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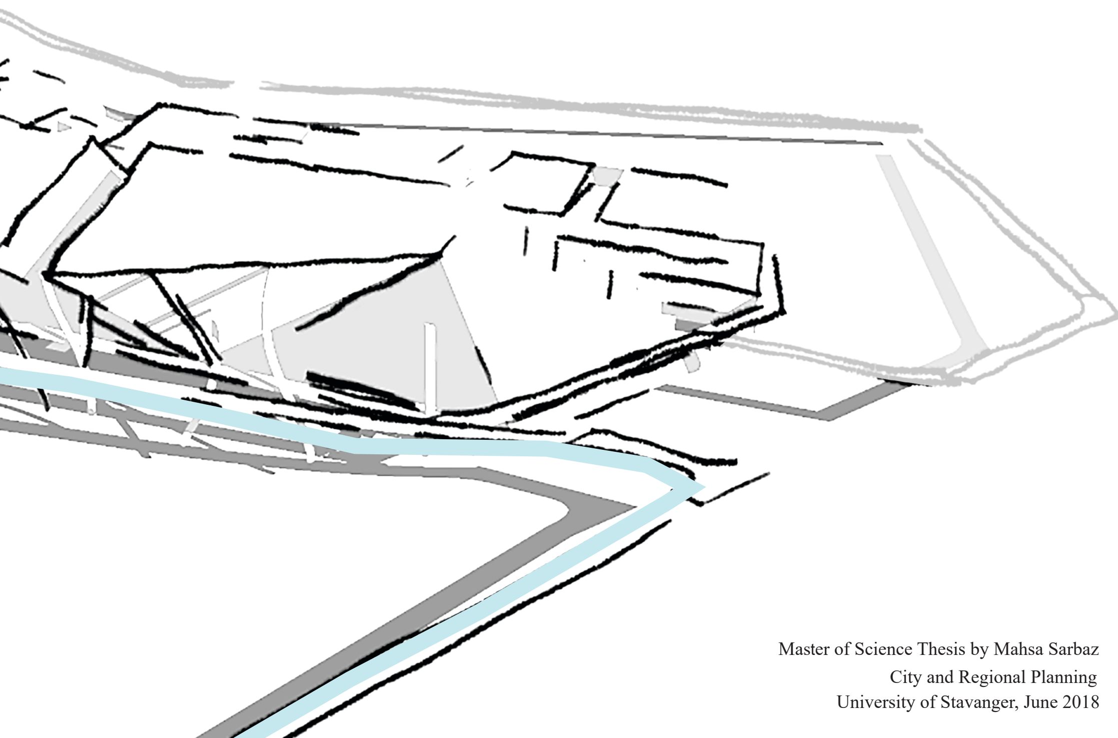
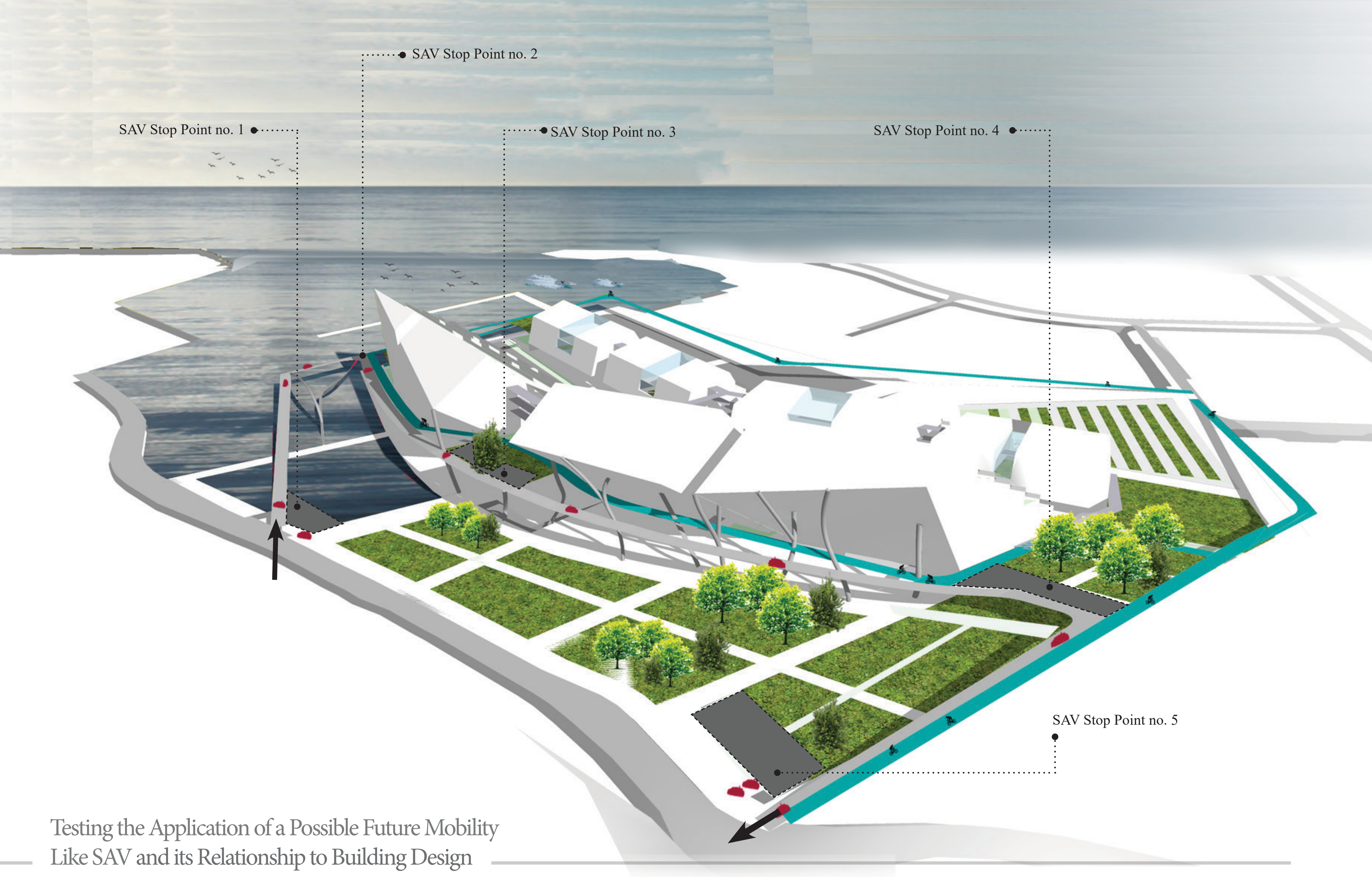
Testing the Application of a Possible Future Mobility Like SAV and its Relationship to Building Design



Master of Science Thesis by Mahsa Sarbaz
City and Regional Planning
University of Stavanger, June 2018



Testing the Application of a Possible Future Mobility Like SAV and its Relationship to Building Design

Mahsa Sarbaz, Master of Science Thesis, City and Regional Planning
University of Stavanger
June 2018

Abstract

Energy use is changing quickly in recent years and the use of renewable sources needs to ramp up in order to conserve the natural resources, and to reduce environmental pollution and climate change. Transportation and Building sectors are among the main influencers in this matter; hence, they have been the main target for solution findings. In this regard, Nearly Zero Energy Buildings (NZEB) in the building sector and shared autonomous vehicles (SAV) in the transportation sector are both aligned with the European Union 2050 low-carbon economy road-map.

The main question that this thesis aims to focus on is to explore:
What would be the relationship between NZEB and SAV through a building design on an actual site (Hinna Park, Stavanger) and their impacts on mobility access, routes, parking spaces, and stairs?

This thesis is a scenario-based design with further studies on the chosen scenario as a simplified feasibility study. First in the analysis chapter, NZEB design factors and possibilities of interaction between NZEB and SAV in different floor levels were analyzed in order to set design criteria. Then, the chosen criteria were used to form the building envelope and program distribution of the building. Finally, in the design outcome chapter, the relationship between SAV application and its impact on access, routes, parking spaces, use of stairs and elevator's congestion were tested.

After exploring different scenarios, the thesis concludes that by the use of SAV application, the large freed parking space could be repurposed to public oriented spaces; and, providing mobility access (SAV, Bike and Walk routes) in different floor levels with a number of strategic stop points would have a positive impact in use of stair and reducing the number or the capacity of required elevators.

Acknowledgements

It has been an intensive period of 2.5 years studying in City and Regional Planning with a bachelor degree in Architecture. Writing this note of thanks on my thesis is the finishing touch of a challenging journey that impacted me not only in the scientific arena, but also on a personal level.

I acknowledge with gratitude to my thesis Supervisor Prof. Harald N. Røstvik at University of Stavanger. The door to Harald office was always open whenever I needed or had a question about my thesis or writing. I am deeply indebted to him for his invaluable guidance and advice on this thesis.

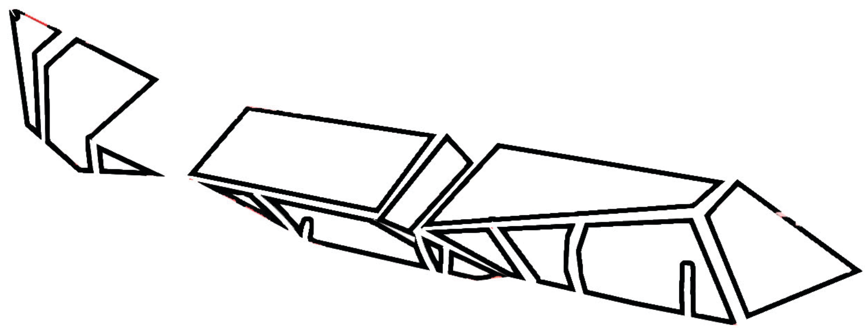
I would like to thank Prof. Reze Jafarpour for inspiring me in the world of Architecture and Prof. Anders Langeland as my first mentor at University of Stavanger. I would also like to express my appreciation to Prof. Daniela Müller-Eie for her continuous support and guidance and special thanks to Stine Thu Johannessen for her unconditional help.

Last but not the least, I would like to thank my friends, family specially my mother for being always there, and my husband for his never ending encouragements.

This achievement would not have been possible without them.

Stavanger, June 2018

Mahsa Sarbaz



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Introduction

This chapter provides background and relevant theories, thesis methodology, site location and site context.

Background

Nearly Zero Energy Buildings (NZEB)

In Building sector, development of NZEB intends to eliminate greenhouse gas emissions by combining energy efficiency, renewable energy generation on site, and grid balancing. NZEB will not belong to the buildings in the future but it is a realistic solution that is gaining momentum globally. European Union has defined nearly zero-energy buildings strategy by setting energy performance of buildings and energy efficiency directives as the main instrument promoting the improvement of the energy performance of buildings within the EU and providing a stable environment for investment decisions to be taken. These directives require all new buildings to be nearly zero-energy by the end of 2020. This will follow up with market tracking and scenarios monitoring in line with European Union target to cut 90% of the greenhouse gas emissions from houses and office buildings by 2050 (European Commission 2018).

Shared Autonomous Vehicles (SAV)

Private vehicles became the main means for personal mobility in the 20th century and have caused many problems such as environmental pollution due to production of greenhouse gases, city congestion and rising need for parking spaces. However, this is changing now due to many factors such as spread use of renewable resources instead of fossil fuels. Parking spaces can consume a lot of space in public areas and private buildings. SAV concept is about switching from personal vehicles to shared driverless vehicles with the use of a mobile application or other means with potential to travel faster, easier and cleaner. SAV will revolutionize the transportation system and the face of cities. It can reduce the vehicle ownership among households and also the required parking spaces in public areas. Although the impact on private areas may vary and yet to be investigated, implementation of SAV could greatly reduce vehicle ownership in multi-dwelling buildings (Maurer, Lenz and Winner 2016).

NZEB and SAV are Aligned with EU Low-Carbon Economy Roadmap

Both NZEB and SAV are in line with European Union low-carbon economy roadmap. This roadmap suggests that by 2050 the EU should cut greenhouse gas emissions to 80% below 1990 levels and all sectors including buildings and transportation should contribute to it. Contrasting to NZEB, which is much ahead in terms of strategy, regulatory regime and implementation, SAV is lagging behind with much more work yet to be done.

Parking Spaces

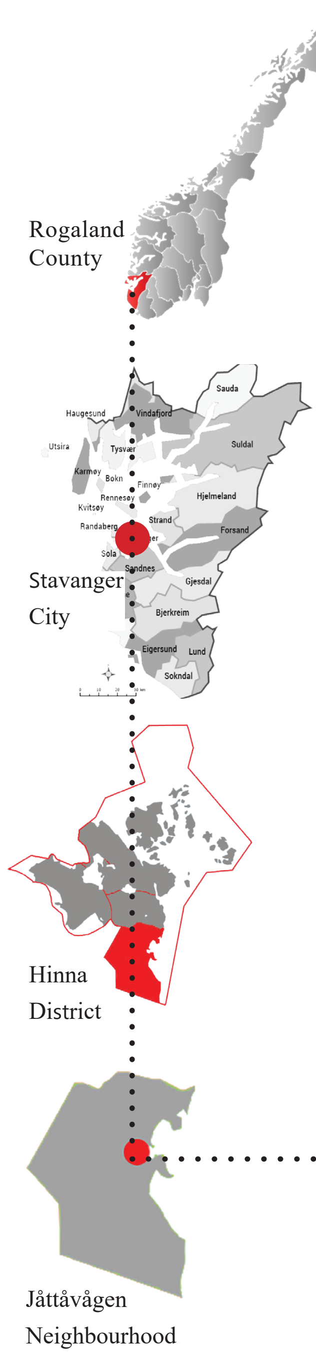
Congestion and air pollution are consequences of the common mobility systems, impacting the quality of life in residential neighborhoods. Parking spaces get more expensive and harder to find day by day. SAV could help this increasing challenge by reducing the required parking spaces. For the purpose of this thesis, NZEB, SAV, and the parking spaces interact closely with each other.

BEVs and Building

In line with the European Union 2050 target, battery electric vehicles (BEV) could lead to de-carbonization in transportation sector. Shared autonomous vehicles could be BEVs that utilize chemical energy stored in rechargeable battery packs. This will be provided by the installation of SAV fast charging stations within the building (European Commission 2018).

Methodology

The methodology used in this thesis was scenario-based design. It started with developing context related hypothetical design scenarios and then analysis of their contextual pros and cons in order to select the most feasible one. Shared Autonomous Vehicles (SAV) is still a conceptual mobility solution and yet to become practical as such. Therefore, use of scenario-based design was relevant in exploring the NZEB design and application of SAV on an actual site. Materials used in the thesis were mainly secondary data from European Union commission and its priorities, Stavanger Municipality and statistics. Various literature regarding SAV concept and, selected examples of NZEB in Europe were studied to provide background and basis in the analysis.



The Site

The site is located on Jåttåvågen in Stavanger Municipality, approximately 7 km from Stavanger city center. It lies between the railway line and Jærveien and is adjacent to the waterfront from the east side. The site is approximately around 51,206 m² and is a part of Jåttåvågen construction project. Jåttåvågen is an important urban development area in the Stavanger municipality and the development of Jåttåvågen must be assessed in a regional scale. The planning of this site should establish a center in the region for various events and activities (Stavanger Municipality 2018).

Site Context

Following figures are bird eye views over the site context and the landmarks around, the highlighted elements are mapped in Fig. 4. The buildings that are highlighted in Fig.1 are the existing buildings on site and are part of the Hinna park project. Fig. 2, is the concrete tower “Skråtårnet”, built in 1984 and was used until 1994. To many, this tower symbolizes the North Sea oil adventure. From October 2007, the tower was opened to the public. Fig. 3 is the Viking Stadium, a football stadium which was inaugurated in May 2004 (Stavanger Municipality 2018).

Fig. 1: Existing buildings (“Skråtårnet”, [image], 2014)

Fig. 2: Skråtårnet

Fig. 3: Viking Stadium (“Viking Stadium”, [image], 2013)

Fig. 4: Site Context map

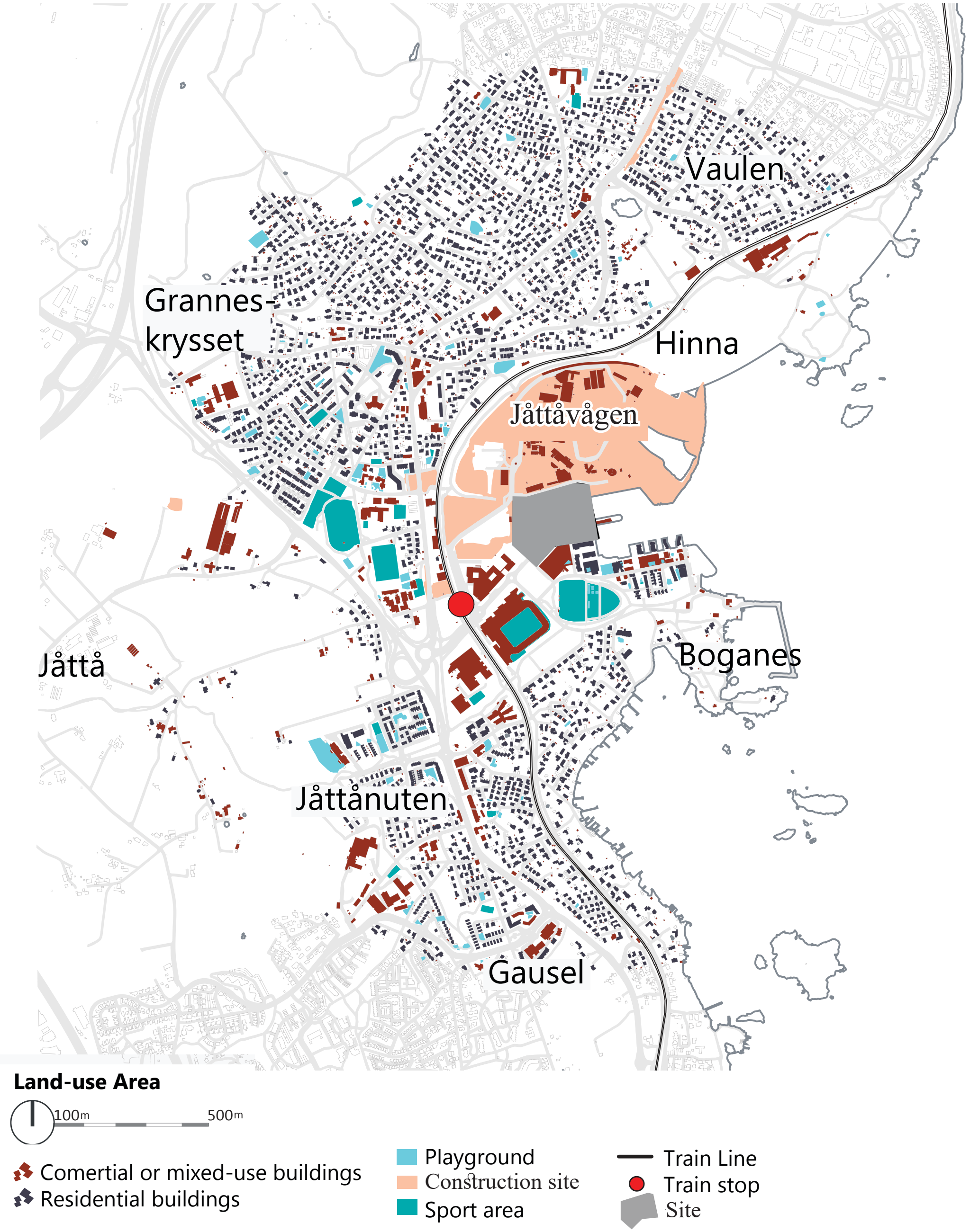
Analysis

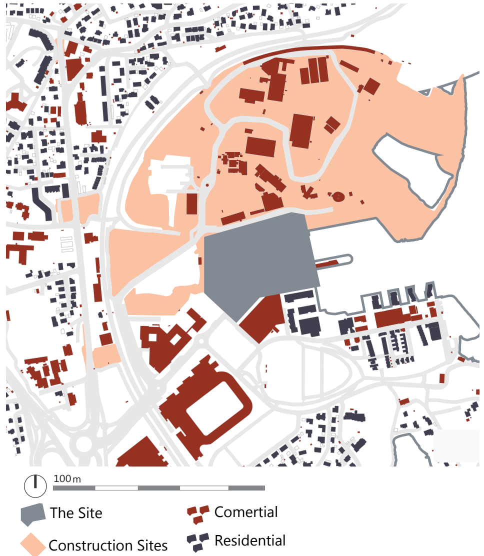
This chapter analyzes the important elements to design NZEB in Hinna park, Stavanger. Different scenarios regarding the possibility of interaction between SAV, Bike route, Walk route, and NZEB were explored. Following topics were analyzed in order to set the design criteria:

- Program Distribution
- Public Transportation Access
- Bike Route
- Climate
- Energy Demand and Supply
- SAV – Impact on Parking Spaces
- SAV – Access
- SAV – Interaction with the Building
- SAV – Stop Points
- Create Landmarks with Bike Route
- Elevators
- Analysis Summary

Program Distribution

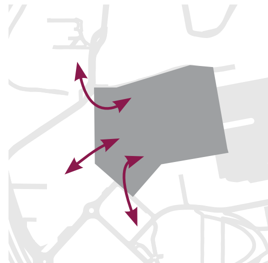
The footprint of residential and commercial buildings as well as land use areas are illustrated in the map below. The Viking Stadium and several sport areas are situated around this site. However, there is not any good quality playground space for kids within 500 m^2 distance from the site.





Construction Sites

The south side of the site is occupied with an office-commercial complex. The north side, on the other hand, is a construction site which is also planned to be a residential-commercial-office complex. Therefore, this site is surrounded by a multi-used built spaces.

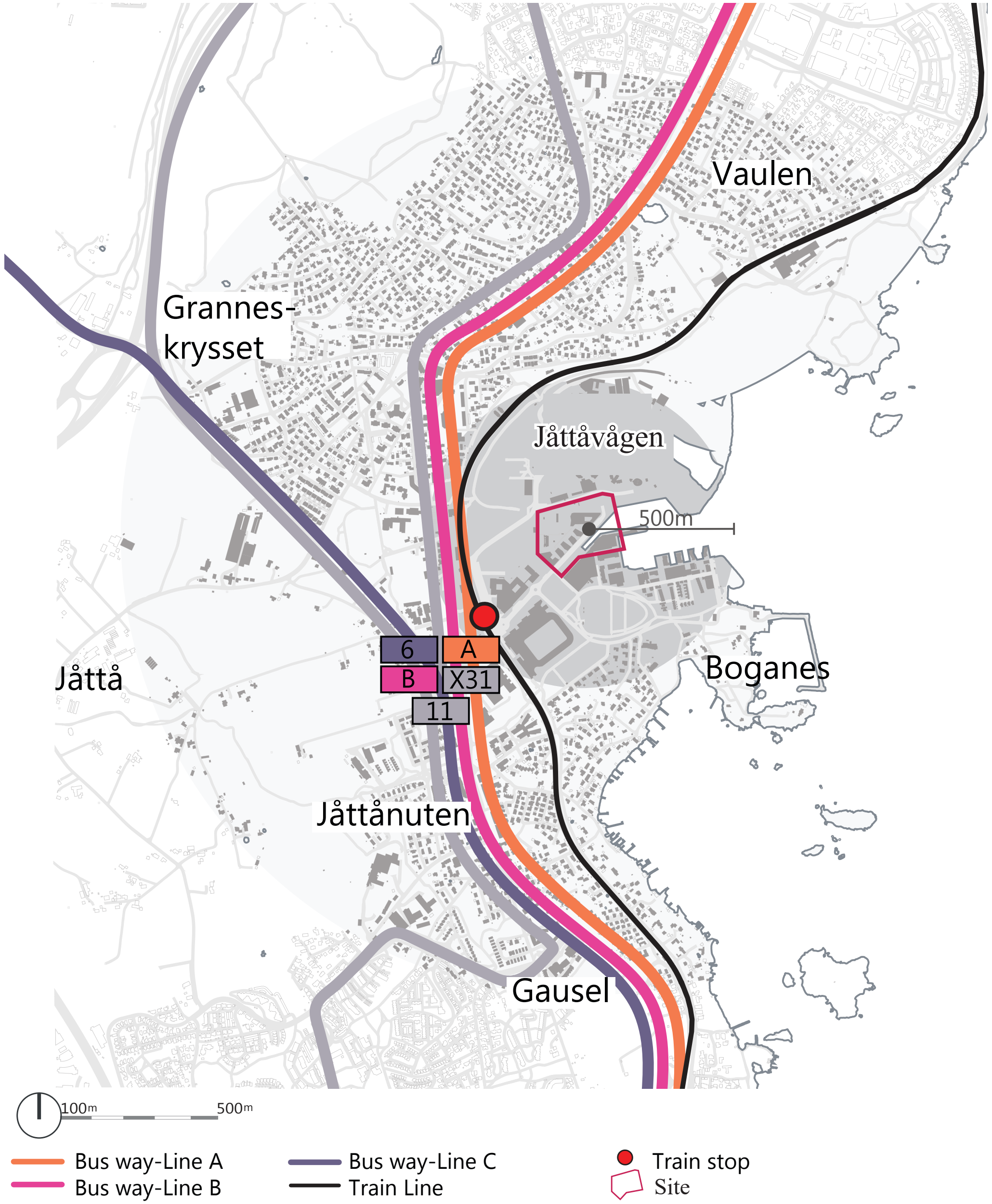


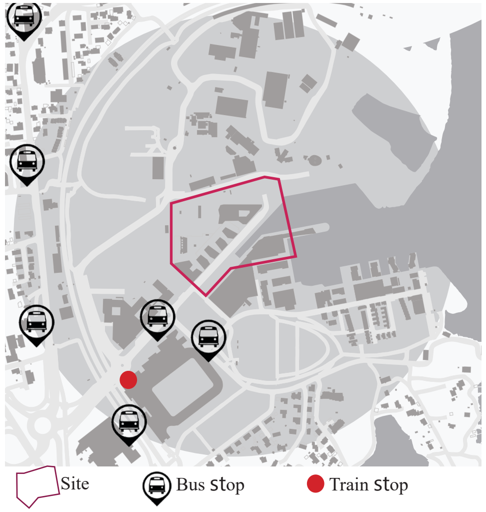
Design Criterion

It was concluded that open spaces on all sides of the site should be designed based on human scale factors to have a positive impact on the residential value of the neighborhood.

Public Transportation Access

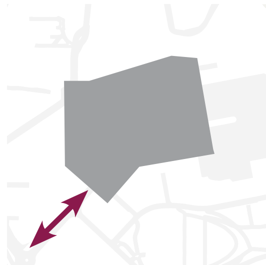
The bus routes, bus stops, as well as the train stations are illustrated in the map below. The site has a good access to a variety of public transportations. The train between Stavanger and Sandnes has a stop with less than 500 meters distance from the site.





Bus Stops

Access to the bus and train stops are from south west side of the site. There are no stops on the north side of the site within 500 meter distance.



Design Criterion

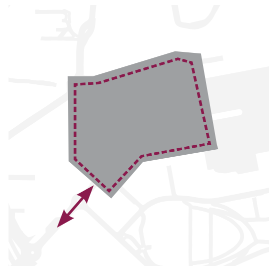
Based on this analysis, the public access should be considered on the south west side of the site.

Bike Route

This site has a good access to a variety of bike routes. The vast area and varied land use provide a good basis for a large proportion of cycling or walking trips. A public seafront platform on the east of the site will constitute an important link in the main road along the sea between Stavanger and Sandnes. The regional, international, and local bike ways as well as bike roads are illustrated in the map below.

International Bike Way

The international bike way passes on the west side of the site. Creating public open spaces that are usable by both cyclists and pedestrians on site could significantly improve the value of the region.



Design Criterion

Based on this analysis, bike routes should be designed to connect open spaces and provide opportunity for passing cyclists to stay and enjoy the open spaces in the entire site.

Climate

Sunlight Exposure

The site has relatively good south sunlight exposure since it is adjacent to waterfront and there is no building on the east side. However, based on the shadow analysis, there are some various shadow impacts in the site by the surrounding buildings (which are red highlighted in Fig. 6) at different times of the day and year as illustrated in Fig. 5.

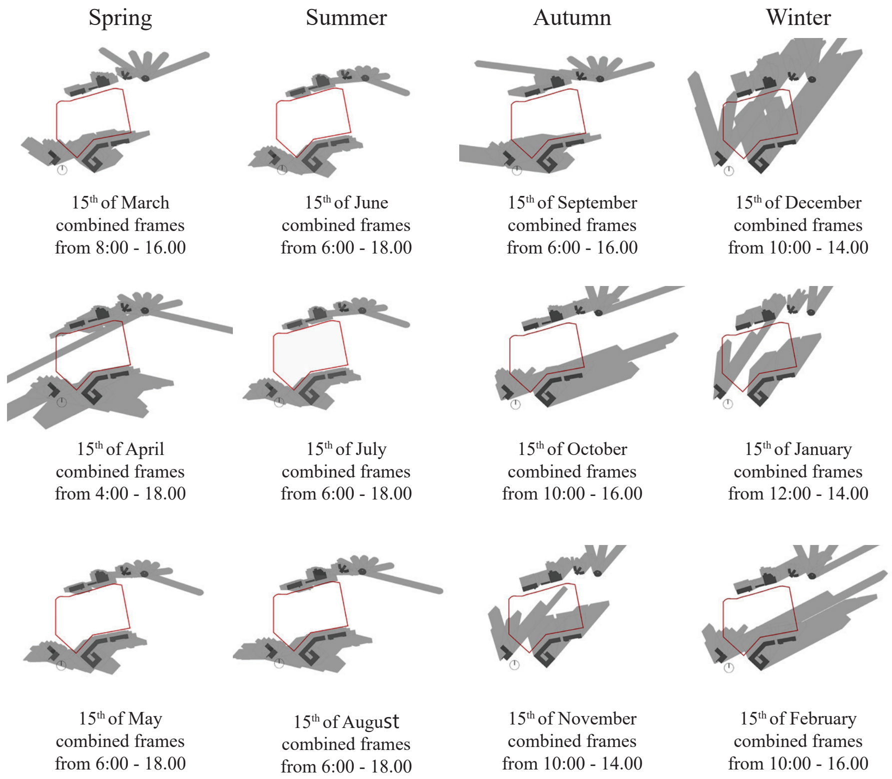


Fig. 5: ShadowAnalysis from January to December

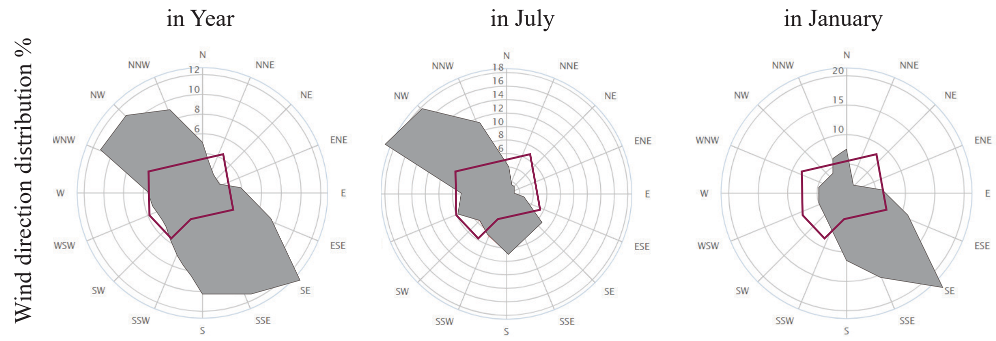
Fig. 6: Surounding Buildings

Analysis Method

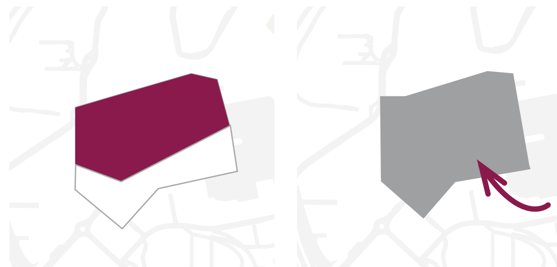
On the 15th day of every month, the surrounding buildings shadows (which are red highlighted in Fig. 6) were framed every 2 hours from sunrise to sunset. Combination of these frames, represents the shadow status in the entire day, as represented in Fig. 5.

Wind Orientation

The dominant wind direction in the area is from southeast in winter and northwest in summer. Considering the situation of the site which is adjacent to the waterfront from the east side as well as the topography of the area, it can be assumed that this site is quite windy. Therefore, selection of wind resistant trees used in the public open spaces could have positive impact on controlling undesirable wind (Windfinder 2018).



Month of the year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	Year 1-12
Dominant wind direction													



Design Criteria

Based on the shadow analysis the design process should consider north side of the site as the best option for maximum sun exposure. Furthermore, as per the presented wind analysis, wind resistant trees should be used in and around open spaces in order to control the prevailing south-east wind during the winter.

Energy Demand and Supply

Application of NZEB focuses on active measures: energy efficiency, generation of energy through renewable sources on site, and grid balancing. For the purpose of this thesis, selection of a suitable renewable source of energy, the type of building, and energy demand & supply relationship between building and transportation were analyzed.

Renewable Sources of Energy

Upon reviewing all renewable sources of energy that could be selected for the building requirements (heating, cooling, electricity, and domestic hot water), solar panel and heat pump were chosen for the purpose of this thesis. These factors were selected based on the high number of implementations (70%) in projects with similar climatic conditions, according to the statistics provided in “Solution sets for net zero energy buildings” (Ayoub et al., 2017).

Solar Panel

The sun is low in sky during winter and autumn in Norway when there is a need for more energy requirements, therefore solar collector panels should be mounted horizontally to provide more energy to be used for heating and domestic hot water generation. Beside mounting horizontally, the angle of inclination and orientation of solar collector panels with solar radiation are also significantly important factors that should be considered (Røstvik, 1994). As the Table 2 signifies, horizontal inclination angle for solar collectors should be 45, 60, and 75 degrees to optimize energy generation for domestic hot water and space-heating. As the Table 1 signifies, angle of orientation for solar collectors should face south at 0 degree; however, variations between 15 to 60 degrees would have little impact on the result on domestic hot water or space-heating.

Degrees form the south	0 º	15 º	30 º	45 º	60 º	75 º	90 º
Domestic hot water	1,00	0,99	0,97	1,93	0,88	0,81	0,73
Space-Heating & Domestic hot water	1,00	0,98	0,95	0,89	0,81	0,73	0,64

Table 1: Orientation of the solar collector in Norway (Røstvik, 1994)

Angle to horizontal	0 º	15 º	30 º	45 º	60 º	75 º	90 º
Domestic hot water	0,71	0,85	0,94	1,00	1,00	0,98	0,88
Space-Heating & Domestic hot water	0,59	0,74	0,89	1,00	1,06	1,06	0,97

Table 2: Inclination of the solar collector in Norway (Røstvik, 1994)

Heat Pump

Since the site is located near the waterfront, both geothermal heat pump and water sourced heat pump could be used as supplementary source of energy. Based on available statistics in Norway, there is a clear difference between average energy consumption in households in 10-149 m^2 areas with or without heat pump in 2012 (the latest available data on Statistics Norway) which was 18,645 kwh and 19,316 kwh respectively (Statistics Norway 2018).

Type of Building

Table 3 represents the usage of energy in households based on dwelling area and house type. As the table signifies, on average multi-dwelling buildings have the lowest energy consumption per households (Statistics Norway 2018).

	Total energy consumption (kwh) in 2012
All types of buildings	20230
Farmhouse	30997
Detached house	25776
Row house with 3 or 4 dwelling	17090
Multi-dwelling building	10899

Table 3: Average energy consumption per household in 2012

Power Blancing Between SAV and NZEB

Installation of BEVs (battery electric vehicles) charging stations where SAV stand by at the stop points, can enable SAV’s battery to charge during pick-ups and drop-offs.

Design Criteria

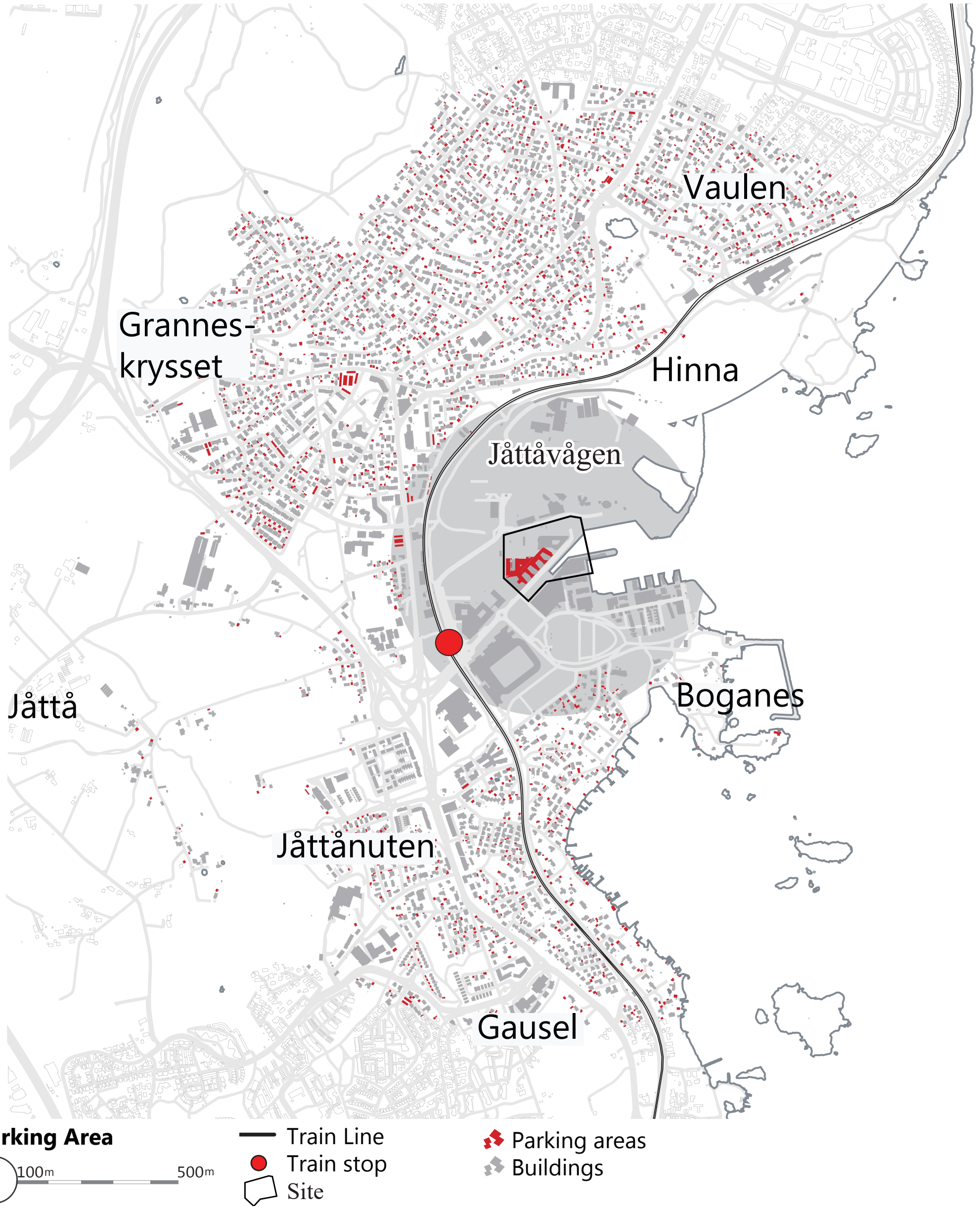
Based on Table 2, for the best results on domestic hot water and space-heating, the angle to horizontal inclination for solar collectors should be 45, 60, and 75 degrees and based on Table 1, angle of orientation for solar collectors should face south at 0 degree.

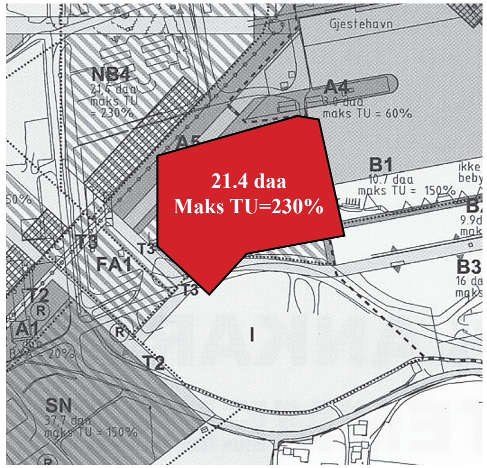
Based on Table 3, multi-dwelling building was selected for the purpose of this thesis due to their lowest energy consumption compared to other building typologies.

Installation of charging stations for SAV during pick-ups and drop-offs should be considered in the design process.

SAV - Impact on Parking Areas

The site is regulated by Stavanger Municipality regulations that require one parking space per 100 m² living space plus 15% for guests per 100 m². The site area is 51,206 m² and has a permit for 21.4 dda and maximum TU of 230%. The parking areas and building footprints are presented in the below map (Stavanger Municipality 2018).





The Minimum Required Parking Space

Based on the Municipality regulations, the site could have maximum 117,774 m² built-in area that would require at least 1354 parking spots and 8,120 m² of space. Not to mention, this is minimum required spaces as the parking area requires space for entrance and exit. However, by the aplication SAV, this space can be freed and used for other purposes

The impact of SAV on Parking Requirments

SAV has many impacts on parking spaces and private households. The impact on private households can vary depending on the type of household settlements. For example, there would be no impact on single family houses while it can have big impact on multi-dwelling buildings where SAV requirements have been implemented. Some important points regarding SAV impacts could be seen as it follows (Maurer, Lenz and Winner 2016):

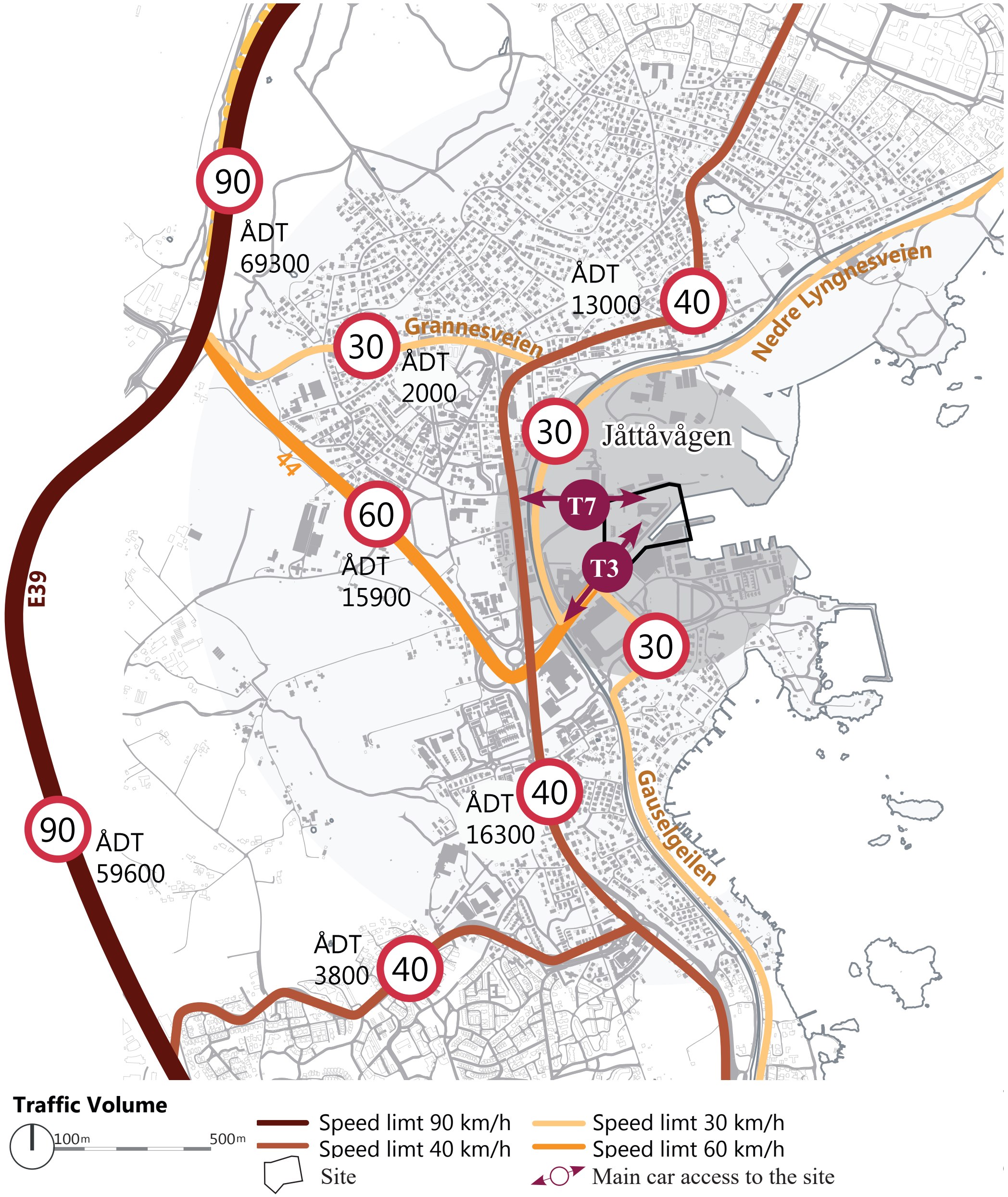
- Reduction in the required parking area
- Reduction in private vehicle ownership
- Reduction in vehicular congestion in public areas e.g. airports, city centers, stations
- Reduction in environmental impact
- Reduction in land consumption and reuse of the freed spaces for other purposes
- Reduction in transportation cost
- Possibility to do other works while driving such as using laptop, reading book, etc.

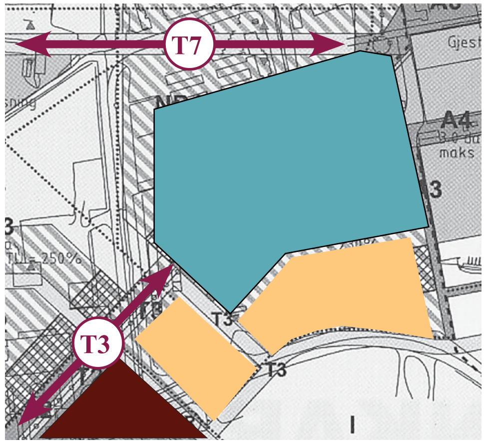
Design Criterion

According to this analysis, the site requires one parking space per 100 m² living space plus 15% for guests per 100 m². No parking area will be considered in the design process and the freed space will be used as public open spaces for various activities.

SAV - Access

The traffic volume in the main roads around the site are shown in the map below. According to Stavanger Municipality, the development in Jåttåvågen and growth in other areas of the region, will increase traffic around the site in all modes of transport (car, bus, and train).





Mixed-Use Buildings
The site
Viking Stadium

Possibility for SAV Access

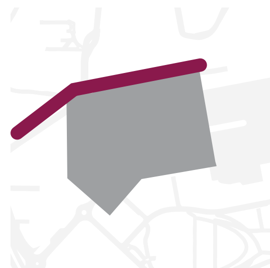
Based on the Stavanger Municipality regulations, T7 in the north, and T3 in the south can provide main car access to the site. However, it can be assumed that the traffic volume on T3 would be more than T7, since it provides main access to E39 through exit 44. In addition, T3 provides main access into Viking stadium.

Stavanger Municipality Goal for the District

According to the Stavanger Municipality, today, 72% of trips are made by cars in Hinna district. Due to several approved and future development plans in Hinna district, the traffic will increase on the road network by 5,000 cars per day. However, the goal of Jåttåvågen is to reduce 50% the car usage and convert it to public transport, bicycle or walking.

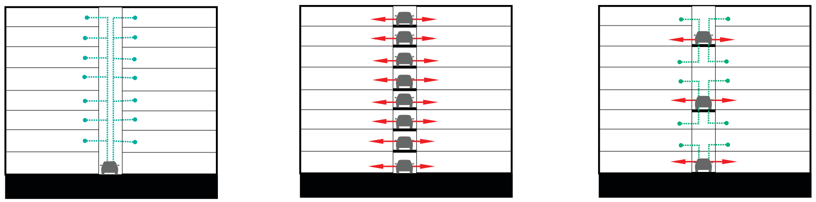
Design Criterion

Based on the mentioned statistics, it was decided to provide SAV access to the site from T7 on the north of the site where there is less traffic congestion.



SAV - Interaction with the Building

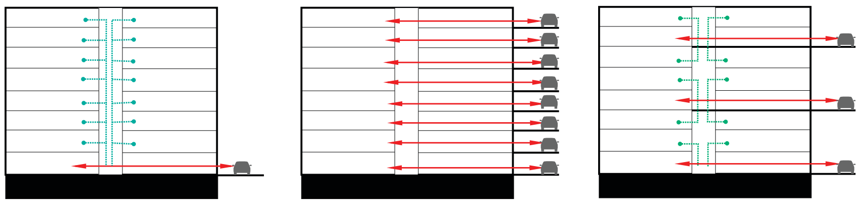
SAV can interact with the building in multiple ways in order to allow access for people. The SAV access could either be placed inside or outside the building, in the ground floor only, in a number of floors, or in all floors. Both options have advantages and disadvantages such as: comfortability and accessibility for people, required infrastructure, dependency on elevators and use of staircases.



A. SAV access from inside at ground floor

B. SAV access from inside at all floors

C. SAV access from inside at a few floors



D. SAV access from outside at ground floor

E. SAV access from outside at all floors

F. SAV access from outside at a few floors

Fig. 7: Scenarios for SAV Access in Different Levels

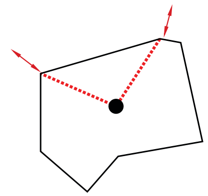
SAV access from inside the building (Fig. 7 A, B, C) requires greater construction cost and security considerations, while at the same time providing better accessibility and comfortability for the residents. SAV access from outside the building in the ground floor (Fig.7 D) provides only one access point which could cause congestion at the elevators and does not promote using staircases. SAV access from outside the building on all floors (Fig.7 E) provides better accessibility and comfortability at a higher cost, due to the required infrastructure. The other option would be to provide SAV access from outside the building on a number of floors (Fig.7 F). In this case, one access point serves one floor above and below the level it is located at. Therefore, residents of these two floors would be encouraged to use the staircase to reach SAV.

Design Criterion

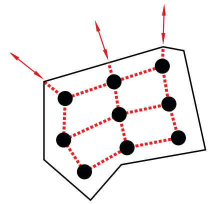
Each of the above mentioned options come with the associated pros and cons. However, for the purpose of this thesis, access from outside the building at a number of floors was considered as the most beneficial option. This factor can be used in other form of model split such as bike and walk routes.

SAV - Stop Points

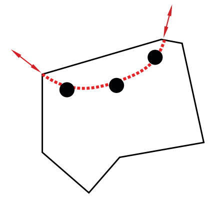
Access points to the SAV road could be designed in various ways. One option is to establish one entrance and one exit with a central stop point on site, as illustrated in Fig.8 A. The other option is to designate a number of entrances with a number of stop points spread around the site, as illustrated in Fig 8. B. Moreover, it is possible to designate one entrance with a number of stop points located at the strategic zones of the site, as illustrated in Fig. C.



A. One entrance and one central stop point for SAV



B. Many entrance points with many stop point for SAV



C. One entrance point with a few stop points for SAV

Fig. 8: Scenarios for SAV Entrances

Option A: One entrance with one central stop point, allows access only at one point that could cause congestion particularly during pick-ups and drop-offs.

Option B: Many entrance points with many stop points allow access from all around the site at the shortest distance without creating congestion. However, this would be costly and require greater infrastructure.

Option C: One entrance with a few stop points located at the strategic zones provides access from strategic zones, minimizing traffic congestion on site. Comparing to option B, this option also requires less infrastructure and construction cost.

Design Criterion

Any of the above options could be selected to plan the entrance and SAV stop points within the site; however, option C would allow easy access for all residents from different parts of the site comfortably without excessive construction requirements. Therefore, for the purpose of this thesis, it was decided to designate one entrance with a number of stop points (option C).

Create Landmarks with Bike Route

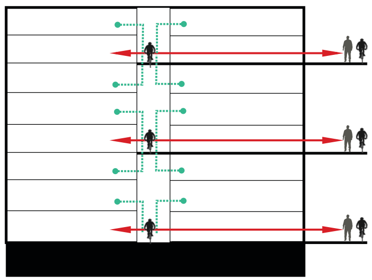
In recent years, many cities such as Amsterdam and Copenhagen invest on constructing bike route infrastructures. These routes must be comfortable and interesting to use in order to encourage people to choose bikes over other modes of transport. A little more attention given to the design process could result in an infrastructure which is not only a route to pass but also a unique and iconic landmark for the region. A good example of this approach is the Snake Bike project in Copenhagen (Fig.9).

Length, total: 230 m
Width: 4.6 m

The Bicycle Snake, Copenhagen, Denmark, 2010-2014 (“Bicycle snake”, [image], 2018)

Design Criterion

Design of an iconic bike route that connects different floor levels and open spaces to attract people to use bikes over other modes of transport was set as an important design principal.



Elevators

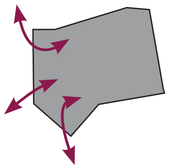
The number of required elevators depends on many factors such as the type of building, the number of users, the volume of traffic in the building, and the waiting time at the elevators according to the regulatory requirements and standards. Calculations regarding the exact number of elevators require further analysis of the building conditions and environmental factors that is not in the scope of this thesis. However, the general recommendation is that for office buildings there should be one elevator for every 45,000 square feet (4180 m^2) of net usable area with the assumption of 12 passenger capacity (800 kg) for each elevator. There should be at least 1 elevator for every 2 and a half floors and in multi-family buildings at least one elevator should serve 60-90 units. In addition, buildings with four to eight floors may need a separate service elevator depending on the type of services provided in the building (Archinect 2007).

Design Criterion

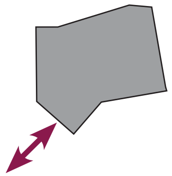
Considering the above assumption, there should be at least 1 elevator for every 2 and a half floors and in multi-family buildings at least one elevator should serve 60-90 units. In addition, buildings with four to eight floors may need a separate service elevator depending on the type of services provided in the building. It is assumed that each elevator should have a passenger capacity of 12 (800 kg).

Analysis Summary

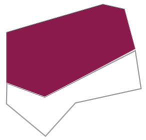
Analysis of the important elements to design NZEB in Hinna Park, Stavanger and the possibilities of interaction between SAV, Bike and Walk routes were carried out in the relevant scenarios. The outcome of the analysis is series of design criteria that should be used in the design process. Summary of highlighted design criteria are outlined in the below graphs.



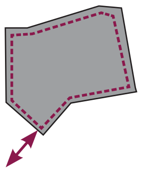
Open Spaces
on all sides of the site should be designed based on human scale factors



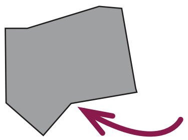
Bike & Walk Routes Access
should be designed iconic to attract people to use bike over other mode of transport and connect open spaces in different floor levels



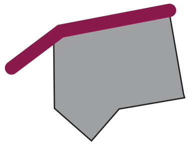
Sunlight Exposure
North side of the site has the best condition



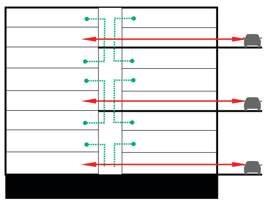
Bike Route
should connect open spaces in different floor levels



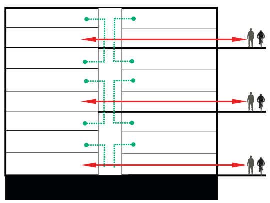
Wind Orientation
use of wind resistant trees in and around open spaces to control the prevailing south-east wind during winter



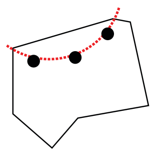
SAV Entrance
should be from the northern side of the site



SAV Access
should be from outside of the building in a few floors



Bike & Walk Access
should be from outside of the building in a few floors



SAV Stop Points
One entrance with a number of stop points should be considered

Design Outcome

This chapter uses the design criteria summarized in the previous chapter to form the envelope of a multi-dwelling building in Hinna park, Stavanger. The relationship between NZEB and SAV including their impact on parking spaces, staircases and elevators were tested based on the program distribution of the building.

Finally, the circulation in each floor is shown in order to present the accessibility to SAV, bike, and walk routes for the residents and visitors.

Following topics were covered in this chapter:

- Building Footprint Scenarios
- Concept Design
- Program Distribution
- Saving Parking Spaces
- Number of Visitors
- SAV Road Access
- SAV Interaction with Bike Route and Public Open Spaces
- SAV Road Interation with Stairs
- SAV Impact on Public Oriented Spaces
- SAV Impact on Elevators
- Circulation Diagrams

Building Footprint Scenarios

Different types of footprint scenarios such as linear, compact, and spread with their design approaches were tested as illustrated in Fig. 9. The selected footprint scenario should meet the design criteria summarized in "Analysis Summary" on page 28.

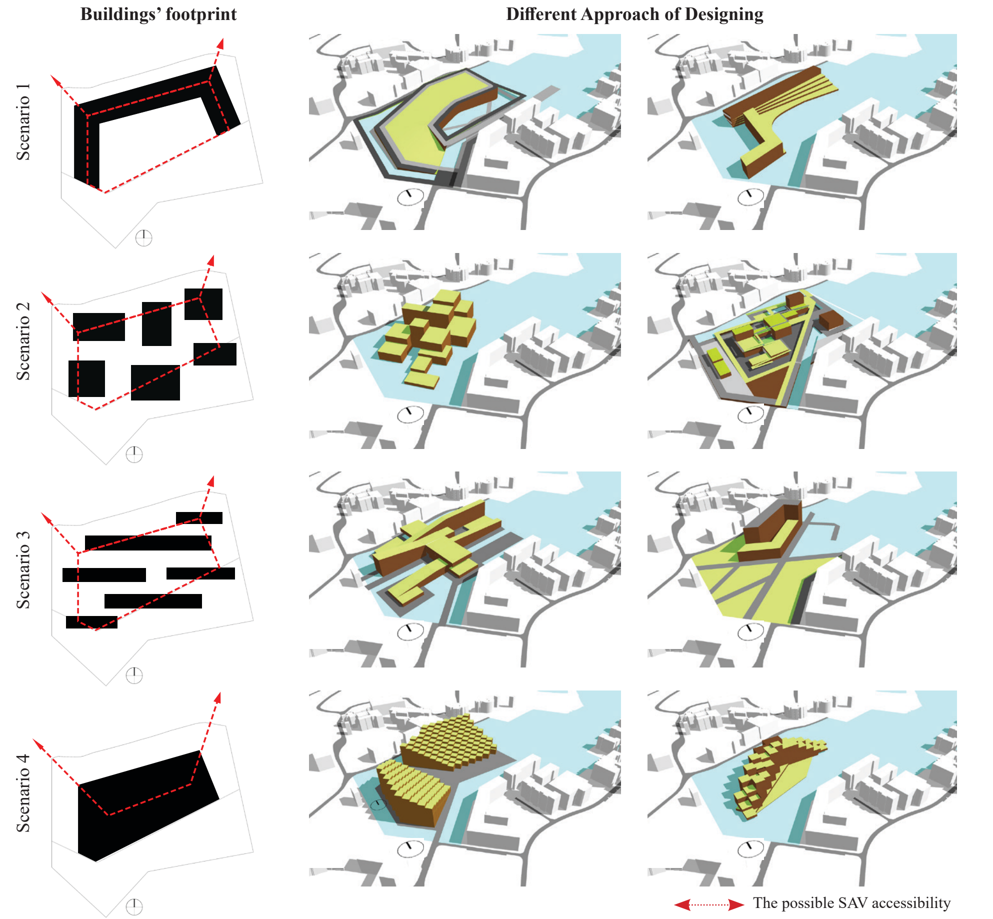
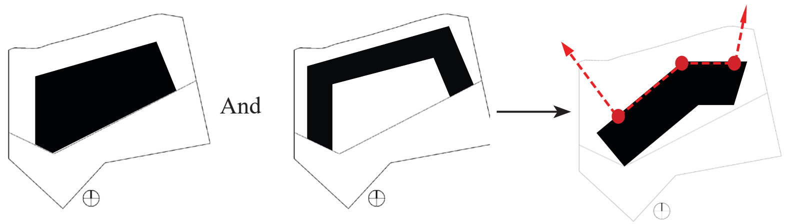


Fig. 9: Building Footprint Scenarios

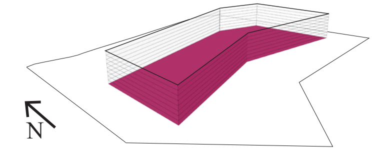
Selected Footprint

None of the footprints can meet all the design criteria completely. For example, scenario 2 and 3 would not be good options since they would require several SAV entrance points. However, combination of scenarios 1 and 4 could be selected since it can fairly meet the design criteria for NZEB and SAV.

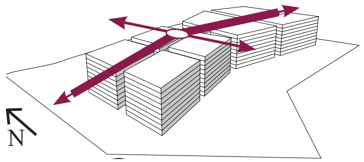


Concept Design

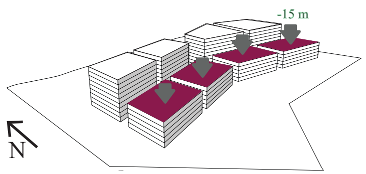
Based on design criteria and the selected footprint scenario, the following steps were carried out in the concept design:



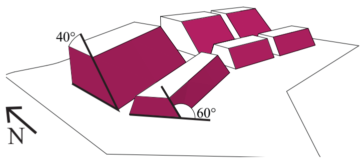
1. Eight floors extrusion based on selected footprint (refer to "Building Footprint Scenarios" on page 33)



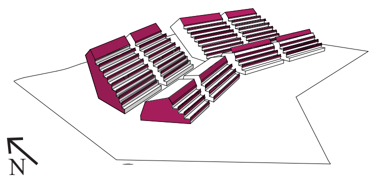
2. Volume division for better pedestrian accessibility (refer to "Public Transportation Access" on page 12)



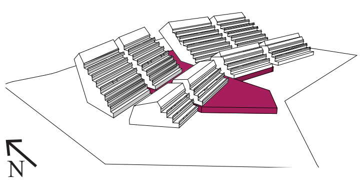
3. View Optimization



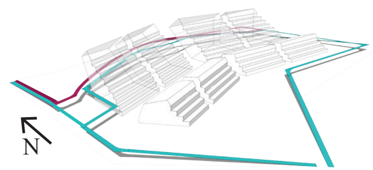
4. Optimizing solar exposure (refer to "Climate" on page 16)

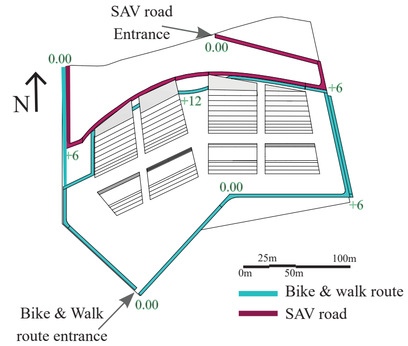


5. Balconies with solar panel hand rails on each floor (Every 50 m^2 residential unit has a private 15 m^2 balcony)

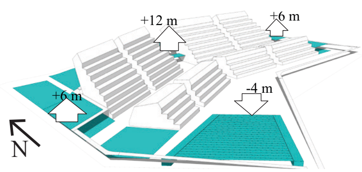


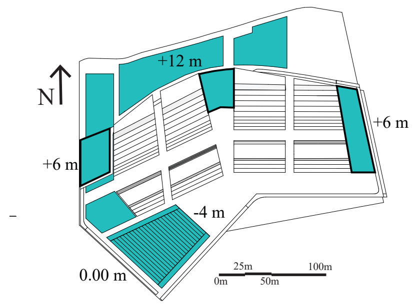
6. Addition of the underground cultural space



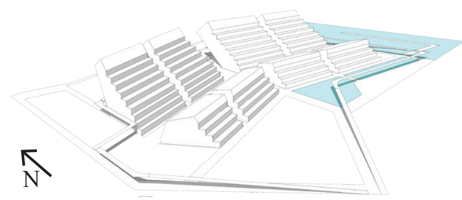


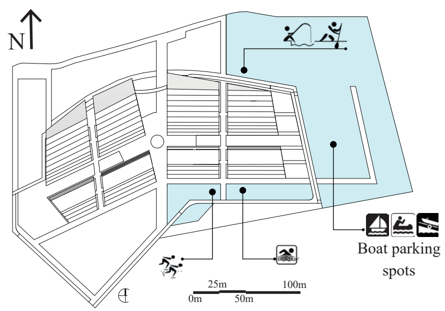
7. Walk, Bike and SAV routes accesses were provided around the building with a 6% sloped ramp. Elevation of the ramp around the building varies from 0.00 to +12 meters





8. Public open spaces in different levels accessible by bike, walk and SAV routes

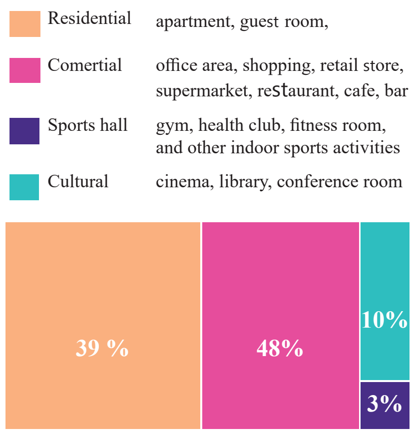


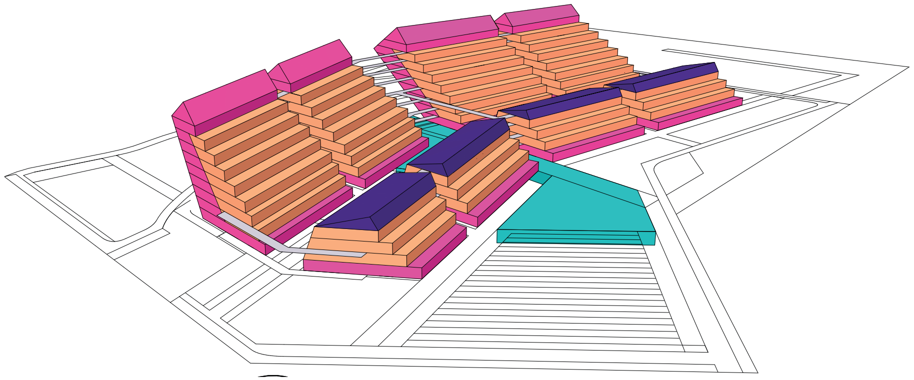


9. Expansion of waterfront to the site to create space for water sports and boat parking spots

Program Distribution

This design includes 118,474 m² usable building area in plot area (BRA) that consists of 39% residential area and guest rooms, 48% commercial areas (offices, shopping centers, retail stores, restaurants, cofe, and bar), 10% sport hall (gym, health club, fitness room, other sport activities), and 3% cultural area (cinema, library, conference room). The program distribution for the building is aligned with the Stavanger Municipality t arget, specifying that the building neighborhood should provide all the required services that residents may need. Table 4 reports the allocated space for the program distribution in the building. The planning philosophy here was to design units that are smaller in size but higher in terms of number and affordability.





Program	Floors / square meter										Sum
	UG	Ground	1	2	3	4	5	6	7	8	
Residential	0	0	6,307	5,383	4,394	2,561	2,496	1,920	1,178	0	24,239
Commercial	0	8,396	3,274	3,553	3,064	2,759	2,173	1,722	1,960	3,108	30,009
Sport hall	0	0	0	0	0	1,773	0	0	0	0	1,773
Cultural	5,940	0	0	0	0	0	0	0	0	0	5,940
Public Green space	4,395	21,075	1,549	2,563	741	658	0	335	258	0	31,574
Internal access/corridor	7,361	9,112	1,623	1,588	1,460	1,000	819	942	900	134	24,939
BRA	17,696	38,583	12,753	13,087	9,659	8,751	5,488	4,919	4,296	3,242	118,474

Table 4: Program Distribution

Saving Parking Spaces

According to the Stavanger Municipality regulations, the building would have required 657 parking space. Every parking space requires roughly 12 m² space and proper maneuvering reference to Table 5. Thus, this building requires 7,877 m² of parking spaces. It can be assumed that this is the minimum spaces saved by eliminating parking spaces.

Area type	No. of parking required
Residential	280
Shopping Center	84
Offices	216
Sport hall	18
Cultural	59
Sum	657

Table 5: Number of Required Parking

Number of Visitors and Residents in the Building

The number of people including residents, employees, and visitors to the building are estimated to be approximately 5,660 persons per day. The method used for the estimation is as following:

Number of Residents

The total residential area is 24,239 m², consisting of 50 m² units for 2 people, which equals to a total of 970 persons.

Number of Employees

The total office area is 21,613 m², allocating 12 m² to every employee, resulting in 1800 employees.

Number of Visitors

In order to estimate the number of visitors to the building, number of visitors to 3 similar shopping centers in the close by area were investigated as per Table 6 (thoneiendom 2018). On average, there has been 18 visitors per day for every 100 m². Thus, the number of visitors to the building can be approximated to be 2890 persons per day.

Shopping center	Madla	Amfa libra	Square
Area (m2)	64,000	40,000	63,000
Number of visitors per day	9,665	8,585	12,615

Table 6: Number of Visitors to Similar Shopping Centers

SAV Road Access

The SAV road is accessible on 3 floors with a total of 5 strategic stop points:

Two stops on the ground floor, two stops on the 2nd floor, and one stop on the 4th floor (Fig. 10). It is designed as a 6% sloped ramp, connecting all 5 stop points together. Stop point no.1 in the ground floor reaches stop point no. 2 at the 2nd floor and goes up to stop point no. 3 on the 4th floor. SAV road goes down to reach stop point no. 4 at the 2nd floor and finally reaches to stop point no. 5 at the ground floor (Fig. 11).

Charging stations for SAV during pick-ups and drop-offs were designed in all SAV stop points.

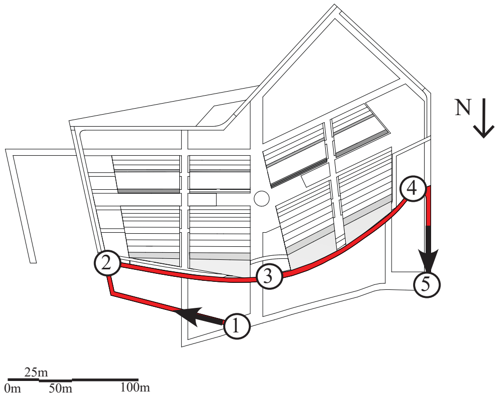


Fig. 10: SAV Stop Point

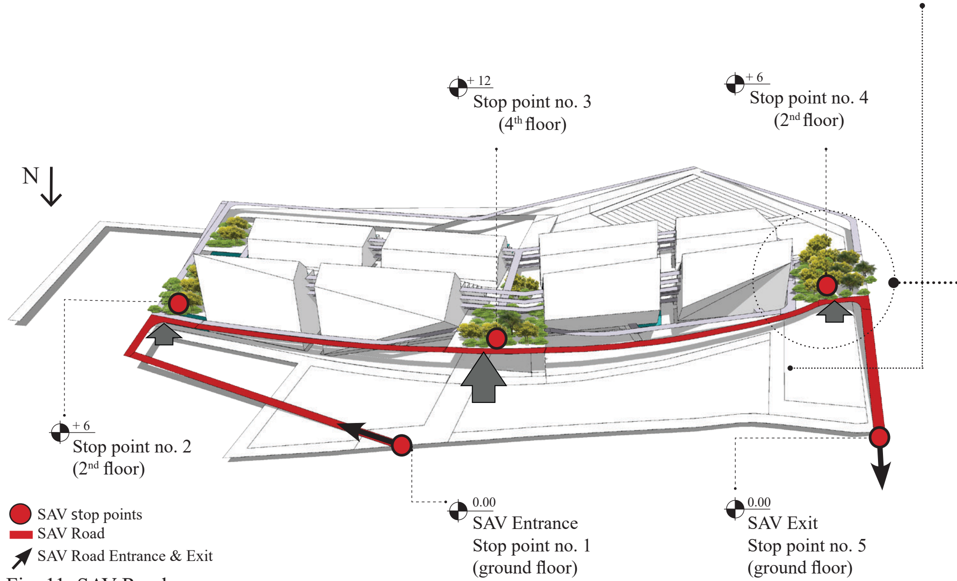
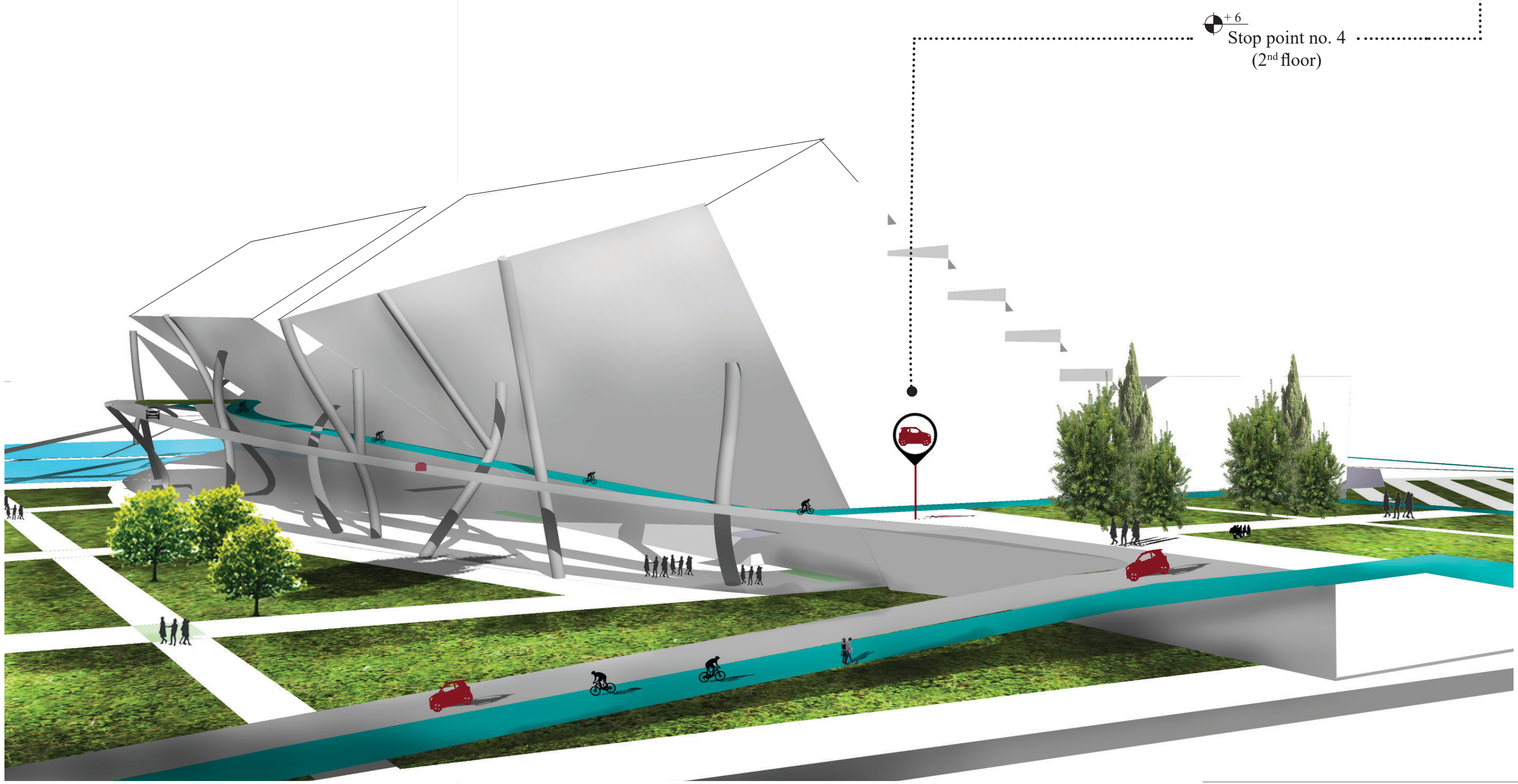


Fig. 11: SAV Road



SAV Interaction with Bike Route and Public Open Spaces

The bike and walk routes are designed as a 6% sloped ramp, connecting public open spaces and SAV stop points on 3 floors. The elevation of the ramp around the building varies from 0.00 to +12 meters. It provides easy accessibility for the residents, employees, and visitors (Fig. 12).

Public open spaces are designed at the same floors where SAV stop point are located and they are accessible by bike and walk routes. They include charging stations for SAV and green spaces that provide opportunity for passing cyclist, residents, employees and visitors to stay and enjoy in the open spaces.

Bike and Walk routes interaction with SAV road and their connection to open spaces in different floor levels are illustrated in Fig. 13.

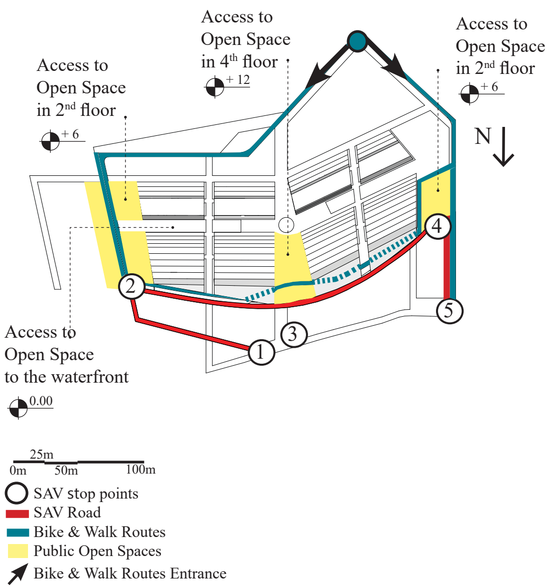


Fig. 12: Bike and Walk Route

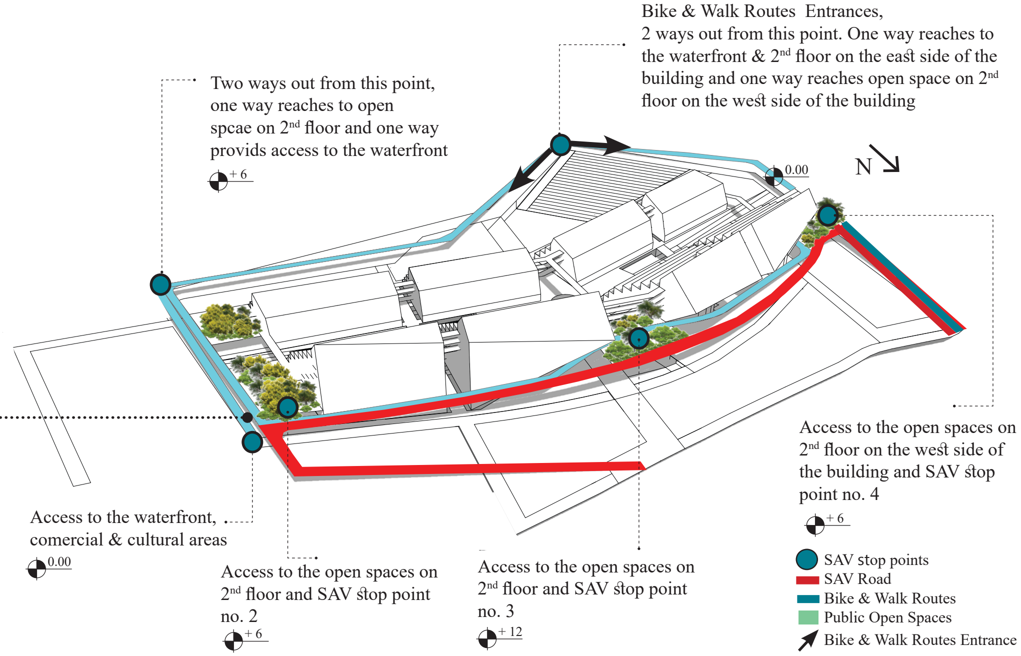
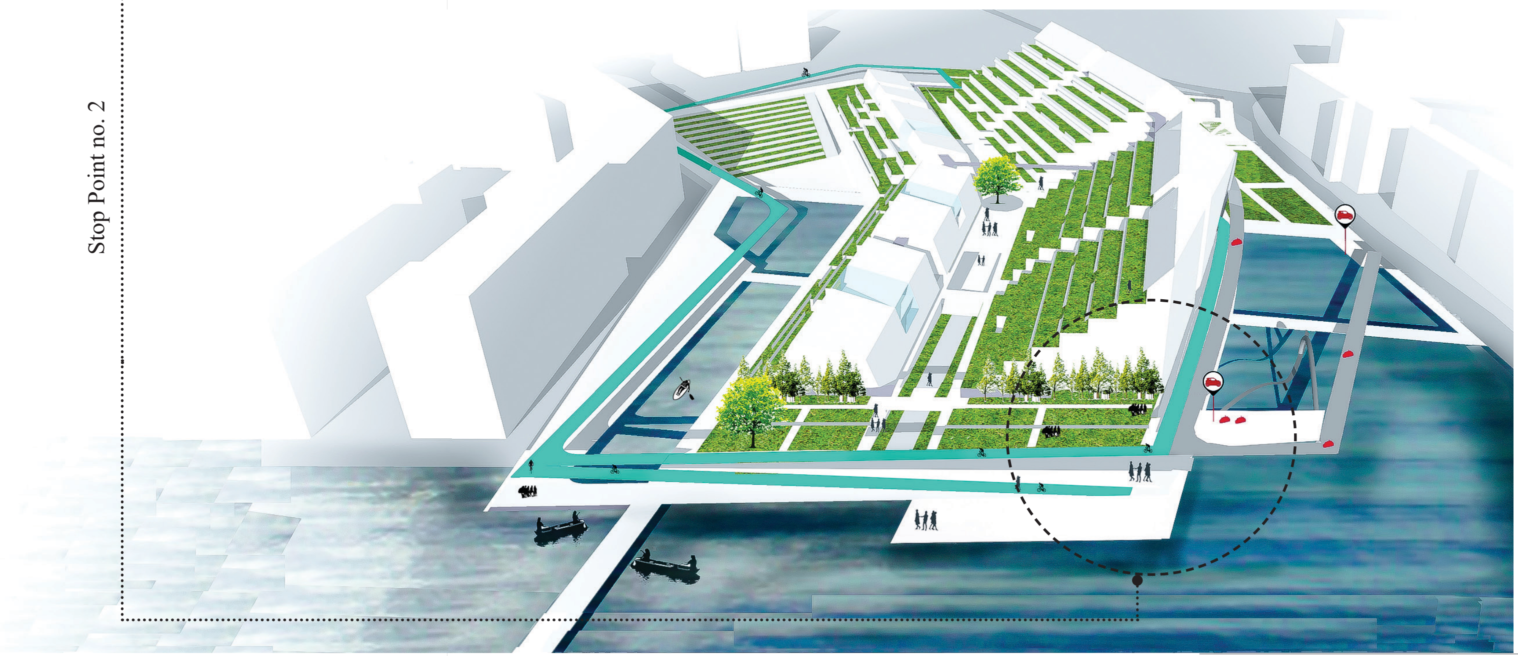


Fig. 13: Bike and walk routes interaction with SAV Road



SAV Road Interation with Stairs

The building was designed in 8 blocks, blocks a, b, c, & d are in 8 floors and blocks h, g, f, & e are in 4 floors. Every block has a staircase as shown in Fig. 14. The 5 SAV stop points and staircases in each block are designed in a way to create maximum interaction between the two.

All the blocks are connected together through internal corridors and they are within proximity of 50 meters to at least one SAV stop point (Fig. 14). And, They have access to SAV stop points in the ground, 2nd, and 4th floors. Each of this stop points are also easily accessible for the levels above and below through the staircase (Fig. 15). Therefore, it can be assumed that with this arrangement residents and visitors would be encouraged to use stairs more frequently as illustrated in .

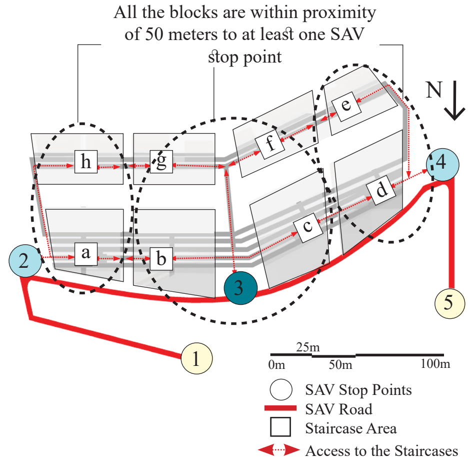


Fig. 14: Buildings' Blocks

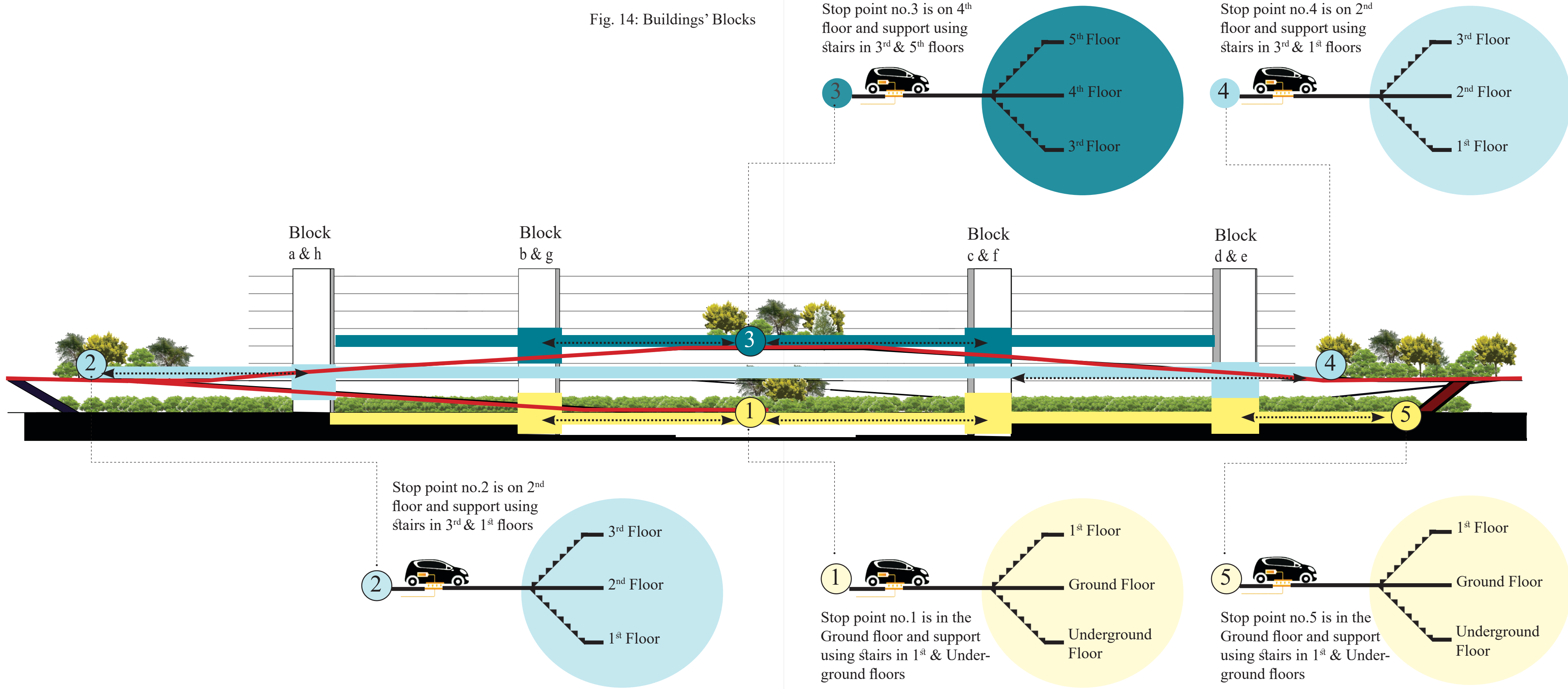


Fig. 15: Access to SAV Stop Point with Ststaircase

SAV Interaction with Public Oriented Spaces

All the public areas including the cinema complex, the sport hall, and the commercial areas are located in levels which are easily accessible from the SAV stop points as well as the walk and bike routes, leaving the elevators mostly for local use (Fig. 16).

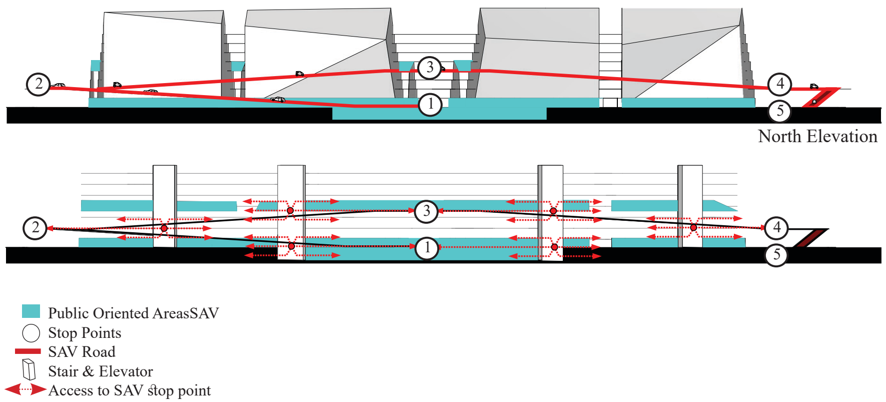


Fig. 16: SAV Interaction with Public Spaces

SAV Impact on Elevators

Based on the previously mentioned analysis (reference to "Elevators" on page 27), a similar building requires the minimum elevator sizes mentioned below:

- Block a, b, c & d (3 elevators, 800kg per block)
- Block e, f, g & h (2 elevators, 800kg per block)

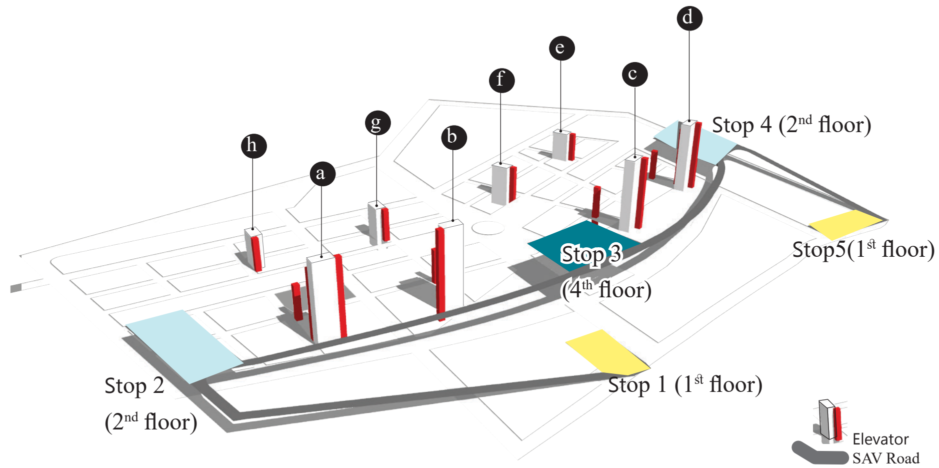


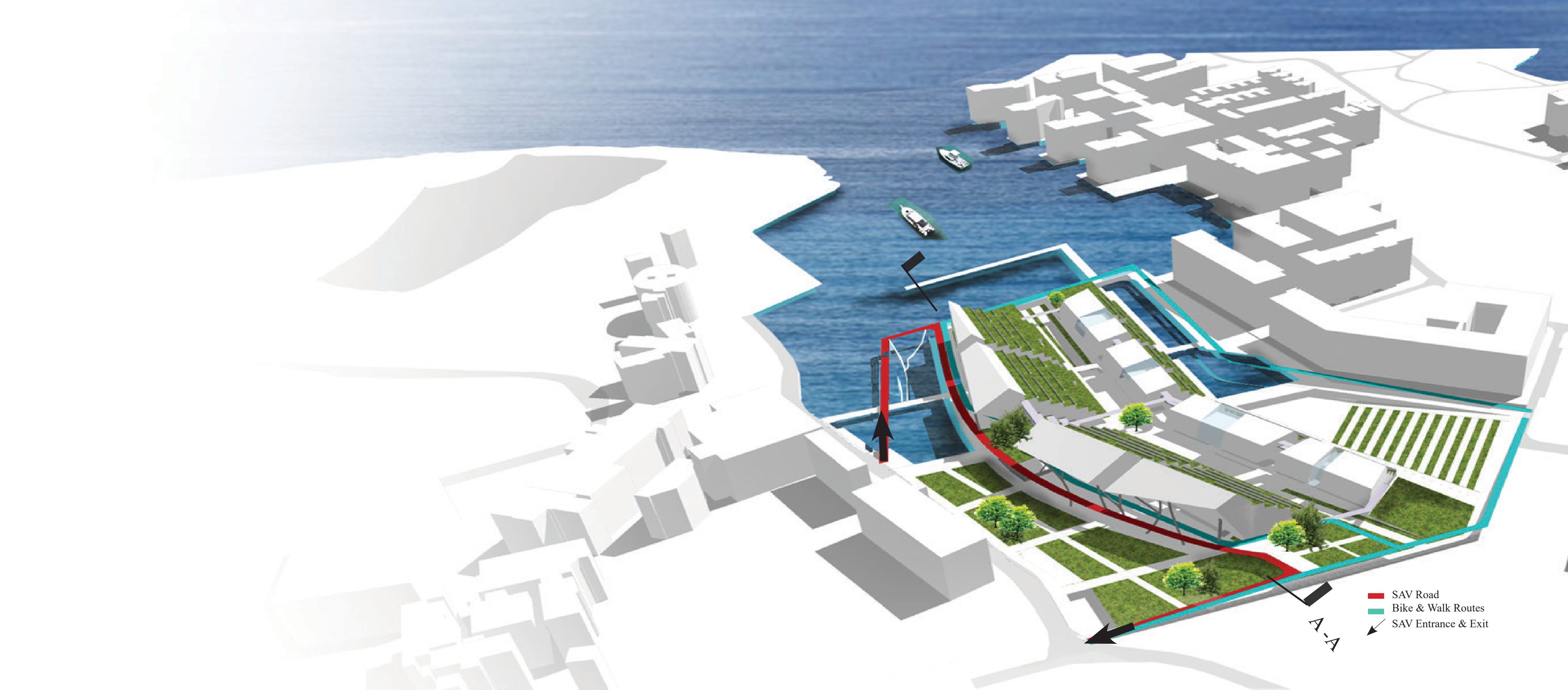
Fig. 17: Elevators in Each Block

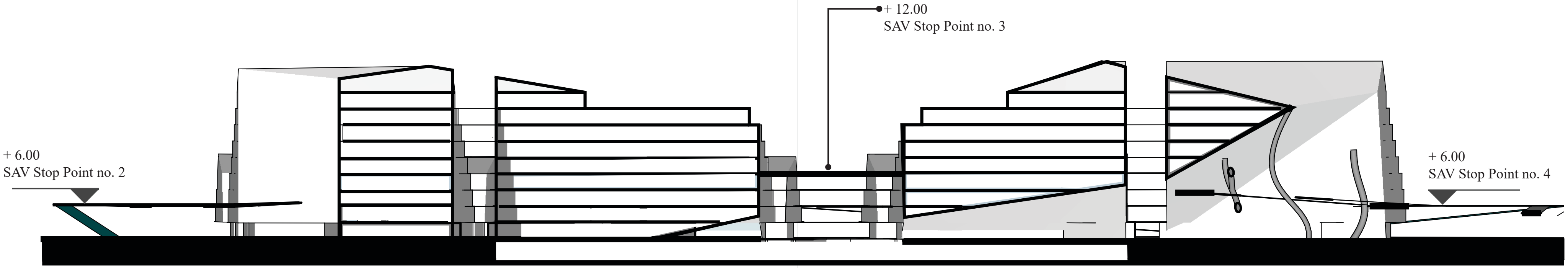
The impacts of elevators in blocks e, f, g, and h are as it follows:

These blocks have four floors that include residential area in the 1st, 2nd & 3rd floors and commercial, cultural & sport hall in underground, ground, and 4th floor. SAV road has stop points in the ground floor (stop no. 1&5), on the 2nd floor (stop no. 2&4), and on the 4th floor (stop no. 3). There are stairs on 3 levels of these blocks, therefore, it can be assumed 50% reduction at least in the number of elevators or their capacity in these blocks without considering the impact of stairs usage.

The impacts of elevators in blocks a, b, c & d are as it follows:

These blocks have eight floors that include residential area from 1st to 7th floors, office areas in 1st to 8th floors, and commercial area, cultural in underground and ground floors. SAV road has stop point no. 3 on the 4th floor serving floors 3 to 5, stop points no. 2 & 4 on the 2nd floor serving floors 1 to 3 and stop points no. 1 & 5 in the ground floor serving ground and underground. Only the residents and employees who live and work on 6th, 7th floor and 8th would use elevators; thus, it can be assumed 30% reduction in the number of elevators or their capacity in these blocks.





Section A -A , Scale: 1: 1000

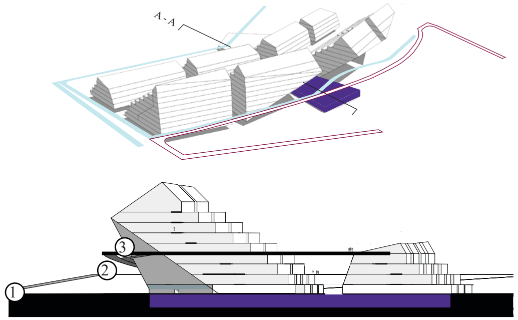
Circulation Diagrams

The circulation diagrams, sections, and north elevations on the floor plans are shown in the following pages.

Under Ground Floor

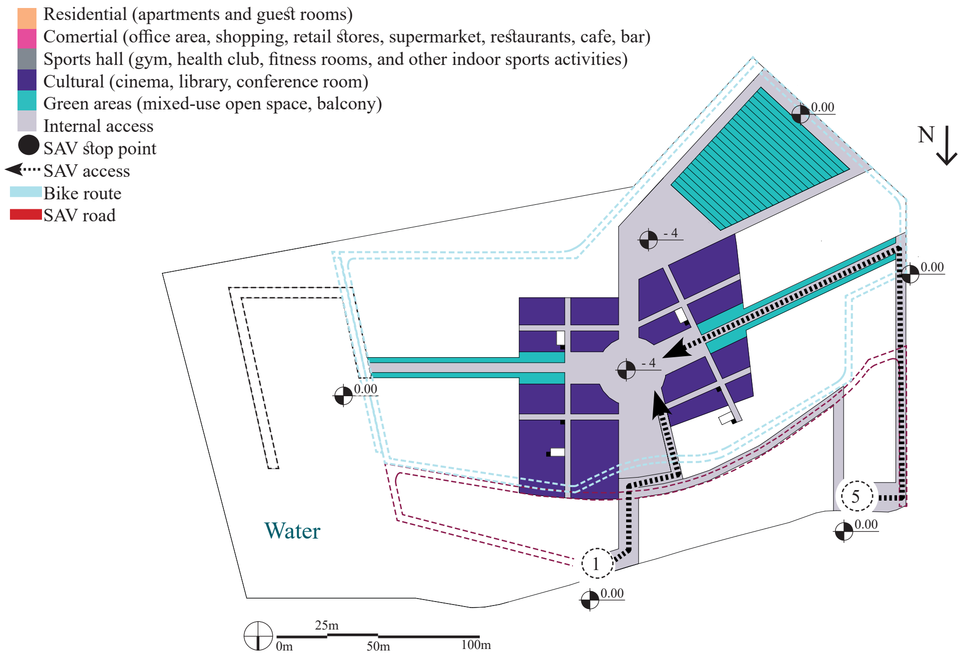
The underground floor are shown as below. This floor includes cultural areas (cinema, library, conference rooms). The total BRA of this floor is 17,696 m².

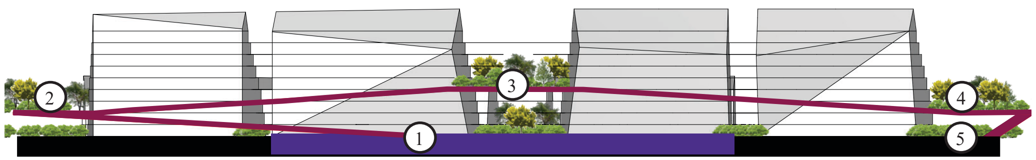
The access to SAV stop points is from one level above (ground floor), stop point no. 1 and 5.



Section A-A

Under Ground Floor



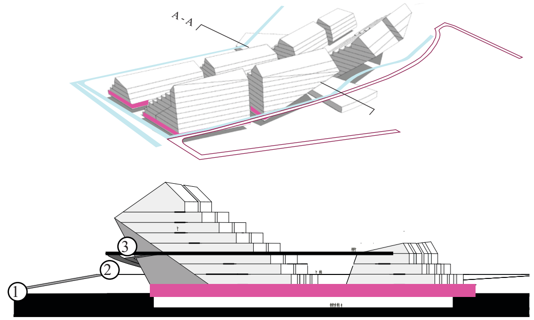


North Elevation

Ground Floor

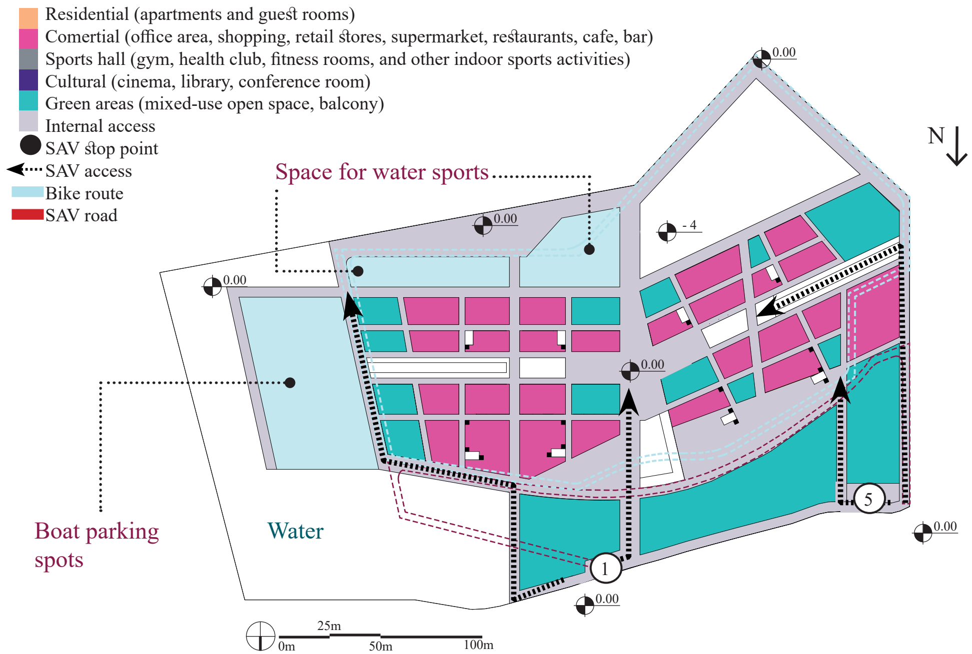
The waterfront was expanded to the site in this level to create space for water sports and boat parking spots. This floor includes commercial areas (shopping, retail stores, supermarket, restaurants, café, and bar). The total BRA of this floor is 38,583 m².

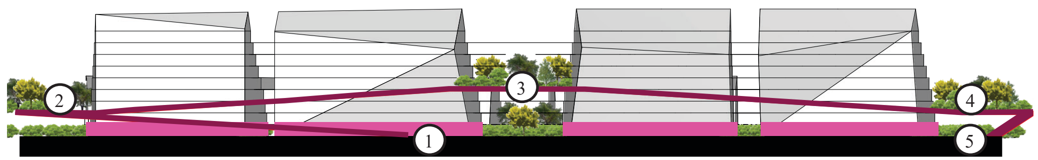
The access to SAV stop points is from the same floor, stop point no. 1 and 5.



Section A-A

Ground Floor



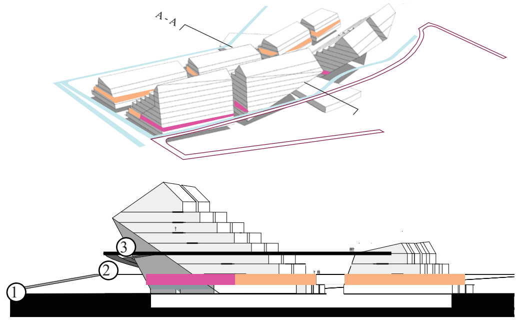


North Elevation

1st Floor

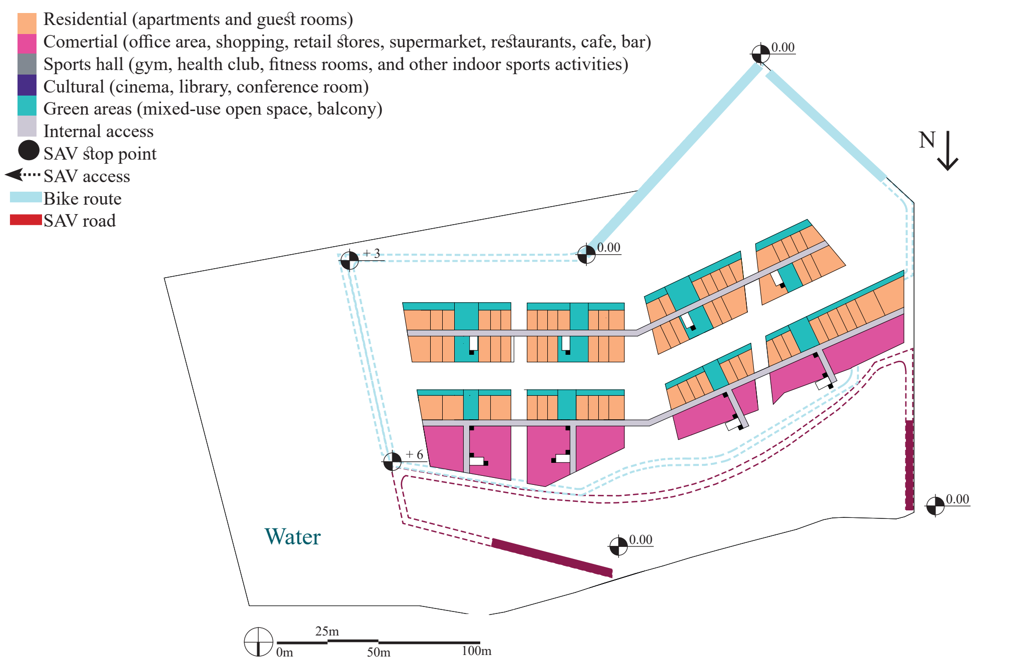
This floor includes office and residential areas. The total BRA of this floor is 12,753 m². Each residential unit has a private 15 m² balcony on average.

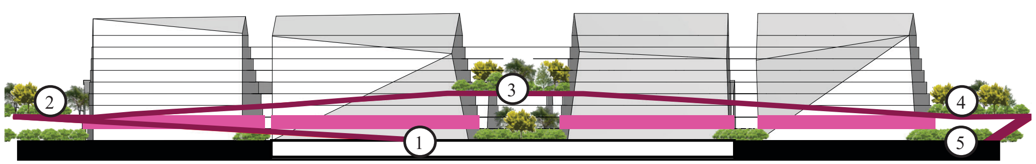
The access to SAV stop points is from one level below, stop point no. 1 and 5 as well as one level above stop point no. 2 & 4.



Section A-A

1st Floor



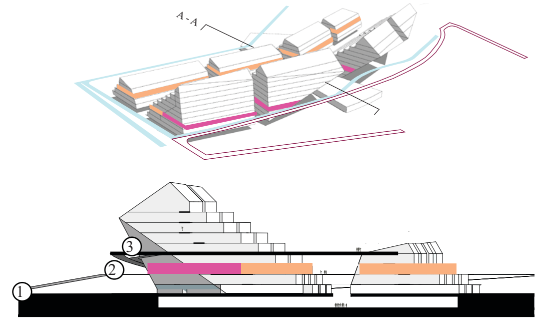


North Elevation

2nd Floor

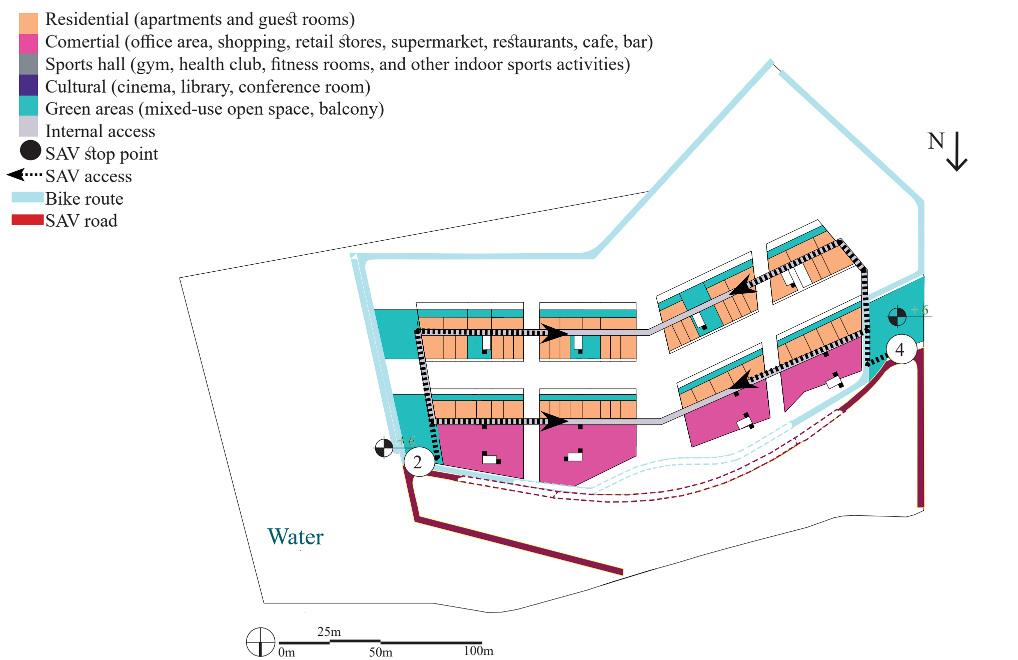
This floor includes office and residential areas. The total BRA of this floor is 13,087 m². Each residential unit has a private 15 m² balcony on average.

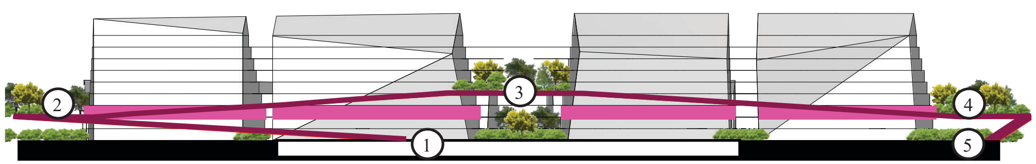
The access to SAV stop points is from the same floor, stop point no. 2 and 4.



Section A-A

2nd Floor



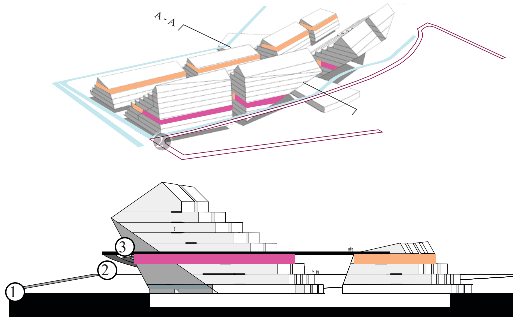


North Elevation

3rd Floor

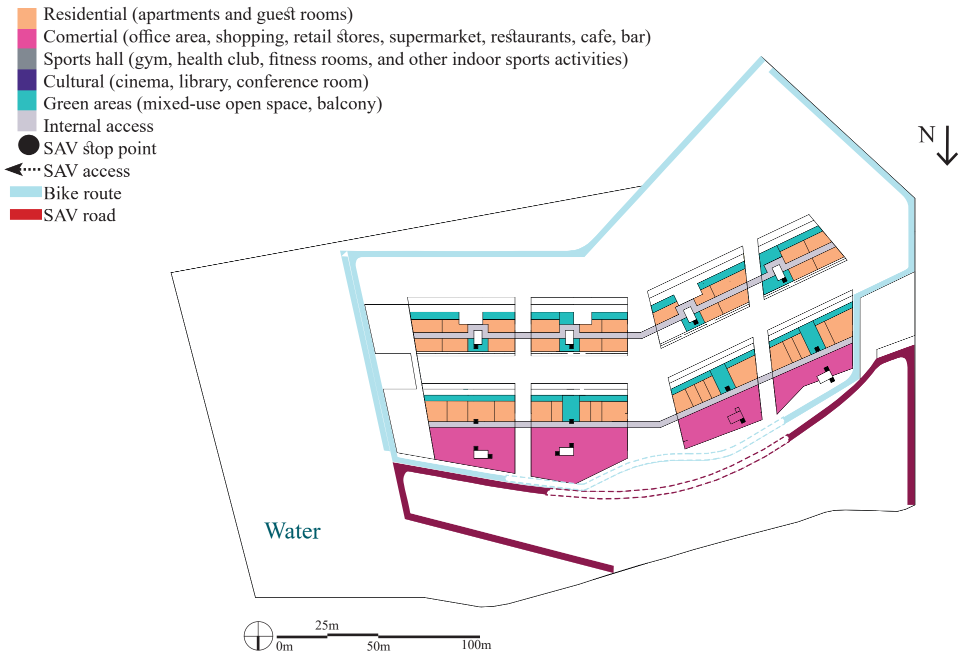
This floor includes office and residential areas. The total BRA of this floor is 9,659 m². Each residential unit has a private 15 m² balcony on average.

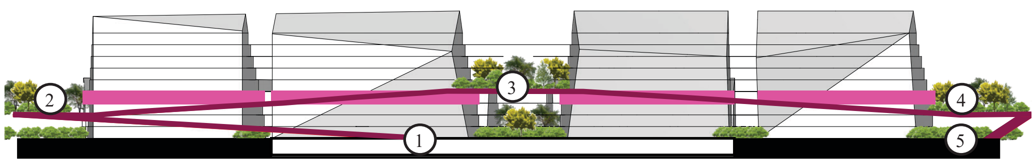
The access to SAV stop points is from one level below, stop point no. 2 and 4 as well as one level above stop point no. 3.



Section A-A

3rd Floor



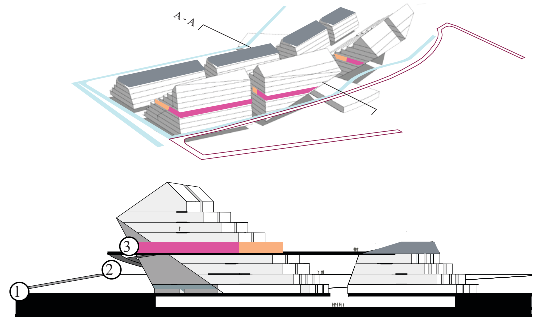


North Elevation

4th Floor

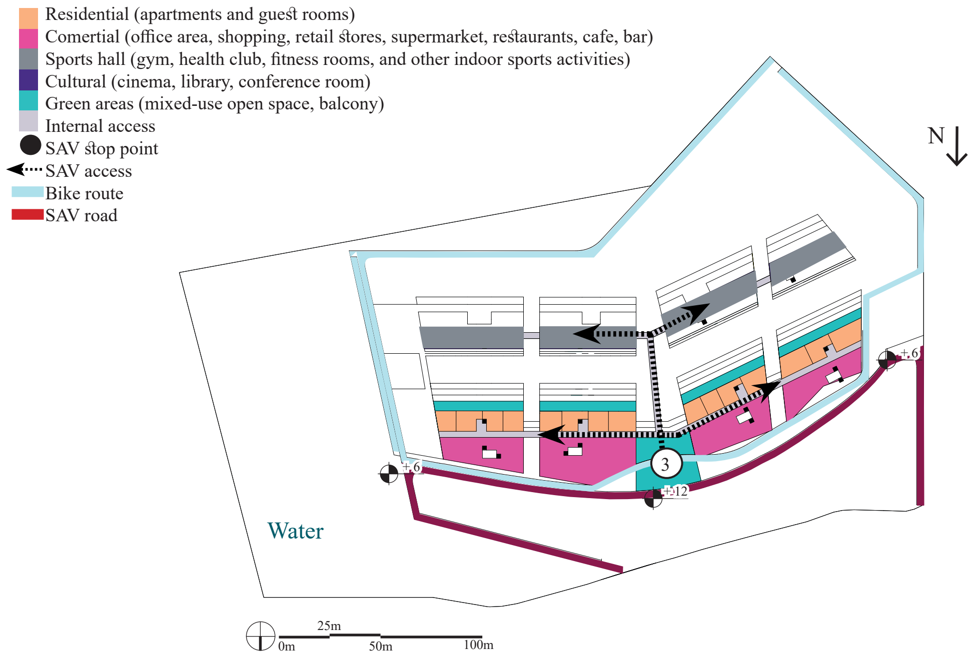
This floor includes office and residential areas. The total BRA of this floor is 8,751 m². Each residential unit has a private 15 m² balcony on average.

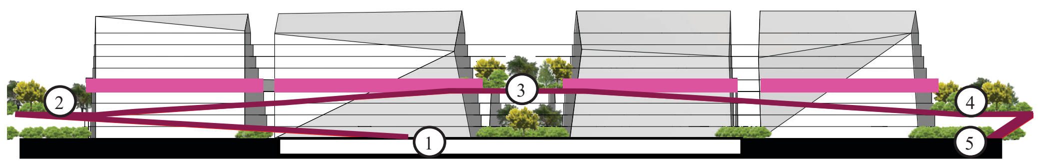
The access to SAV stop points is from the same floor, stop point no. 2 and 4.



Section A-A

4th Floor



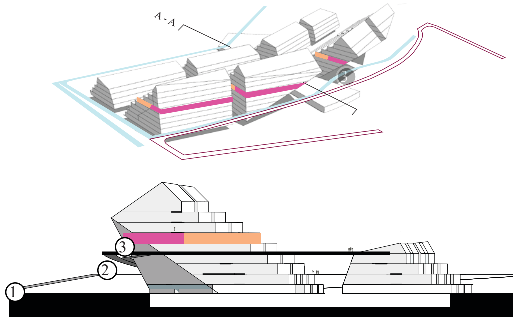


North Elevation

5th Floor

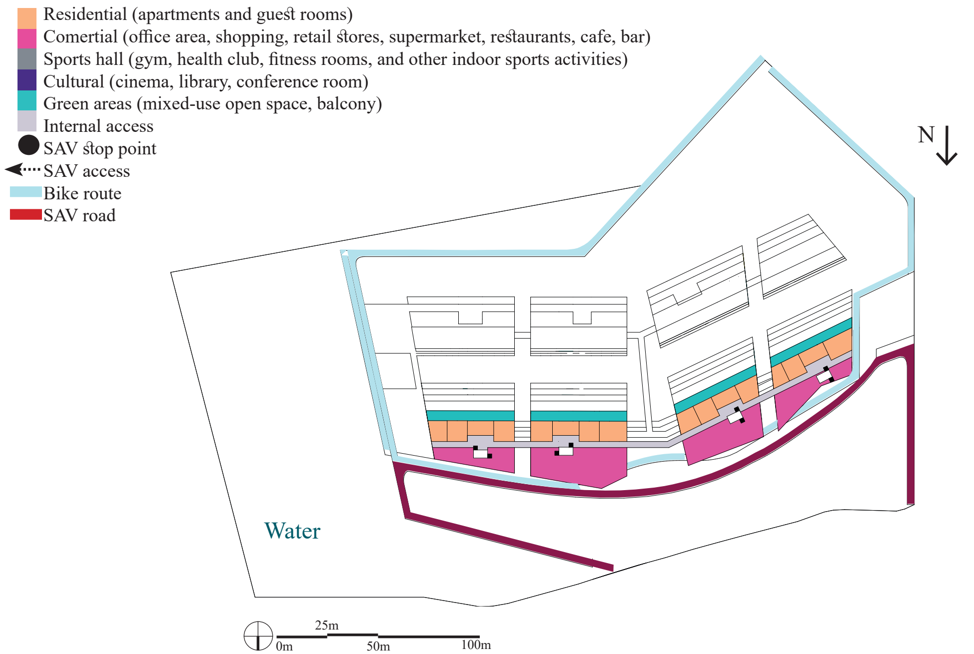
This floor includes office and residential areas. The total BRA of this floor is 5,488 m^2. Each residential unit has a private 15 m^2 balcony on average.

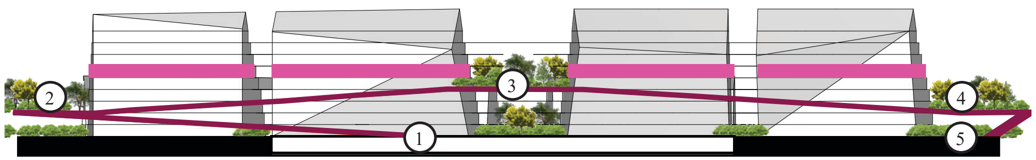
The access to SAV stop points is from one level below, stop point no. 3.



Section A-A

5th Floor



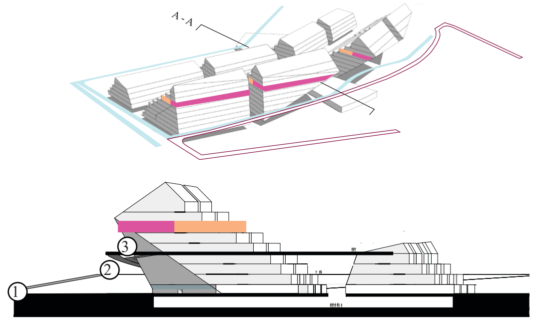


North Elevation

6th Floor

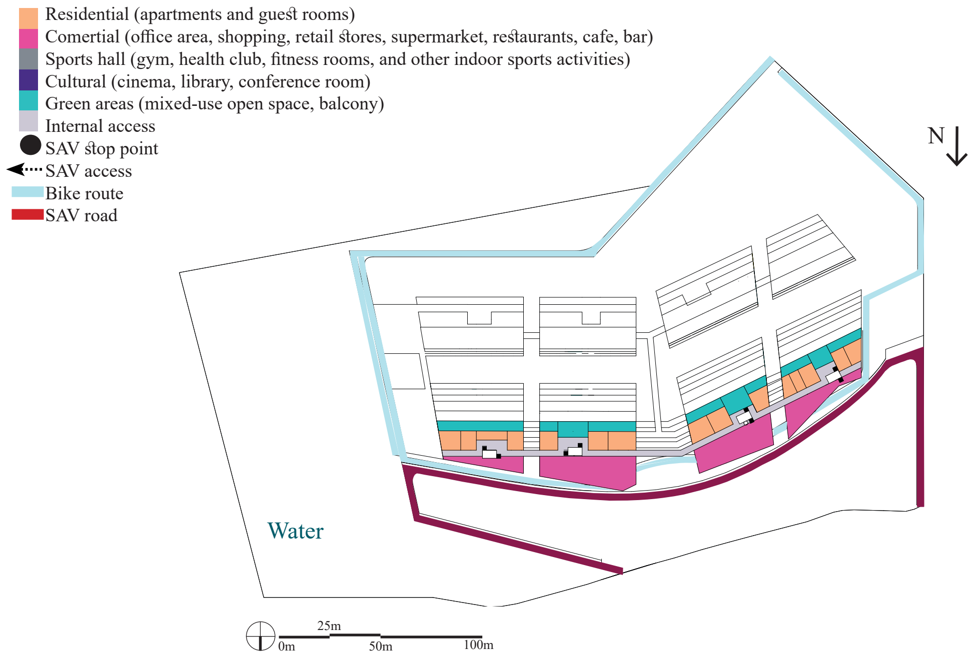
This floor includes office and residential areas. The total BRA of this floor is 4,919 m^2. Each residential unit has a private 15 m^2 balcony on average.

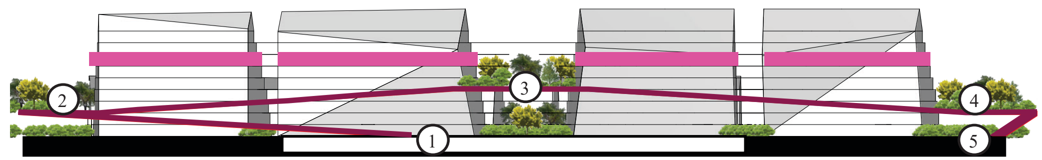
The access to SAV stop points is from 2 levels below, stop point no. 3.



Section A-A

6th Floor



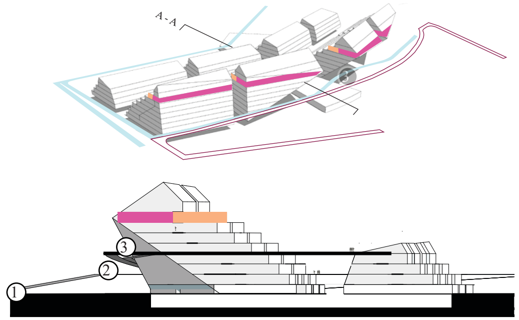


North Elevation

7th Floor

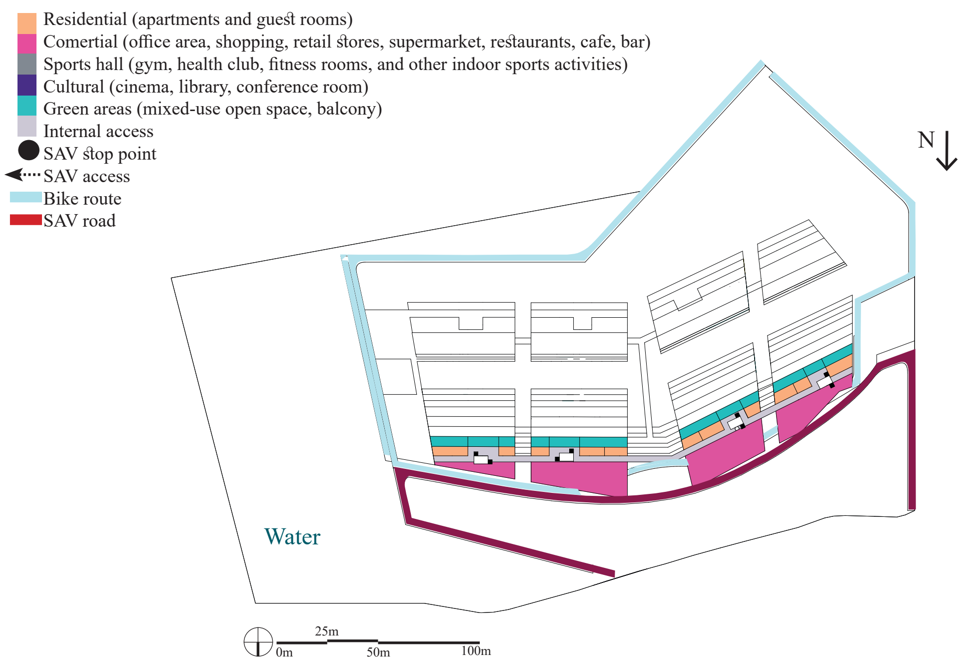
This floor includes office and residential areas. The total BRA of this floor is 4,296 m^2. Each residential unit has a private 15 m^2 balcony on average.

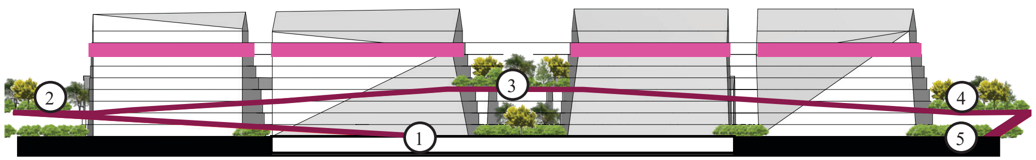
The access to SAV stop points is from 3 levels below, stop point no. 3.



Section A-A

7th Floor



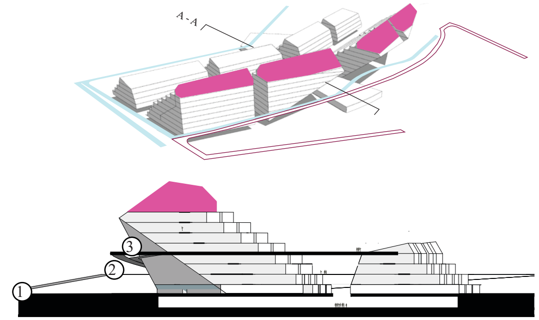


North Elevation

8th Floor

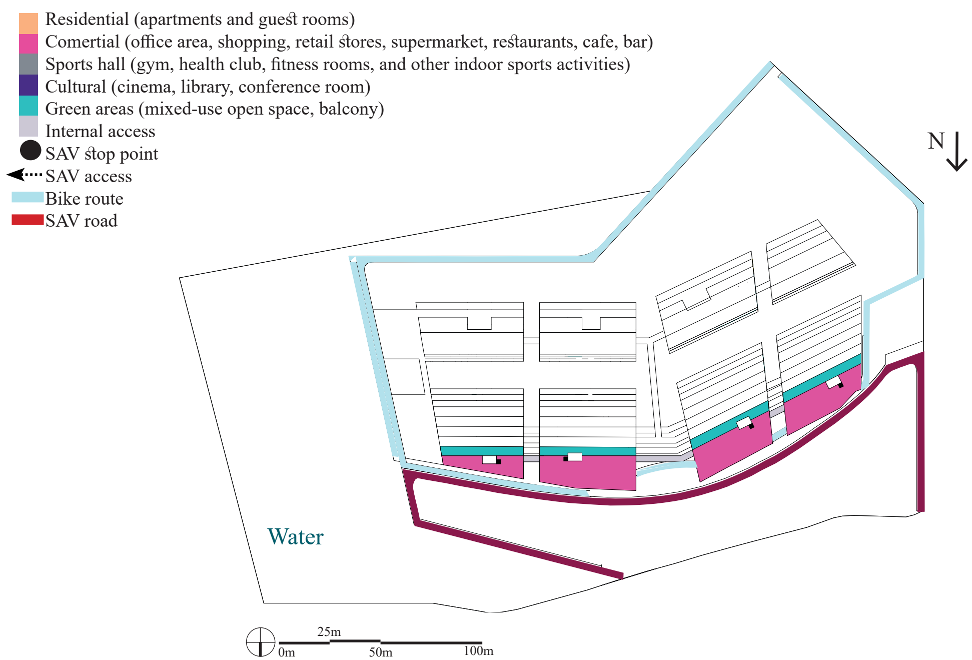
This floor includes office and residential areas. The total BRA of this floor is 3,242 m^2. Each residential unit has a private 15 m^2 balcony on average.

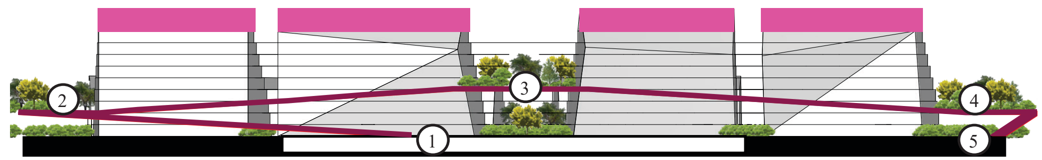
The access to SAV stop points is from 4 levels below, stop point no. 3.



Section A-A

8th Floor





North Elevation

Summary

The mission of European Union 2050 roadmap is to provide a practical, independent and objective analysis of pathways to achieve a low-carbon economy in Europe in preventing more climate change. Climate change may impact many sectors and without cooperation among different sectors not much will be achieved. Building and transportation sectors have major role in this matter. The main question that this thesis aimed to focus on was to explore:

- What would be the relationship between NZEB and SAV through a building design on an actual site (Hinna Park, Stavanger) and their impacts on mobility access, routes, parking spaces and stairs?

The thesis in reply to the main question studied different scenario and used the following criteria in the design process of building:

- Elimination of parking spaces and repurpose them to public open spaces
- Design of open spaces on all sides of the site based on human scale factors to have a positive impact on the residential value on the neighborhood
- Easy accessibility to SAV road, bike and walk routes by elevating them to the different floor levels
- Designation of SAV stop points in different floor levels at strategic points of the building
- Design of an iconic bike route that connects different floor levels and open spaces to attract people to use bikes over other modes of transport and provide opportunity for passing cyclists to stay and enjoy the open spaces in the entire site
- Design of SAV stop points and stairs in a way to create maximum interaction and encourage use of stairs over elevators congestion free

The thesis concluded that by the use of SAV application, the large freed parking space could be repurposed to public oriented spaces; and, providing mobility access (SAV, Bike and Walk routes) in different floor levels with a number of strategic stop points would have a positive impact in use of stair and reducing the number or the capacity of required elevators. It should be noted that this conclusion is not definite and was based on many assumptions and conceptual design aligned with European Union 2050 goal that requires more research and project proofing.

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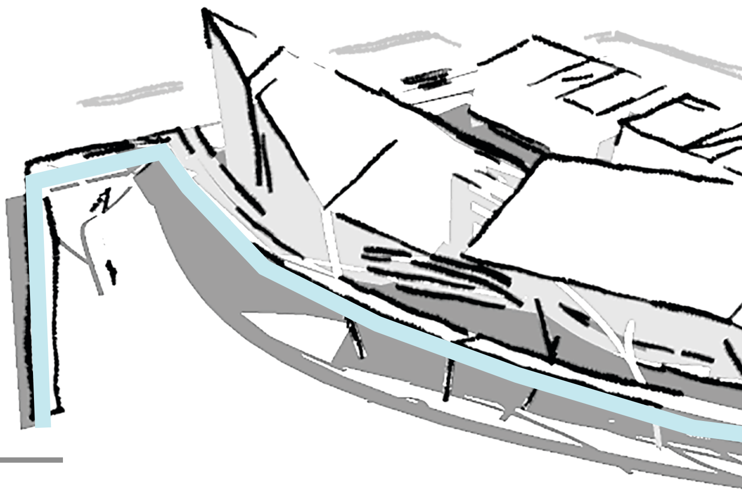

University of Stavanger
June 2018