraints and large number of housings, these apartments mostly designed according to the uniform units repeating in a certain manner. The organization of these units should be done in such a way that the quality of life, users comfort and environmental criteria reach an appropriate level of satisfaction. The aim of this research is to define a guideline and consequently generating a form that could meet these requirements.

Besides the advantages of HDH, there are several disadvantages which decrease the quality of life inside. Although using uniform blocks could facilitate the construction processes but for instance arrangement of these compact units would obstacle the availability of natural light inside. One of the aspects of this research is to create a form of housing units in such a way that natural light could be evenly distributed inside houses.

Flexible buildings are intended to respond to changing situations. Due to the characteristic of uniform units, there is a possibility to adapt the inside of buildings to different functions. It can be achieved by adding or removing partitions between units. Therefore, arrangement of units could influence the demand for different spatial organization to fulfill the whole program. For instance by combining two or three units, three types of room apartments can be created.
The circulation spaces including horizontal or vertical units are in the close relation with each residential space. Optimum use of these spaces besides considering appropriate garden traces or public streets in each floor are among the principals affecting the design process. Reaching these aspects by organizing uniform units is required to define a set of rules. These guidelines will make a strategy and will be considered as a basic of design processes. However, due to the complexity of these rules and difficulties in their combinations, the need for using computer program is inevitable. A computer program as a tool with its own language could measure different complex possible solutions. Thus these rules are required to be clearly compiled in the computer languages by writing an algorithm in such a scripting tool to generate building forms. At the end the outcome of this rule-based design is to generate a building form in a computer program which could meet the criteria and fulfill the requirements. This design can then be evaluated with respect to volume, footprint, number of floors, number of units, circulation path, number of balconies and relationship between each apartment.

3- Shape grammar:
Geometry is the basis of everything. According to Stiny, design is calculating with shape and rules, and shape grammars are mathematics. They let us to calculate in algebras of shape\(^1\). The complexity of shape is retrospective. It is an artifact of the rules that depends on how they are actually applied. Without rules, there is no complexity. And with rules complexity varies, up and down\(^2\). Shape grammars are the algorithmic systems used to analyze existing designs or create new ones. In spite of using text or symbols to express conceptual representations, shape grammar helps to generate innovative designs through computational method with shape and rules. Numerous probabilities of rule selection and application of these rules may cause emergent design solutions. The characteristics of shape grammars make them ideal for use in a generic design tool generated toward innovation.

4- Algorithmic Architecture
Recent theories of form generation in architecture have focused on computational method of formal exploration and expression. Algorithmic architecture involves the designation of software program to generate space and form from the rule based logic inherent in architectural program. The critical interface between shape grammar and genetic algorithm is the use of designs shape code.

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2 - et al
In design, shape grammars, topological properties, mathematical models are algorithmic processes aimed at exploring unpredictable properties. A particular characteristic of algorithmic architecture is that they do not require an explicit solution strategy but merely a way to evaluate solution. A further advantage is that designs can be evaluated for their performance in several areas at once.

It means that genetic algorithm creates a selection of shapes based on the rules used for the generation of design. These can create very magnitude alternations which then can be evaluated with respect to their physical attributes.

There are several issues that would make architects eager to deal with algorithm in the initial stage of their design process:

1. As a result of technological development, future world is going to be much more complex. The effect of these developments in architecture would represent a more complex form derived from technological achievement. Thus, architecture is in the close relationship with other sciences especially mathematics and biology.

2. The algorithmic architecture creates a vast number of solutions based on simple rules. This evolutionary architecture has a potential to inspire architects toward innovative approach.

3. The large number of generated outcome means that resulting designs may have unanticipated properties. The results conform to designers aesthetic ambitions and would free up the designers to be able to focus more on creative approach.

4. A large number of designs can be quickly evaluated and the most successful ones promised to the architectural requirements can be selected.

5. Architects should try to explore new tools for being able to design in a different and more efficient technique than traditional approach.

This project attempts to develop an algorithmic method in such an innovative approach for supporting the initial stage of architectural design. In this process rules and algorithms are applied to the cellular automata CA that can perform computations.
5- Cellular Automata:

Cellular automata is a computational method which can simulate the process of growth by describing a complex system by simple certain rules. The interest in architecture is the ability of cellular automata to generate patterns from organized patterns which might be able to suggest architectural forms. One of the most fundamental properties of CA is the type of grid on which it is computed ranging from one dimensional introduced by Wolfram, two dimensional by Conway and to three dimensional which was introduced by Ulam. In this matter certain rules determine the status of each block.

There are several issues influence the shape organization and generate various forms. All of these issues define a certain rules that could process to develop the unexpected and architecturally possible forms. An algorithm is used to evolve CA based on these defined rules. The rules give rise to sophisticated emergent computational strategies and then these strategies can be analyzed using a computational mechanism.

This research is aimed to present the characteristics and shape grammar rules of geometric patterns in the cellular automata computational method. It attempts to develop a method in the initial stage of design process to find an innovative solution of the designs problem. In order to be useful, this should be in such a framework that could respond to designer’s stylistic ambition and meet the functional requirements of the program.

A design language is defined by several shape grammar. For instance, regarding right connection to the circulation space, shape grammar consists of the vocabulary between density, housing units and circulation space. This interaction is based on a rule to create various combinations between housing blocks and circulation blocks, ensuring that all blocks are adjacent to the circulation space in a certain density that different type of housing could be created.
6- Method and Implementation:

The CA model is implemented by Rhinoscript in the Rhino software. A representation in Rhino program gives a possibility to easily manipulate a final shape in the 3D model while at the same time making a series of alternatives.

A form generation first starts by asking for a unit dimension as well as number of units in each row, column and height. User would then be asked to choose the circulation cells which will be remained intact in each floor and consequently determine the position of initial cells floor by floor. Each cell could have two statuses; exist or die, visible or invisible. In each level, circulation spaces will remain unchanged while user can control the status of other cells. At the end, user will be detached from the process and the second stage will be begun.

intNumbX = number of cells in the x direction; columns
intNumbY = number of cells in the y direction; rows
intNumbZ = number of cells in the z direction; height
boxdim = cells dimension

In this stage, computer program will starts to investigate the status of each cell and its neighbors respectively. Then according to the architectural guidelines and algorithmic rules a new status; exits/die will be stored as a record. By finishing the investigation and calculating the new status for the whole units, it will apply to each unit cells and then new pattern would be replaced. This process repeats in a certain number of “iteration time” and generates a various alternatives of units’ combination while meeting the rules and architectural conditions in each cells.

7- Architectural Guidelines:

Algorithmic architecture is required to be defined by the certain number of architectural guidelines. These guidelines should be translated in such a scripting language in the computer program that could define a certain number of rules to perform shape organizations. This technical research is aimed to generate building forms by scripting an algorithm in cellular automata as a computational method with respect to certain number of architectural guidelines. These architectural conditions correspond to a required density, proper access to the circulation spaces as well as access to the appropriate amount of natural light.
The major principle in this design associates to the number of density. This is an attempt to design a high density housing (HDH) in the Netherlands. The number of density in the CA computational method is translated in such a way to be between 35% - 75%, and due to the total number of cells, each unit should meet this requirement 35% < \Delta < 75%.

\( \Delta \): required density around each cell

The topology of cells organizations is based on 2D cellular automata; the arrangement of 8 cells around each unit. These neighbors exert an influence on a specific cell to define its status depending on the principles. In this process, first, current situation would have been investigated and then by calculating and operating the rules, its status would be modified.

There are several data relating to each unit such as type of cells, initial status, circulation status, light status and etc. which should be stored in such a matrix. Each unit of this matrix can be determined by three values \((i, j, k)\) and each of these units have certain number of properties as represented in the follow:

\[
\text{Arrsrf}(i, j, k) = \text{Array (object, count, type, status, circulation status, local horizontal light status, public horizontal light status, local vertical light status, public vertical light status)}
\]

Arrsrf\((i, j, k)\)(0): Physical attribute of the units
Arrsrf\((i, j, k)\)(1): number of cells counting from 0 to n
Arrsrf\((i, j, k)\)(2): type of cells

\[
\begin{align*}
\text{Arrsrf}(i, j, k)(2) &= 0 \text{ circulation cells} \\
\text{Arrsrf}(i, j, k)(2) &= 100 \text{ first round cells with respect to the circulation space} \\
\text{Arrsrf}(i, j, k)(2) &= 200 \text{ second round cells with respect to circulation space}
\end{align*}
\]
Arrsrf(i,j,k)(3): current status of each cells
    Arrsrf(i,j,k)(3) = 0 death cells
    Arrsrf(i,j,k)(3) = 1 existed cells

Arrsrf(i,j,k)(4): returns the status of cells based on circulation rules
    Arrsrf(i,j,k)(4) = 0 a cell do not meet the circulation requirements
    Arrsrf(i,j,k)(4) = 1 a cell meets the circulation requirements

Arrsrf(i,j,k)(5): returns the status of local light rules in the horizontal direction
    Arrsrf(i,j,k)(5) = 0 a cell do not meet the local light rules in the horizontal direction
    Arrsrf(i,j,k)(5) = 1 a cell meets the local light rules in the horizontal direction

Arrsrf(i,j,k)(6): returns the status of general light rules in the horizontal direction
    Arrsrf(i,j,k)(6) = 0 a cell do not meet the total light rules in the horizontal direction
    Arrsrf(i,j,k)(6) = 1 a cell meets the total light rules in the horizontal direction

Arrsrf(i,j,k)(7): returns the status of local light rules in the vertical direction
    Arrsrf(i,j,k)(7) = 0 a cell do not meet the local light rules in the vertical direction
    Arrsrf(i,j,k)(7) = 1 a cell meets the local light rules in the vertical direction

Arrsrf(i,j,k)(8): returns the status of general light rules in the vertical direction
    Arrsrf(i,j,k)(8) = 0 a cell do not meet the total light rules in the vertical direction
    Arrsrf(i,j,k)(8) = 1 a cell meets the total light rules in the vertical direction

7-1- Circulation:
In order that each housing units could be accessible, it should have a proper connection to the circulation spaces. These spaces consists vertical circulations as vertical shafts continuously pass through whole floors as well as horizontal ones which might vary in each floor.
Each cell regarding its juxtaposition to the circulation space can get a value of 0, 100 and 200 which define its type in a certain pattern.

\[
\text{Arrsrf}(i,j,k)(2) = 0; \quad \text{circulation space}
\]
\[
\text{Arrsrf}(i,j,k)(2) = 100; \quad \text{first round cells next to the circulation space}
\]
\[
\text{Arrsrf}(i,j,k)(2) = 200; \quad \text{second round cells next to the first round cells}
\]

In that matter, the process first starts by finding the type of a cell and then investigating its neighbor's situation. Housing units can get two value types; 100 or 200 depending on its closeness to the circulation space.

7-1-1- First round cells:
In this pattern each cell is surrounded by 8 neighbors. Depending on its situation, neighbors can be categorized in three parts:

\[\begin{align*}
\text{a} = \text{number of circulation spaces around it; type} & \quad 0 \\
\text{b} = \text{number of first round cells around it; type} & \quad 100 \\
\text{c} = \text{number of second round cells around it; type} & \quad 200
\end{align*}\]
A cell is defined as a first round cell once it is directly attached to at least one circulation space. Therefore, in the neighbors there is at least one circulation space next to that and then the rest of neighbor cells can be considered to be either first \((b)\) or second round \((c)\) cells. However, some of these cells are alive while some of them are dead. The number of existing cells is called as prime and therefore, these values can be equal or less than the normal value of related cells.

\[
a' = \text{number of existing circulation spaces} \quad a' = a > 1
\]
\[
b' = \text{number of existing first round cells} \quad b' = b
\]
\[
c' = \text{number of existing second round cells} \quad c' = c
\]
\[
0 <= a + b + c <= 8
\]
\[
0 <= a' + b' <= 7
\]
In order to define the circulation rules, density, type of housings and connectivity should be taken into account.

- Due to the required density \( 35\% < \Delta < 75\% \), each cells should have certain number of neighbors around it, \( 3/8 < \Delta < 6/8 \)
- Second round cells could not be existed unless there is a connection to the first round cells.
- Investigating a situation of first round cells can be considered in two ways:

1) \( b \leftrightarrow c \)

First round cell known as \( b \) is required for the existance of second round cells known as \( c \). In other words, second round cells should be attached to first round cells not circulation cells. Thus in this pattern in order to have an appropriate connection between them \( b' = b \), while \( c' \) can be changed depending on the required density in the total neighbors,

\[
\text{Rule a)} \quad a) b' = b \\
\beta) 0 < c' < (c' - 1).
\]

Generating a new pattern besides the above rules depends on the primary status of each cell. In that matter, a cell can have an existing value of either 0 (death) or 1 (alive). Depending on the organization among these values, a number of cells in a pattern would start to grow or decrease and even meet a stable situation. Therefore, the outcome of circulation rule stored in the \( Arrsrf(i,j,k)(4) \) can be considered as follow:

<table>
<thead>
<tr>
<th>( Arrsrf(i,j,k)(3) = 0 )</th>
<th>( Arrsrf(i,j,k)(3) = 1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>0</td>
</tr>
<tr>
<td>( \beta )</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
2) \( b > c \)

In this pattern, the number of existing second round cells can vary, but it should meet the required density and play as a transition space. However, the number of \( b' \) should not be less than \( b/2 \), due to density and connectivity. Since \( b \) is higher than \( c \), the max number of existing second round cells \( c' \) can be \( c \). It is also necessary that \( 3 \leq b' + c' \leq 6 \).

**Rule b)**

\( \alpha \)

\( \frac{b}{2} \leq b' \leq (b - 1) \)

\( \beta \)

\( 0 \leq c' \leq c \)

Same procedure in this rule is required to be considered for the new status of a cell. The result of the circulation rules depends on the existence status of a cell either death or alive is represented as follow:

<table>
<thead>
<tr>
<th>The result of circulation rules (b) in the first round</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( ArrsrF(i,j,k)(3) = 0 )</td>
<td>( ArrsrF(i,j,k)(3) = 1 )</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>0</td>
</tr>
<tr>
<td>( \beta )</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Different types of cell organizations in the first round cells due to the above mentioned rules are represented as follow:
First round cells organization

Regarding circulation rule
7-1-2- Second round cells:
Second round cells are surrounded by 8 neighbors including first (b) and second round (c) types while there is not any circulation space around it. Investigating the situation of this pattern depends on required density, connectivity between them as well as types of apartments.

There are three types of unit apartments: studio, one bedroom and two bedrooms. The two latter ones can only be created in the second round cells and as illustrated in the following pictures, around specific second round cell in the middle the number of first and second round cells are equal in two bedroom apt. or more in the one bedroom apt. Therefore, there must be a right communication between each cell. Investigating the pattern and calculating the situation can be done in three ways:

- Studio
- 1 bedroom apartment
- 2 bedrooms apartment
1) $b < c$:
This situation consists less 1st round cells than 2nd round ones:

$b = \{1, 2, 3\}; \quad c = \{7, 6, 5\}$

Due to the connectivity principles $b'$ should get its max number, $b' = b$; while with respect to the required density there would be a possibility for $c'$ to get different values, $2 \leq c' \leq (c-2)$ and $3 \leq b' + c' \leq 6$

**Rule a)**

$A) \quad b' = b$

$B) \quad 2 \leq c' \leq (c-2); \quad 3 \leq b' + c' \leq 5$

<table>
<thead>
<tr>
<th>$Arrsr(i,j,k)(3) = 0$</th>
<th>$Arrsr(i,j,k)(3) = 1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>$\beta$</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

2) $b = c$

In this pattern $b = 4$ and $c = 4$. Therefore, min and max number of $b'$ and $c'$ can be calculated according to the required density. Besides that it should be considered that the number of existing first round cells should be equal or higher than 2nd round cells.

**Rule b)**

$A) \quad 2 \leq b' \leq 3$

$B) \quad 1 \leq c' \leq 2; \quad 3 \leq b' + c' \leq 5$

<table>
<thead>
<tr>
<th>$Arrsr(i,j,k)(3) = 0$</th>
<th>$Arrsr(i,j,k)(3) = 1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>$\beta$</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
3) $b > c$

In this pattern, a total number of 1st round cells are more than 2nd round ones.

$b = \{5, 6, 7\}; c = \{3, 2, 1\}$

Due to the required density and type of housings, second round cells should keep its value $c' = c$; however, there is a need for appropriate connection between them. Therefore, min and max number of existing second round cells $b'$ can be found with respect to the number of $c'$. Different types of unit organization of this pattern are represented in the following pictures;

**Rule c)**

\[ a) \ 2 \leq b' \leq b - 2 \]

\[ B) \ c' = c \quad 3 \leq b' + c' \leq 5 \]

<table>
<thead>
<tr>
<th>$\text{Arrsrf}(i,j,k)(3) = 0$</th>
<th>$\text{Arrsrf}(i,j,k)(3) = 1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>$\alpha$</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Second round cells organization
Regarding circulation rule
7-2- Light:

One of the main challenges in the housing apartment is to deal with natural light. This matter becomes more important once architects confront with the various numbers of housing units especially in such a high density housing project. Each house should have an access to the natural light in such a way that all areas be covered and not to be left any dark spaces inside. The aim of this research is to calculate the organization of unit cells and generate the building forms in such a way that they could properly access to the natural light.

The procedure of investigation is based on two main directions; vertical and horizontal ones. Depending on each direction, the area that light would pass through might vary. According to the angle of sun radiation in a day, more amount of light could pass through the windows in the vertical direction than horizontal one. Therefore, investigation in the horizontal direction should be done in the wider area in comparison to the vertical direction.

**Fig. pattern in the horizontal direction**

**Fig. pattern in the vertical direction**
Receiving an appropriate amount of light in each cell depends on one fact: no obstacle in its way to sky. In that matter, each cell should be able to transfer the light from its front side to the cells in behind. This feature is then defined as the local rules for each cell. A combination of these rules in each area either horizontal or vertical as well as in each row will determine the final light status of a given cell.

7-2-1- Vertical Direction:
In the 3D model of a cell organization, each cell in the vertical section can access to the light from four directions; 2 in the X-Z (-x, +x) and 2 in the Y-Z (-y, +y). The cells in the perimeter area are directly attached to the outside from their one or two sides in the edges or corners respectively. But the status of the cells in the middle should be investigated from four above mentioned directions.
In each pattern light should pass through area in such a way that the most bottom cell could have an appropriate amount of natural light vertically. There are several possibilities regarding the local organization of these cells. However, some of them are acceptable while the rest of that might not appropriately transfer the light to the next cells. Each unit can be considered in three levels, upper, middle and bottom one. The cells in each pattern would be divided in three parts; inner edge, outer edge and inside cells. A series of cells organization is represented as follow.
These types of patterns correspond to the inner edge cells. Several alternatives are derived from organization among upper, middle and lower level cells. A cell in the middle should be empty. The upper nine cells have one empty cell in the middle row and the other nines have two empty ones. In the horizontal direction the number of empty cells in the bottom is increasing from 0 to 2 while vertically it confronts with the same changes in the upper level.
These types of cells organization relate to the cells inside of a vertical area. Two cells in the middle row should be at least empty in such a way that one of them is located in the center. In the extreme narrow formats, two cells in the top, two cells in the middle and two cells in the bottom are full (alive). However, two of them as represented in the follow are able to transfer the light downward. In the wider format where there are more amounts of empty cells light can easily pass through.
In the outer edge cells (p-b), there is a need for having two empty cells in the middle row. Depending on the direction (x-z or y-z) on cell in the bottom and one in the middle of the top row should be at least empty. Among these formats, only tow ones could transfer the light downward.

The final representation of cells organization in the vertical direction depends on the combination of local rules in each row. In order to combine these local rules in a main rule, a value; inter was defined. This value controls the local light status in each row. Finally this combination among local rules creates a general rule in each direction. For example as can be seen in the following pictures, the total cells meeting the local rules in the second row should be between the range of 2 to 3, $2 \leq \text{inter} \leq 3$. This value in the 4th row should be in the range of 3 to 5, $3 \leq \text{inter} \leq 5$.

A specific cell would reach an appropriate amount of light; arrsrf $(i, j, k)$ (8) - 1, once the general rule is to be met. This process would repeat in each of the 4 directions, $\pm X$, $\pm Y$ to find a final light status of a certain cell.
Three different samples regarding the light status in the vertical section of a certain cell are presented as follow. Two of them do not get enough light, however the last one does.
7-2-2- Horizontal Direction:
The process of light investigation in the horizontal section is relatively the same as that in the vertical one. But there are differences between desired local rules as well as general one in a certain pattern. Since in the horizontal section more amount of light is required to pass through, the investigation is being done in the wider area than vertical pattern.
The perimeter cells are directly attached to the outside from one or two sides. But the inner cells can access to the natural light from 8 different ways, 4 in the X direction and 4 in the Y direction. Thus four patterns in each direction would be created and are required to be investigated.

In terms of local light transfer, there are several cells combinations around each cell in the upper, middle and bottom part. There are several representation of cells organization in each direction. A cell in the middle should be empty and with relation to the status of adjacent cells a series of alternatives would be created. However, some of them do not meet the min. requirements in order to pass the light through their neighbors. Besides that, depending on the location of a cell in the pattern, different choices would be selected and applied to the cells.

The organization among these 9 cells is based on a simple rule. Arrangement among empty and full cells in each row would create a vast number of alternatives. Each cell could get two statuses; 0 or 1. Totally there are 512 representations made out of these 9 cells; however, some of those created pattern are fully blocked and the rest are needed to be investigated. As represented in the following pictures they are divided into three main generations and each one has a certain number of alternatives. The division is based on changing the number of empty cells in the middle as well as alternating the status of cells in the upper and bottom rows horizontally and vertically.
The organization among these patterns is based on having three empty cells in the middle row. The number of empty cells in the bottom row is increasing from left to right while it also increases in the upper row from top to bottom.
In this pattern there are two empty cells in the middle and one of them in the central cell. Again same process happens for the cells in the bottom and above cells in order to create different number of alternatives.

Second generation of horizontal cells organization
Regarding light rule in the horizontal direction
In this last generation, there is only one empty cell in the center. With respect to having enough space, there are only 7 numbers of patterns which can freely transfer the light from upper row to the bottom one. The rest of them are either blocked or create a narrow space which are not suitable.

On the other hand, meeting the demand for natural light depends on the arrangement of proper local rules in each row defined as a general rules. Therefore, investigation is based on both local and general rules. In that matter, depending on meeting the local and general rules, there would be some alternatives that in spite of having some unit cells in their way through outside, light could appropriately reach a certain cell.
Do
For s = 2a To 2a + 1
For p = 0 To 2b
X = i + s
Y = j + p
Z = k
\[ arrsf(i, j, k)(6) = 1 \]
Next
Next
\[ \text{inter} = \text{inter} + \text{arrsf}(X, Y, Z)(5) \]
Next
Next
\[ s = \{0, 1\}; p = \{0\} \]
\[ s = \{2, 3\}; p = \{0, 1, 2\} \]
\[ s = \{4, 5\}; p = \{0, 1, 2, 3, 4\} \]
\[ s = \{6, 7\}; p = \{0, 1, 2, 3, 4, 5, 6\} \]
\[ s = \{8, 9\}; p = \{0, 1, 2, 3, 4, 5, 6, 7, 8\} \]
\[ s = \{2a, 2a+1\}; p = \{0, 1, 2, ..., 2b\} \]
Loop

The final light status of each cell depends on meeting the local as well as general rules which can be 0 or 1. A cell has an access to the natural light in the horizontal section once the final value becomes 1, \( arrsf(i, j, k)(6) = 1 \).
8- Final Outcomes:

In order to create a series of shapes that would meet our principle architectural rules, an algorithm firstly investigate an initial pattern. By controlling the first pattern, based on the attachment to the circulation spaces, new pattern would be defined, however this pattern is still required to meet the light rules. Therefore, creating different alternatives would happen by different types of attachment, density requirement, as well as controlling to fulfill lighting rules. In the following pictures, a series of alternatives are illustrated. They are based on a grid of 12x9 and 3 stories height. In that way, firstly, a location of circulation spaces as well as initial cells of each floor would be applied in a certain manner. Then the results of applying rules after 30 times of iteration would be kept. This process with the same location of circulation spaces and existing initial cells would be repeated in 3 times and at the end the result could be compared to each other respectively.

Initial Pattern generated by a user

![Initial pattern; 1st floor](image)
![Initial pattern; 2nd floor](image)
![Initial pattern; 3rd floor](image)
1\textsuperscript{st} Generated pattern after 30 times of iteration

1\textsuperscript{st} floor pattern  2\textsuperscript{nd} floor pattern  3\textsuperscript{rd} floor pattern

2\textsuperscript{nd} Generated pattern after 30 times of iteration

1\textsuperscript{st} floor pattern  2\textsuperscript{nd} floor pattern  3\textsuperscript{rd} floor pattern
3rd Generated pattern after 30 times of iteration

1st floor pattern  2nd floor pattern  3rd floor pattern
As can be seen in the above picture, from left to right, there are a series of cells attached to the circulation spaces shown with the red color. While those green cells should be attached to the red ones, they should be organized in such a way to be able to reach enough amount of light from outside. This process can be done even horizontally or vertically. A part of these pictures that could well show the horizontal light access can be seen in the 2nd generated pattern. There are a large number of accumulated cells in the 2nd floor which do not face to the outside in an appropriate horizontal way. However, by comparing the 3rd floor with the second one, it is clearly illustrated that the number of cells in that floor has extremely decreased. The effect of this event and cells organization would influence on creating a way to pass natural light to the beneath cells.

- Wing A
- Wing B
- Wing C
- Wing D & E

Four different alternatives relating to the design project.
Part 3
Design Process
1- Housings

Due to the programmatic function, this project is aimed to create a series of studio, one bedroom and 2 bedrooms apartments\(^1\). Basically, each type of housing is a proportional module of a unit with 5.4 by 5.4 m\(^2\). As described in the research section, the result of scripting an algorithm is a series of cells organized in a certain manner. The main characteristics of these patterns are firstly having appropriate access to the circulation spaces, and secondly having at least one side oriented through external light while meeting a certain number of density.

In order to design an interior space of housing which could be expanded in a different series of cells organization, it was necessary to first realize a situation of each cell through outside and its neighbours. Therefore, in the post-processing of cells organizations and in the way of coming back to the design process, we had to first get to know about the status of each cells. As can be seen in the following picture, there are lots of combination among cells creating different housing apartments.

\(^1\) - In some sentences, Studio might be called as “One unit apartment”, one bedroom apartment as “Two unit apartments” and two bedrooms apartment called as “Three unit apartments”.
However, due to the fact of architectural issues, some of those patterns are not acceptable. For example, some of them can be considered as either one or two room apartments and it would make a confusing pattern in the whole blocks. Therefore, the final results which could fulfil the major aspects of architectural guidelines can be divided into 9 types, illustrated in the following picture.

<table>
<thead>
<tr>
<th>Different types of housing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>In the middle</td>
</tr>
<tr>
<td>1 room apartment</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>2 room apartments</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>3 room apartments</td>
</tr>
</tbody>
</table>

Besides that, it is necessary to know about the position of external sides accessing to the outside in order to be able to design an interior spaces. In addition to the status of each individual unit, a combination of one, two or three unit apartments makes complicated patterns and it is required to simplify the design process. For example, a mirror condition of one type of three unit cell would make a completely unpredictable pattern in terms of knowing from which side it is either blocked or open through outside. However, by shifting a third cell one layer upward, a new simplified type of duplex housing could be generated.
The first step of interior housing design is to know the situation of periphery walls through external world. Basically there are four types of opening which can be seen in every building. In that matter, each one can be considered as one unit apartment while a combination between two, consequently creates different types of two unit apartments.
However, in order to consider all types of housing apartments in different situations, we need to focus on two basic types:

- Single Orientation Unit
- Double Orientation Unit

Depending on the position of core elements including kitchen, toilet, bathroom and interior stairs, entrance position and the depth necessary for each space, several typical variations could be designed.

1-1- Single Orientation Unit:
Units with one side looking through outside could have two types; core elements arranged along transverse wall or along longitudinal walls. The location of wet zone; kitchen and bath as well as vertical shafts depend on the neighbouring houses in the vertical and horizontal direction.
In the more common type of single orientation unit, the core elements are arranged in a zone parallel and adjacent to the entrance side. Entrance is through this zone into the main spaces of the apartment, thus letting the major rooms open to the proffered side of the building. The kitchen and bath are interior spaces with mechanical ventilation. Some examples of this type of housing are Lake Shore Drive apartment design by Mies Van der Rohe, Marina City in Chicago designed by Bertrand Goldberg, Capsol tower designed by Kisho Kurokawa and WoZoCo's housing in Amsterdam designed by MVRDV.
Marina City, Chicago, USA, 1964, Bertrand Goldberg

Capsule tower, Tokyo, Japan 1972, designed by Kisho Kurokawa
In the scheme of having wet zone on the longitudinal side, kitchen could have a look through outside like the Horizon Apartments designed by Harry Seidler in Sydney Australia. This can be considered in one hand as a disadvantage of taking a space of exterior surface which could be better use for living and sleeping area, and on the other hand it can be considered as a benefit of having natural light in the kitchen.
The influence of vertical shaft location as a result of housing arrangement in the vertical and horizontal pattern would exert an influence on the right decision of core elements position. An awkward plan can be a one with the kitchen in one side and bathroom on the other side.

In this project, a right location for the core elements was designed in such a way to have an efficient relation between unit and its neighbours in terms of mechanical systems and to minimize the left over spaces.

Due to the alternation of housing in each floor, the most significant issue in the design of housing is a way to find a proper relation between houses in the vertical direction. This aspect would create different possibilities of placing core elements in a right manner.
An appropriate area regarding Shaft Location

<table>
<thead>
<tr>
<th>1 unit apartment</th>
<th>2 units apartment</th>
</tr>
</thead>
</table>

Typical Studio apartments
Scale: 1:200
Single Orientation Unit in this project can be seen in two housing types; one unit apartment and 2 units apartments. The former one is open through outside at least from its front side. Two unit apartments can be divided into two part, a first half is a type of unit with one external surface, one interior side and two blocked exterior ones. However, the second half is a type of double oriented unit looking through outside.

1-2- Double Orientation Unit:
Double oriented unit types come in many variations and can be collected together in many different ways. The corner type or the one which is called 90 degree double orientation can be seen as single oriented unit by dividing it into tow parts while one of the three closed walls has been open up.
One example of one or two story corner units included the atrium houses at Schwerzenback in Switzerland by Kunz and the Candilis, Josic and Woods projects which often consists of buildings planned to gain the corner advantage even to the extend of creating site arrangements consisting of many staggered plan building in an overall system designed to maximize peripheral surface.

Some terrace housing projects where the roof of one house becomes a terrace of the upper one utilize a more complex version of double oriented unit type. The drawing of Alto terrace house at Kauhtua shows the three dimensional view of the stepped back housing with openings to three sides. Another example of terrace housing is a Habitat '67 design by Moshe Safdie. This project with 3 types of housing creates a living environment with staggering forms and series of terrace roofs.
Terras Housing, Kauttua, Finland, Alvar Alto, 1938

Typical Floor plan of Habitat '67, Canada, Moshe Safdie, 1967

Section of Habitat ‘67, Montreal, Canada, Moshe Safdie, 1967
As illustrated in the earlier pictures, in this design-research project, there are two main types of two unit apartments, one with entrance along one edge and one with entrance from corner. The latter case can be considered in two different directions and they might have overlapping when they are stacking on top of each other. Thus, that overlapped area should be considered in such a way to be designed efficiently in terms of core elements as well as required spaces for the mechanical systems.
Typical one bedroom apartment (2 unit cells); entrance from the edge

Scale: 1:200
In the case of three room apartments which is a kind of duplex housing, interior stairs can be situated either along the longitudinal or perpendicular to that. The former one, longitudinal type which also called as “dumbbell” consists of stairs along one side and the major living spaces positioned along the outside surfaces where an opening through private outdoor space is as possibility while keeping the core elements in the interior. In some case, there is a void in one end and the concentration of parts in the middle.
Perhaps a good example of this type of housing is Le Corbusier's Unite d'Habitation, a building that has been slightly copied in Europe and the rest of the countries in the world. A double loaded, skip-stop corridor gives access to a two level unit with kitchen, dinning and living area at entry level while bedrooms and bathroom are located above. Here, the core elements, including the stairs are interior, although the stairs rises from a double height living room.
Unite d’Habitation, Marseilles. Le Corbusier, 1952
In this design-research project three unit housings (2 bedroom apartments) can be categorized into two major types; one with access from a side and one with access from a corner. However, depending on the location of adjacent units, interior spaces vary case by case. It was the most difficult process to minimize this type of housing into two or three unit forms. In addition to housing neighbors, the relation between cells in the vertical direction had a significant influence on the positioning of core elements and other spaces such as bedroom, living rooms and dining room.

In the type with entrance along one side, wet zones including bath, toilet and kitchen are located in the middle. There are two alternatives for the housing type with an entrance along its edge. The wet zone is located in the middle and while the vertical shaft is kept in one location, the rest of spaces are mirrored along the longitudinal central line. This type includes an interior stairs situated in the transverse sides. In the ground level, living and dining room are located in both sides of kitchen located in the middle. The upper level includes bathroom, toilets and master bedroom as well as one single bedroom which have an access through external natural light.

Type C1-1; two bedroom apartments (entrance from the side); Scale 1:200
Type C1-2; two bedroom apartments; entrance from the side
Scale 1:200
In the second type with an access from the corner, interior stairs is located along the longitudinal edge which does not have an access through external light depending on the neighbor housing. Dining room and living room in the both sides of kitchen look through outside. In the upper floor a master bedroom and a single bedroom alongside a laundry room are situated in the both side of bathroom situated in the middle. The location of bathroom is on the top of the kitchen in the level below where they both could access to the one vertical shaft.

**Type C2: Two bedroom apartments; Entrance from the corner**

**First Floor**
Scale 1:200

**Second Floor**
Scale 1:200
Arranged in 5 wings, a series of working and living spaces organized around a central yard. Wing A consists of commercial spaces in the ground level, shopping stores in the first level and dwellings up to four stories on top. In compare to that, wing E which has a physical relation to the wing D includes offices in the ground level and a series of housing apartments above. The rest of those wings designed in such a way to create parking lots in the ground level and housing units on top one with different zoning in the vertical direction. The manifold interaction of units and empty spaces creates a continuous access through light for each housing while at the same time recalling a range of private to public zone for the inhabitants. The position of units ensures that each unit has a degree of privacy, while providing views through the site in different level. Therefore, terraces in those blocks can be ranged from public to private while at the same time activities range from public to private from bottom to top. The upper floor of dwellings can be considered as a semi-public space where only inhabitants of each block can use that. Besides that, projection and recessions provide some apartments with a private terrace on top of the roof of underneath house. In dome cases, there is also a projection outward which creates an iconic architectural and memorable environment for the users.
Three different alternatives of housing blocks
<table>
<thead>
<tr>
<th>Type of Housings in different wings (A-E)</th>
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</thead>
<tbody>
<tr>
<td><strong>Number of housings in different wings</strong></td>
</tr>
<tr>
<td><strong>Type of Housings</strong></td>
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<tr>
<td>----------------------</td>
</tr>
<tr>
<td>Studio</td>
</tr>
<tr>
<td>Type A1</td>
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<tr>
<td>Type A2</td>
</tr>
<tr>
<td>One Bedroom</td>
</tr>
<tr>
<td>Type B1</td>
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<tr>
<td>Type B2</td>
</tr>
<tr>
<td>Two Bedrooms</td>
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<tr>
<td>Type C1</td>
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<tr>
<td>Type C2</td>
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<tr>
<td>Total</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Space Area of Program Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
</tr>
<tr>
<td>Commercial</td>
</tr>
<tr>
<td>Office Space 1</td>
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<tr>
<td>Office Space 2</td>
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<tr>
<td>Retail</td>
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<tr>
<td>Supermarket</td>
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<td>Residential</td>
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<td>One Bedroom</td>
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<tr>
<td>Two Bedrooms</td>
</tr>
<tr>
<td>Parking lots</td>
</tr>
<tr>
<td>Cafe/Restaurant</td>
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<tr>
<td>Restaurant</td>
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<td>Sport center</td>
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<tr>
<td>Gymnasium</td>
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<tr>
<td>Sauna</td>
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<tr>
<td>Multifunctional</td>
</tr>
<tr>
<td>Conference Hall</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

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2- Circulation Spaces:
Building forms resulting from the collecting together of many units into a single building are closely tied to a number of possible circulation options. The type of circulation spaces can be categorized in different ways; such as private access, multiple vertical access, corridor systems and double-loaded split-level systems. However, the main focus in this project is a multiple vertical access. This type can be built up to five stories without elevators, however, more often three stories is a limit for walk-up multiple access buildings. This type of circulation space was very common in Europe and a consequent rapid construction of high-rise building.

In spite of most vertical access which serves 2-4 units per floor, each vertical access of this project is designed in such a form to make a possibility for serving 8 units per floor with semi-private entrance to each apartment. Since the system permits vertical staking it becomes a kind of vertical row house or row houses stacked upon row houses. If a vertical access core is greatly extruded and centralized, the result is a tower, which may be described as a group of units hooked together along a vertical street.

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3- Structural Systems:

The construction of buildings is based on huge structure supported by a series of central cores and concrete columns. The difficulties for the arrangement of columns exerted an influence on the architectural organization of different functions stacked vertically on top of each other. The distances between axis of each column had to be considered in such a way to fulfill the requirements of different zoning from bottom to top; parking lots, offices, shopping stores and dwellings. Therefore, according to the dimension studies, the structure which could efficiently used for those functions is based on 5.4 by 5.4 m grid. However, in the utmost external side of each wing, the cells in the second round of the grids are cantilevered by 5.4 m long span. This outstanding characteristic would resemble the technological development of this project. Due to the long span of the floor and according to the dead load and live load of the housing units, it was necessary to have some calculation simulation modeling to ensure the safety of the building. The result of this simulation modeling of displacement and principle stresses are presented as follow.
Structural grid of floor plan, reinforced concrete columns with the span of 540 cm situated around a central concrete core.

A part of housing apartment which clearly represents the distribution of forces through the building.
A 3D drawing of one part of the project chosen to be analyzed in the computer program regarding structural stability

Simulated model generated in the Diana structural software
Simulation modeling of displacement in vertical direction
4- Mechanical Systems:

Mechanical systems are an inseparable part of each building. Choosing an appropriate mechanical system and considering its required spaces have a significant influence in the design processes. In an integrated design approach, the effect of mechanical designs besides structural ones comes hand in hand forward the design process. Although in a small scale of housing apartments, the effect of different aspects can be reached more easily but in a kind of high density housings the influence of this cooperation becomes more challenging.

A space for water supply, drainage and rain water pipes alongside ventilation ducts, a shaft should be considered in such a place to minimize the waste spaces in the horizontal and vertical directions. In the horizontal direction it should be located in such a place with a close relation to the wet zone including kitchen and bathrooms. An awkward solution is the one where kitchen, bathroom and shafts are located in different positions. In the vertical direction, considering different functions accumulated on top of each other has a significant effect on right location and dimension of space for mechanical objects. In this project there are three different functions including offices, shopping stores and housing apartments which are located vertically on top of each other. In addition, the complex organization of housing units in a series of patterns should be taken into account in order to optimize a number of shaft locations.

As can be seen in the following picture, different housings; studio, one and two bedrooms apartments, overlap each other in a certain manner. Therefore, these spaces can be considered as wet zones chosen for kitchen and bathrooms. Although housing units have different floor plans which in some case mirrored along a center line, but the spaces for mechanical objects, shafts continue vertically from bottom to top.

1 - These types of housing can be seen in the typical floor plan of one bedroom apartment called as B1-1 and B1-2 as well as two bedrooms apartment called as C1-1 and C1-2.
Shaft locations in a grid plan

Wet zone in the studios, one and two bedrooms apartments
Natural air in the housings is circulated through operable windows controlling by inhabitants need. However, ventilation in the public zone; offices and shopping stores in the ground and first floor respectively is regulated centrally by mechanical systems. Meeting human comfort is also required to consider the amount of heating and cooling needs. Although buildings skin, facades and material used should be selected in order to minimize the environmental impacts and reduce the energy consumption but there is a need for heating and cooling sources. There were three heating/cooling systems including heat pump, heat recovery system and floor heating which were discussed regarding their efficiencies and adaptability in this project. For example heat recovery system is more suitable in those spaces with no operable windows while floor heating is only able to warm up the spaces. Therefore, due to the large volume of housing apartments and characteristic of different mechanical systems, heat pump seems to be more suitable in this project.

Heat pumps are cooling machines that draw energy from the environment in a cyclical process raising it to a higher temperature level which is then suitable for heating purposes. This technology moves heat from a low temperature heat source to a higher temperature heat sink. The most common type of heat pump is the air-source heat pumps which transfer the heat between in inside and outside air. They can do the work of heating and cooling so there is no need for installing separate systems. Besides that, they work efficiently since they transfer heat rather than burn fuel or create it.

Mechanical zone in plan and section  Heat pump diagram