Beyond the Autonomous Vehicle:
The New Mobility Hub

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Abstract

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This thesis studies the complications and issues that arise in the future when the use of the autonomous vehicle becomes mainstream and more widespread in the city. The autonomous vehicle is a car that can control itself without human intervention. As opposed to the conventional car, which is parked 95% of the day; the self-driving, autonomous vehicle is in constant motion during most of day and rests during the night. This major shift in vehicular will no doubt raise questions regarding the future typologies of parking infrastructure. This thesis will argue that this new type of automotive system requires a new type of parking infrastructure that will be able to serve as a hub for autonomous vehicles while informing a new relationship between humans and machines.

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CHAPTER 1

INTRODUCTION

1. Problem/Issue:

The idea of the autonomous vehicle has existed since soon after the original invention of the car itself. Throughout the 20th century various versions of automated cars have been proposed, variously controlled by radio, computers and even by the human brain. However, it is only in the last decade when this science fiction fantasy has begun to become a reality. High technology companies and major car manufacturers have all been working on their own version of self-driving vehicles that will not only change people's daily life but will also radically impact the built environment (Figure 1).

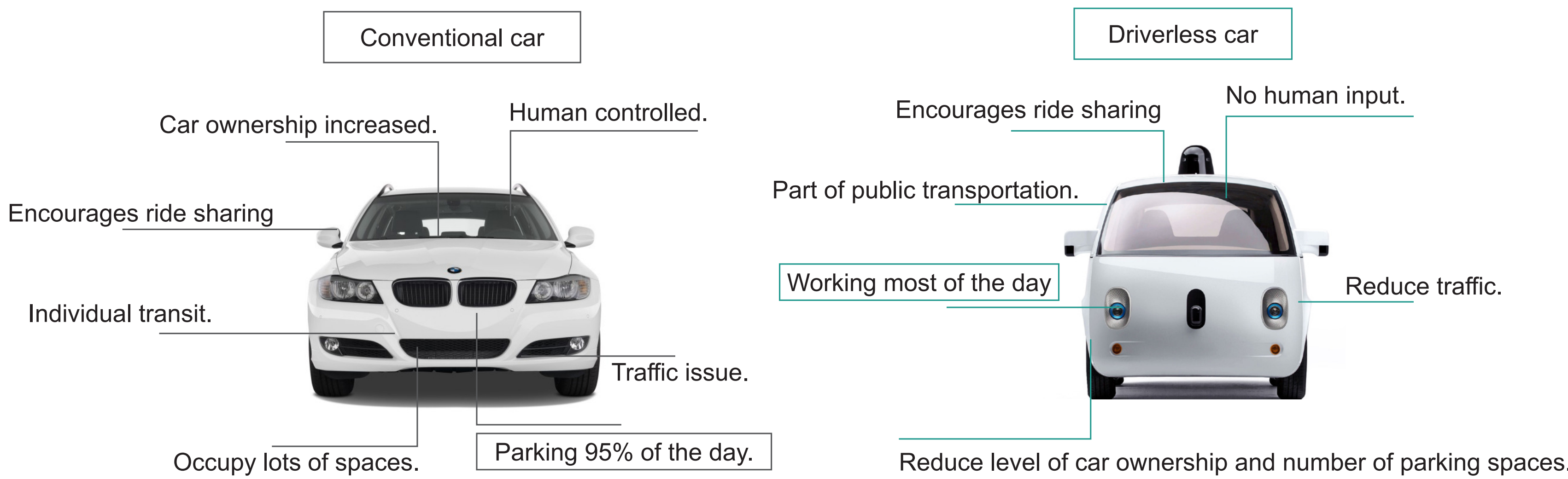

Figure 1. The difference between conventional car and driverless car.

Photo source: https://www.motorauthority.com/news/1066424_2011-bmw-328i-and-335i-xdrive-models-recalled-for-loose-driveshaft-bolts
http://sportauto.cn/new/2016/08/03/google-car/

The largest impact will be felt in city centers where predictions are that in the next 15 to 20 years the wider use of these more maneuverable vehicles will contribute to a major reduction in the amount of city space used for parking (Nourinejad, Bahrami, Roorda, 2018). Urban planners and transportation engineers have agreed that the automation of cars will have a major impact on road infrastructure and parking systems.

The concept of the “first and last mile” refers to a journey from a origin spot to public transit and from transit to the final destination. This means that the driverless car can serve as a part of public transportation system to provide short trips to and from transit stops, especially in suburban areas. Less dense suburban locations are typically the last places to receive public transportation. Even in the future as urban centers grow, suburban perimeter housing will still exist and will require supplementary transportation. As AV cars will be constantly moving throughout the city, private ownership of vehicles will become less necessary because of the improved ride-sharing concept that has the potential to reduce individual ownership (Nash, 2016).

However the expected impact on the city rely not only on changes in the operation of conventional versus autonomous vehicle but also on the way this will affect parking infrastructure. As opposed to the conventional car, which is parked 95% of the day; the self-driving, autonomous vehicle works most of day and rests during the night (Figure 2). Thus, what changes will this bring to the city when parking spaces will no longer be filled during the day. There will be a car park revolution in the future, raising the question of what the typology of parking infrastructure in the city will be in the future. It is time to think about the impact of future transportation infrastructure beyond the autonomous vehicle, and onto the architecture of the city.

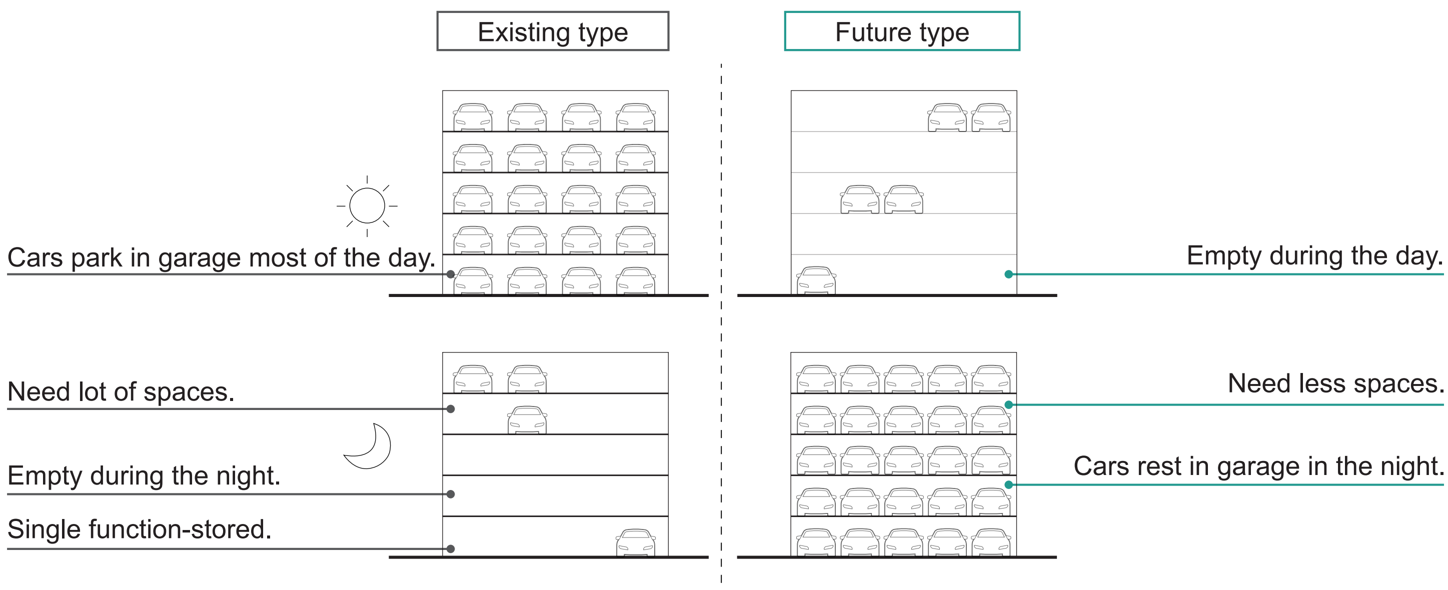

Figure 2. Parking concept changes.

2. Thesis statement:

This thesis argues that autonomous cars represent a revolution in transportation that will have a major impact on the built infrastructure of the city. Research indicates that the reduction in overall number of cars, the decrease of parking spaces and the rise in car sharing will change the way the built environment will function and look in the future. However, these major changes to the future of parking infrastructure must respond to the character of the autonomous vehicle. The thesis proposes that there will be a car park revolution in response to the new era of driverless technology (Figure 3).

Thus, this thesis will analyze the needs of the self-driving car in order to identify potential sites for designing the future parking infrastructure in the city. The proposed prototype of car park facility will not only serve as a car hub but will also express the changed interaction between human and machine. The design of a mobility hub will function as a place of rest for the AV cars but will also provide flexible programs and spaces for the users at the same time.

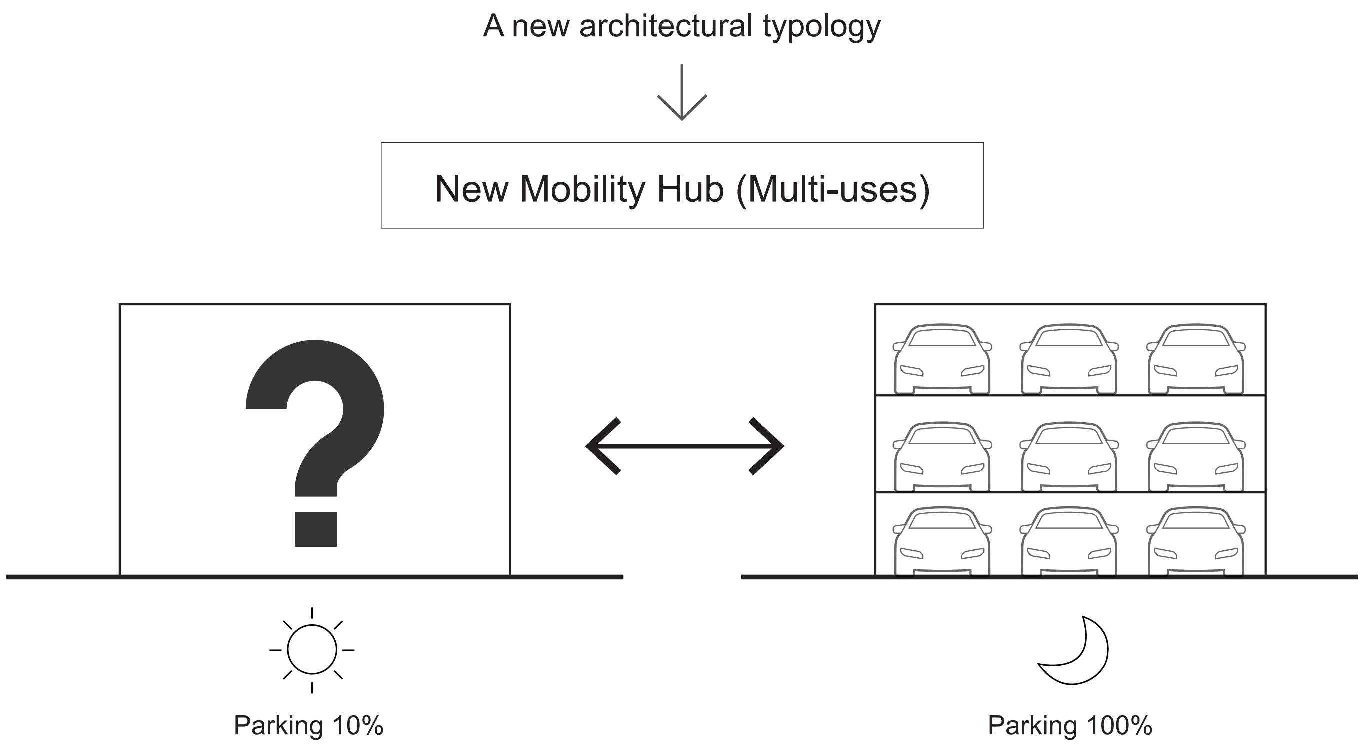

Figure 3. A new parking typology.

3. Project

The thesis design project is a new mobility hub which not only provides services for the AV, but also includes multiple programs for users, serving as node in the city's future parking infrastructure. The proposed facility will transform constantly into different type of spaces offering multi-functions that respond to different usage patterns throughout the day and night. Research shows that self-driving car parks will first emerge in less dense cities because of the lack of transportation options for large numbers of commuters. Thus the project site will be located at the west of Northgate light rail station in North Seattle area where there is a high concentration of transit activity.

4. Methodology

This thesis aims to design a new mobility hub that responds to the changes in transportation infrastructure caused by the autonomous vehicle. The literature review will analyze the self-driving car and ride-sharing concept and their impact on the city. The site and program of the proposed design project will be defined by the understanding of a new type of mobility in the city of Seattle.

CHAPTER 2

LITERATURE REVIEW

1. Introduction

Radical changes in transportation brought about by the autonomous car will have a major impact on the built infrastructure of today's cities. Parking spaces will become less present in the city due to the effect of the ride sharing concept and the reduction in the number of cars. Moreover, concept of parking will change because the AV will move constantly throughout the city in the day. Thus, the AVs will park less because they will stand and wait only for their briefly for their next services. Although the existing parking lots and garages will no longer be needed, cities will still need spaces for cars to "temporarily rest" rather than be stored for long periods. The new kind of car park infrastructure revolution will happen in the future. This thesis proposes that a new kind of "mobility" hub is needed that responds to the changed human and machine interaction created by the autonomous vehicle.

This chapter is divided into three sections. First, the autonomous vehicle, then the ride sharing concept and lastly "the first and last mile" will be analyzed in terms of their defining characteristics. Based on this analysis, the thesis will demonstrate how the autonomous vehicle will have a major impact on the built infrastructure of the city. Finally, case studies will be used to understand how the new mobility infrastructure will change station design approaches to the AV and users. The intention of this chapter is to illustrate the AV's influences on the built environment, and the need for a new type of mobility hub that can better serve the changed interaction between humans and vehicles.

2. AVs as the users

1) Definition of the AV

The development of automobiles over the last hundred years not only demonstrates technical progress but is also evidence of human achievement. Recently the concept of the autonomous vehicle has received a great deal of attention from car manufacturers and urban planners. However, the idea of a driverless vehicle is not new, emerging first in science fiction novels in the 1950s. With advances in automotive technology, people have begun to make this fictional idea into reality (Herrmann, Brenner and Stadler, 2018, p.3).

The autonomous vehicle, also known as the self-driving or driverless car is a vehicle with driver assistance systems which combined with sensors, cameras, radar and artificial intelligence to navigate between destinations without human input. The simpler explanation is that the self-driving system takes the responsibility for all driving operations all the time. With this completely automatically controlled system, a vehicle has no driver, meaning all of its occupants are passengers or users (Herrmann, Brenner and Stadler, 2018 p.96). High technology companies and car manufacturing firms have been developing their own versions of autonomous cars including Audi, BMW, Tesla and Google.

The U.S. National Highway Traffic Safety Administration (NHTSA) states that today there are six levels of automation of vehicles (Figure 4). Beginning with Level 0, humans are fully in control of the automobile which means there is no driving assistance systems at all. With Level 1 vehicles, although Advanced Driver Assistance System (ADAS) aids the driver with single or multiple supports, but not simultaneously. Level 2, with multiple advanced driver assistance systems takes control of more of the driving tasks. From Level 1 and 2, the driver still has the power to take over full control of the driving function and must monitor the systems and surroundings. Level 3 can be considered as the beginning of the autonomous vehicle. ADAS can almost control the vehicle, but the driver needs to be prepared to take over the car under some circumstances. At Level 4, the car dominates all of the driving functions in certain circumstances such as on the highway. Margaret Rouse states that the system can full master the vehicle at Level 5 (Rouse, 2018). Although today most car manufacturers have only reached level 3, they are confident that level 5 autonomy will be ready by 2025.

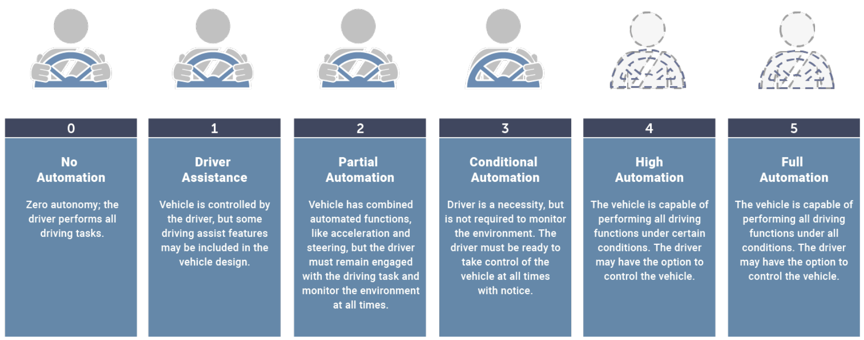

Figure 4. Six level of Autonomous Vehicle. Source: NHTSA

2) The ride-sharing concept

The future of transportation in the city is an important and pressing issue as the urban population continues to grow. The existing physical infrastructure is deteriorating due too traffic increases and environmental concerns. Alternative modes of movement especially in the city are being developed from better transportation systems to ride-sharing networks. The ride-sharing concept came from the idea of the sharing economy which is based on the idea of a hybrid market of owning and exchange. Statistics show that personally owned cars are typically not occupied for 95% of the day. With only one person on many trips, several spaces in the car are unused, referred to as “underused assets” (Herrmann, Brenner and Stadler, 2018 p.341). Transportation experts and urban planners agree that the future lies in the idea of “shared mobility” that includes car sharing, carpooling, van pooling and other “platform based” ride services. Ridesharing is defined as when independent drivers, who often own their car, sign up with “platforms”. This kind of app-based car sharing like Uber or Lyft has become established in the market , using communication technology to link drivers up with customers who need rides (Ajmal, 2017).

However, the majority of these companies still rely on the traditional system of a human operator who owns their own car but “shares” it with others on a temporary basis (Nicoll and Armstrong, 2016). As driverless technology continues to improve, the ride sharing concept of AVs has the potential to become even more efficient when the vehicles are driverless more efficient because they are driverless.

The ride-sharing concept provides the potential to better utilize underused cars by making them continually in motion, reducing the need for car ownership. By combining the ride-sharing concept with driverless cars, customers do not have to make an initial investment of car ownership. A more efficient system results where people only have to pay for the service when they actually need and use it.

Andrea Holmes notes that there are three ownership models of the AV; private ownership, shared ownership or single occupancy and shared use or multiple occupancy. With the private ownership model, the AV only replaces privately-owned automobiles, so the number of cars will continue to increase in the future (Holmes, 2017). In this model, the city still needs to provide the same amount of parking spaces as today or even more.

Moreover, KMPG, a professional service company, predicts that the sales of personally-owned vehicles will drop sharply from 5.4 million to 2.1 million units sold by 2030 in the U.S. KMPG also shows a study that driverless systems could reduce more than half of the demand for self-owned sedans in the United States by 2030 (KMPG, 2017). Both concepts of shared ownership with single and multiple occupancy will reduce the amount of parking spaces. Also, the reduction of self-owned cars in the United States. Holmes states that single occupancy will require car parks located in cheaper areas on the periphery of towns because there will still be a large number of cars. On the other hand, multiple occupancy will significantly decrease the number of cars and the parking demand (Holmes, 2017).

3) First / Last Mile

"First and Last mile" is a phrase originally used in telecommunications and supply chain management (King, 2016). In recent years, the first and last mile concept is used in transportation planning to describe the movement of passengers at the beginning or end of an individual trip from a public transportation stop to a final destination (Goodman, 2005). People have a number of options of transport to finish the travel journey. For example, they may choose to walk, bike, bus or even take a car. Transportation planner, Jarrett Walker has stated that commuters will walk to a public transportation hub if the distance is less than ¼ miles. However, in some cases if the travel distance is greater than walking distance or may be difficult to access by foot. This gap from origin spot to public transit or from public transit to the destination which is called the first and last mile (Metro and SCAG, 2014).

Public transit agencies and cities usually provide bus services to help passengers fill this gap, however, recently public transportation agencies have begun to combine car ride sharing concept to provide more options to complete this short trip to and from public transit stations, such as Uber and Lyft. The first and last mile is important idea that will bring many benefits for the future transportation network. Moreover, besides bike, walk and bus, the car is one of the most popular commute option from home to public transit and from transit to the destination (Figure 5).

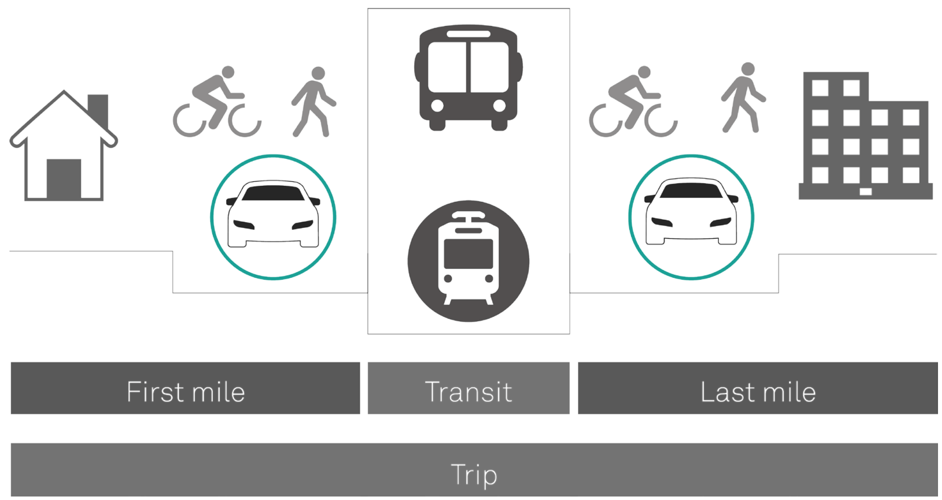

Figure 5. First and last mile trip.

4) The AV needs

The automobile has generated traffic and parking problems since it first arrived in the world. Cities require parking space almost everywhere, and these parking lots, and large parking garages requirement are a critical link between the automobile and the urban form (Manville and Shoup, 2005). Parking plays an important role in a city's transportation system because a traditional automobile spends 95% of its lifetime sitting in a parking spot (Mitchell, 2015). However, a city full of autonomous vehicles changes this pattern meaning the AV will work most of the day, and rest during the night. The AV will thus circulate frequently for 24 hours service (Thakur, Kinghorn and Grace, 2016).

In the next decade, parking modes will be as fully redefined as the automobile will be. The self-driving car will be able to virtually precisely park by itself in the future meaning fewer parking spaces will be required. Current research by parking analytists shows that each conventional car requires at least 10 feet by 18 feet of stall meaning a current vehicle needs an average of 300 square feet parking space (Figure 6). On the other hand, the driverless vehicle only needs 7 feet by 16’ per stall which means it only requires 112 square feet parking space per vehicle (Barth, 2017).

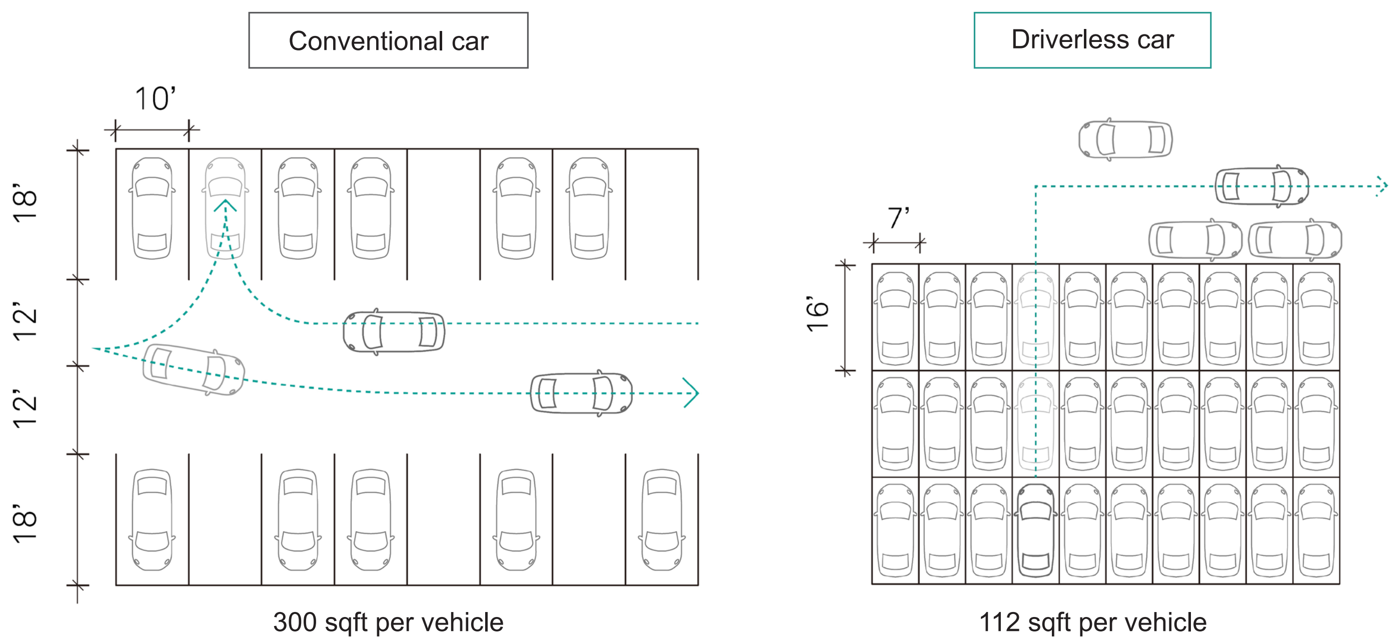

Figure 6. Driverless car saves more spaces.

According to the Los Angeles Times, the AV may not even need to park, since they will be simply driving around in the city 24-7 until they are needed or they will stand and wait for the next service. Also, other parking specialists agree that some driverless vehicles will simply navigate around instead of parking (Baumgardner, 2016). Although the driverless cars will park less frequently than traditional automobiles, they still need spaces to rest. As car manufactories continue to enhance the driverless technology the way they park also has been improved. The cars can let their users off in the city and then automatically head back to a rest area on their own. The users can use apps to send a request service for the AV to pick them up at a designated area after they have completed their business (Herrmann, Brenner, Stadler, 2018 p.304).

Furthermore, the improvement of the ride-sharing networks will also shape the future demand for parking in the driverless era. Studies by urban planners and transportation engineers have tried to understand the impact of the AV on parking demand based on the shared ownership model. If the automobile becomes a service facility, users will only hire it when they need it. The parking demand will be limited to between waiting and pick-up times. Car parks will need to be located at important destinations where there is a high demand by commuters for alternate forms of travel (Holmes, 2017).

Throughout the world, while suburban locations in other countries often have more efficient transportation networks, the United States lacks effective methods of mass transportation meaning suburban areas always require automobiles are often the major transportation option for individuals that live areas that lack public transportation (Patel, 2018). Moreover, recent studies also indicate that the AV could sharply improve traffic conditions in the suburban areas. An example of this is Allston, Massachusetts, just outside of the city of Boston. Research indicates that passenger travel times in Allston will decrease 12.1% by utilizing mobility-on-demand. The World Economic Forum predicts that mobility-on-demand will mostly replace the use of individual vehicles rather than public transit (World Economic Forum, 2018).

Moreover, the future parking infrastructure will be transformed into waiting areas and service facilities where AVs are maintained and recharged, in preparation for their next service (Holmes, 2017). The future parking facilities will require less room for the operation and movement of the vehicle and its passengers in the form of elevators and staircases (Nourinejad, Bahrami and Roorda, 2018). Research also indicates that the AV will have three narrow driving lanes which is different than the conventional car's because the third lane will be an inter-island gap which serves as a buffer zone or a waiting area. For instance, as seen in Figure 7, the blue car wants to leave but it is blocked by two green cars ahead of it (Figure 7). At this situation, the strategy is to provide a space that could let two green cars stay, also allow the blue car leave (Nourinejad, Bahrami and Roorda, 2018).

Like electric cars, AVs can let their passengers out in a drop-off area in town and then re-charge independently. Charging stations could also provide other services such as maintenance and repair. Eventually some analysts predict that there could be a wireless charging infrastructure at stop lights, intersections and traffic signs (Herrmann, Brenner and Stadler, 2018 p.305).

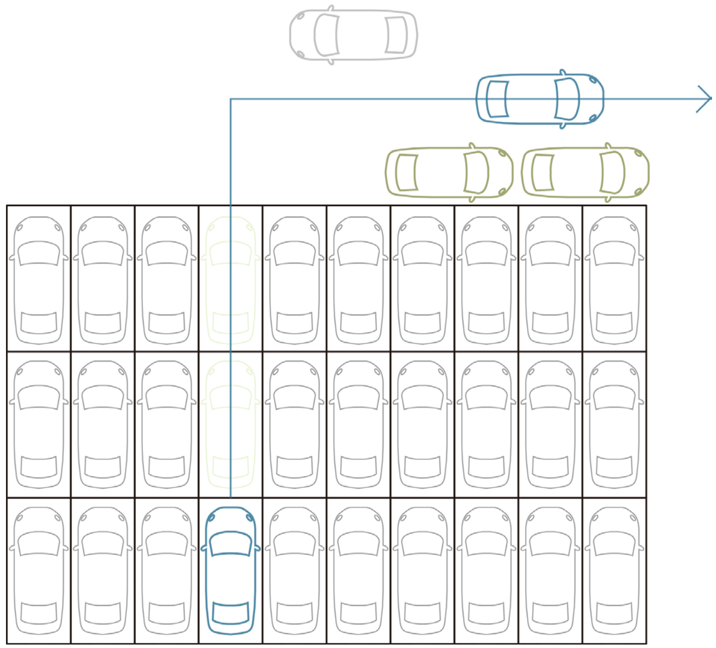

Figure 7. Inter-island gap.

3. AVs and the urban

1) AVs influence on urban city

The idea of combining the ride-sharing systems with a new type of driverless vehicle promises to radically change the way people move through the city. Shared autonomous vehicles offer the potential of changing not only the character of urban transportation but also the physical characteristics of the built environment. According to the concept of first and last mile, the driverless car will be a part of a public transportation system that provides short trips to and from transit stops (King, 2016). Car parking facilities will require to be placed at key destinations in the suburbs where there is a high demand of travelers seeking alternate means of the alternate way of travel. Suburban locations are the last places to receive public transportation. Even in the future as urban centers grow, less dense perimeter housing will still exist and require supplementary transportation.

The journal, *Business and Industry* observes that in urban environments vehicles typically are in use for only 5 percent of the time- in other words they are parked 95 percent of the day (Mitchell, 2015). On the other hand, the majority of the existing space dedicated to cars is for parking, either in surface lots or in parking garages. Much of traffic congestion in the city is caused by the time consuming and increasing difficult challenge of finding a parking spot. The space required for vehicle storage, including exiting and entering has created a hardscape which has caused a lack of green spaces and pedestrian unfriendly climate in many cities. The AV can reduce surface parking square footage because of its maneuverability and constant flow of movement. According to the Huffington *Post*, the use of the autonomous vehicle means urban parking lots are dead or dying, also resulting in the change of the use of the curb in the city. Currently the average width of a parking spot in the United States is between 8 and 9 feet due to the need to safely move drivers and passengers in and out of vehicles. A driverless car can park in a smaller parking spot without any collision with the adjacent vehicle (Grinberg and Wiseman, 2013 & 2017).

According to Will Baumgardner, the AV could reduce 75 percentage or more of parking spaces in major cities across the country (Baumgardner, 2016). This smaller vehicle footprint also has an impact on the streets of the city and sidewalks. Jerome Unterreiner of HOK architect, has argued that “AVs will greatly impact and positively influence the built environment, especially the street edges, by establishing a more robust and extended relationship between the building and the street.” (Innovation Insider, 2018). Driverless cars offer the possibility that the land can be utilized for other purposes that have more of a benefit to the public (Herrmann, Brenner, Stadler, 2018, p.304). These huge changes will cause the transformation of urban spaces in the future. As a result, numerous urban planners or landscape architects have already started to reimagine the future cityscape.

2) AVs influence on existing infrastructure

The impact of the AV in the city also extends to the existing urban's infrastructure dedicated to the storage of the car. The enormous amount of space dedicated to automobile can be seen in a bird's eye view of a city (Herrmann, Brenner and Stadler, 2018 p.304). Urban downtowns across the entire country are filled with multi-stored parking garages that occupy a great deal of high value real estate. These structures were typically built to serve one simple function which is the storage of the car. In *The parking Garage: Design and Evolution of a Modern Urban Form*, Shannon S. McDonald observes, (McDonald, 2007) "The parking garage is a large, imposing desolate and often stark structure." She traces the history of this building type from its origins as converted house stables to the "strictly functional, multi-storied austere ramp-system structures" that dominate cities today. However, she argues that they can be built better to have a stronger relationship with their surroundings. Real estate developers, urban planners and architects agree that the existing urban parking garage is rapidly becoming obsolete. Occupying valuable real estate in urban cities and inefficiently designed, this aging infrastructure poses a new challenge in the face of changes in automobile technology. According to Boston.com, self-navigating cars require less space to move, park and maintain, as driving lanes can be narrower and staircases and elevators for circulation of drivers are no longer needed (Salomon, 2016).

The California research firm Arrowstreet has estimated that the demand for parking space will decline by 5.7 billion square meters by 2035 in the United State. The existing aging infrastructure of parking garages has been designed to serve the sole purpose of storing human driving machines. However,the widespread use of AVs will change this pattern since they are able to serve passengers almost the entire day, and stopping and resting only when they are repaired or charged. This new kind of car function will change the way people think about the parking facility because these future car parks have the potential to have multi-functions or programs. New technology in transportation like the shared AV vehicle will radically alter current needed functions in the movement of cars and people. Driverless cars will drop passengers before entering their parking facility and head to a location by their self-driving system or be called to the next service spot by a user's applications of smartphone. This automated efficient movement of the car opens up greater possibilities for a new kind of parking infrastructure that incorporates other kinds of uses for people on the street.

3) Theoretical Synthesis

This research demonstrates that the autonomous vehicle has the potential to make a significant contribution to the built environment that along with the ride-hsaring concept will bring about changes in the ownership of cars. The self-driving system replaces human control over the vehicle in order to reduce the possibility of car accidents and traffic jams. Many urban planners, architects and car manufacturers have predicted that entire cities will be impacted by the AV era. This new technology of transportation will change the relationship between humans and their vehicle. The driverless car can almost considered like a living being that can move and park independently, and with the same life pattern with human, they will not just stay in the garage entire day. Therefore, like its passengers, the AV also needs facilities to use, for rest, repair and charging. This new concept of mobility in the city will fully alter the built infrastructure in order to adapt to the advent of the autonomous world.

4. Precedent Analysis

The precedent analysis section analyses two case studies that show innovative approaches inspired by the autonomous vehicle. The study of Blueprint for Autonomous Vehicle project enables an understanding of how the design principles of the AV can be applied to the future infrastructure. Examining AUDI Urban Future Initiative helps to learn about the integration of driverless cars and lifestyle into the city.

1) Blueprint for Autonomous Urbanism

The nonprofit association called NACTO (The National Association of City Transportation Officials) studies cities in relation to transportation issues (Figure 8). Their project, Blueprint for Autonomous Urbanism is a vision of a future city where autonomous technology is used as a tool to improve the public realm and the lives of all urban residents. This purpose project has two main sections that concentrate on the future of city streets and new mobility systems.

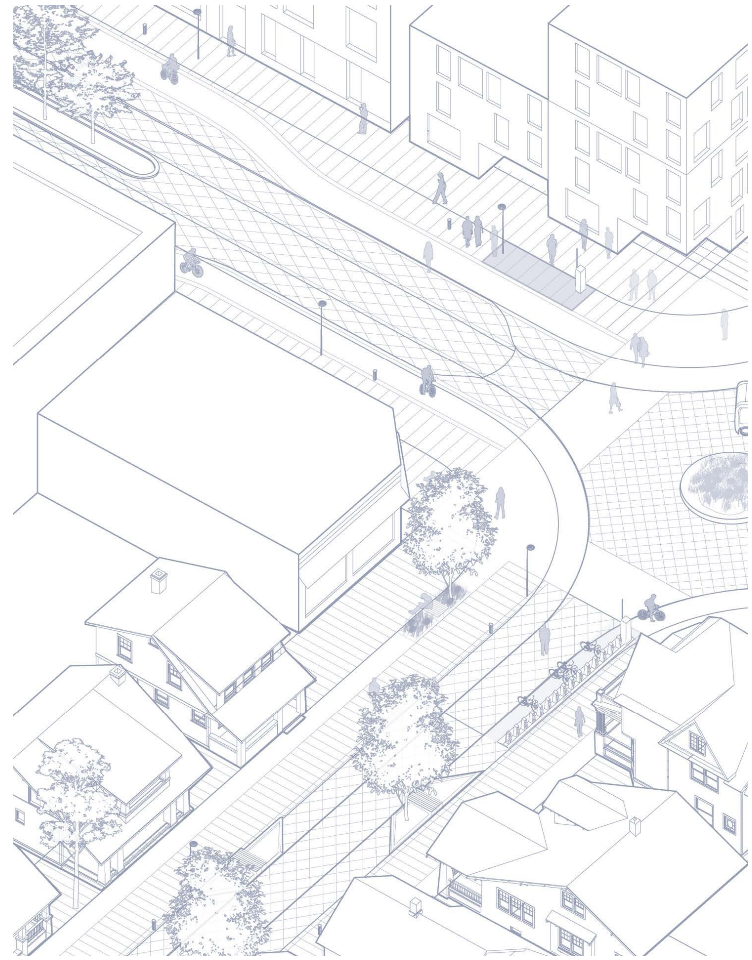

Figure 8. Blueprint for autonomous Urbanism.
Source: NACTO

First, NACTO first imagined imagine the future street as a dynamic place that prioritizes pedestrians, bicyclists and transit commuters. At an urban planning scale, the street system is classified into six levels from large to small scale including a multiway boulevard, major transit street, downtown street, neighborhood main street, residential street and minor intersection. These six street types provide a clear hierarchy that can adapt to the AV era- for example, the main access lane would provide new pick-up and drop-off spaces, Mobility hubs at the major intersections in neighborhoods would also provide marked zones for pick-up and drop-off spaces incorporated with the new mobility network.

Second, the Blueprint also envisions a new mobility system that can integrate transit and shared services with traditional bus route and rail lines. Although the study predicts automated transit will become a major transportation in the future city, it also provides an idea about upgraded bus routes that can feed more users into the AV system. Furthermore, the project envisions integrating flexible services that automated shared vehicles can help provide within the existing transportation network, reducing the amount time and congestion in travel. Autonomous technology plays an important role in an integrated system that carries a passenger from “door to door”. The AV technology not only can serve as the backbone of the city mobility system, but also can serve a crucial task for individual passenger trips (NACTO,2017).

2) AUDI Urban Future Initiative

Many car manufactories and high technology companies have been developing their own version of driverless cars. For example, AUDI has not only been working on the evolution of automobiles but has also on providing an architectural solution that integrates with humans and machines. The site of the proposed project is Union Square in Somerville, a district in the center of the Boston area. Somerville is a testing ground for AUDI's new autonomous technology because more than 40 percentage of its residents are between 18 and 34 years old. This young population could be considered as the ideal test laboratory for the future of urban mobility, according to Philip Parsons, an urban planner and strategic consultant (Chin, 2015).

From the city infrastructure perspective, the Audi Future Initiative project proposes a future urban mobility in a smart city according to three main concepts, which are advanced arrival, adaptive flow and mobility revolution (Figure 9). Advanced arrival means the minimization of the footprint of parking. Adaptive flow is a traffic flow which is controlled by online technology. Mobility revolution includes autonomous vehicles, mobility as service and regulations and pricing (Corneil, 2016).

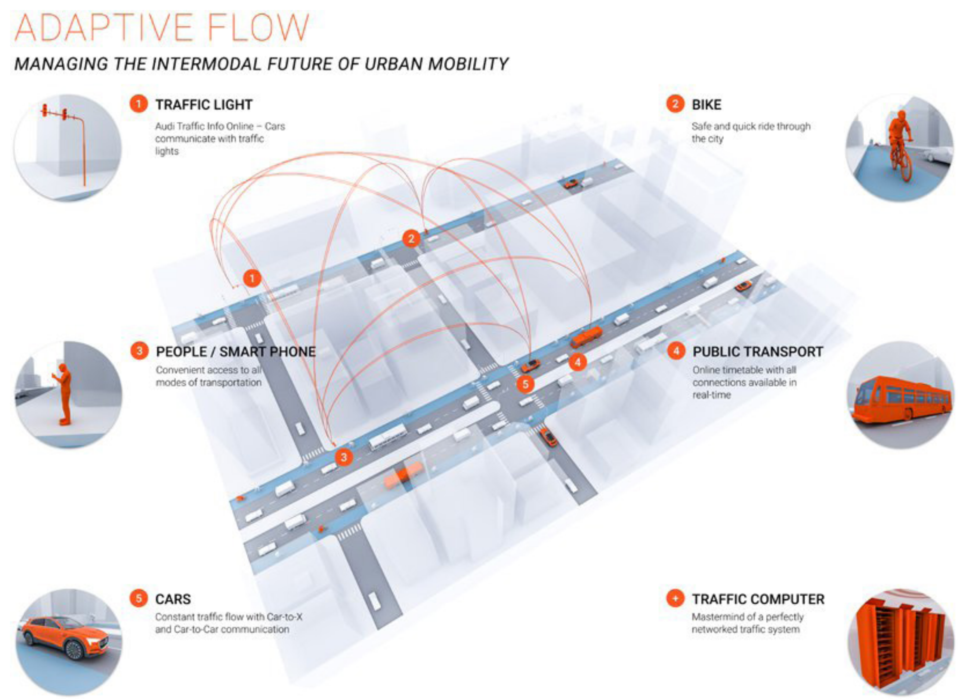

Figure 9. Adaptive Flow. Source: AUDI urban future initiative

The project envisions that the city of Somerville will reduce the footprint of the car by 60 percent in 2040 (Corneil, 2016). The four story urban garage has two main systems consisting of the user with service apps and the car with self-parking technology (Figure 10). Passengers would get more direct access to urban life and spend more leisure time on the ground or upper levels. The car will park itself, and self-charge while waiting. There are two stories of underground AV parking with an inductive charging system. Therefore, this project shows the design principles of the AV era from a future mobility system in a hypothetical building design.

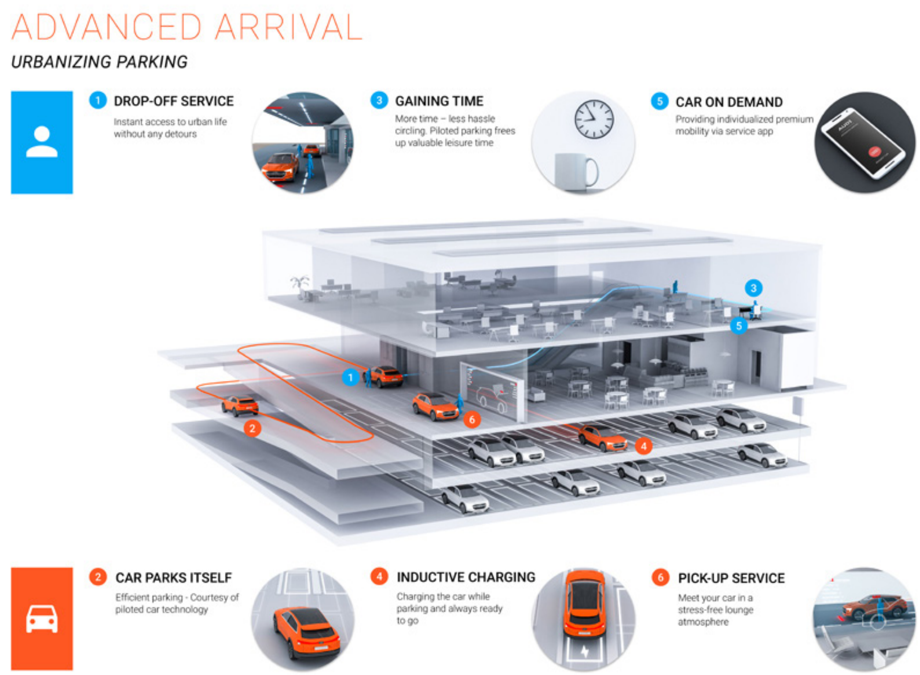

Figure 10. Advanced Arrival. Source: AUDI urban future initiative

3) Synthesis

These case studies provide different approaches to adapting the integration between human and machine from two scales. Blueprint for Autonomous Urbanism outlines a human vision for adapting the AV world at an urban scale from the mobile network to the streetscape. The AUDI Urban Future Initiative attempts to apply the AV technology to a building project that expresses the integration of users and car systems. The design project proposed in thesis will use the design principles of both these precedents as a reference for developing an architectural design that relates to the scale of this urban infrastructure.

CHAPTER 3
DESIGN METHODOLOGY

1. Thesis Goals and Objectives

This thesis states that a new parking revolution will occur in the near future due to the impact of ride-sharing, and the AV technologies on the city. The goal is to integrate the new mobility system and driverless technology into a new parking infrastructure design in order to respond to the new autonomous world. The design objective is to create a future mobility hub that expresses the changed interaction between human and vehicle. The hub will not only be able to service the AV, but also provide leisure facilities for the passengers.

2. Site Selection and Analysis

The research of the literature review forms the foundation of the site selection. Studies in autonomous technologies and car sharing demonstrate the AV will have a tremendous influence on urban parking infrastructure. The existing parking garages and parking lots will be demolished and turn into other uses, such as commercial, residential or green spaces in the future (Henderson and Spencer, 2016). Cities will have more opportunities to dedicate public spaces for the use of urban residents (NACTO,2017).

The concept of first and last mile is an important one for the for the future transportation system because the car is one of the most popular commute option from home to public transit and from public transit to the destination. The research shows that the future car parking infrastructure will be located at key destinations that can meet the high demand of travelers by offering other alternatives. The city of Seattle serves as an example where the mobility hub can be located in a variety of different places (Figure 11). No matter urban or suburban are, the hubs require a connection to public transportation systems. Even in the future as urban centers grow, less dense perimeter housing will still exist and need supplementary transportation. The major transit terminals serve many suburban passengers who have fewer transit options.

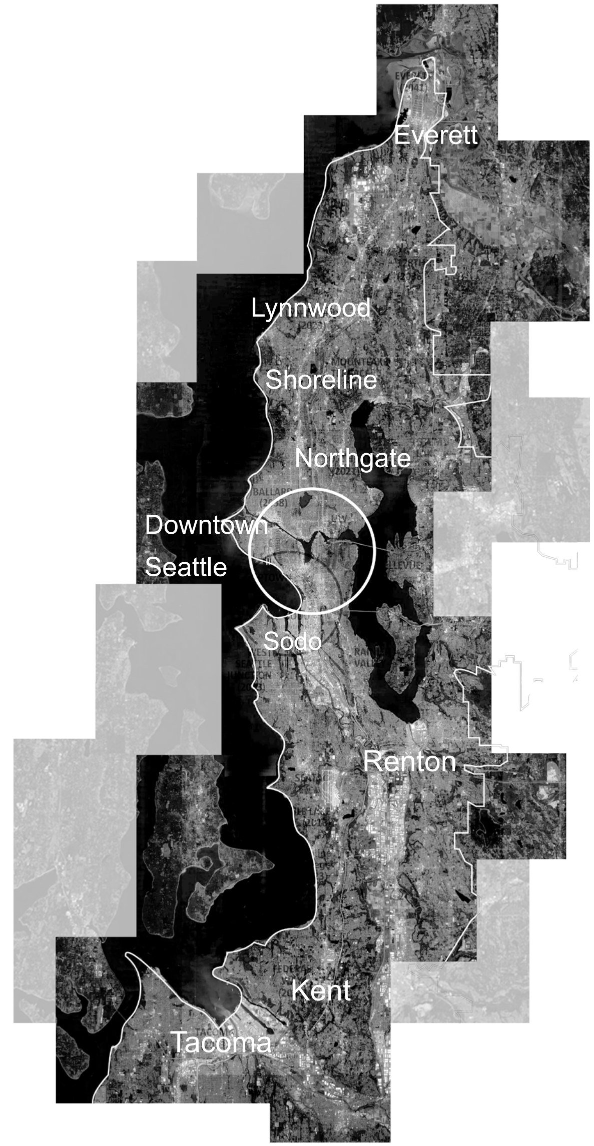

Figure 11. Cities of Seattle.

Throughout the world, while suburban locations in other countries often have more efficient transportation networks, the United States lacks effective methods of mass transportation which means suburban areas always need automobiles to be the major transportation for individual travelers (Patel, 2018). Also, the light rail stations are the places that meet the high demand of commuters. The station is the key destination because people use public transportation to commute (Figure 12). According to the concept of first and last mile, the driverless car can function as one of the public transportation systems to provide short trips to and from transit stations (King, 2016).

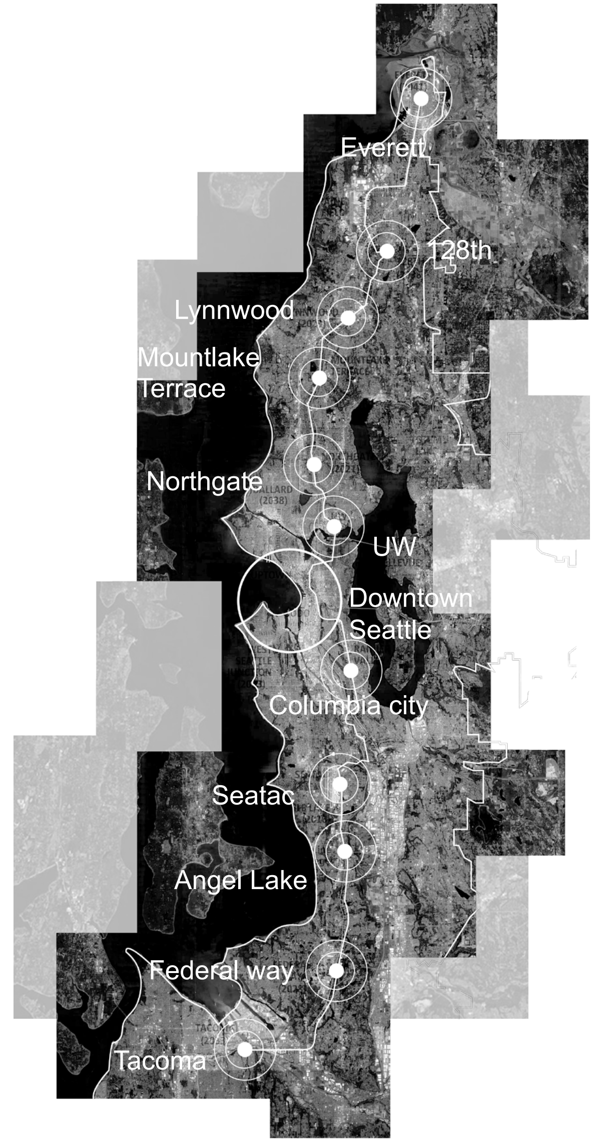

Figure 12. The future light rail expansion stations of Seattle area.

Thus, based on the literature review and case studies, the chosen site for the design project is Northgate in north Seattle, Washington (Figure 13). A north Seattle neighborhood, Northgate will be the terminus of light rail system because it is the site of one of the most heavily used regional transit centers of King County Metro Transit (Figure 14). For example, there are twenty-eight bus routes traveling throughout King County that stop at the Northgate Transit Center. A 2012 Metro survey reported that over 6,000 riders a day use the transit center, and the majority of riders at the center get there by car.

The Northgate Transit Center will integratethe proposed project with existing with transit, bus lines, vehicle routes, bike trials and pedestrian sidewalk. The Northgate light rail station is predicted to have approximately 15,000 daily boardings and will continue to be a major transit hub for the entire North Seattle area (City of Seattle, 2015).

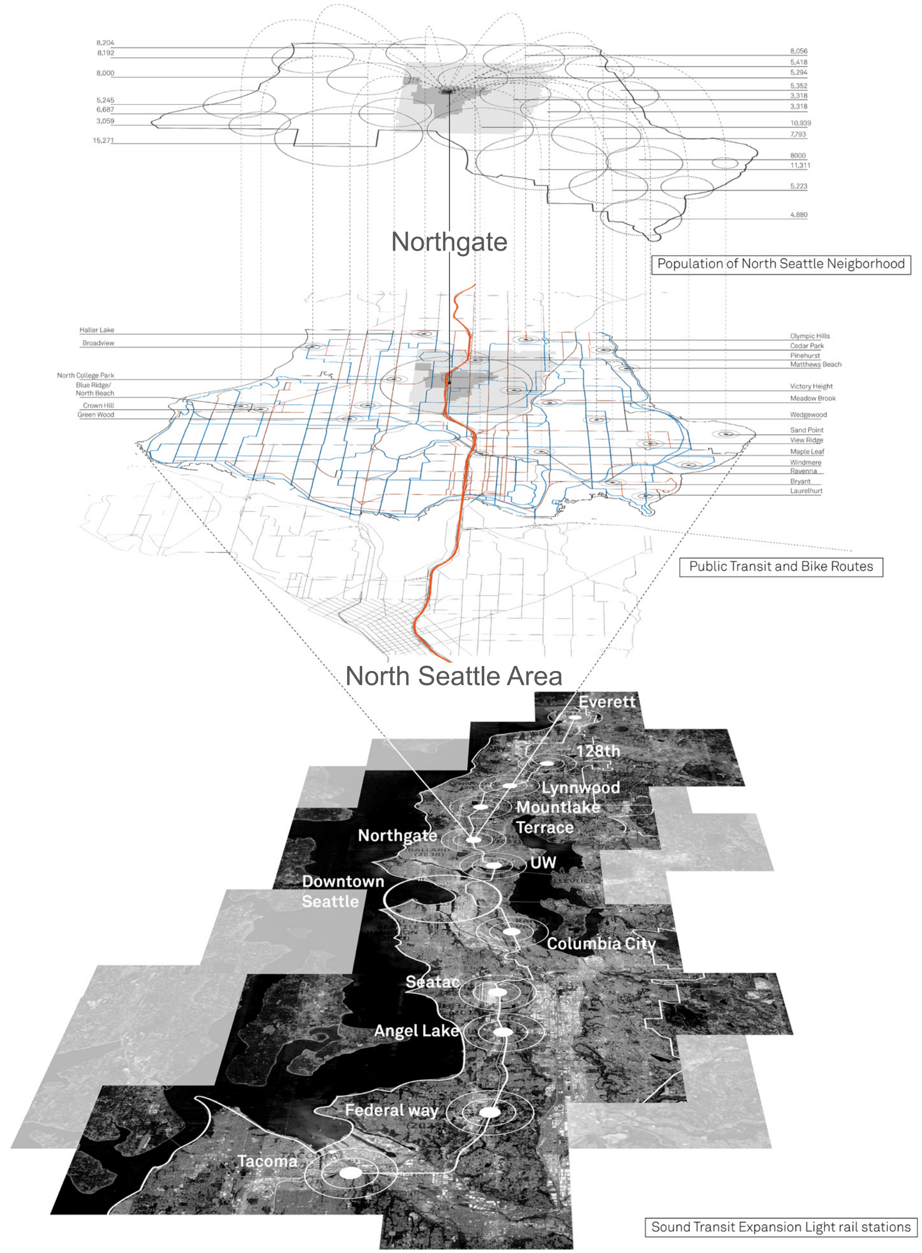

Figure 13. Site analysis. Source: Wagda GIS Data

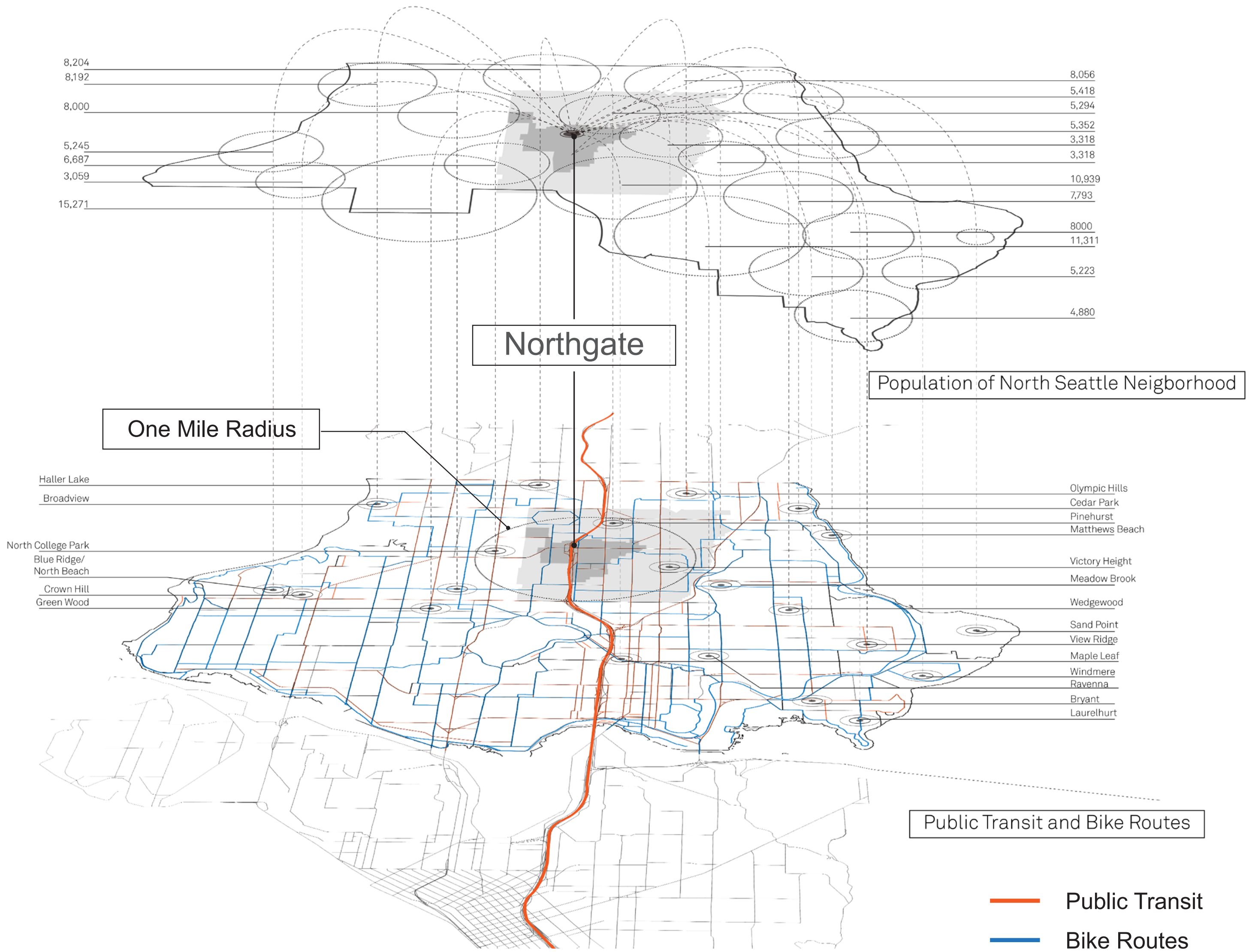

Figure 14. Neighborhood analysis. Source: Wagda GIS Data

The goal of the thesis is to create a universal prototype of the car hub, so one site has been chosen as an example in the Northgate area. The site is currently a surface parking space of Northwest Outpatient Medical Center, located at west of Northgate light rail, north of Seattle college, and west of I-5 highway which is the main Interstate Highway on the West Coast (Figure 15). The site analysis shows that I-5 highway blocks any connection between east and west in the north Seattle area. There will be a future pedestrian bridge to re-connect east and west of north Seattle (Figure 16). However, the design project also has potential to be another connector to solve this issue providing more opportunities for movement through the neighborhood. Moreover, the design project will serve as a multi-function space which could offer more activities for college students and neighbors who live in the area.

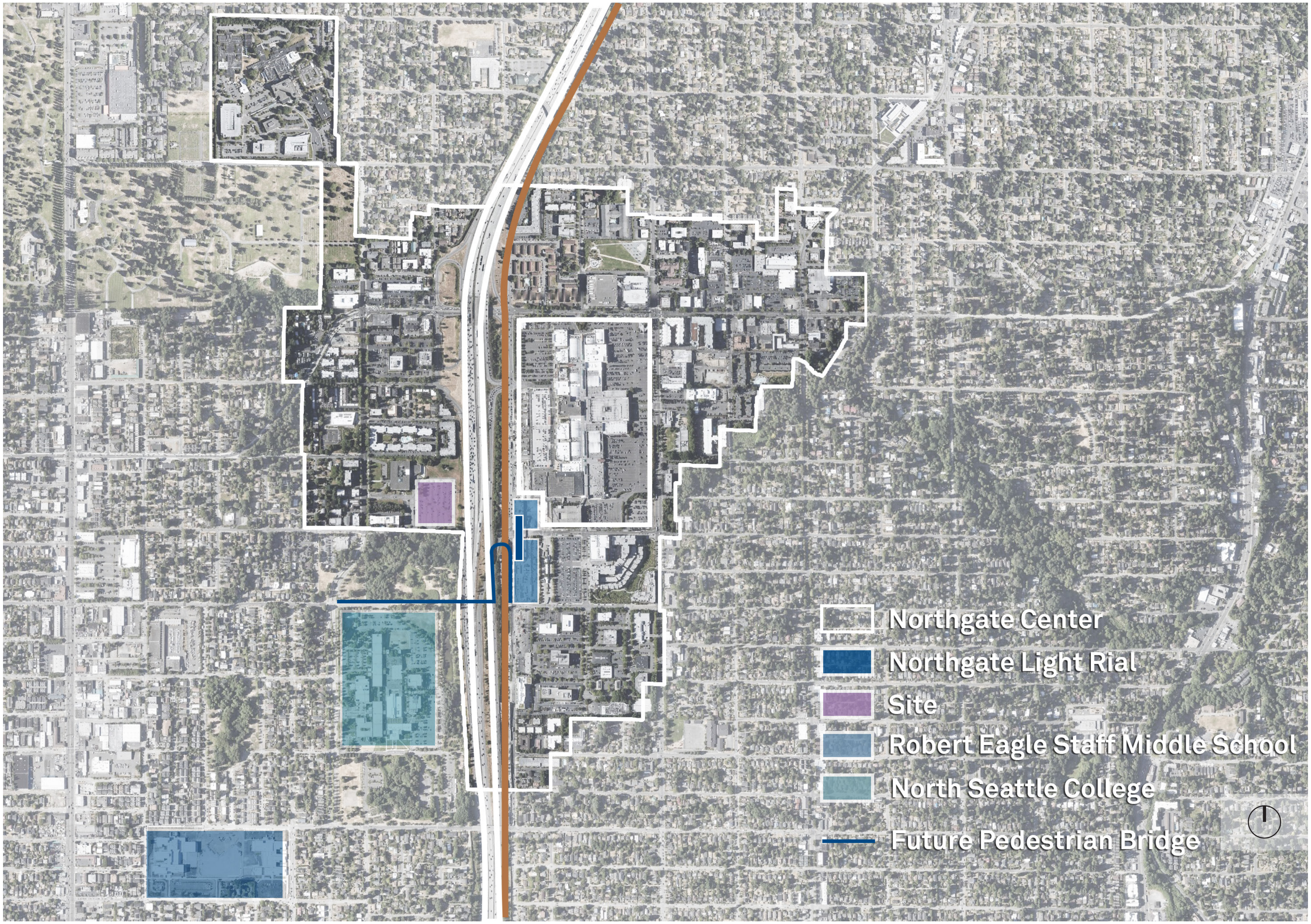

Figure 15. Vicinity map.

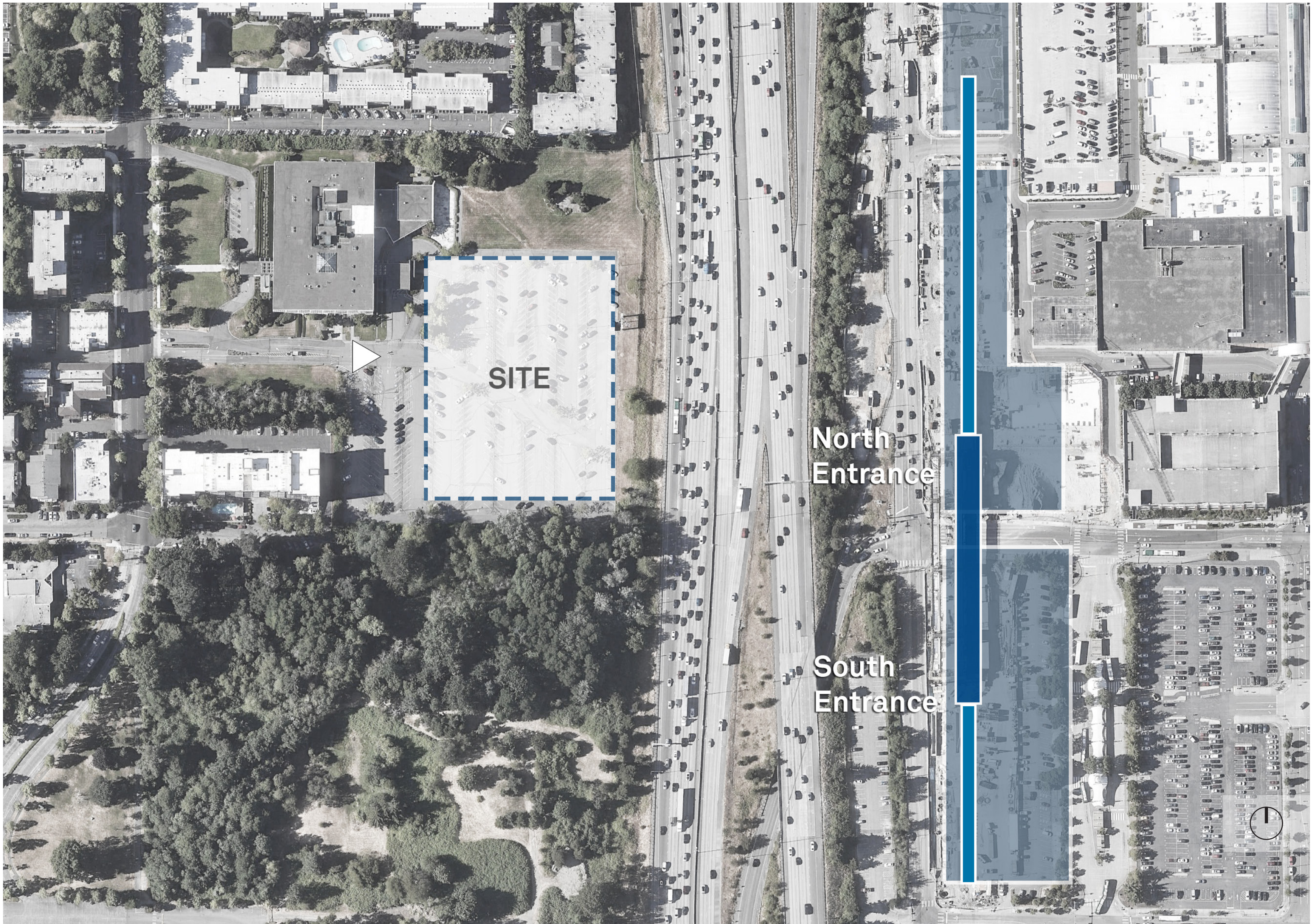

Figure 16. Site map.

Figure 17. Site photo looking East.

Figure 18. Site photo looking Southeast.

3. Program of Spaces

The thesis objective is to create a new mobility hub that transforms the relationship between cars and humans. As shown in the literature review, car park stations will be converted from simple functional storage into multi-use hubs for cars and passengers (Holmes, 2017). The design idea is to provide multi-function spaces for cars and people. Thus, the programs require flexibility and movability allowing the spaces to be changed and easily adapted (Figure 19).

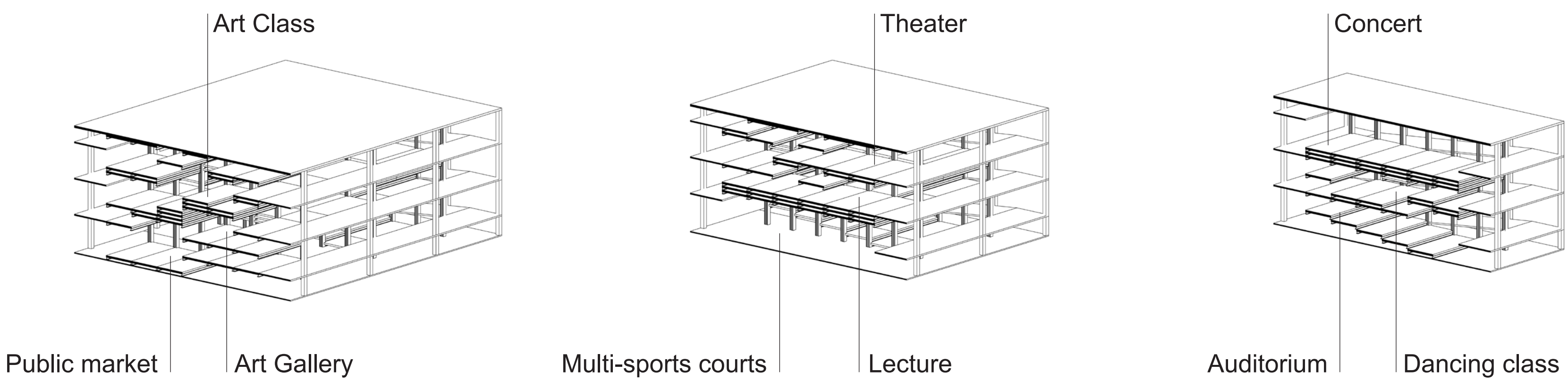

Figure 19. Program diagram.

CHAPTER 4
FINDINGS

1. Design concept

This thesis aims to create a new architectural typology to response to the new autonomous world. According to the previous research, the conventional cars and the self-driving vehicle have different functional patterns. The inversion of the parking timing patterns will cause major parking infrastructure changes. Therefore, the design concept focuses on how a parking space changes interactions between human and machine (Figure 20).

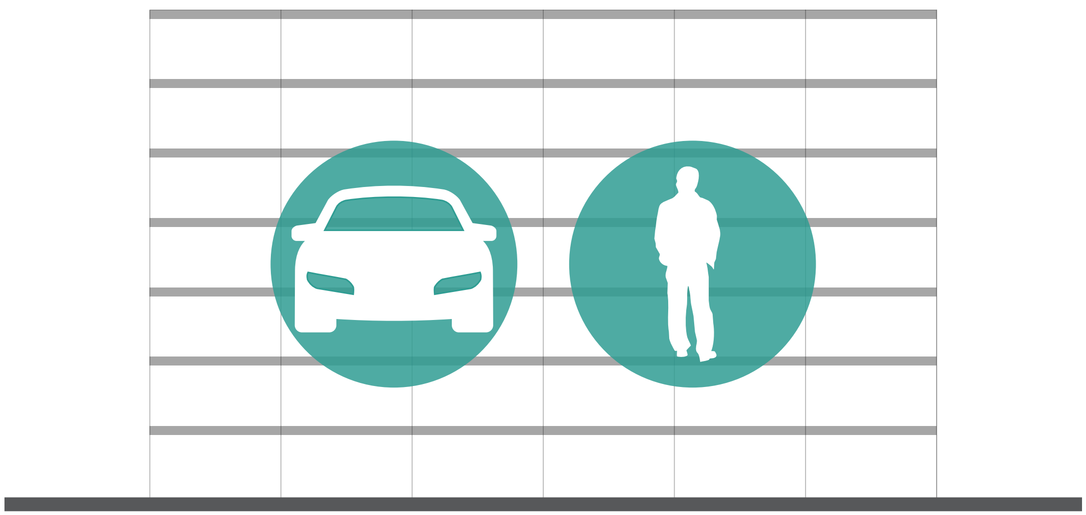

Figure 20. Concept diagram.

2. Design strategy

The new mobility hub is a new kind of architectural typology with the intent to create spaces for the interaction between people and autonomous cars. According to the new typology concept, this thesis seeks to organize all the design modules and components of parking space in order to generate the typology design, for example, movable floor, prototype, module, component, opening, energy, circulation, time frame and program (Figure 21).

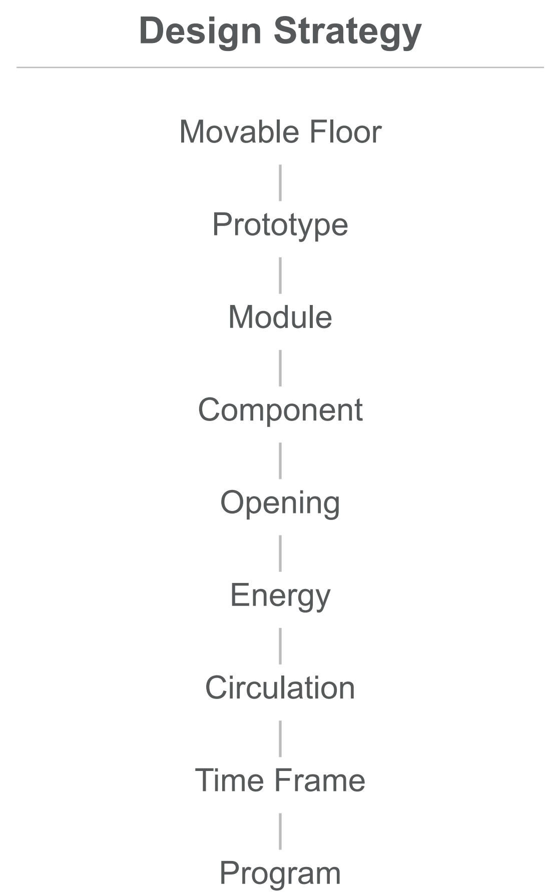

Figure 21. Design strategy diagram.

1) Movable floor

The height of the parking garage is typically is designed 7’0” for regular parking spaces, it usually lower than a typical building but storage is its single function. The design challenge in the design of parking is to understand how people utilize a space which is only for the machine. The entire structure component function as a mechanical system that uses movable slabs to create multi-height spaces for people use when the spaces are empty during the day. On the other hand, it also provides multi-height spaces, and mixed-activities for human and the machine when the AV rest or being charged. The main design strategy is using movable slabs to represent the changed interaction between people and cars (Figure 22).

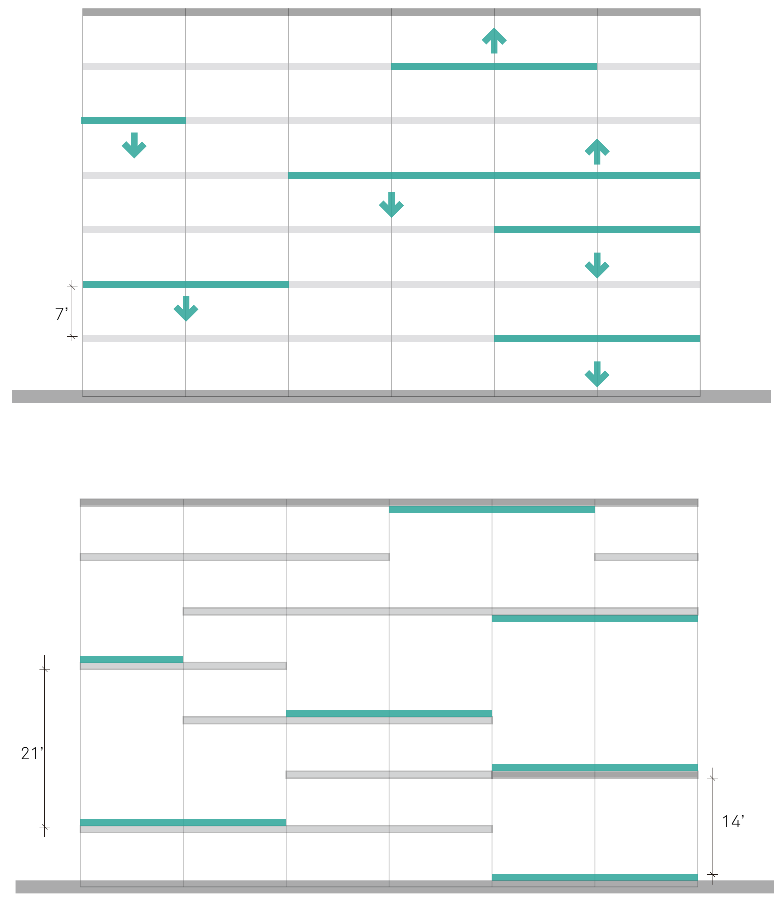

Figure 22. Movable floor concept diagram.

2) Prototype

Based on the movable floor idea, there will be some different parking scenarios. As seen in Figure 23, the first diagram shows the garage section with 90% parking during the night. The second diagram indicates how only 10% parking provides large spaces. The third diagram illustrates 20% parking provides one large and one small spaces. 30% provides multi-function spaces (Figure 23). Therefore, the proposed design selects a 20% occupation rate of cars as a case study. Figure 24 shows 16 combinations that could happen under 20% of car parking condition, such as two large spaces or multi small spaces (Figure 24).

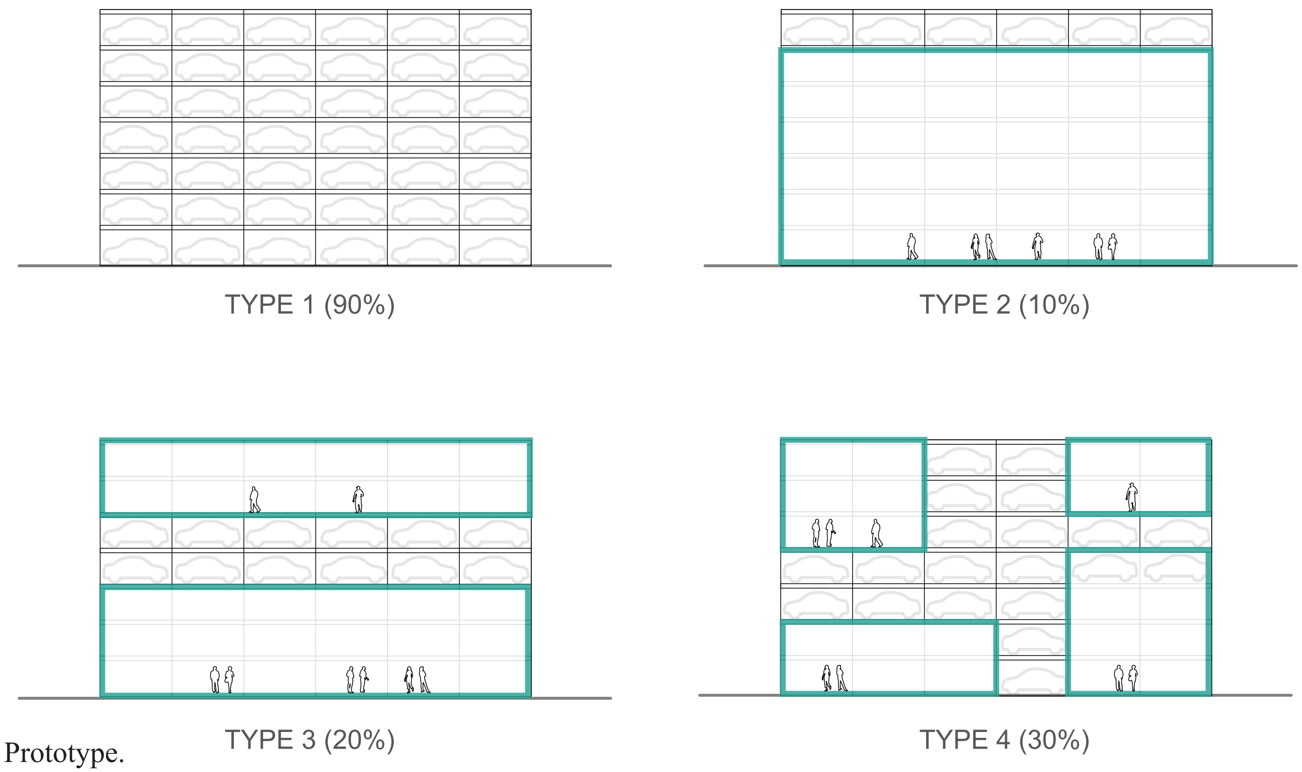

Figure 23. Design Prototype.

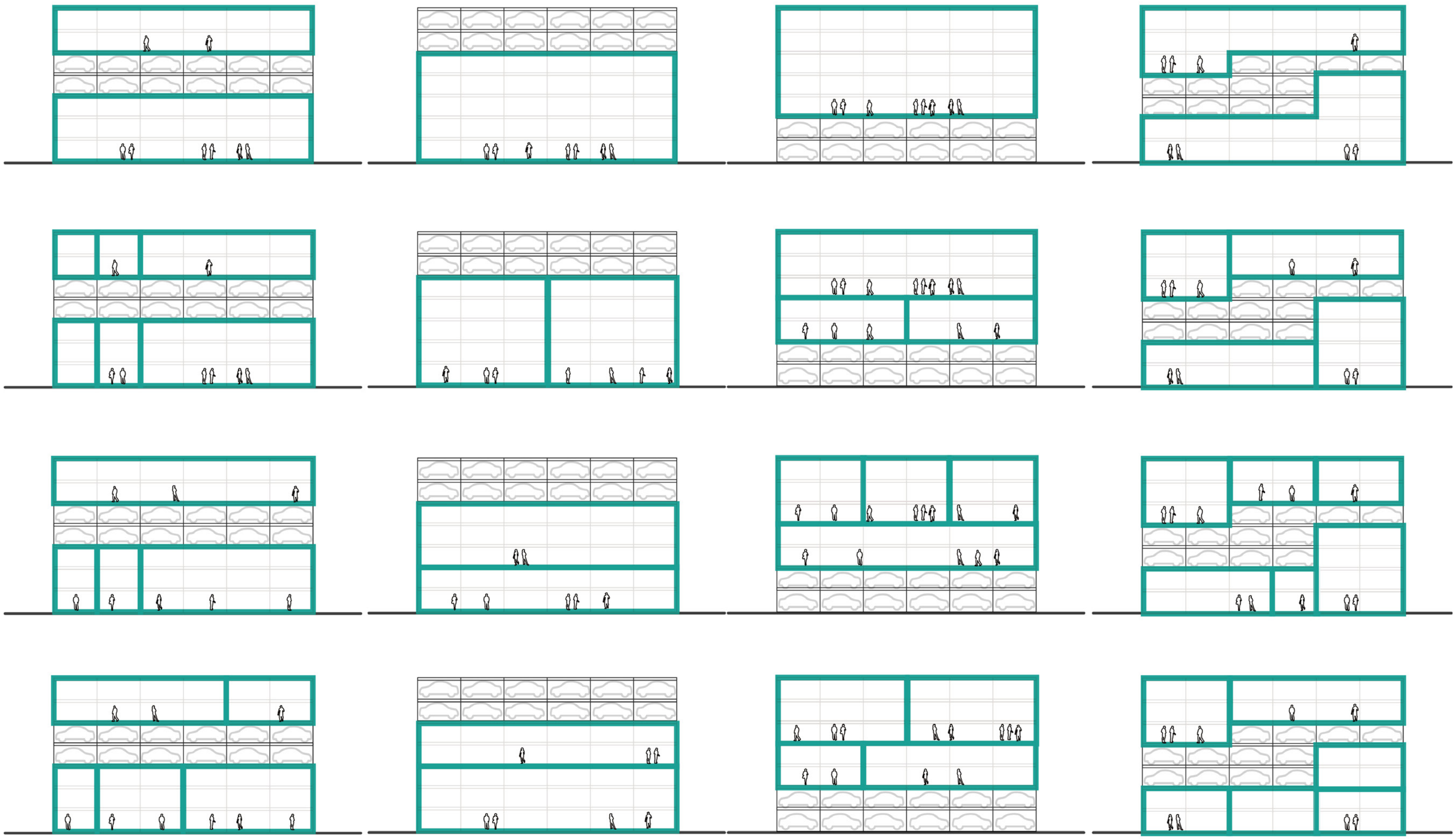

Figure 24. TYPE 3 (Combinations).

3) Module

The idea of the module in the design of the hub is based on the basketball court which also has the potential to serve multi-activities, such as a volley ball court and a table tennis court. According to the AV needs, the determination of the module as a unit of space begins with 7’x16’ car stall. One movable slab could contain 7 cars, and a basketball module could fit 42 cars which means 7 Cars on the row, and 6 cars on the column. Each slab can move independently meaning each basketball court module will have ability to transform into different combinations to provide many activities (Figure 25).

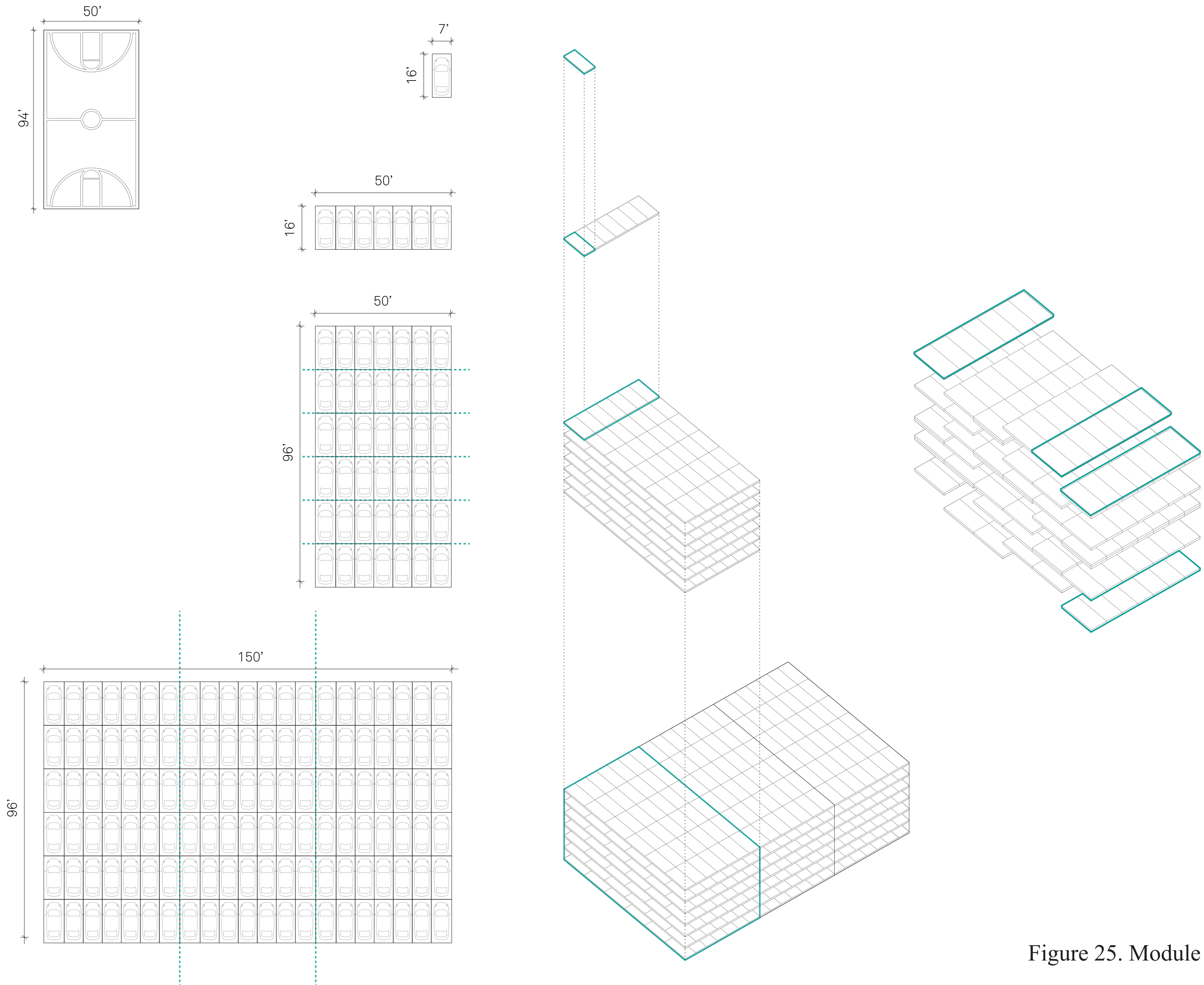

Figure 25. Module diagram.

4) Component

The component idea shows that the layout of this new architectural typology in a way that considers the structure. In the component diagram, the movable slabs are surrounded by ramps with movable openings and solar panels on the roof. This diagram is divided into two sections which are movable slab components and movable opening components (Figure 26).

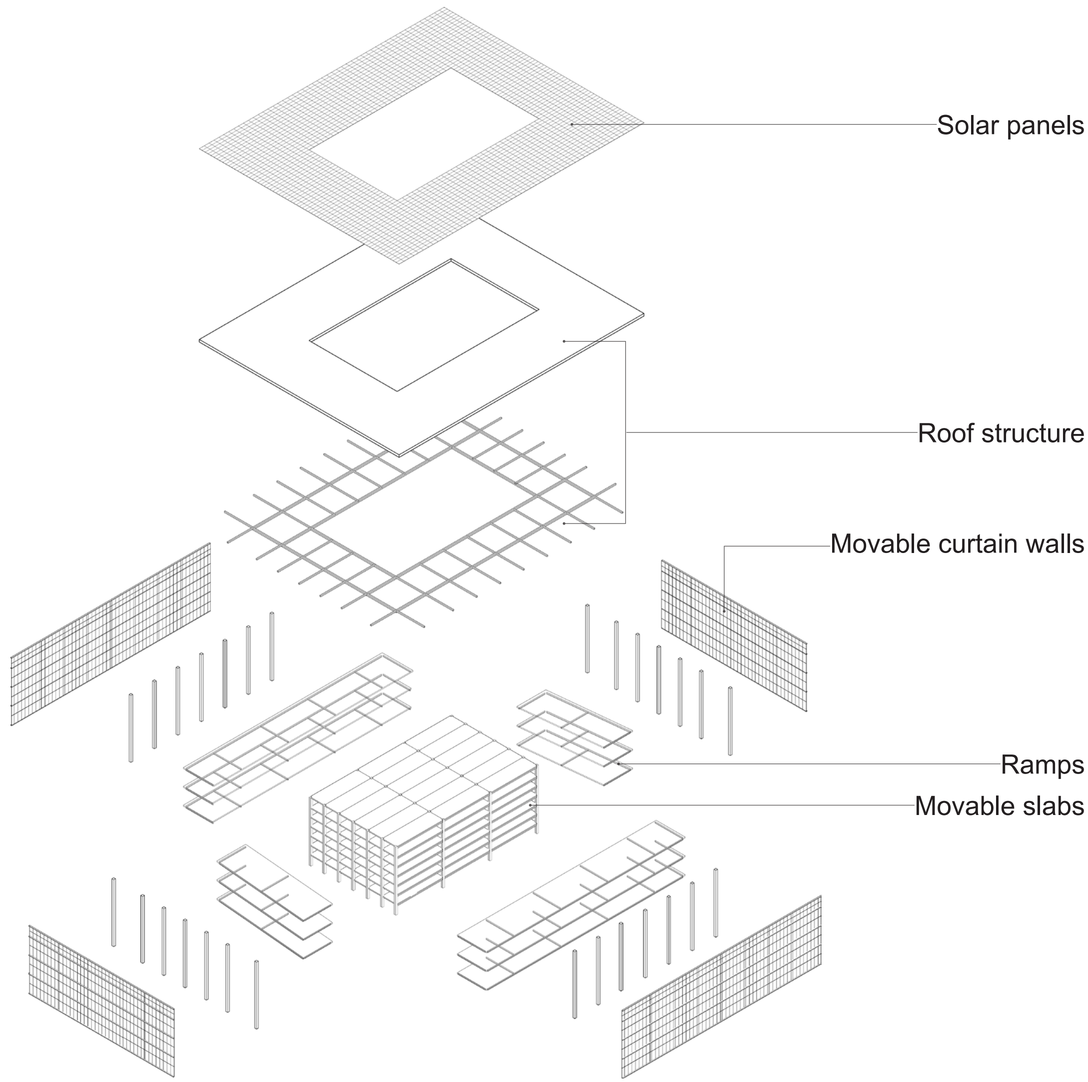

Figure 26. Component diagram.

i. Movable Slab Component

According to the literature review, a self-driving parking stall space only requires space 7 feet by 16 feet. Also, according to the module study, the dimension of the movable slab is 16 feet by 50 feet. These diagrams show how the movable slabs work. Based on this research, a single16 feet by 50 feet composed concrete movable slab is supported by two 16 inch deep steel beams. Two steel beams rest on two steel columns, each column has two independent tracks to allow the slab moves independently (Figure 27).

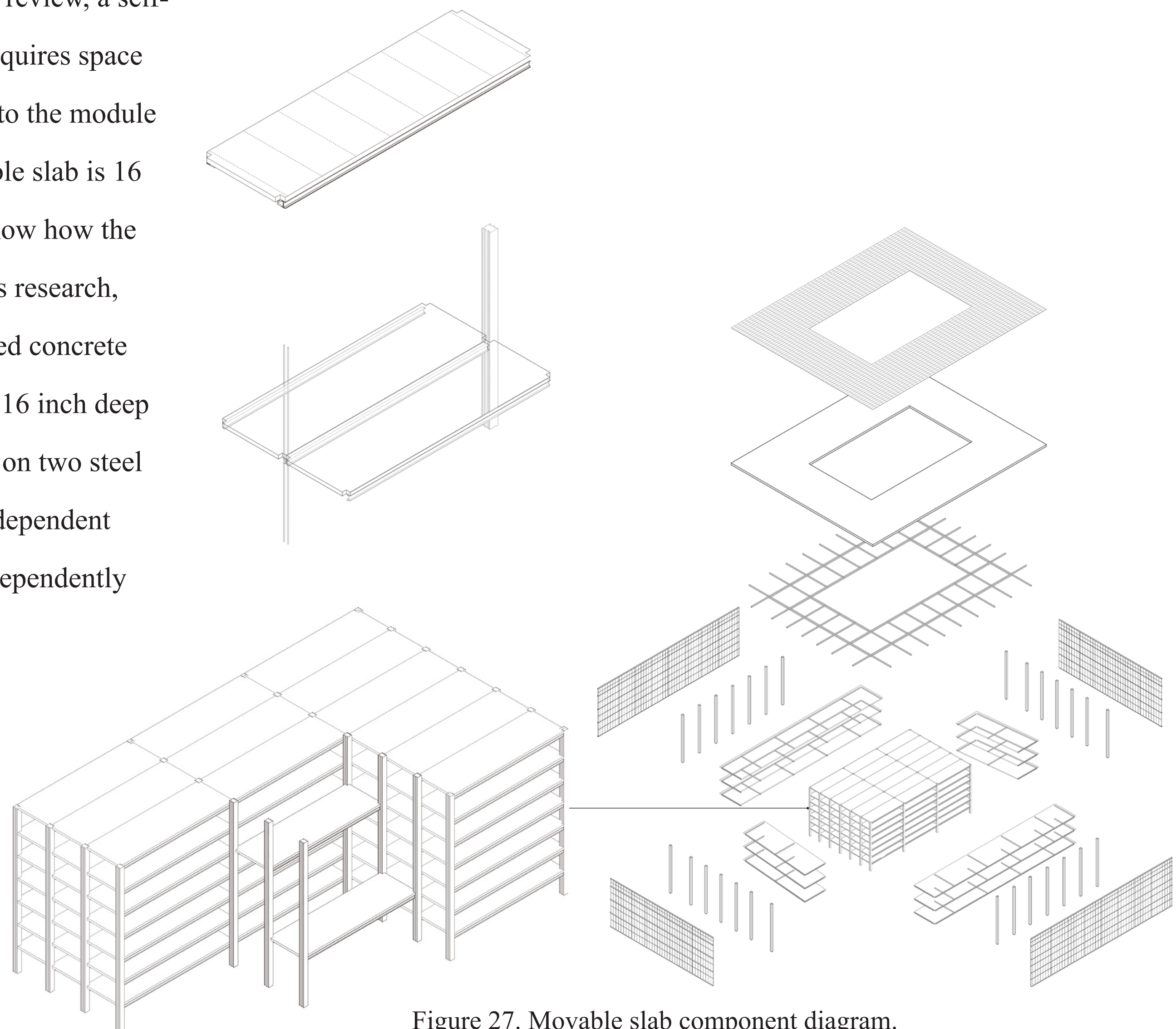

Figure 27. Movable slab component diagram.

ii. Movable opening component

The design intent is to generate multi-function spaces for humans and cars. Following the movable idea, windows are also designed as the movable components. The movable curtain wall could open automatically depending on the program. Figure 28 shows how a movable curtain wall component is composed of four curtain panels that are supported by two steel columns. Each column has three tracks to allow each curtain panel to move independently (Figure 28).

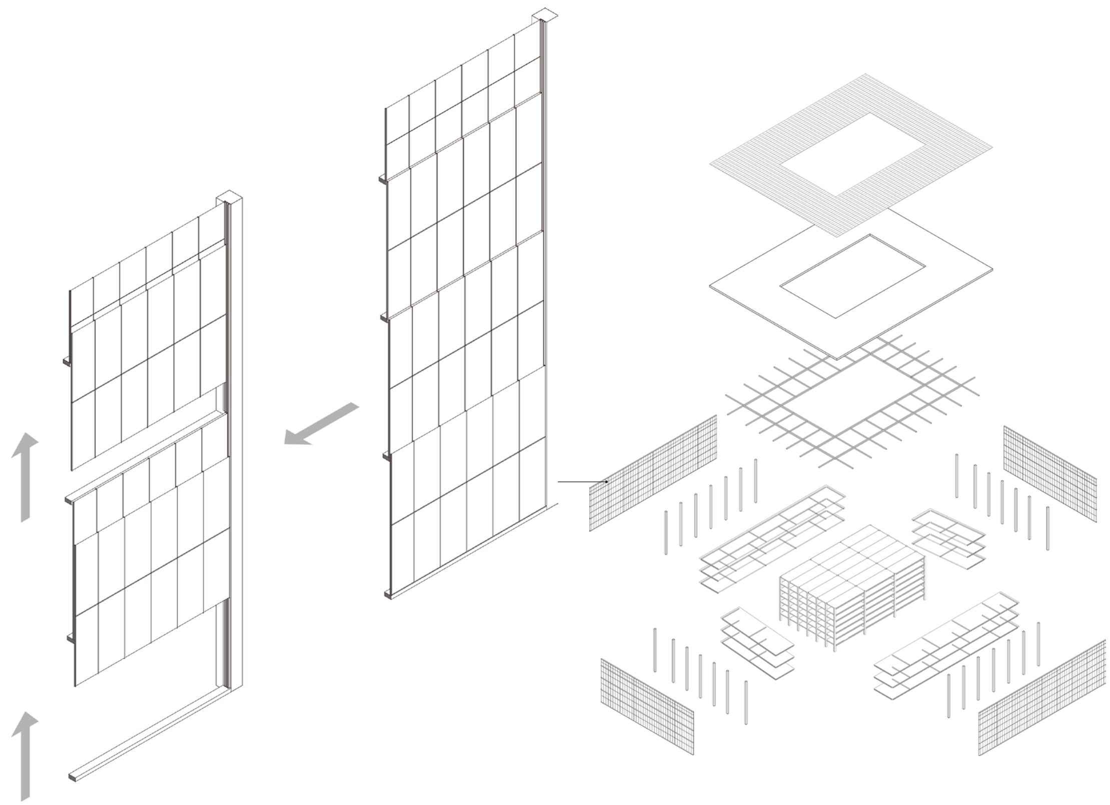

Figure 28. Movable curtain wall component diagram.

5) Energy

The new mobility hubs contains many electric autonomous vehicles that all need electricity. This building produces energy for the cars by using solar panels. According to the research, one driverless car typically will need 2500~4000 watts per day (Vaish, 2013) Ben Zientara said that “the average roof in the United States gets about 4 hours of usable sun per day.” The maximum that a solar panel can produce is 320 watts per hour. Using 4 hours of usable sun light, one typical solar panel will generate 1280 watts per day (Zientara, 2012). Therefore, one driverless car needs two solar panels (Figure 29). Based on the calculations that the hub will contain 882 cars, there will be 1,764 panels on the roof (Figure 30).

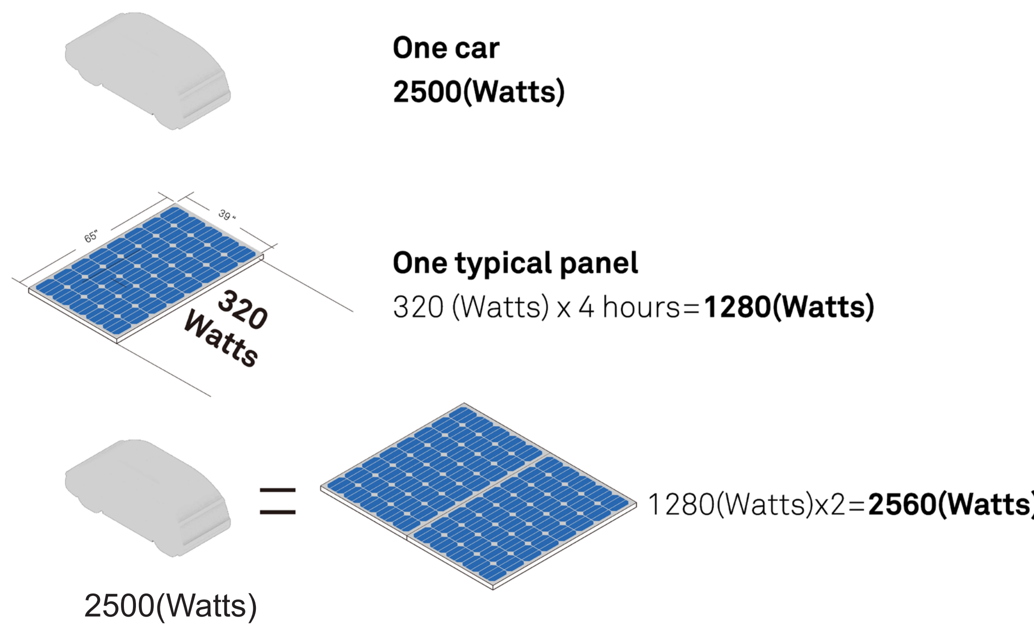

Figure 29. Energy diagram.

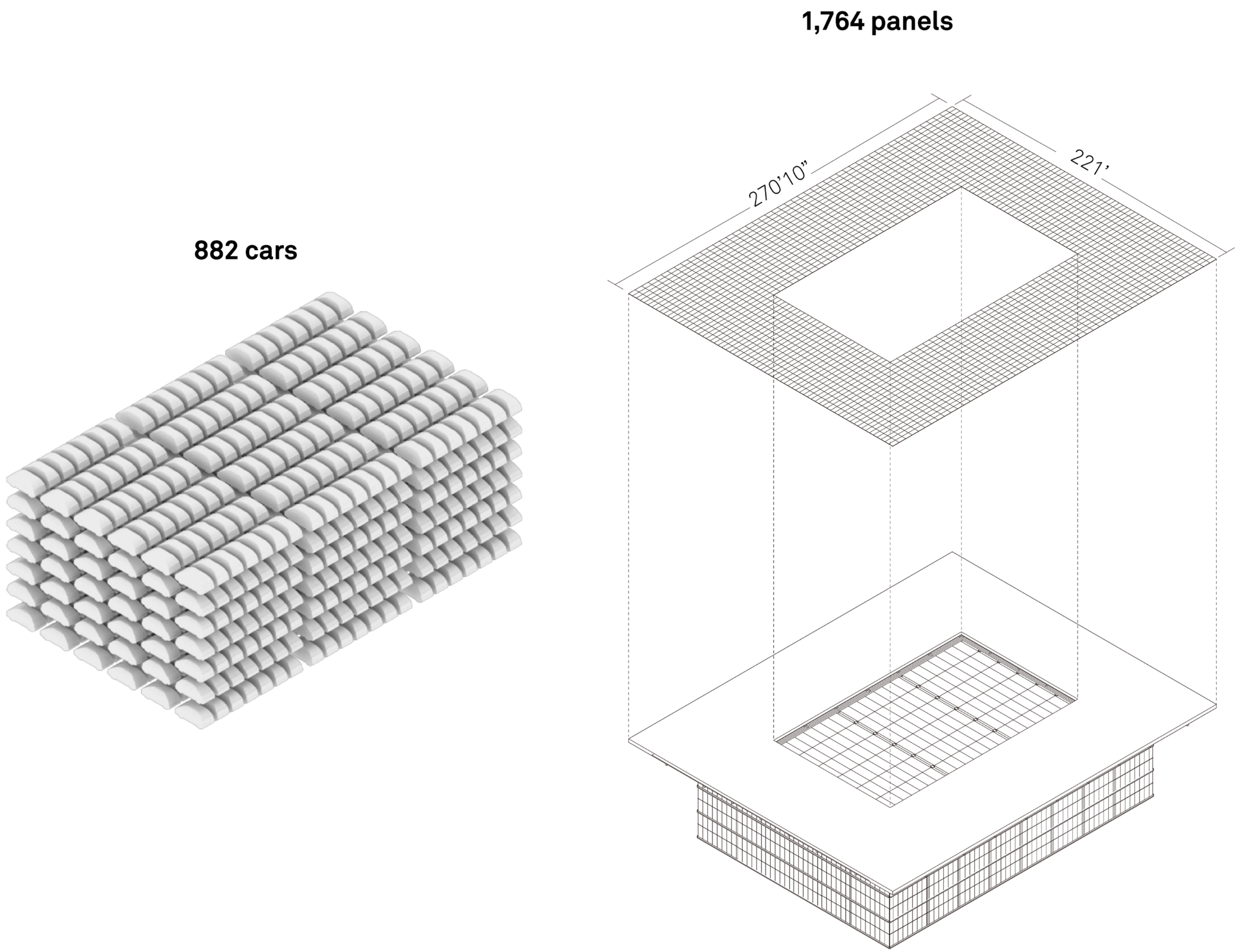

Figure 30. Solar panels on the roof.

6) Circulation

According to the literature review, the AVs are able to park by themselves without any intervention, since they have high tech sensors to prevent crashes with cars and people. Therefore, in this building, there are two ramps and two flat service roads on each side. Also, each floor has one service road, cars and people share the same circulation and same ramps (Figure 31 & 32). In this new architectural typology, there will be 3 drive lanes and a pedestrian path and a bike path (Figure 33). The research shows that the extra lane will be an inter-island gap which serves as a waiting area to allow the inside cars to go out, and to prevent conflicts with human (Nourinejad, Bahrami and Roorda, 2018).

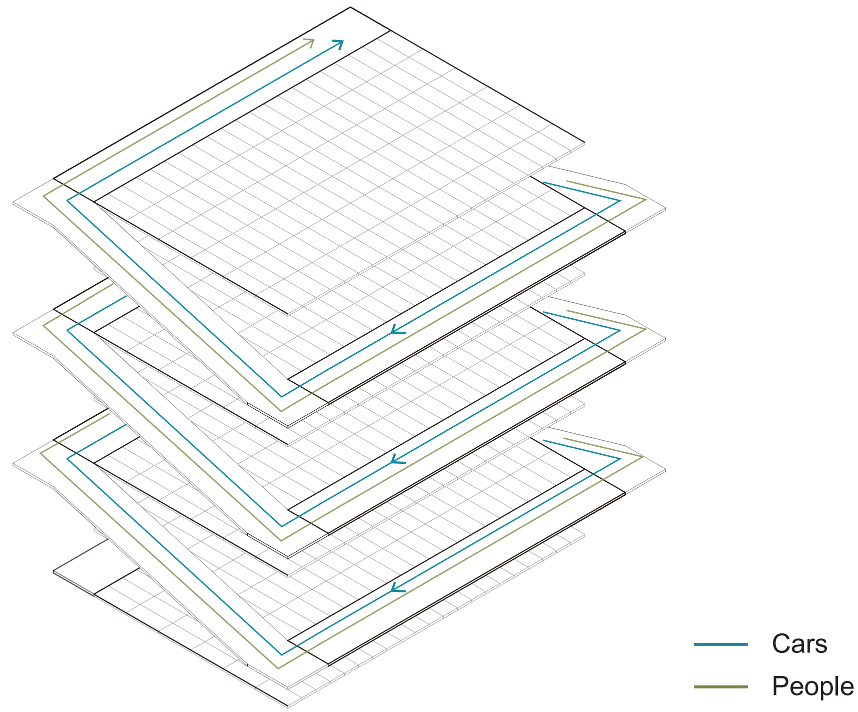

Figure 31. Circulation diagram.

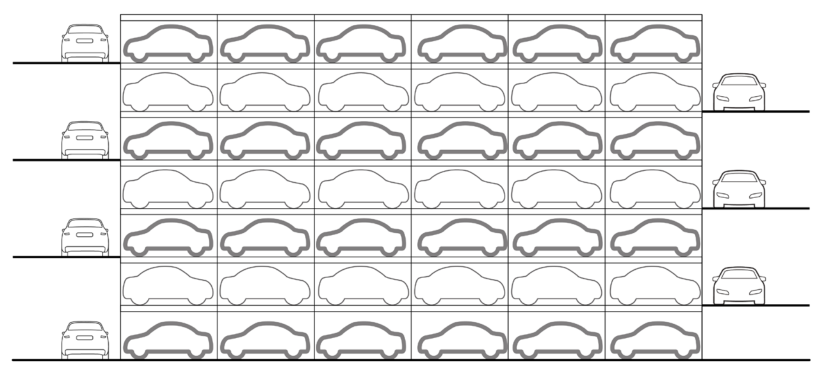

Figure 32. Car parking direction.

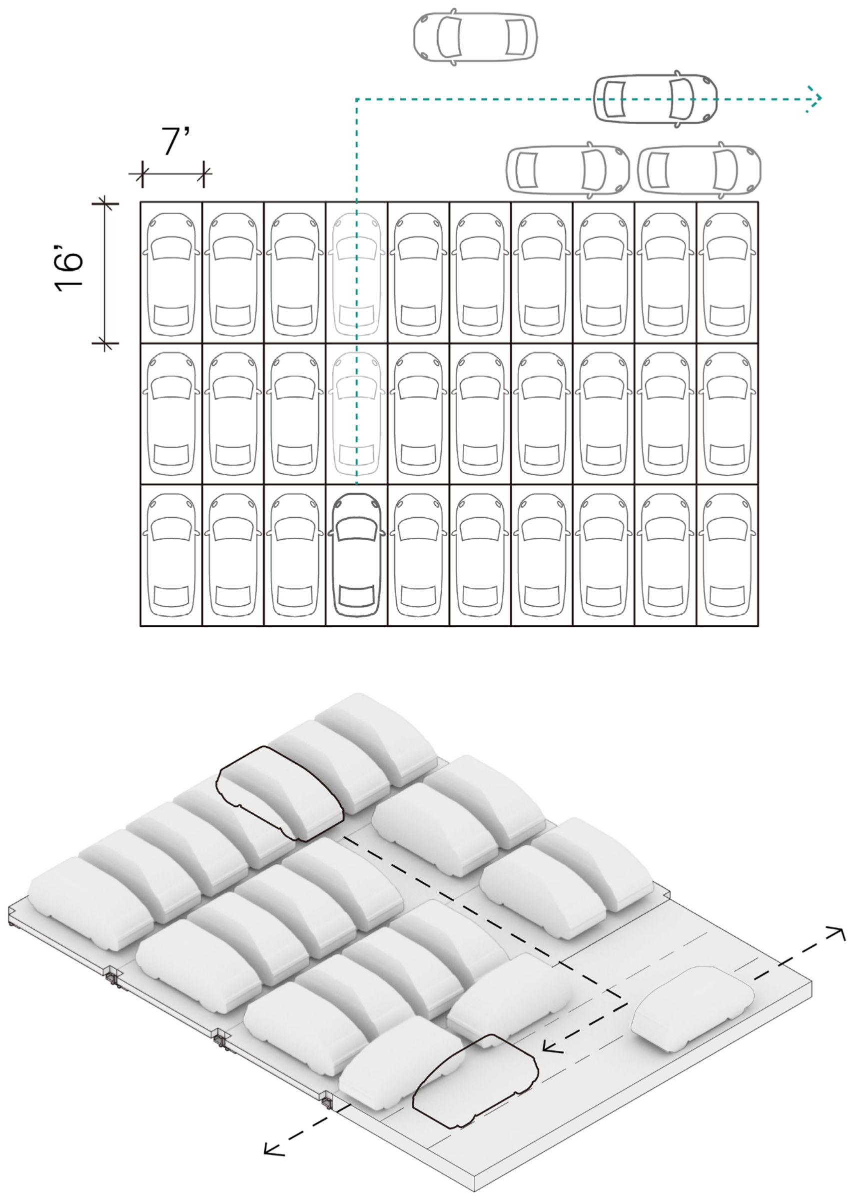

Figure 33. New parking concept.

7) Time frame

The Time frame idea is to prevent the conflicts happening when people and cars meet in the same time zone, and to enhance the efficiency of the AVs circulation. This new typology is designed for 24 hour use. The new mobility hub is programmed so that the AVs will primarily occupy almost of the entire space during the night from 9 p.m. to 5 a.m. On the other hand, the users mainly utilize the space from 7 a.m. to 9 p.m because there will only be 10%~30% of cars in the space.

Day and night usage time both have an hour buffer time which are from 5 a.m. to 7 a.m., and 9 p.m. to 11 p.m. Moreover, the 5 a.m. to 7 a.m. time zone allows the cars go out of the building, providing time for the movable slab to transform into another type. Also, 9 p.m. to 11 p.m. provides a buffer time zone for people to leave the building (Figure 34). However, the cars will still go in and out during the day.

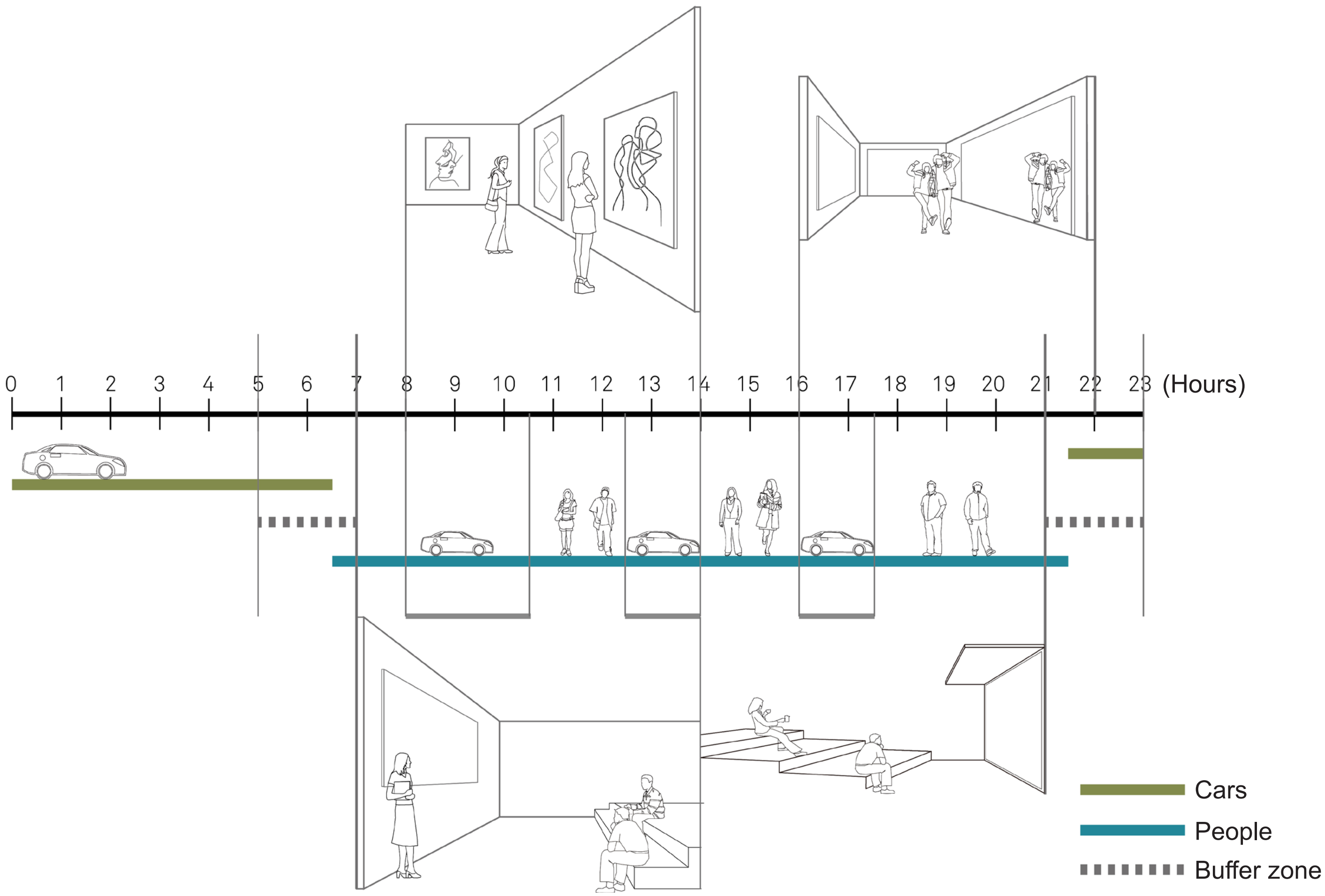

Figure 34. Time frame diagram.

8) Program

The movable slabs create may opportunities for flexible programs in the mobility hub. Each basketball module will have different configurations that support a wide variety of activities including. Provide many activities (Figure 35, 36 & 37). Such as, public market, theater, lecture and gallery. Even a concert space. The movable slabs will become seating or sometimes even transform into walls.

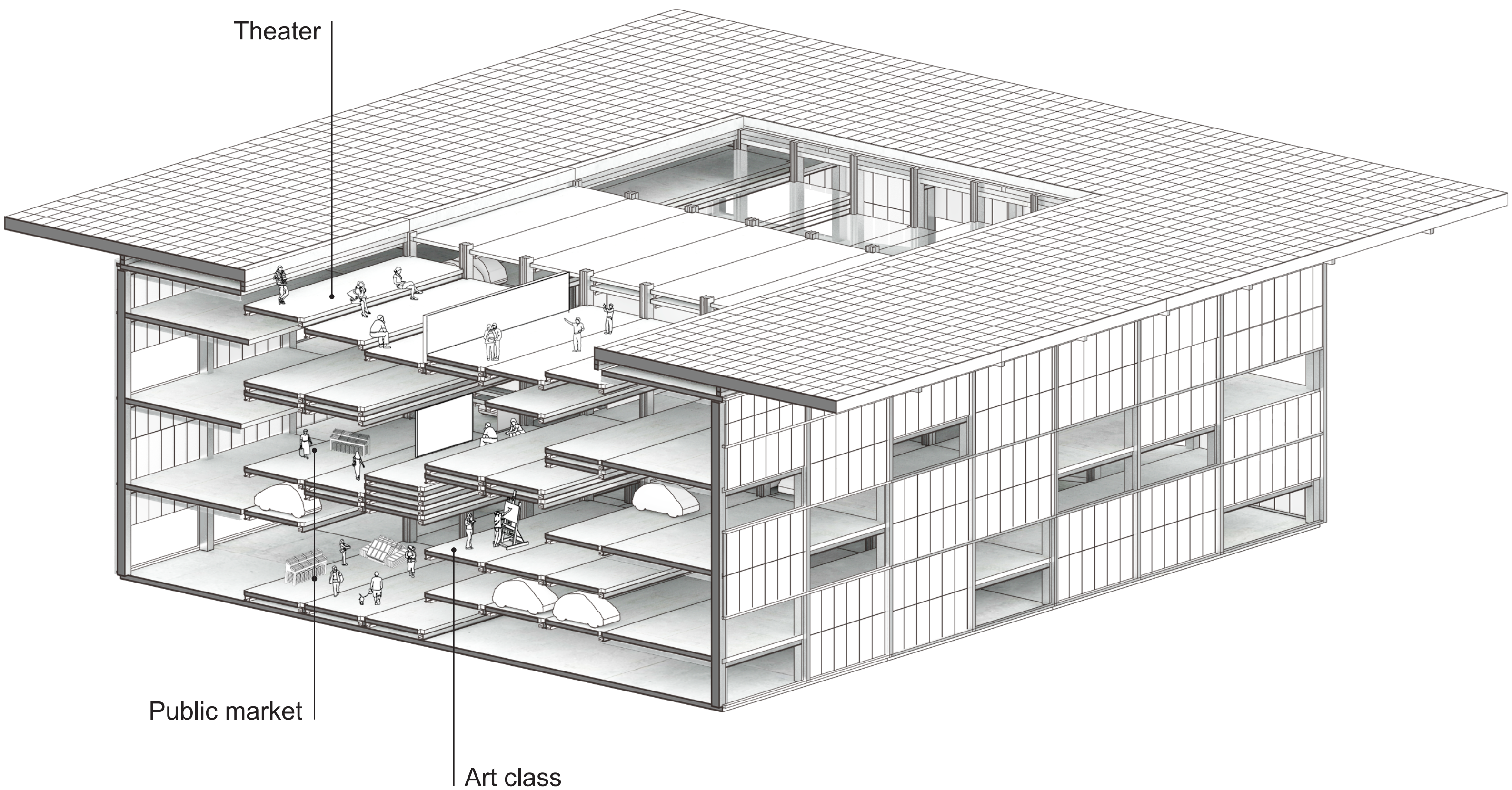

Figure 35. Multi-use program-scenario 1.

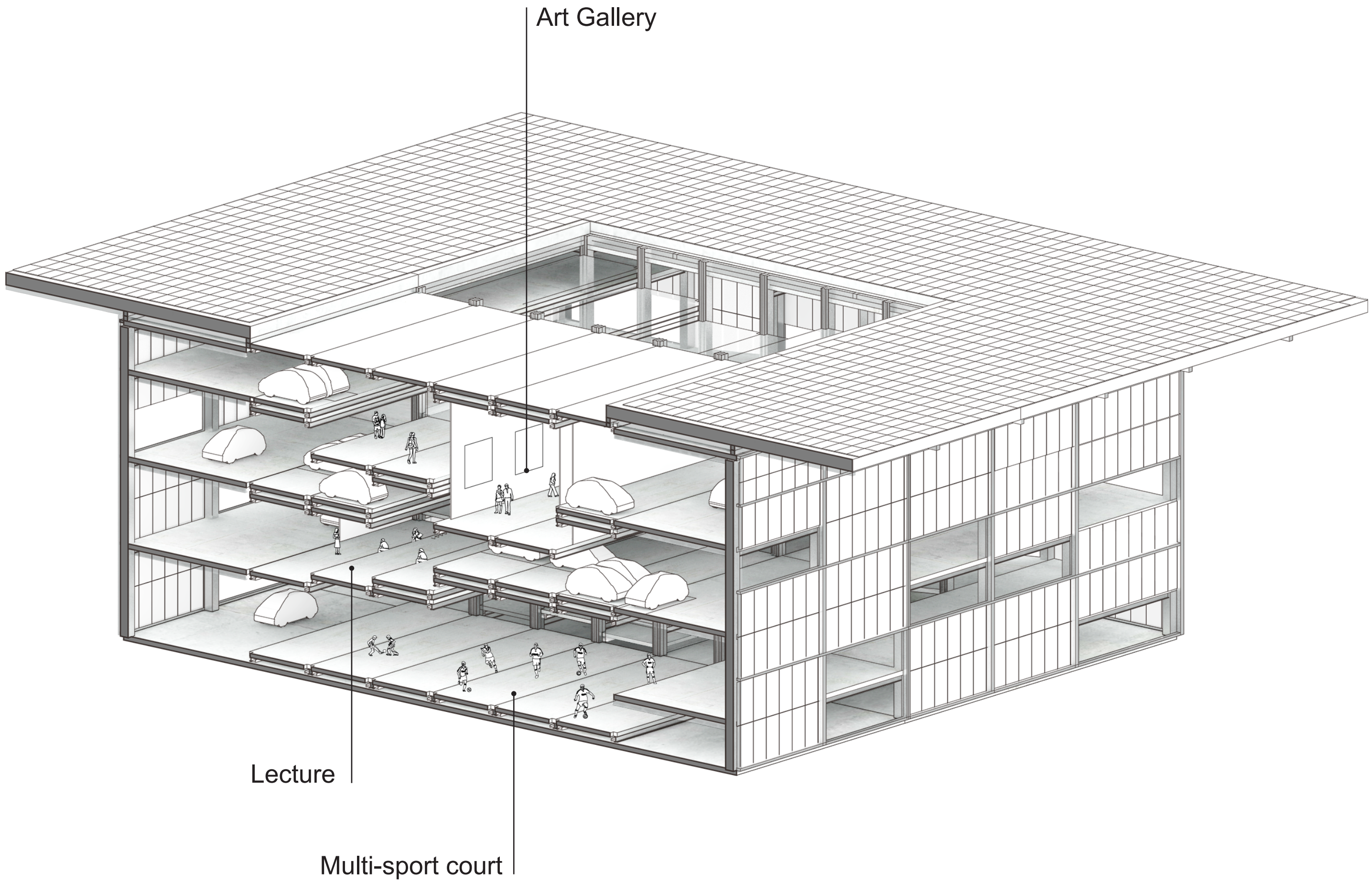

Figure 36. Multi-use program-scenario 2.

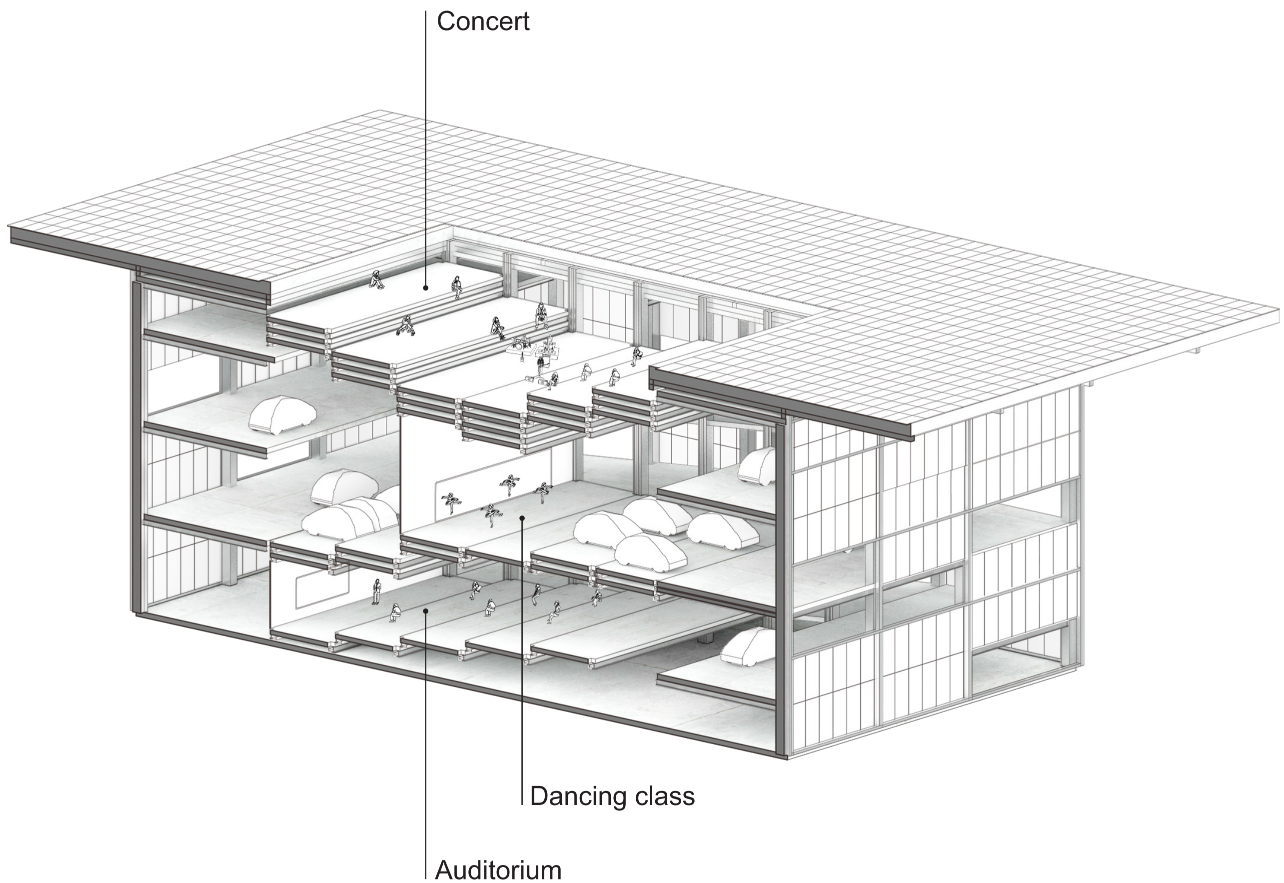

Figure 37. Multi-use program-scenario 3.

3. Overall Design

1) Site response

The site is on the west of Northgate mall and Interstate 5 highway, and north of North Seattle college. The site is currently a surface parking lot of Northwest Outpatient Medical Center. The site analysis shows that the I-5 highway obstructs west and east connections at Northgate area. The site has opportunities to become a connector to weaken the influence of I-5. The design project proposes a second new pedestrian bridge from Northgate light rail that crosses the I-5 highway connecting the drop-off area in front of the building entrance (Figure 38). Since Meridian Avenue N is the only road connect to the street system, it is considered as a main entry. The design project also suggests that the rest of the spaces could be designed to become a public green space.

The plan shows the both circulation of both car and peoples on the site (Figure 39). Cars enter the site from Meridian Ave and use the north building entry into the hub. People come from the Northgate light rail by using the pedestrian bridge to cross I-5 highway and go down to the drop off space in front of the hub entrance.

Figure 38. Site plan.

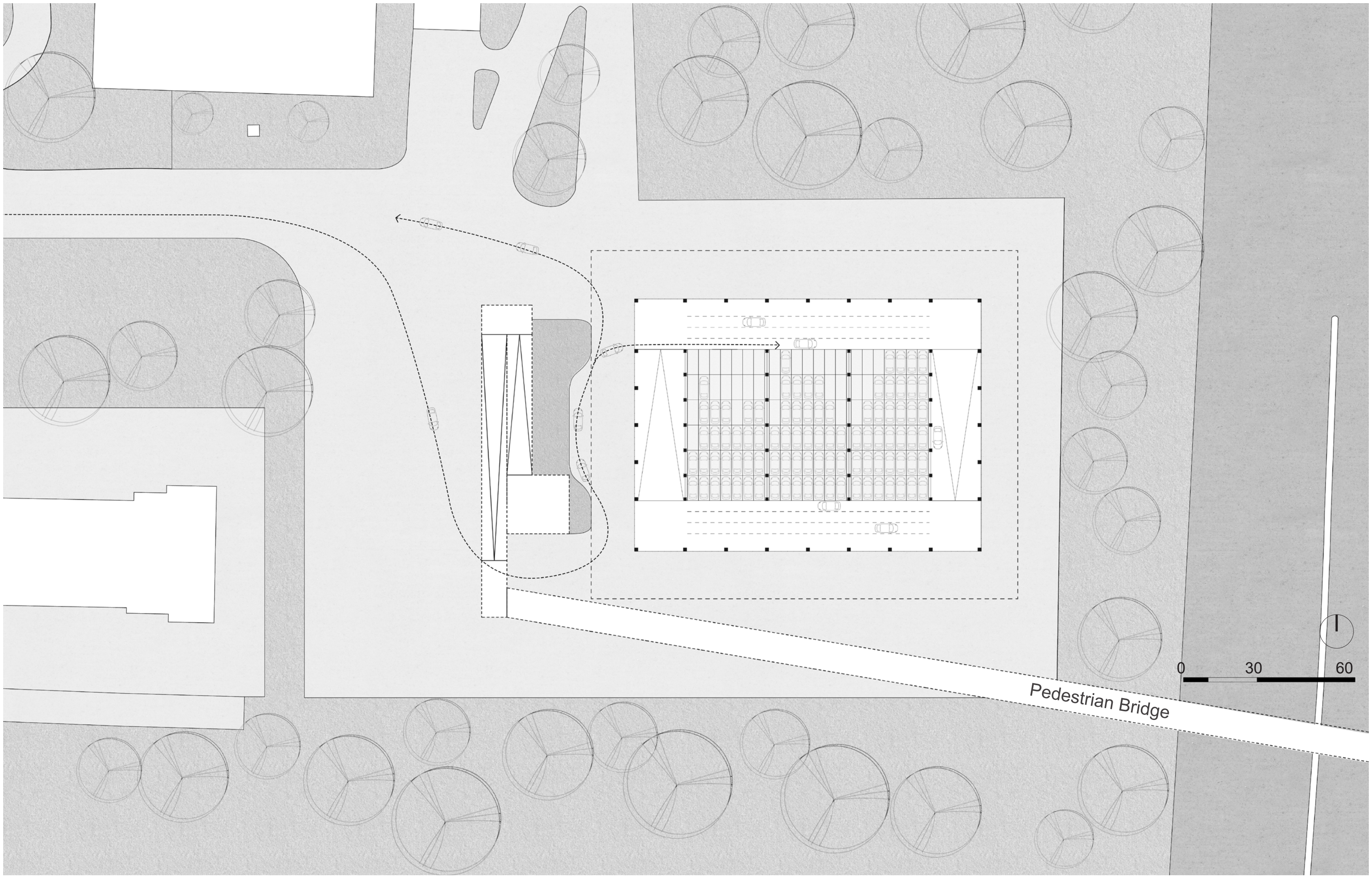

Figure 39. Plan.

2) Spatial concept

The following renderings show the overall design concept and spatial experience. The first two spatial concept diagrams illustrate the intent of the design in adapting to the changes in transportation infrastructure in the future. Not only cars fully occupy the space during the night, but also people and cars integrate in the same space (Figure 40 & 41). The interior renderings present the spatial quality of the mobility hub. A lecture space, art gallery and sport court show the movable slab concept creates many possibilities for different activities that represent autonomous vehicle and human use of the same spaces at the same time (Figure 42, 43 & 44).

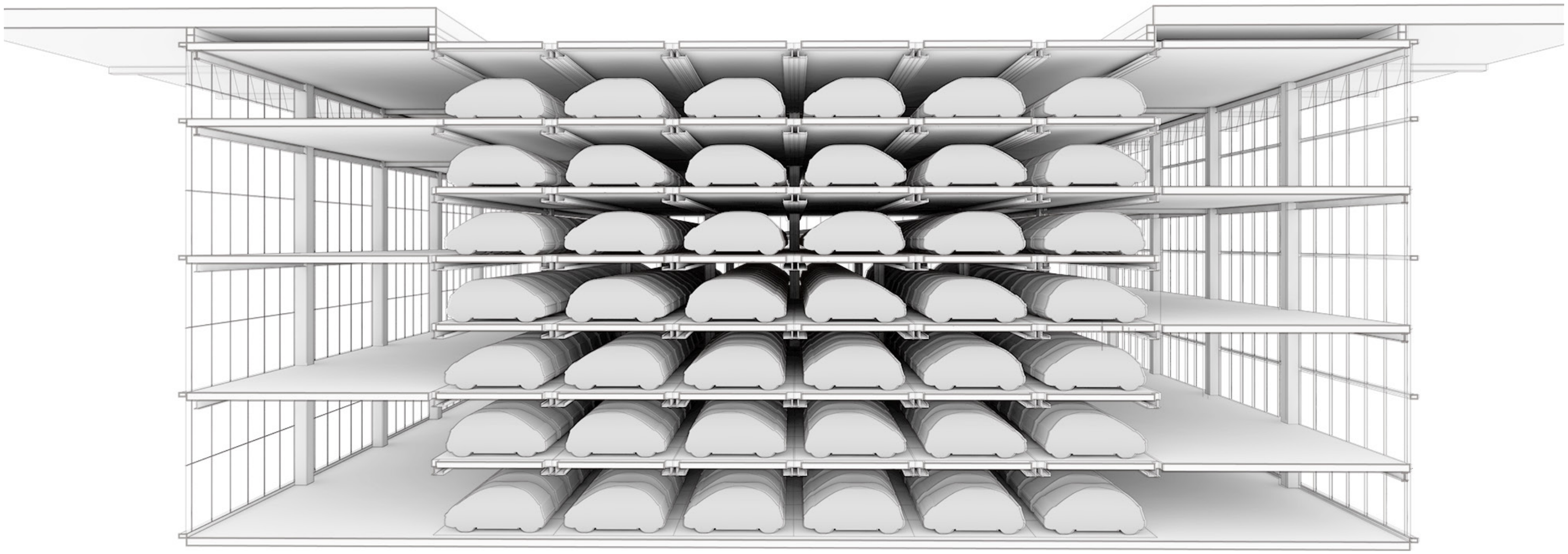

Figure 40. Spatial concept-space is fully occupied.

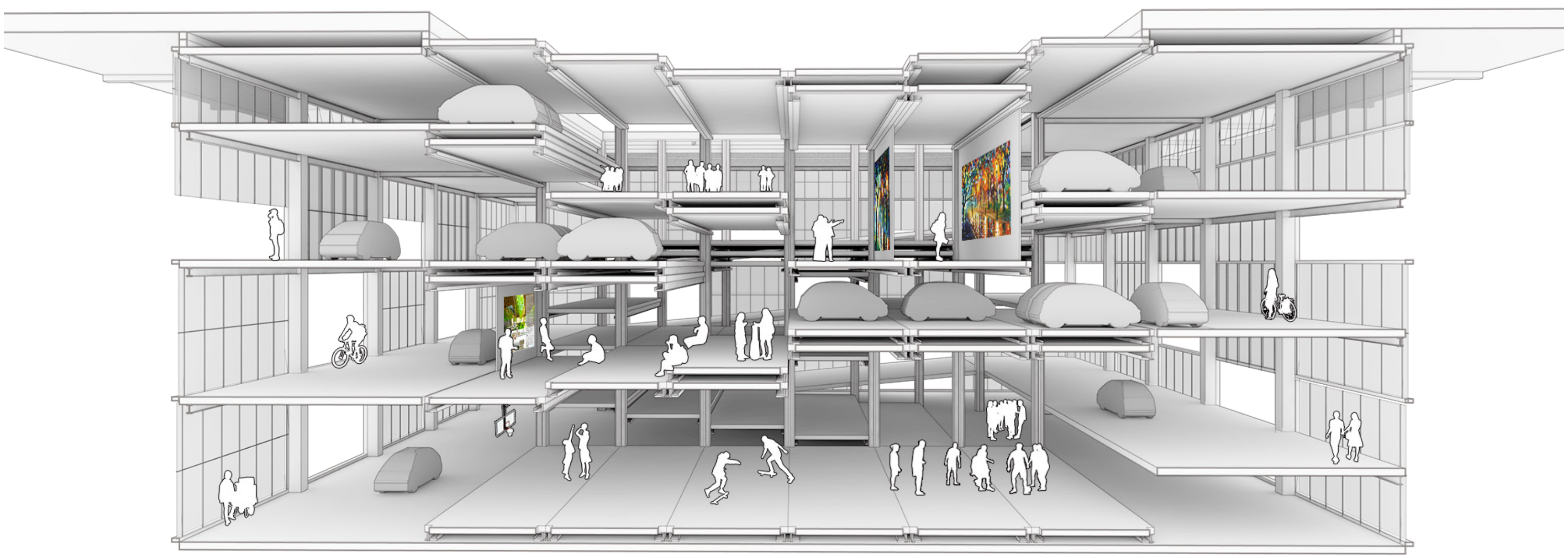

Figure 41. Spatial concept-human and machine are in the same space.

Figure 42. Lecture space.

Figure 43. Art gallery.

Figure 44. Multi-sports court.

Figure 45. Exterior perspective looking south east.

CHAPTER 5
CONCLUSION

With the development of autonomous vehicle technology and ride sharing concepts, city's transportation infrastructure will face tremendous changes. Self-driving cars are smarter and cleaner than conventional cars and also they have the same daily working routine as human. As a result they offer the potential to bring many benefits to the future urban environment. They also will change the way the basic character of parking infrastructure in the future. The design intent is to explore typologies of parking infrastructure to respond to this new era of technology. Moreover, in the past, the relationship between cars and people has been one of separation, meaning they each have their own space. However, the autonomous vehicle will function safely and without any pollution, meaning they can easily live with human. This phenomenon of AV technology has also raised other questions about the nature of relationships when driverless cars integrate with people, and what kind of spatial experience that architectural design can provide for humans and machines. Therefore, this thesis seeks a universal architectural prototype module that will be one possible solution that not only integrates people and cars but also adapts in ways that reflect the differences in the urban surroundings.

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