Driverless Car Transit Hub

by
Winny Ko

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

ABSTRACT

The world is moving towards automation, and manual labour is quickly becoming obsolete to avoid unnecessary human error in complex processes. As an example of this evolution, in twenty to thirty years, a new era of driverless technology will revolutionize modern transportation systems. This technology will not only change road systems themselves, but it will also alter the way people live their lives. Urban planners will exchange the need for parking lots for a new requirement for drop-off zones. Such change will transform the workforce commuting paradigm. It is up to the architects and urban planners to create innovative plans to design city systems that bring citizens from point A to point B in the urban metropolitan regions seamlessly without sacrificing the flexibility of where citizens may need to go. An additional challenge in this driverless shift is to use the existing cityscape and public transit infrastructure to accommodate the new transportation technologies as the fixed form of an established metropolis prevents immediate mass reconstruction and rebuilding. This thesis presents the case that an inter-modal transit hub can effectively integrate driverless car technology into a city's public transit system to improve efficiency and flexibility while maintaining the city's traditional legacy of transport networks and urban built form.

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TABLE OF CONTENTS

AUTHOR'S DECLARATION **II**

ABSTRACT **III**

ACKNOWLEDGMENT **IV**

LIST OF FIGURES **VI**

1. INTRODUCTION **1**

2. DRIVERLESS CAR **13**

2.1 Driverless Car Technology 14

3. THE DAILY COMMUTE IN TORONTO **21**

3.1 The Daily Commute in Toronto 23

3.2 Don Valley Parkway and Gardiner Expressway 26

3.2.1 Don Valley Parkway 26

3.3 Gardiner Expressway 30

3.3.1 The Planning Process 30

3.3.2 Construction and Maintenance 32

3.3.3. The Future Hybrid or Removal Options 34

4. THE METROLINX PLAN AND A POTENTIAL THESIS PROJECT **39**

4.1 Metrolinx 40

4.2 The Design Thesis Site 42

5. PRECEDENTS OF MASS TRANSIT HUBS AND DRIVERLESS CAR GARAGES **47**

5.1 Precedents of Transit Hubs & Mass Terminals 48

5.2 Transbay Transit Center 49

5.3 Toronto's Union Station Revitalization 52

5.4 Rotterdam Central Station 54

5.5 Driverless Car Garages 58

5.6 Future Predictions 64

6. SYNTHESIS & DESIGN INTENT **67**

6.1 Synthesis & Design Intent 68

6.1.1 Design Intent 70

6.2 Site 72

7. THESIS DESIGN PROPOSAL **81**

7.1 Design Proposal 82

7.2 No more parking- Drop off & Pick up zones 82

7.3 Self-parking cars 112

7.4 Connection to Public Transit 116

8. CONCLUSION **125**

ENDNOTES **129**

BIBLIOGRAPHY **132**

LIST OF FIGURES

1. **Chapter 1**
   - **1.1. Car Ownership Comparison Between Major Cities**
     By author
     Data from: Kenworthy, Jeffery R., and B. Felix Laube. "Patterns of Automobile Dependence in Cities: An International Overview of Key Physical and Economic Dimensions with Some Implications for Urban Policy." *Transportation Research Part A: Policy and Practice*, (1999): 698.
   - **1.2. Reference Map Of Toronto, Canada Indicating The Cityscapes**
     By author
     Data from: "Open Street Map." *OpenStreetMap Contributors.* Accessed October 30, 2017. https://www.openstreetmap.org/#map=18/43.63646/-79.39730&layers=D.
   - **1.3. Reference Map Of New York City, Us Indicating The Cityscapes**
     By author
     Data from: "Open Street Map." *OpenStreetMap Contributors.* Accessed October 30, 2017. https://www.openstreetmap.org/search?query=New%20York%20City%2C%20.US#map=12/40.7746/-73.9998&layers=D
   - **1.4. Reference Map Of Hong Kong, China Indicating The Cityscapes**
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   - **1.5. Existing Toronto Skyline Taken In 2016**
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   - **1.6. Predicted Toronto Skyline In 2020 By Professional Illustrator, Robery Koopmans & Urban Toronto Forum Contributor, Scott Dickson**
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3.1. Modes Of Transportation In Toronto Indicates Major Mode Is By Car, Truck Or Van - As A Driver
Top: By author.
Data from: Campbell, Jason. 2011 National Household Survey. *Toronto: The City of Toronto*, 2013.
Bottom: Campbell, Jason. 2011 National Household Survey. *Toronto: The City of Toronto*, 2013.

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3.7. Historic Picture Of Gardiner Expressway Looking West On Oct 21, 1969
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4.1. **Metrolinx Service Area And Future Proposals**
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4.4. **Integrated Site Plan With Existing And Future Transit Proposals**
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5. **Chapter 5**

5.1. **The Number Of Passengers Public Transportation Vs Passenger Car Carry**
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5.2. **Transbay Transit Center In San Francisco, US Rendering**
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5.14. **Steps Of Traditional Parking**
By author.

5.15. **Steps Of Advanced Driverless Car Parking**
By author.

5.16. **Advanced Car Vs Normal Car Timeline Showing The Time Passenger Can Save On A Daily Basis**
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5.19. **Future Of City With Driverless Cars Concept**
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6. **Chapter 6**

6.1. **Mind Map Of Driverless Car Technology**
By author

6.2. **Parti Of This Thesis**
By author

6.3. **Site Plan Analysis - Land Use**
By author

6.4. **Site Plan Analysis – Speed**
By author

6.5. **Site Plan Analysis – Views**
By author

6.6. **Site Plan Analysis - Green Space**
By author

7. **Chapter 7**

7.1. **Perspective Of The Drop Off And Pick Up Location**
By author

7.2. **E-W Section**
By author

7.3. **N-S Section**
By author

7.4. **Site Plan**
By author

7.5. **Ground Level Plan**
By author

7.6. **Mezz Level Plan**
By author
7.7. **2nd Level Plan**
By author
7.8. **3rd Level Plan (Typical For Level 4-6)**
By author
7.9. **Perspective From DVP Southbound Into The Complex**
By author
7.10. **Drop Off Process**
By author
7.11. **Speed Diagram On Drop Off/ Pick Up Location**
By author
7.12. **Control Points**
By author
7.13. **Perspective within The Pick Up Area**
By author
7.14. **P1 Level Plan**
By author
7.15. **P2 Level Plan**
By author
7.16. **Inductive Charging**
By author
Data from: Biesbrouck, Tim. " Charging while racing electric, it may have a great future." *Electric Autosport*. Last modified November 30, 2011. Accessed Septemer 15, 2017. https://www.electricautosport.com/2011/11/charging-while-racing-electric-it-may-have-a-great-future.
7.17. **Architectural Standard from Architectural Record - Parking Lot Dimensions**
The American Institute of Architects. *Architectural Graphic Standards*. New Jersey: John Wiley & Sons Inc., 2007.
7.18. **Cross-Section Of Different Levels Of Grade**
By author.
7.19. **Exterior Perspective Looking Towards Streetcar Broadview Station**
By author.
7.20. **Circulation Diagram**
By author.
7.21. **Perspective Of The Main Hall**
By author.
7.22. **Perspective Of The Master planning In The Future**
By author

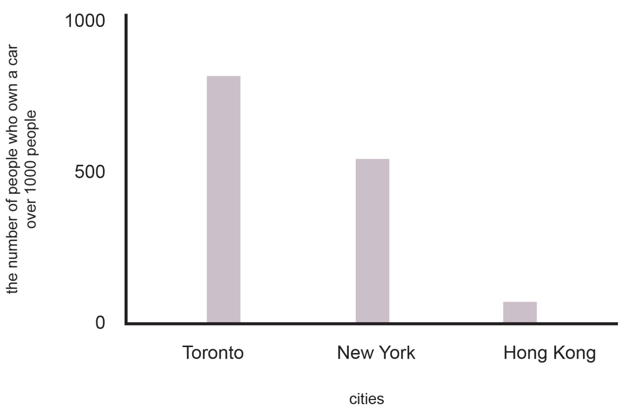
8. **Chapter 8**
8.1. **Reserving The Seat In Future Scenario**
Doe, Fabian. "Self-Driving Car." *Archiplain*. Last modified March 22, 2017. Accessed April 22, 2017. http://archiplain.com/self-driving-car.
8.2. **Performing Task In A Driverless Car**
Stinson, Elizabeth. "Ideo Imagines The Wild Future Of Self-Driving Cars." *Wired*. Last modified November 18, 2014. Accessed August 15, 2017. https://www.wired.com/2014/11/ideo-imagines-self-driving-cars.

1.

INTRODUCTION

1.1 Introduction

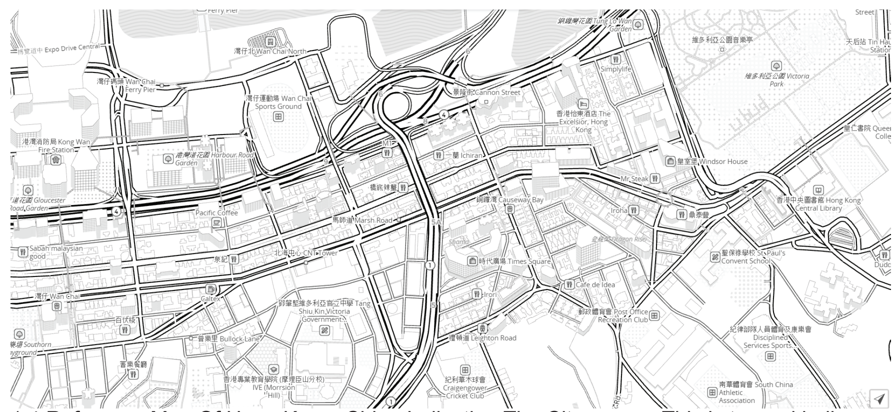
When I first came to Toronto as an immigrant, I noticed that the majority of the residents needed a car to get around the city. Growing up in Hong Kong, public transit was always within reach, and there was never a schedule to follow as they came every two to ten minutes to connect me to any place I needed to be. Toronto has the one of the highest car ownership ratios with 706 cars owners for every 1,000 people. Whereas dense cities like New York has 557 and Hong Kong has 78 by context.[1] (Figure 1.1, 1.2, 1.3, 1.4)



1.1 Car Ownership Comparison Between Major Cities. Among the three cities shown above, the citizens of Toronto highly relies on cars.

1.2 Reference Map Of Toronto, Canada Indicating the cityscapes.

1.3 Reference Map Of New York City, US Indicating the cityscapes



1.4 Reference Map Of Hong Kong, China Indicating The Cityscapes. This is to read in-line with figure 1.1. Toronto has the lowest population density among the three cities, and it shows the highest in car ownership.

The importance of car ownership in North America has been a problem since the post-World War II economic and building boom and the emergence of sprawl. North Americans left the city centers to live in suburban areas on urban peripheries. Toronto, one of the fastest growing urban cities in Canada, holds a population of 2.7 millions, according to the result of 2016 census. In the future, it is expected to grow exponentially.[2] In 50 years, the population will double being closer to 5 million, and 13.1 million in the Greater Toronto Area (GTA).[3] All the new waterfront condos of the last twenty years of building boom will no longer be enough to sustain the growing population. The City has planned more skyscrapers throughout its urban area to accommodate this anticipated growth. Artists Robert Koopmans and Scott Dickson have illustrated the new Toronto skyline, predicting the look of the city in 2020 with all buildings that are either under construction, planned or recently proposed.[4] (Figure 1.5 & 1.6)

1.5 Existing Toronto Skyline Taken In 2016. Toronto has many tall buildings close to the waterfront and along Yonge St., and in the future, there will be more proposals on building tall buildings, refer to figure 1.6.

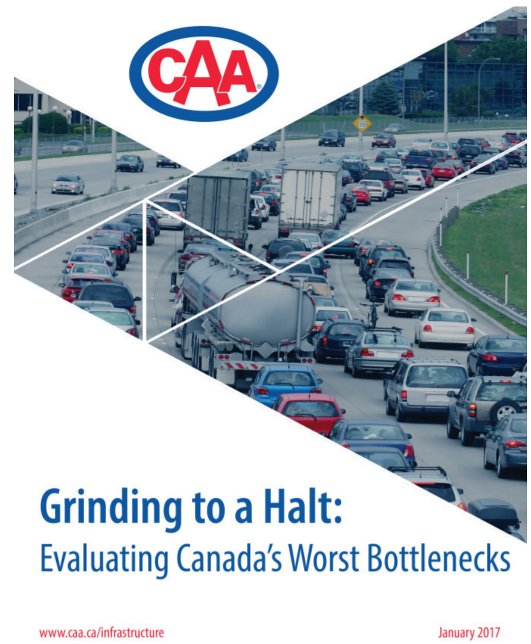
1.6 Predicted Toronto Skyline In 2020 By Professional Illustrator, Robery Koopmans & Urban Toronto Forum Contributor, Scott Dickson. This is a rendering of what Toronto skyline would look like with all the proposals built.

Toronto's landscape and transit system are a hybrid system combining the automobile influence of the United States, Australia with the public transit from Europe.[5] A resident can find eight-lane highways, two-lane local streets and streetcars. The city roads are primarily used to move people from outside of the GTA and the GTA itself to get to the city's downtown business core. The public transit system is mainly designed for people to travel within the city. At the boom from 1945 to 1960, the Ontario government promoted car-oriented suburbanization which caused the road network to expand rapidly with the construction of expressways like the 400 highway series.[6] (Figure 1.7) In the research of Anne Nolan, Adjunct Associate Professor of School Office Social Sciences & Philosophy at the University of Dublin, she noticed having access to a car began turning into a necessity rather than a luxury over these years. The correlation between income and car ownership has been declining as well.[7] Many citizens living in the suburbs own a car, and the importance of highways in Toronto and the GTA is vital because it affects city growth and social benefit.

The City of Toronto is bounded by four major highways: Highway 401, the Don Valley Parkway (DVP) or Highway 404, the Gardiner Expressway, and Highway 427. In a recent study by the Canadian Automobile Association (CAA), they found that three out of four of the highways mentioned above were amongst the top four of Canada's 20 worst highway bottlenecks.[8] (Figure 1.8)

Compared to the United States, Toronto's bottlenecks would rank the worst in North America, costing the commuters more than 3 million hours each year standing at these

1.7 Aerial View Of Highway 400 & Highway 407 In Toronto, Canada. Toronto is bounded by 4 major highways, and the level of intersection shown is very common.



CAA

Grinding to a Halt:
Evaluating Canada's Worst Bottlenecks

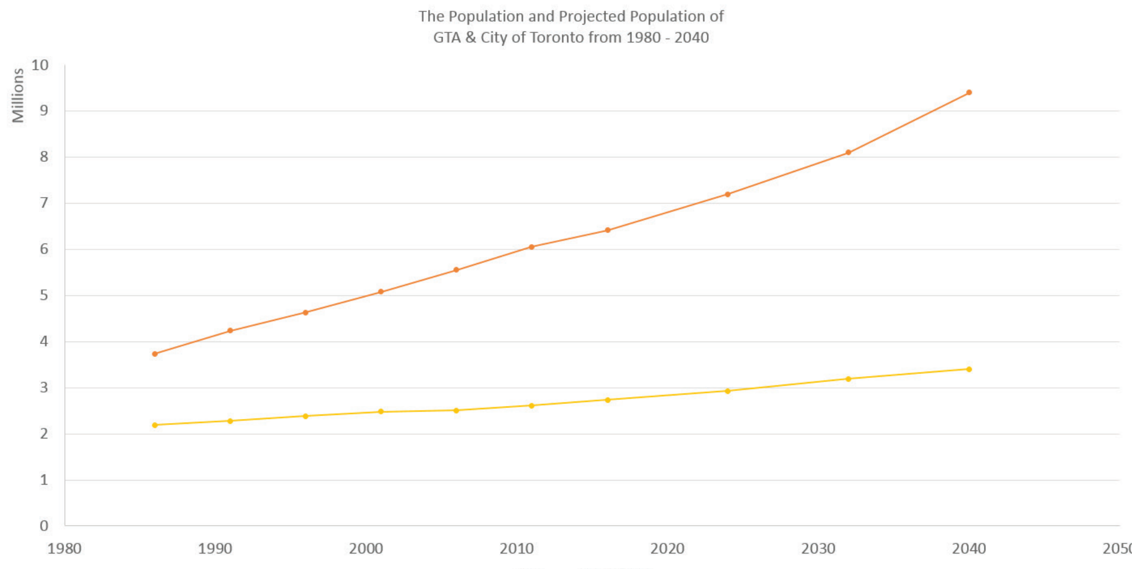
www.caa.ca/infrastructure January 2017

1.8 CAA Report To Study The Worst Bottlenecks In Canada. This report statistically shows Toronto highways have very bad bottlenecks, and traffic.

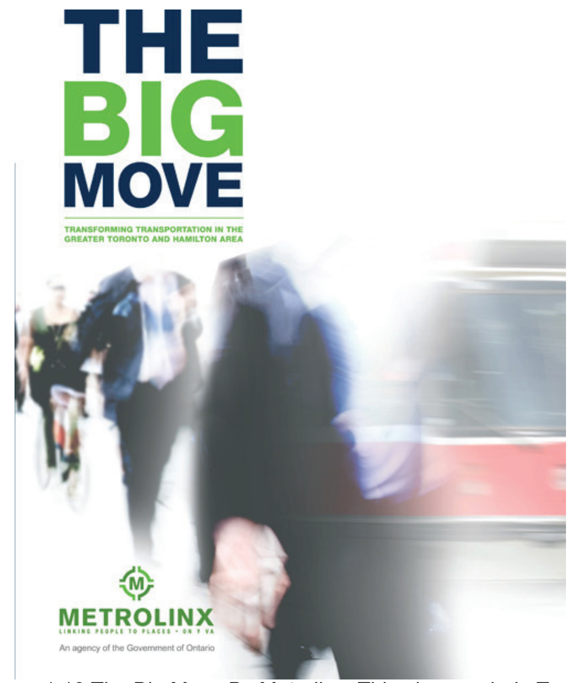
bottlenecks.[9] The study showed how ineffective the traffic system is, and the highway system seems problematic compared to the convenience of public transit of in the City of Toronto. With the increasing population each year, the Toronto expressways have not had any new significant constructions since 1971. The city only had 2 million residents then compared to the 2.6 million residents now and circa 8 millions in the broader regional GTA.[10] [11](Figure 1.9)

This design proposal thesis seeks to question how we can improve our day-to-day efficiency and comfort as a commuter, having the flexibility to travel to places the passengers need to go after being dropped off, how the passengers could get dropped off safely at a driver-less car transit hub, how to manage getting a large amount of cars in and out of a building during rush hours, the program of the mega structure, the connection to various public transit systems, the fine line of what should remain as manual versus automatic, and using Toronto as a prototype (where the citizens complain about commuting all the time). They could see this infrastructure in their daily routine and helping them to work more effectively in less time and return home safely and comfortably.

Recent studies have made the City of Toronto understand the weight of the situation and urban planners understand that a solution is necessary. Metrolinx, an agency of the government of Ontario, was created in 2006 to begin planning a more integrated transport system. This organization was designed to transform regional transit system to suit the growth of the population in a project called “The Big Move”.[12] (Figure 1.10) With new projects



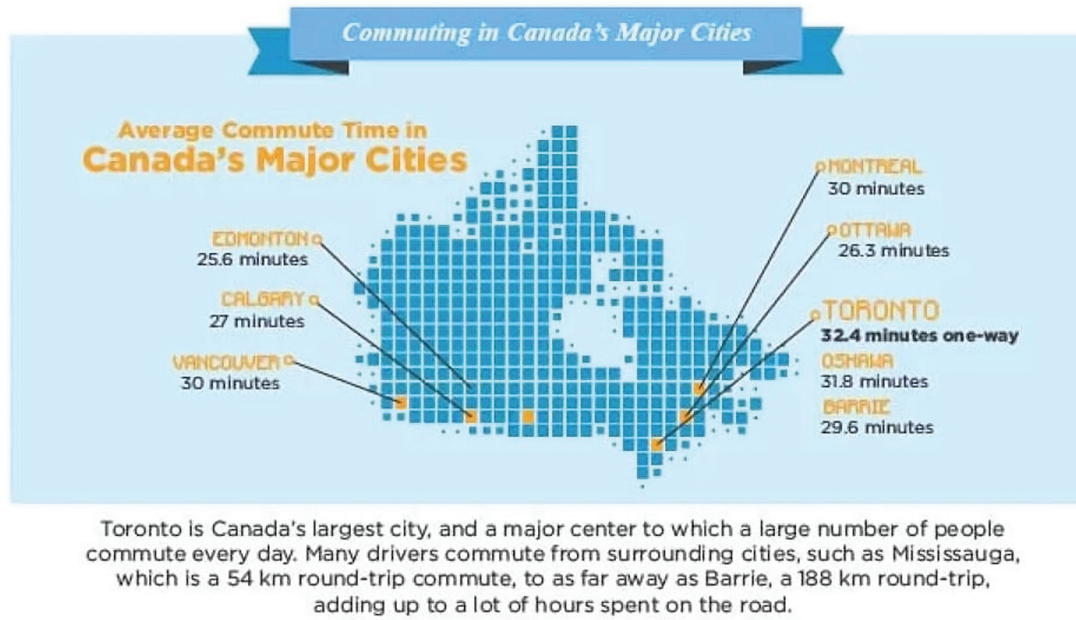
1.9 Population Of City Of Toronto From 1971 To 2016 Indicates The steady growth In the City. This is to show the population growth in Toronto, yet there were no major updates of widening the highways for all those years.



1.10 The Big Move By Metrolinx. This plan can help Toronto to be more connected to the surrounding cities by improving the transportation system.

happening inside the City core, their proposal is to lower the auto traffic by improving existing subway lines, creating new regional rail, light rail transit (LRT) planning a relief line to serve the area with greatest impacts. Getting people connected to a transit system is a worthwhile goal to cultivate, but an added problem still to be examined is bringing people from their home to the transportation system?

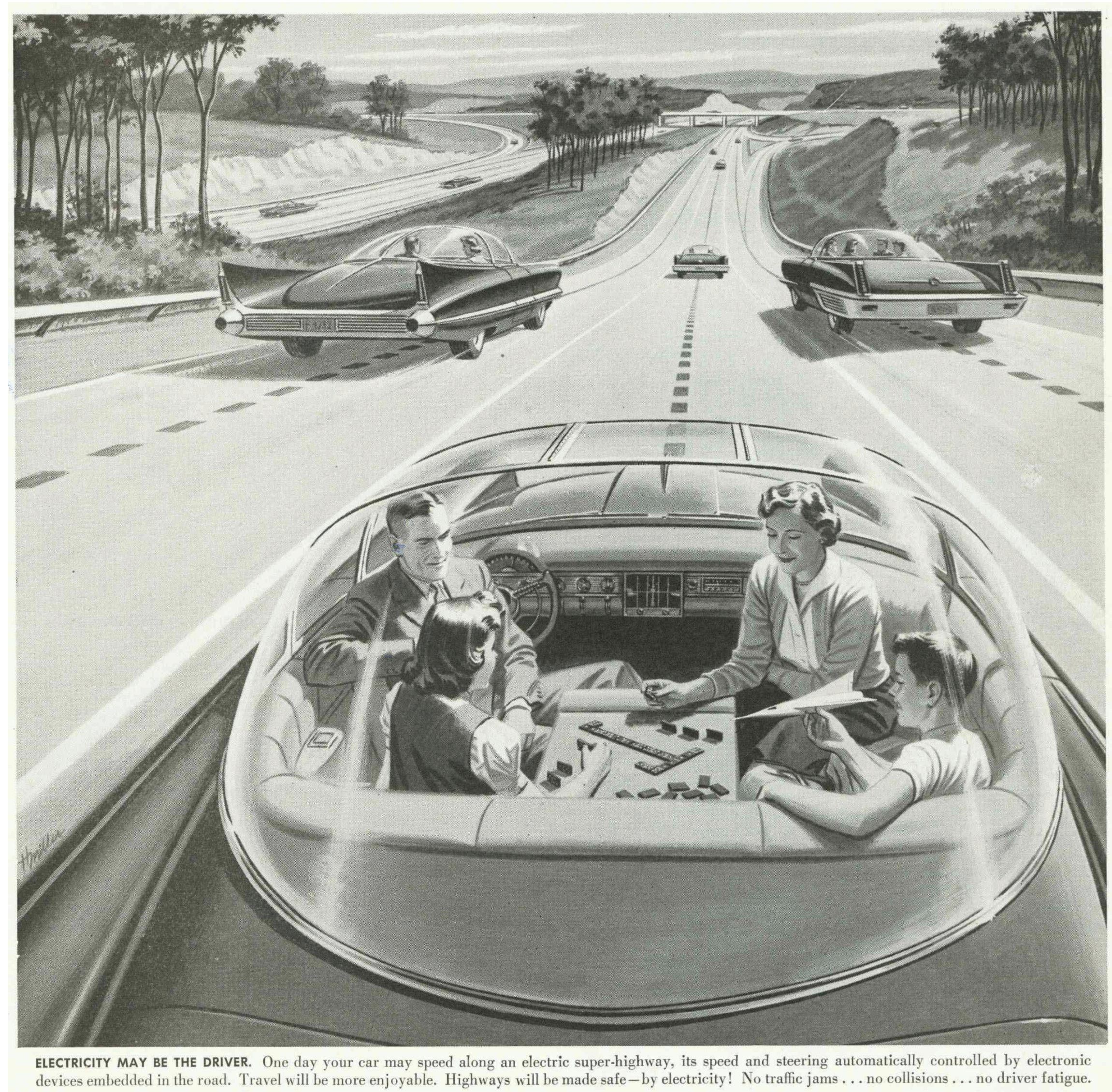
There may be a solution to the above in the evolution of the automobile industry; driverless cars will transform the way we live and build. In Canada, 80 percent of residents use a car, truck or van as the mode of transportation to go to work.[13] On average, a Torontonian's commute time is 32.8 minutes one-way, which comes to a total of more than a one hour commute.[14] (Figure 1.11) This number varies for all commuters in Ontario. 30 percent of the commuters in Oshawa, 28 percent in Toronto, and 27 percent in Barrie experience more than 45 minutes or more to commute to work in 2011.[15]



1.11 Commute Time Across The Cities In Canada To Indicate Toronto Has The Worst Commute Time Comparing To All The Major Cities. Toronto has the worst commute time across Canada's major cities as some passengers are travelling a long way to their workplace everyday.

By using driverless cars as a commuting vehicle, residents can use the time now wasted focusing on the stop-and-go traffic on getting work and personal tasks completed. Not only can it benefit the individual’s life, but also, it can take advantage of using efficient digital co-ordination of traffic to prevent traffic accidents and avoid human error. Roads will be safer and the system should reduce the number of accidents.[16]

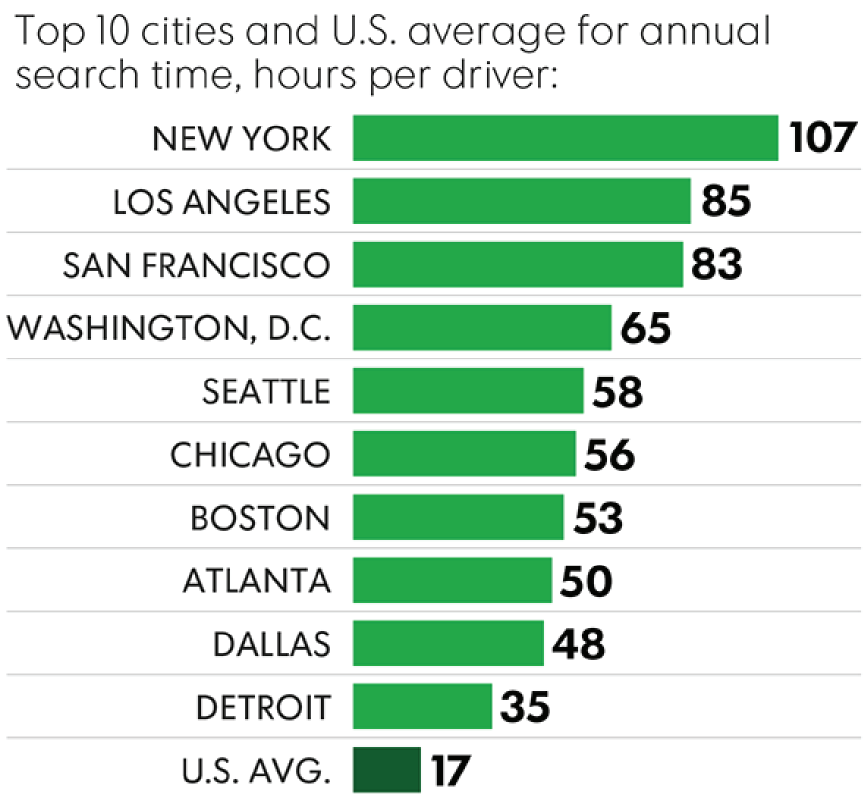
It may complicate the issue of liability when driverless accidents do happen. The City or Province will need to regulate around driverless cars. Many automobile companies and tech companies, like Audi and Google are developing and putting a significant amount of funds for research and development. Slowly, driverless cars will emerge into normality and meaning of car ownership will be shifted as most people’s needs will mostly be met at least for getting to work. (Figure 1.12)



1.12 Driverless Car Concept. This is concept sketch drawn from the 70’s. At that time, the artist already had a vision that car will be driverless one day so family can spend more time together while travelling.

The purpose of this thesis is to develop a type of infrastructure that minimizes the time the commuter takes on the road in the future and how efficiently it can move people from point A to point B with the technology of driverless cars. To cooperate with the automobile revolution, the architecture must adapt to allow people to move efficiently and quickly. A driverless car inter-modal transit hub is proposed in this thesis design work where the Gardiner expressway and Don Valley Parkway (DVP) are intersected.

Because this is such a new topic in architecture, all the research has been gathered from articles and websites about driverless cars, and the Audi Urban Future Initiative, a platform for international and interdisciplinary dialog about the future of driverless cars. The purpose of this type of architecture must be carefully designed to bring the cars from the suburbs to directly connect to the public transit within the city. Once the car goes into the city, it will act as a relief to the central rail and subway station, Union Station in Toronto, as an example to transport many people in a fast pace. A new garage based inter-modal nexus would minimize the amount of cars wandering around trying to find a parking spot and the amount of time wasted inside a car. When searching for a parking spot, the driver is spending extra time and gas beyond the actual commute time to look for one. This creates more idling on the street which creates and traps air pollution emitted by vehicles just looking for a parking spot. (Figure 1.13) This thesis would offer a new choice to commuters traveling into the City of Toronto, and provide a seamless transition from their residential area on the urban periphery to the city center transit.



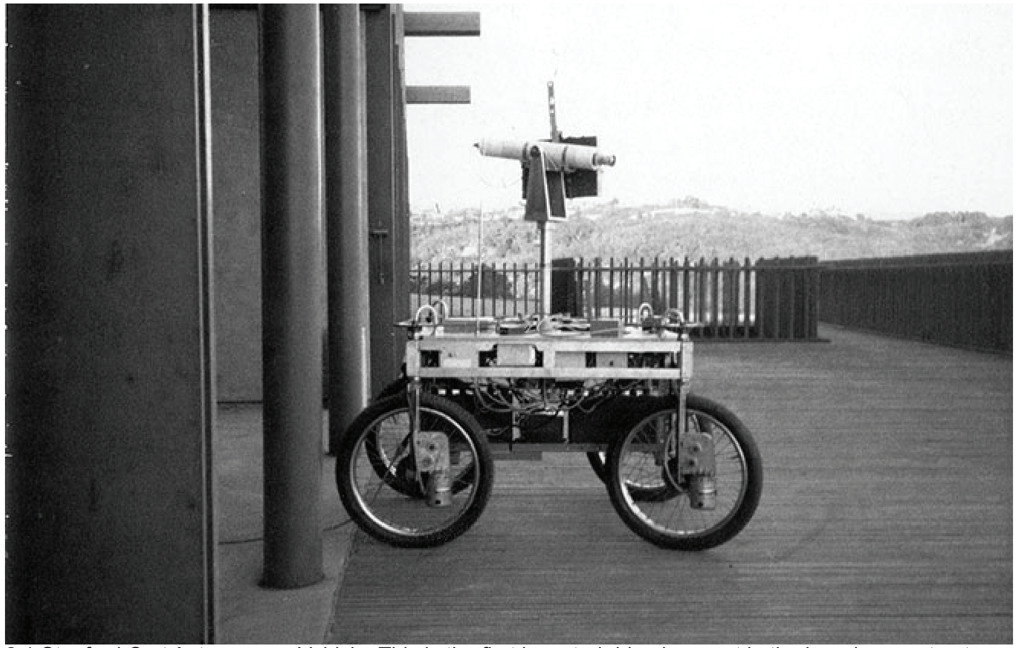
1.13 Hours Spent On Finding Parking In Cities Across US. Looking for a parking spot can be troublesome in Toronto as well. Due to the limited and high parking fee in downtown area, the drivers will have to look for alternatives for a better choice. This graph is to show commuting does not only mean the time we wasted in traffic, but finding a parking spot also contributes to the total commute time.

2.

DRIVERLESS CARS

2.1 Driverless Car Technology

Many erroneously believe that driverless cars have only been around for approximately ten years. Originally, the concept of a driverless car (also known as an autonomous car) was first exhibited in General Motor's (GM) Futurama exhibit at the 1939 World's Fair.[17] At that time, there were cars designed with robotic engineering that used a video camera to capture the road imagery. The actual first driverless car was built in the year of 1977,[18] (Figure 2.1) by S. Tsugawa and his team at Japan's Tsukuba Mechanical Engineering Laboratory.[19] The car was equipped with two cameras that utilize a simple computer for signal processing, and the maximum speed it could go was 30 km/h. As the technology and the research develop by 1994, the cameras could even detect the road markings, the relative position of the vehicle and can also sense the surrounding vehicles. One year later, there was a challenge called "No Hands Across America," and the goal was to go from Pittsburgh to Los Angeles, driven by a robot from the Carnegie Mellon University.[20] (Figure 2.2) Many tests and experiences were performed after the "No Hands Across America" challenge, from driving in the rough and bumpy environment to urban settings.



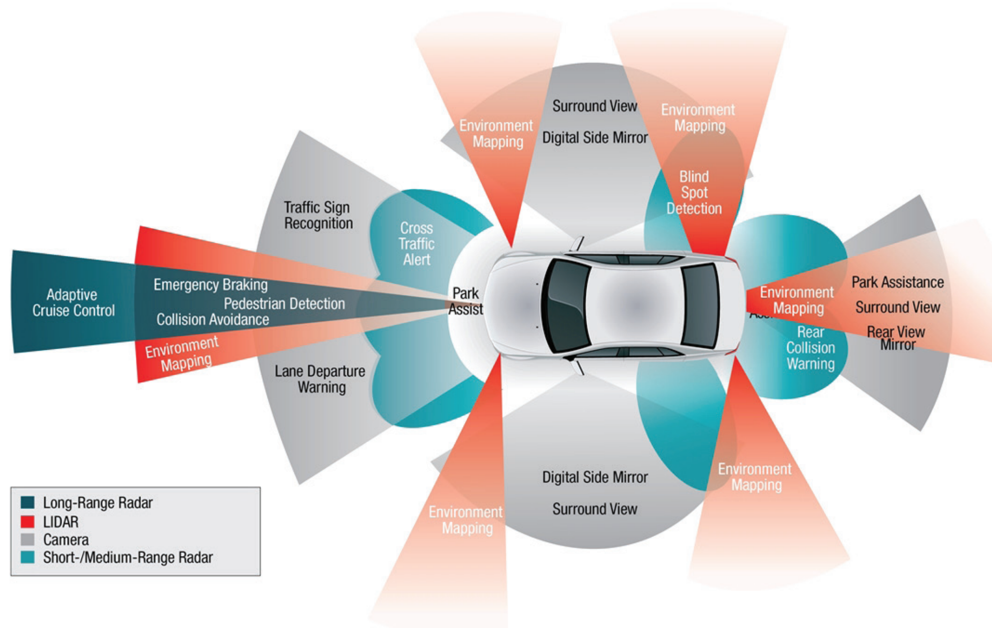
2.1 Stanford Cart Autonomous Vehicle. This is the first invented driverless cart in the bare bones structure.

2.2 No Hands Across America. During the development of driverless cars, tests were carried out to examine the technology with two men sitting inside the car while the car drive themselves. This gave the engineers many confidence to improve and research more on the technology.

The first tech company to truly launch a fleet of driverless car was Google. They set up The Google Driverless Car program and have been putting this technology into a Toyota Prius hybrid.[21] (Figure 2.3) Until today, Google has claimed that it has been doing quite well. They have adapted information on the road and used Google Map Data to generate the exact position of where the car should be.[22] As more automotive and tech companies investigate and research this topic, the driverless car is quickly becoming a safer and plausible mass society reality. Companies such as Audi and Tesla have been testing out autonomous technology, and more recently, Ford, GM, and Blackberry joined the race.[23]

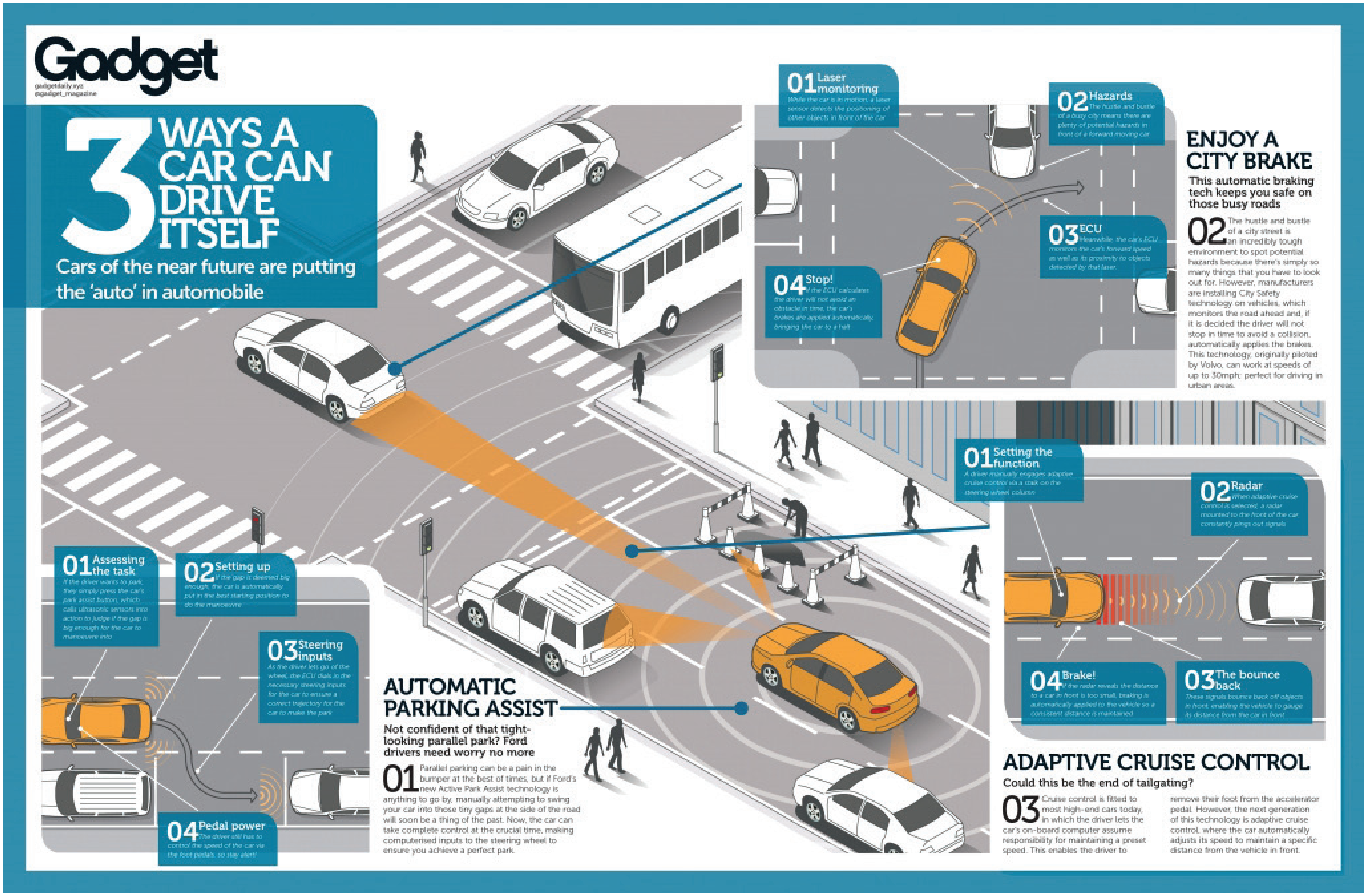
2.3 Google Driverless Car - Toyota Prius. This is one of the driverless cars that the fortune 50 companies are trying to get their hands onto developing the technology because they want to be the leader of the industry.

Testing continues in the U.S. and U.K. to put the driverless cars on the roads. Locations were selected carefully throughout Britain and each of the locations were designed to examine each aspect of driverless car performance, such as safety, legal and insurance, and public reaction.[24] More technologies and sensors have been implemented into the driverless car to increase the level of accuracy and minimize the chance of an accident. Cars have radar sensors to watch surrounding vehicles and also use video cameras as a pair of eyes to look at the road signs and traffic lights. Despite the progress, there are ongoing arguments and controversies about the money and liability problem about driverless cars. (Figure 2.4)



2.4 Diagram Explaining The Driverless Car Technologies. A driverless car can be driverless is because of the help from all the radars, cameras and sensors that the car manufacturer has to offered. The car is constantly calculating the factors it is going to face to avoid unexpected incidents

As the technology matures, driverless cars will increase in efficiency and with the ability to organize traffic better overall will ease the congestion and reduce carbon dioxide release into the atmosphere. Increased digital co-ordination will further reduce the chance of accidents. When the technology becomes increasingly refined, residents could put down their hands and let the vehicle to do its work. (Figure 2.5) Now, there are 33 companies which are involved in the research and design process. This is the future of the automotive industry. [25]



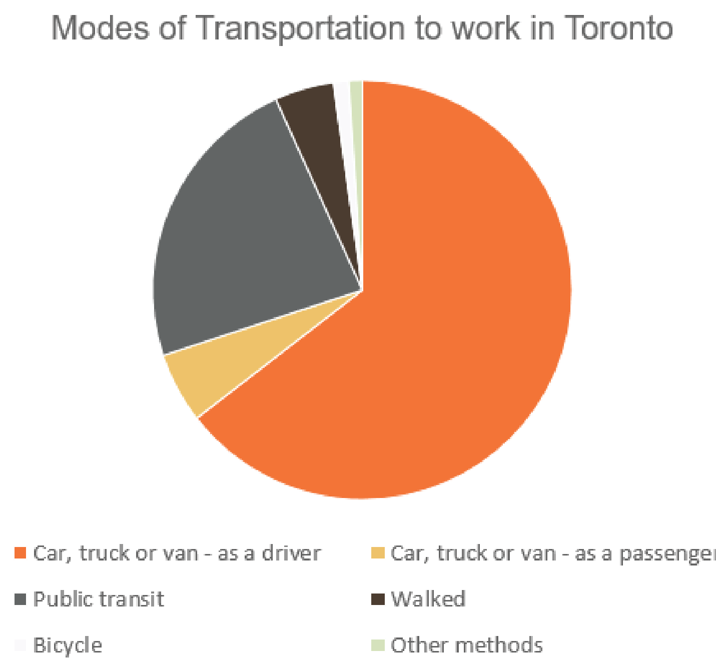
2.5 Diagram Indicating The Driverless Car Interacting With Surrounding. To further explains how driverless car functions, this diagram shows in detail how does each safety feature help.

3.

THE DAILY COMMUTE IN TORONTO

3.1 The Daily Commute in Toronto

Each morning, 52.9 percent of working Torontonians were on the road driving to work according to 2011 census. The rest of the 47.1 percent of people took transit, walked and biked to get to work.[26] (Figure 3.1) On the outer scope of the GTA region, 90 percent of the people outside Toronto rely on a car to drive to work.[27] Looking at it this way, people drive because of perceived efficiency. They want to get from point A to point B in as little time as possible, and also they want have the flexibility to drop by a friend's place after work.



Mode of transportation	
Total employed population aged 15 years and over with a usual place of work or no fixed workplace address by mode of transportation 95	1,174,610
Car, truck or van - as a driver	567,555
Car, truck or van - as a passenger	53,380
Public transit	429,275
Walked	85,475
Bicycle	25,350
Other methods	13,585

3.1 Modes Of Transportation In Toronto Indicates Major Mode Is By Car, Truck Or Van - As A Driver. It shows statistically the majority of the working class uses a car to travel to work everyday.

The main transportation rail and bus terminals in the City of Toronto are Union Station, Toronto Coach Terminal, and large shopping malls such as Scarborough Town Centre and Yorkdale Mall. The oldest and most used terminal is Union Station at the intersection of Front St. and University Ave. It is Canada's busiest and most important multi-modal passenger transportation hub. (Figure 3.2) This national historic building, built in the year 1927, currently handles more passengers than Pearson International Airport, carrying more than 63 million each year[28] Union Station services the Via Rail, GO train, Maple Leaf, The Canadian, commuter trains and connects them to the Toronto Transit Commission (TTC) subway system. This station holds more volume compared to bus centres like the city centre Toronto Coach Terminal services Greyhound, Coach Canada, New York Trailways, Ontario Northland, and suburban terminal line Yorkdale and the Scarborough Town Centre which service the TTC subway, Greyhound and Coach Canada. The advantage of these primary terminals is that they are all next to the highway, which carry people from outside Toronto to get into the city easily.

To focus on the Downtown Toronto area, the expressway that serves the area is the Gardiner Expressway, which is also the closest highway to Union Station. It runs on an east-west axis connecting to the Don Valley Parkway and Highway 427. Every morning, during the peak hours of inbound traffic, 6,100 people come from Bathurst Street using the East- bound and 5,200 people come from DVP on the Westbound.[29] (Figure 3.3) Many people get off the highway at the York/Yonge exit where to access Union Station. Others prefer to drive to work and park around Union Station because it is still time and cost-effective.

3.2 Great Hall Of Union Station In Toronto, Canada. This station is the main station in downtown Toronto, and it carries a large amount of people from the GTA to the city everyday.

3.3 AM Peak Hour Traffic Volume Map To Show The Number Of Cars Going Through DVP & Gardiner Expressway. This map shows the importance of the Gardiner Expressway & DVP through the number of vehicles that use those two highways every morning to get around the city.

3.2 Don Valley Parkway and Gardiner Expressway

The thesis design proposal is located on east of the DVP and Gardiner Expressway intersection. This location offers a great opportunity for a future transit hub because not only there are two major highways intersecting, but also the development of the future Go RER, TTC Subway Relief Line, and the streetcar.

3.2.1 Don Valley Parkway

The Don Valley Parkway is a 15km long highway that runs in the north and south direction.[30] (Figure 3.4). The south end is connected to the Gardiner Expressway, and the north end is connected to Highway 401. It is the closest north to south highway that gets connected into Toronto downtown area, which is one of the reasons why this highway is always over burdened with cars. During rush hours, a capacity of 100,000 vehicles per day could be reached, which is 40% more than its intended capacity.[31]

In 1954, a highway was proposed through the Don Valley to provide access to the city's financial and industrial areas at that time when the number of automobile was growing drastically. In an era of car movement, the Don River Valley was portrayed as an obstacle to efficient traffic movement. Twelve years later in 1966, the newly completed highway was completed to the north end of Highway 401.[32] The new DVP was seen as a connection to nothing at that time because, in 1966, the area north of Eglinton Avenue was considered beyond the city region's suburbs. The decision made by the planners seemed questionable at that time because they built a road that was seen

3.4 Don Valley Parkway Context Plan. This map is to show where the highway is in comparison to downtown Toronto. It is the major highway that brings traffic from north to south into the downtown core, and carrying people to and from the Gardiner Expressway on the south end.

as unnecessary. What they were actually doing was reacting to the future revolution of traffic volume.

The DVP remains the only artery from north to south that enters to the downtown core of Toronto. In 1971, the Spadina expressway, now known as the Allen Road was stopped midway during construction. By political pressure from city center neighborhoods, the Ontario government Cabinet stopped the road completely and it was a very ground-breaking moment. To travel to downtown on the DVP from the north at a speed of 90 km/h without stopping.[33] (Figure 3.5). "People love to hate the Parkway… but Metro would not have developed nearly to the extent that it has if that hadn't have been available. You can't imagine the city without that road….". Said by the DVP project engineer, Murray Douglas, during an interview in 1992. The city network was all about vehicular movement, and how much citizens rely on their cars.[34]

Similar to the situation with the Gardiner Expressway, the first of Toronto's urban expressways, the capacity of 160,000 that DVP carries in 2001 was well beyond the intended capacity of 60,000 cars daily. Due to the exponential growth of the population and usage of cars in GTA region, use of this highway is over saturated and overloaded by traffic on the roadway.

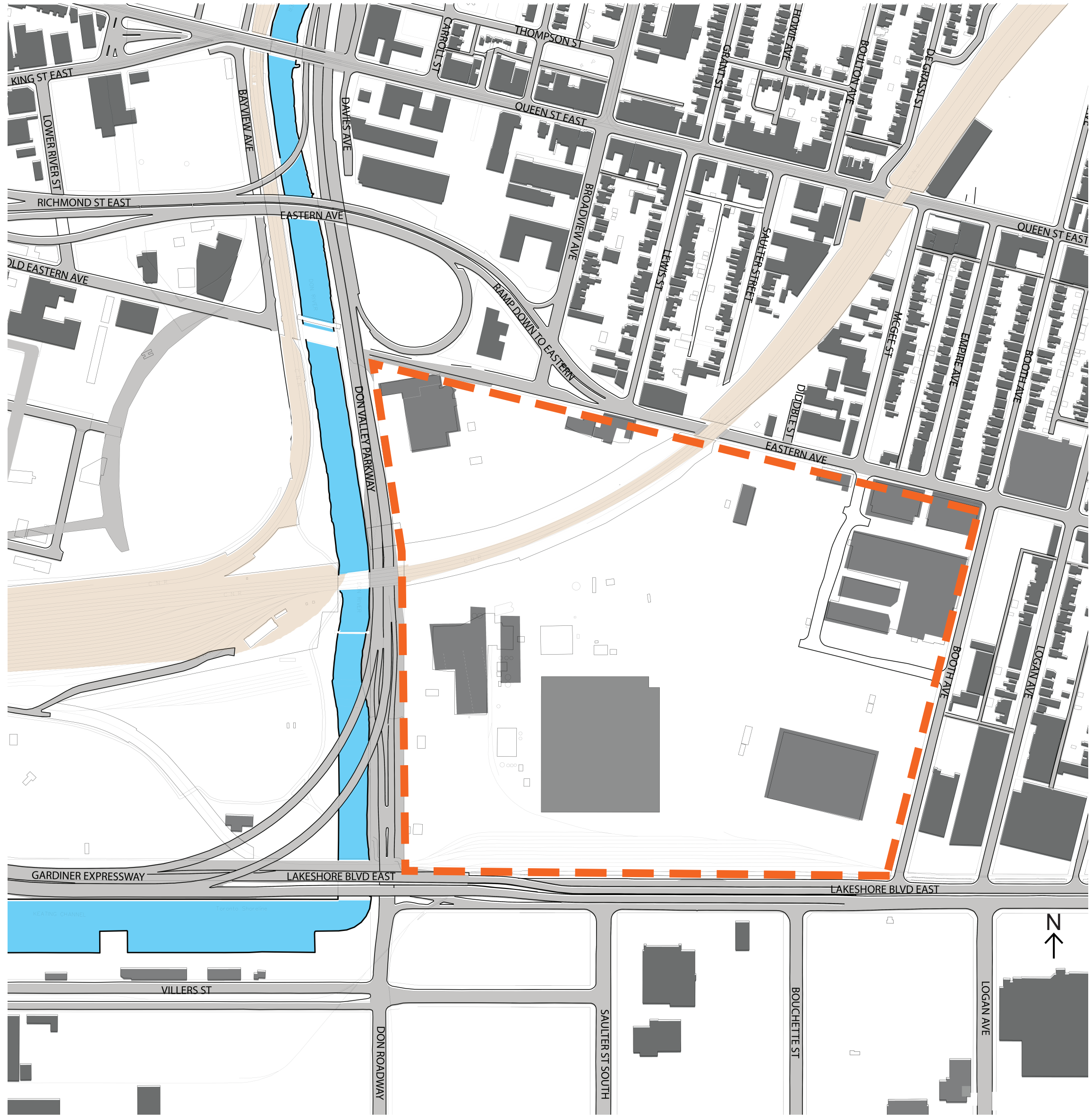
3.5 Historic Picture Of Don Valley Parkway. This is a picture of the Don Valley Parkway looking south and it was taken on the day of opening. It was the first time in era that drivers could drive unobstructively and without traffic lights to access to the downtown.

3.3 Gardiner Expressway

The thesis design proposal is also situated adjacent to the east end of the Gardiner Expressway, where the DVP ends on the south, and the flow of traffic changes direction. (Figure 3.6) The Gardiner is the only highway that serves the traffic in downtown core. It is such a critical artery to Toronto to the east since it connects the commuters coming from DVP and Highway 427, and the Queen Elizabeth Way (QEW). From the west this highway has always been seen as a problem by the majority of Toronto's citizens, there are proposals to alter the layout and service of this expressway which are captured in the design thesis.

In 1955, the 18km-long Gardiner Expressway was established and completed in 1964 to support the growth of population after World War II in Toronto.[35] (Figure 3.7) It is a major component of Toronto transportation network and its global economy. This Gardiner Expressway was named after the chair of Metropolitan Toronto Council, Frederick G. Gardiner, who also supported the Spadina Expressway and Don Valley Parkway on the east end of The Gardiner.[36]

On its other end, it connects to Highway 427 and QEW. (Figure 3.6) The elevated part of the expressway deteriorated as it ages, carrying 160,000 vehicles daily, and causing concrete and reinforced steel to break down leading to accidents from falling concrete.[37] The maintenance issue is continously debated on whether the city should tear it down or maintain this 60 years-old expressway.



3.6 The Boundary Of Thesis Site. The site is the on east side of the intersection of Don Valley Parkway and Gardiner Expressway. Currently, there are many industrial buildings, and surrounded by commercial and residential buildings.

3.7 Historic Picture Of Gardiner Expressway Looking West On Oct 21, 1969. This nearly 50-year old highway was built to sustain the population at the time. It was not meant to coop with the exponential growth in population and tall buildings in Toronto nowadays.

3.3.1 The Gardiner Planning Process

At the beginning of 1947, the City proposed a Waterfront Highway, a four-lane highway located from Humber River to Don River. During the meeting in November 1947, the city approved the plan for the expressway that was originally named ‘Lakeshore Expressway’. A month later, the Board of Control abandoned the project due to the shortage of steel during that period just after World Was II.[38]

In 1954, the expressway plan was back on track and Frederick G. Gardiner had proposed to increase the expressway from a four-lane to a six-lane highway. [39] The project revival was caused by heavy traffic congestion on Lakeshore Street at that time. The planning was extended from the Humber River to Woodbine Avenue to alleviate the extent of the congestion and budgeted with an estimated amount of $20 million. The construction planning started at grade level and moved upward to a raised deck towards the east, which increased the cost to $50 million. The route planning was directed to Margison Babcock and Associates, an engineering firm. This proposed plan was rejected by the City of Toronto and Toronto Harbour Commission. Margison needed to move the route further north, and Metro approved this plan and budgeted $31 million for the sections. The adopted proposal required the removal of ten acres of Canadian National Exhibition (CNE) land, the removal of the original CNE Dufferin Gate and two CNE buildings. As a compromise, the new Metropolitan Toronto Government (Metro) filled in Lake Ontario to sustain the extra land to provide a better highway network to Toronto.[40]

3.8 Historic Picture Of Gardiner Expressway - 1954- 1963. This highway starts to deteriorate very fast because the designer did not consider the amount of road salt that will corrode the material, reinforcement and the performance of the elevated highway.

3.3.2 Construction and Maintenance

Construction of the expressway started at Queensway & Keating Avenue (now known as Lakeshore Blvd East) to the end of Woodbine Ave in 1955. Since the downtown roads would still need to operate during the time of construction, the process had been broken into segments to allow daily operation of driving and finished in the year of 1966. (Figure 3.9) The total cost of the project turned out to be $110 million, which originally had claimed to be $50 million.[41]

This massive structure was developed in the busiest location in Toronto and had caused some demolitions at that time, such as the Sunnyside Amusement Park around Humber Bay area, and 'South Parkdale' residential neighborhood built in the 1800's at Jameson Ave. The elevated portion of Don River to Leslie Street was intended to connect the Scarborough Expressway to the east. However, the plan to the future Scarborough was canceled and that eastern Gardiner portion demolished in 2001 as requested by the Crombie Commission and Gardiner Lakeshore Task Force in 1990. [42] (Figure 3.8)

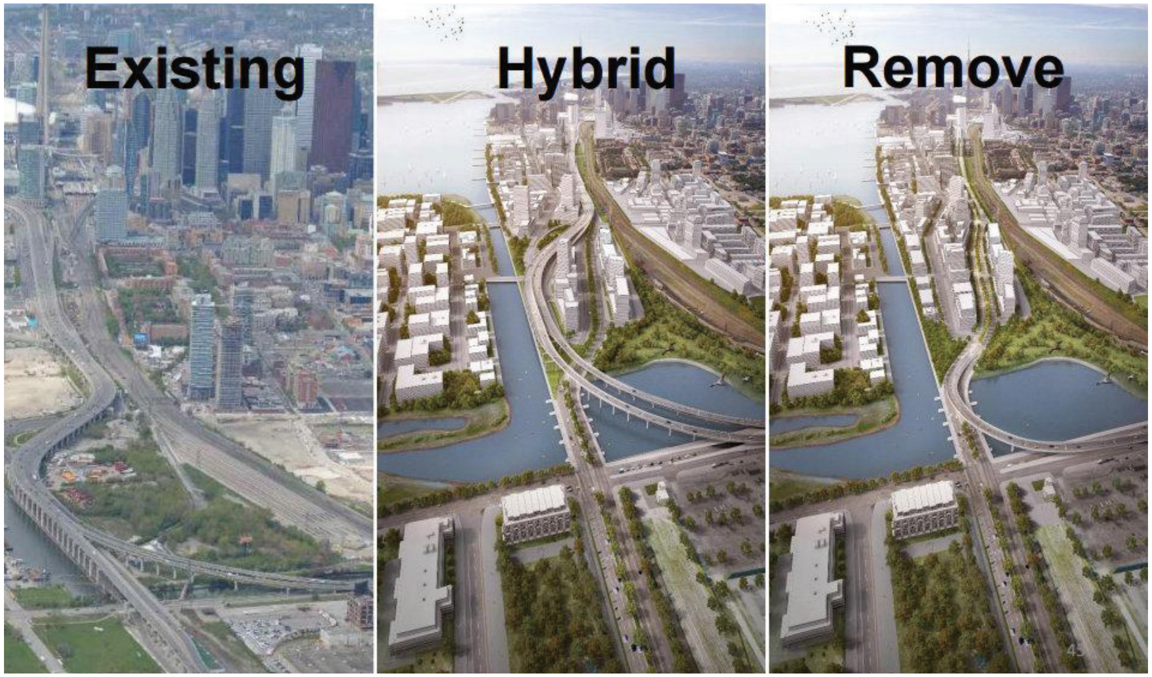
After the completion of the expressway, the city expected daily of 40,000 to 60,000 vehicles traveling on the Gardiner Expressway in 1963. Within five years of vehicular usage, the expressway started to experience traffic congestion. To solve the problem, the Metro Toronto proposed a plan to increase the expressway to an eight-lane highway, but at that time, the city of Toronto did not have any funding for it. In the 1990s, maintenance and extensive repair was required for the elevated portion and it was discovered that some parts of the structure

3.9 Historic Picture Of The Demolition Of Eastern Portion Of Gardiner Expressway. This portion was demolished due to the proposed transit plan on the other end did not happen as planned. Therefore, the portion that was built for the connection was torn down.

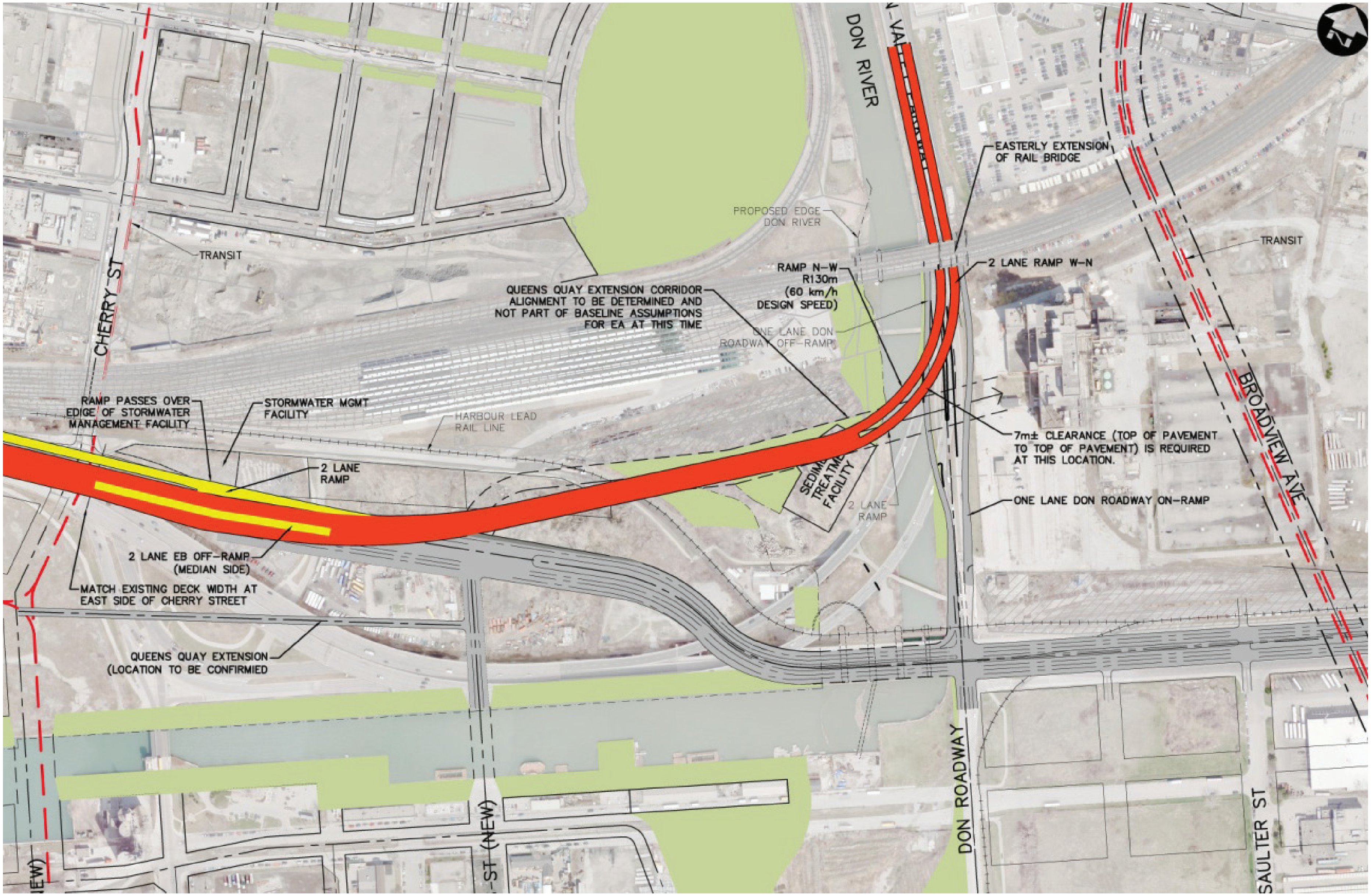
were not sitting on bedrock. Each year starting in the 1990s, remedial work had been continuously done all over the structure and beneath the Gardiner. The corrosion from winter road salt, an issue overlooked by early engineers and developers caused the need for patch work on the concrete and steel to prevent salt water erosion. The city pays $8 million per year to repair the problem.[43]

3.3.3 The Future Hybrid or Removal Options

The Gardiner was carrying a city population of 1.31 million in 1955, and to 2.79 million by 2015, which was more than double of that 60 years ago.[44] This aging expressway has come to a stage that patchwork onto the structural materials cannot be made any longer, as accidents of falling concrete have been an issue. There were debates on whether they should tear down the highway or use a hybrid option, which is to replace the elevated eastern segment and add and remove certain on-off ramps. Both options have their advantages from looking at the city development, economic, and financial state. The hybrid option allows the major economic developments to stay in the downtown core while keeping the city moving. On the other hand, the removal option involves less costs and provides a chance for the Waterfront development.[45] (Figure 3.10) On June 11, 2015, the city council had voted and the results were on the hybrid option by 24-21.[46] (Figure 3.11) The construction work would start in 2019 after the environmental assessment from the west to the east. Meanwhile, repair works will still need to finish on the elevated portion of expressway.

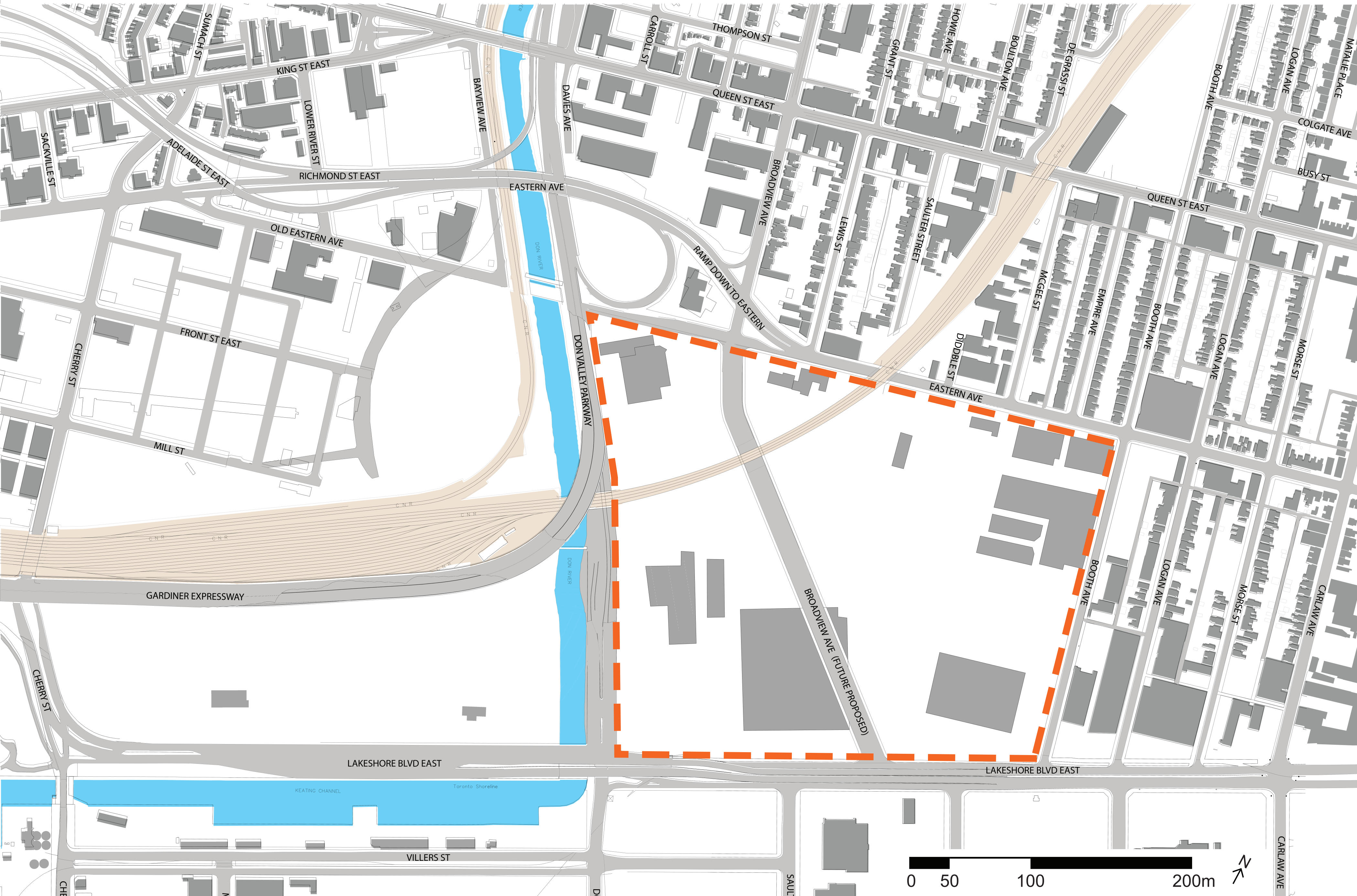


3.10 Proposed Options Of Gardiner Expressway. These are the options that the city planned for the old Gardiner expressway because the city could not support cost of the endless maintenance.



3.11 Hybrid Option Of Gardiner - Final Decision. The final decision is the hybrid option, which will create a boulevard at the east end by demolishing the existing ramp, and re-decking a portion of the highway by shifting it north while maintaining the number of lanes.

As the hybrid option of the Gardiner Expressway is implemented along with the transits proposed (Figure 3.12), in 20 years time, the thesis design transit hub will be a transferable strategy for all the major intersections of highways in Toronto.



3.12 Integrated Site Plan With Future Proposal of Gardiner Expressway. This site plan shows the hybrid option of the Gardiner Expressway by relocating it immediately south of the existing CNR and deleting the connection to Lakeshore Blvd. The future planned extension to the Broadview Ave is also shown on this plan to show future streetcar proposal through the site.

4.

THE METROLINX PLAN AND A POTENTIAL THESIS PROJECT

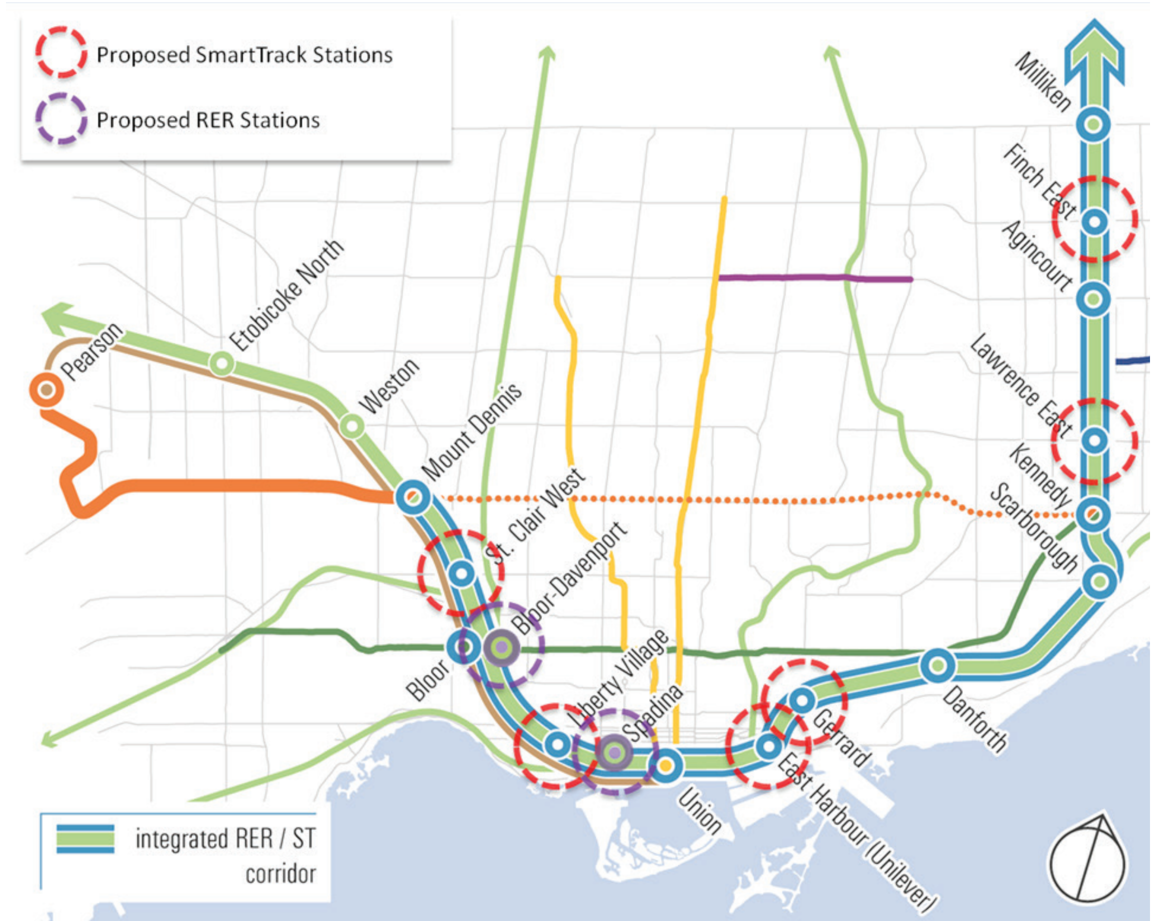
4.1 Metrolinx

In 2006, the Metrolinx Act was created to improve the transit system in the GTA and Hamilton area. Within two years' time, the plan of The Big Move was implemented. The Big Move is more than connecting stations and proposing new LRT lines. [47] It is also about the idea of moving a lot of people in the future efficiently as the population in the GTA is rising each year, and bringing the transit system in Toronto back to the modern efficiencies.

Many governmental agencies are involved in making this Big Move happens, such as the GO Transit, TTC, Presto automated fare system, VIVA bus in York Region, and much more. They involve all modes of transportation in the process to make this plan viable. The plan branches to Durham, York, Peel, and Halton. (Figure 4.1) So far, the UP transit line to connect to the Toronto Pearson Airport has been completed, upgrading the Presto system and implementing devices in stations, digging down for the Eglinton LRT line, and reconfiguring the Union Station Rail Corridor.[48] Metrolinx is creating the largest transit system build out in Canadian history.

4.1 Metrolinx Service Area And Future Proposals. This shows an overall proposal for connecting cities outside the GTA to make Toronto more accessible.

To incorporate the old network and the new additions of the Metrolinx "Big Moves" expansion, new stations will need to be constructed to accommodate the changes. At the mouth of the Don River where DVP southbound ends and turns into the Gardiner Expressway, Metrolinx and the city have proposed a new station of the TTC Subway relief line, Broadview Station, with expected completion in 2031, as well as the extension of the LRT transit system.[49] (Figure 4.2) That piece of under-developed land,now the Unilever Precinct consists of 24.9 hectares and owned by a private owner, First Gulf.[50] First Gulf, as a developer and property manager, sought an opportunity from the city to invest in the land for a variety of non-residential uses in October 2015.[51] This also included the proposal by the international OMA (Office for Metropolitan Architecture) during the competition of Gardiner Expressway transformation.



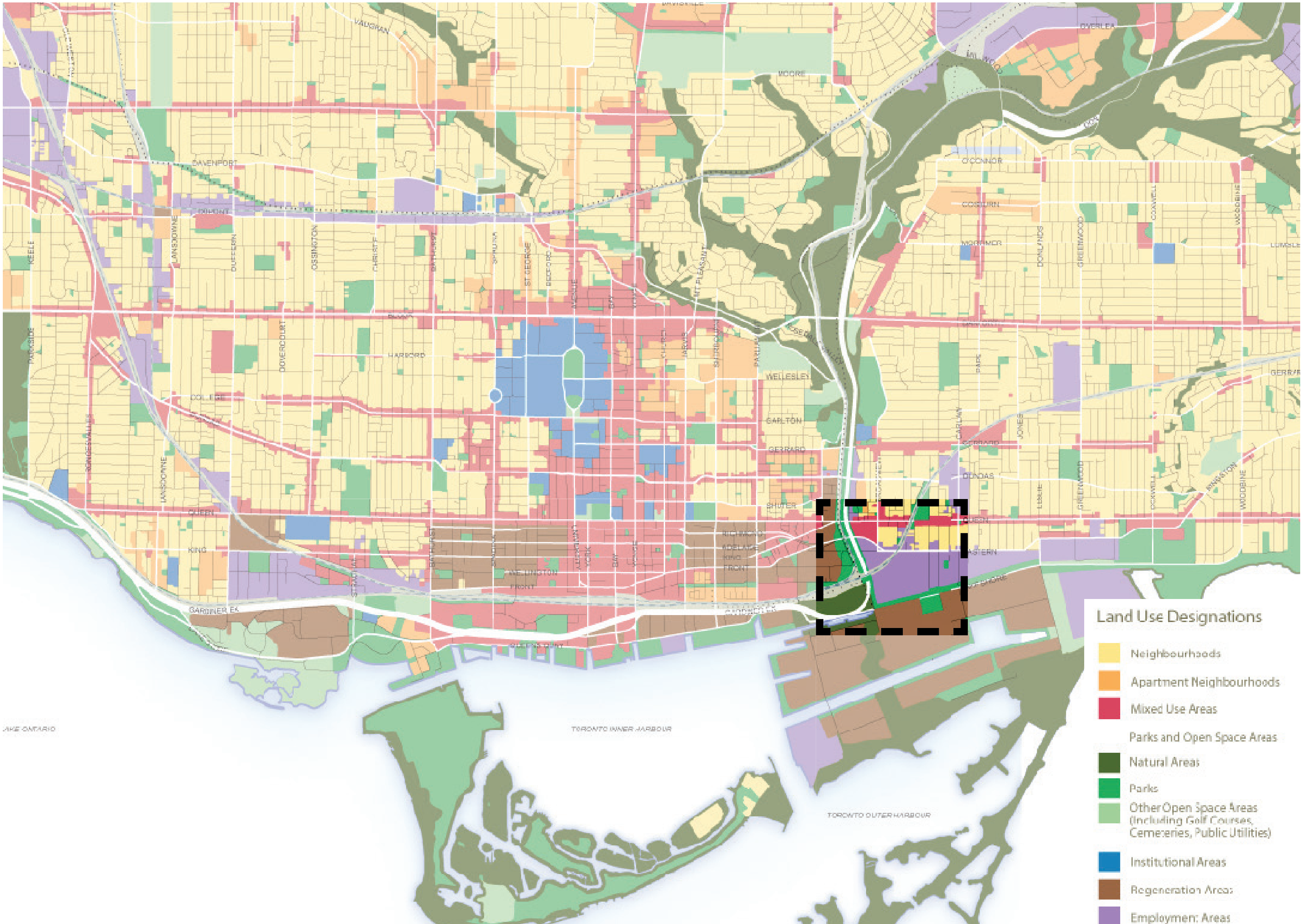
4.2 Station Map Of Proposed GO RER. This is a map of where the future GO RER is and will intersect, and it will help to locate where the most ideal location is to place the transit hub.

4.2 The Design Thesis Site

The site proposed for this thesis design work is bounded by Eastern Ave and Lakeshore Ave in the North-South direction, and th DVP and Booth Ave from East to West direction (Refer to Figure 4.2 on the previous page). Split into north and south by the existing GO Train rail corridor, the majority of the land is located on the south side of the rail corridor, and the city has zoned the north side as an 'Area of Influence'. Currently, the use of the land is a car dealership and has been marked as employment land use purpose. (Figure 4.3) The reason why this land has been vacant for a long time is due to the lack of accessibility, and also the west of the site at the water edge is in consideration for the flood protection through the proposed Eastern & Broadview Flood Protection Municipal Class Environmental Assessment.[52] The City has pushed the development forward by requesting funding from the Government of Canada and Province of Ontario for the commitments of the Port Lands Flood Protection Project in November 2016.[53] As mentioned above, the City of Toronto and developers finally see an excellent opportunity to transform the land into an employment project along with the push from Metrolinx and TTC transit system.

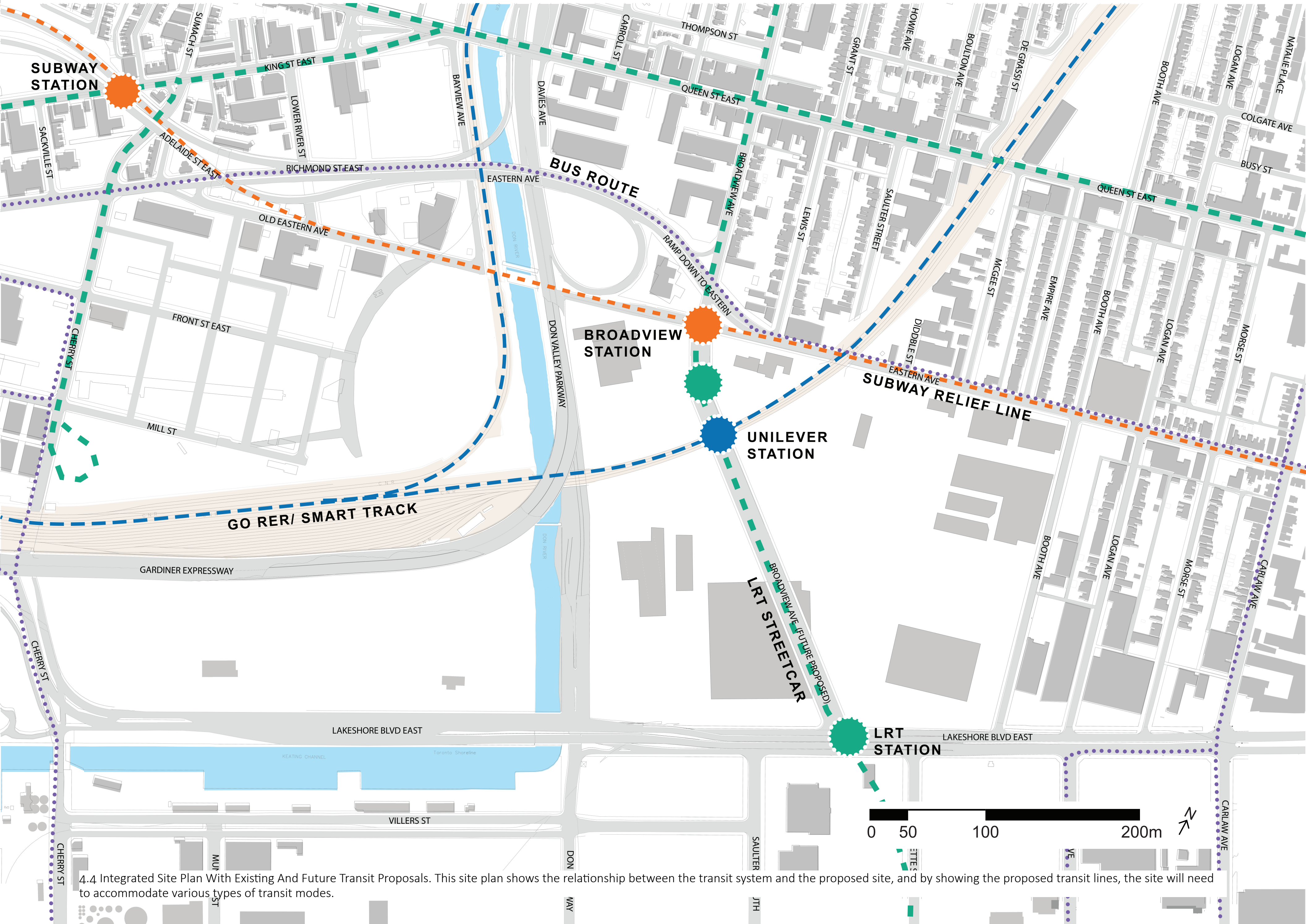
There are some challenges for this particular site: the fact that it is the future flood mitigation function where naturalizing the river's mouth was approved by Ontario, the multi-modal transit system, such as the Smart Track RER and cycling and street networks, the scale of this site, uncertain plans for pulling the Gardiner back. All these challenges will be answered by planners and architects, and often professionals to turn this site into a reality. "Nothing will happen without unlocking the transit piece" – Councilor Paula Fletcher.[54]

On the north side of the site, facing Eastern Avenue, is where the city has proposed the Broadview Station of the new Relief Line, along with the Smart Track/RER that is going to expand on the existing GO Train lines. Possibility of extending the LRT system to Lakeshore in the future is also a consideration. This location has many potentials to be unlocked as the next Union Station in downtown Toronto, especially when the transportation capacity reaches the top in the coming years. The intersection of systems of the public transit system creates activities and brings Torontonians a more convenient way of commuting.



4.3 Toronto Land Use Map Indicating The Site Is Labeled As Employment Area. And the surroundings are residential area and green spaces.

4.4 There are many public transit opportunities in the nexus of transit infrastructure on the design thesis site shown on the map on the right. It shows the proposed relief subway line in orange, the proposed LRT streetcar route in green, and new stations for the GO Train RER, as well as new stations for the other two ways of transportation.



4.4 Integrated Site Plan With Existing And Future Transit Proposals. This site plan shows the relationship between the transit system and the proposed site, and by showing the proposed transit lines, the site will need to accommodate various types of transit modes.

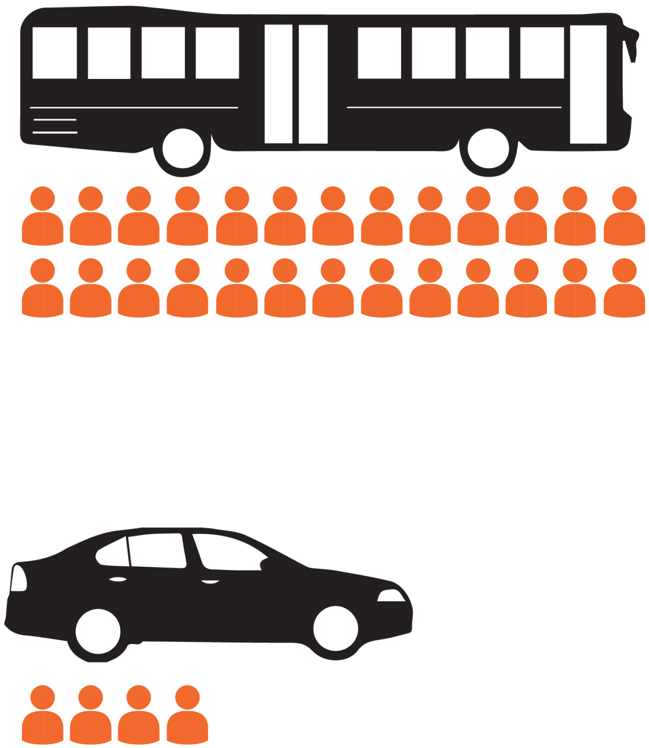
5.

PRECEDENTS OF MASS TRANSIT HUBS AND DRIVERLESS CAR GARAGES

5.1 Precedents of Transit Hubs & Mass Terminals

Public transit in a city is much more crucial than simply moving people around. Any type of transportation can promote agglomeration, and public transit makes it possible because it moves a significant amount of people to a destination.[55] (Figure 5.1) Consider this: if roads are only accessible by cars, traffic will be so congested in accommodating many people at once, versus using a bus that will reduce traffic by grouping people in one confined space. It also has an interlocking relationship to the economy to a city, said by a publisher in Urban Studies, Chatman and fellow planner Robert Noland of Rutgers University, that "The hidden economic value of transit could be worth anywhere from $1.5 million to $1.8 billion a year".[56] The larger the city is, the more hidden economic value there is. Therefore, a transit center is a central place for transporting many people to a destination all at one time and creating economic activity.

The following case studies look at precedents on large transit centers, and the functional relationships that make this architecture work.



5.1 The Number Of Passengers Public Transportation Vs Passenger Car Carry. Public transportation carries more passenger and can reduce the number of cars on the road.

5.2 Transbay Transit Center

The Transbay Transit Center in San Francisco, California, US. is located in the heart of downtown San Francisco, and the San Francisco Bay Area. (Figure 5.2) The project started to break ground in December 2008, and currently is still under construction nearing the finishing phase. The original Transbay Terminal was built in 1939. At that time, the terminal was used to accommodate rail systems, and designed to transport 35 million people annually. [57] The Loma Prieta earthquake happened in 1989, and the terminal suffered from severe structural damage. Voters in the city decided to extend the services and modes of transportation to replace the former Transbay Terminal to connect the city region Bay Area counties.[58]

The new building spans from 2nd Street to Beale Street, and Mission St and Howard St. and the footprint of the building is 5.4 acres. Compared to Toronto, the block is almost the distance from Jarvis Street to Yonge Street. (Figure 5.3) This regional terminal architecture is more than 1 million square feet, and servicing 11 different transit systems.[59]

Designed by Pelli Clarke Pelli Architects, who have experience in transit architecture, the project costs $6 billion USD in total, and it will be the "Grand Central Station of the West." [60] The building itself consists of five floors along with retail, a rooftop park, and main transit concourses for multi-modal public transit. The ground floor is the primary circulation area of the transit center, that people can access using the main escalators to access

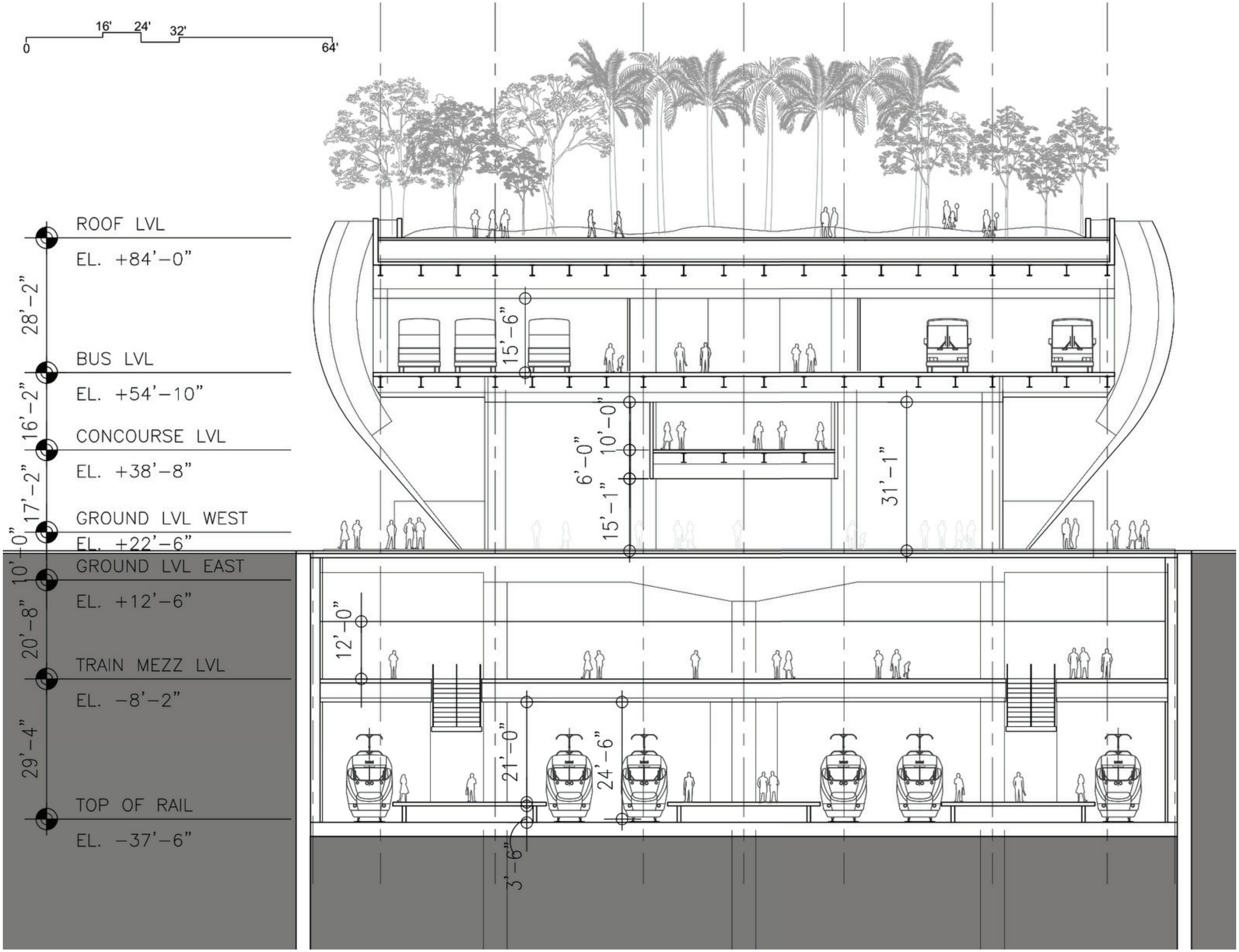
5.2 Transbay Transit Center In San Franciso, US Rendering. This rendering is to show the scale in relationship to the buildings beside it.

5.3 Transbay Site Plan. This site plan shows the transit center spans over 4 streets in the city of San Franciso.

other types of transportation, and also include automated ticket kiosks. (Figure 5.4)

The second floor is the bus deck level. In this case, there is a ramp reaching up from the ground floor up to the second floor surrounded by a central passenger waiting area. Moreover, when the commuters move one level up by escalator, they will arrive to the landscaped roof park. Designed by PWP Landscape Architecture, the park offers a view overlooking the city with amenities such as restaurants, amphitheater, and kid-friendly zones.[61] On the other two levels, the lower concourse and train platform, there is a waiting area, ticketing, and bike storage facilities.

In addition to the extensive programs and transit systems, this development will create a new neighborhood in the vicinity. The proposal outlined new offices, residential buildings, parks, and retail. Moreover, it was also focused on improving the pedestrian experience and biking amenities. A transit system not only will revitalize and improve only on the transportation, but it will also provide more access and create a neighborhood to have work-life around it.



5.4 Transbay Section. This section shows the individual transit system in relation to each level. The lowest level is for trains and the second level is for bus.

5.3 Toronto's Union Station Revitalization

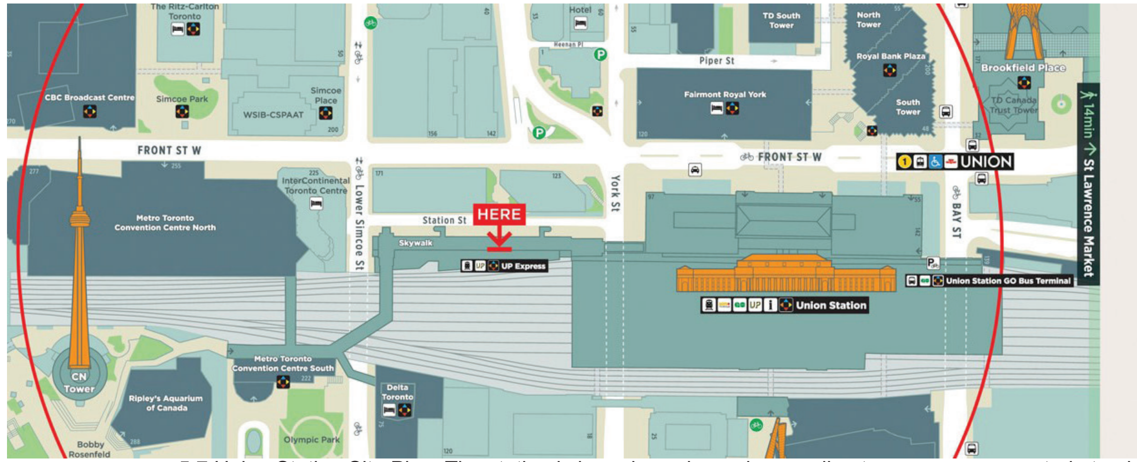
Union Station in Toronto has been the central hub for transportation in the city since 1927 and since 1914 as the main rail terminal. It has been continuously updating the programs to keep it up to date and be able to handle the growth Toronto has experienced.[62] (Figure 5.5, 5.6) Union Station is the main gateway to Toronto, and it is the busiest passenger transportation hub in Canada, with daily passengers of a quarter-million, serving more passengers than Pearson Airport, the main airport of Toronto.[63] This transit hub is important because it provides a multi-modal traveling port to their passengers, and it is located within the downtown core and financial district.

The construction of the original building began in 1914 and opened 13 years later due to the shortage of materials during World War I. In 1904, parts of the earlier building were destroyed by the Great Toronto Fire.[64] This building truly makes a mark on Canadian architecture as one of the finest classical Beaux-Arts railway station in Canada. It was also listed as a National Historic Site of Canada in 1975, a Heritage Railway Station of Canada in 1989, and the Ontario Heritage Act in 2006.[65]

5.5 Union Station Revitalization Rendering In Toronto, Canada. The station is undergoing a revitalization to sustain more travelers with time.

5.6 Aerial Rendering Of Union Station Revitalization. This revitalization will also bring an additional structure to the existing architecture.

Union Station is one of Canada's largest train stations built in the early 20th century, standing on a block on Front Street between Bay Street and York Street. (Figure 5.7) It provides a connection to the subway, commuter rail, commuter bus, passenger rail, and bicycle.[66] Currently, Union Station is undergoing a major revitalization by not only repainting the walls, fixing damaged floors and roofs, but also improving the efficiency of how commuters travel nowadays and providing a large canopy over the waiting area to make it more weather proof.[67] The City of Toronto's main objectives are to improve the quality and capacity of pedestrians, restore the historical elements, and to transform the station where activities happen around it. The train concourse will provide better access, with the connection to PATH systems, new entrances, vendors will be more involved and there will be more fast-food vendors than restaurants), the larger platform will expect a doubling number of passengers in the future, and lastly, more attention paid to smart buildings with green technology. [68] These efforts have all been put in to improving the quality of commuting while increasing the efficiency of traveling is the ultimate goal. (Figure 5.8)



5.7 Union Station Site Plan. The station is large in scale, and expanding to cover numerous train tracks.

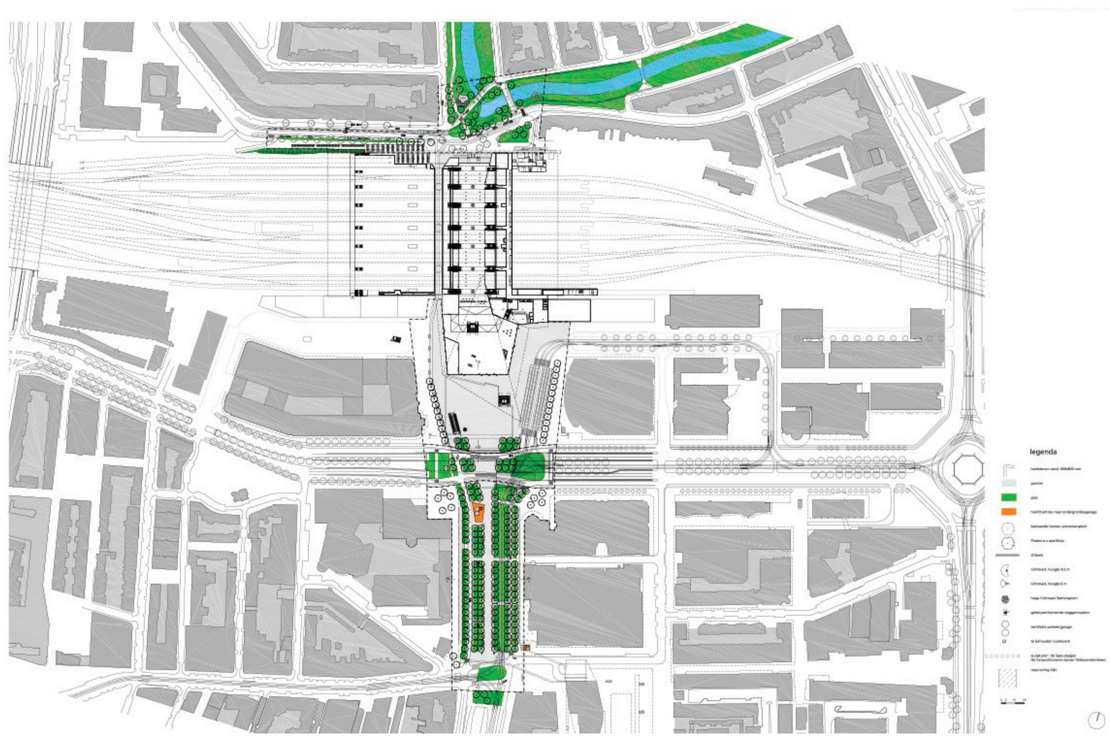
5.8 Union Station Revitalization Section. This section is a great tool to study the width of train platform and how to access numerous trains from a concourse level.

5.4 Rotterdam Central Station

The Rotterdam Central Station in Rotterdam, Netherlands was newly constructed and opened in 2014, and currently serves more than 110,000 people daily.[69] This massive structure of 50,000 square meters was designed by Team CS, which is a cooperation of Benthem Crouwel Architects, MVSA Meyer and Van Schooten Architecten, and West 8.[70] (Figure 5.9) It is a completely new structure since prior to this central hub, Rotterdam never had a central railway station for the passengers to get around, but had four stations in the surrounding area. The goal behind building a new central station was due to the increasing number of trains going in and out of the city daily, between Amsterdam, Brussels, and Paris. By 2025,the projected number of passengers will be roughly 320,000 people. [71] The municipality needed a new facility to improve the efficiency, capacity, comfort, and allure of arrival in Amsterdam.

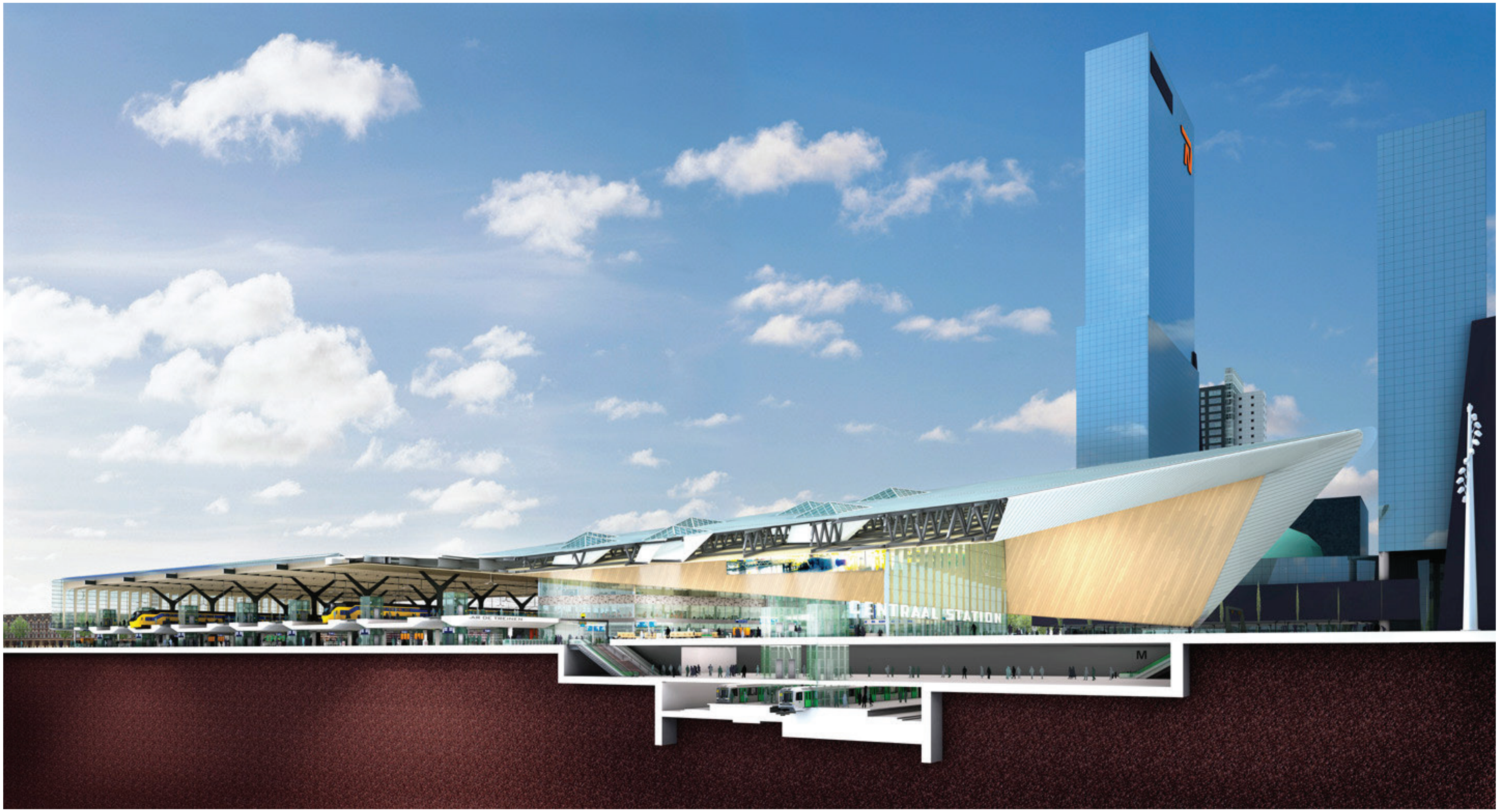
5.9 Rotterdam Central Station in Rotterdam, Netherlands Perspective. This is an example of modern and iconic transit hall architecture.

The former station was designed in 1957.[72] Where the original railway is situated, it divides the city into two parts. (Figure 5.10) On the north of the station, there is a vibrant city, and on the south side, it is full of residential blocks. There was a narrow underpass to connect the two parts of the city together, but in the 1990s, the location became a popular spot for muggings, harassment and drug dealing.[73] Although the city tried to regulate and enforce the activities happening in that area, it never succeeded due to the atmosphere of the alleyway. To change this place into a more welcoming gathering space, the architects designed the large assembly hall of the station so ample daylight can enter, along with brightened train platforms. The architecture has solved the urban problem and improved it by increasing the quality of the architectural elements and making an overall safer space to be.[74]



5.10 Rotterdam Central Station Site Plan. This site plan is to show the large scale of central station that it spans across the city.

The new design incorporates various modes of transportation, including train, metro, bus, taxi, and a car garage to facilitate 750 vehicles, and bicycle shed for 5,200 bicycles.[75] (Figure 5.11) The people described this building as a master-structure due to the size of the space. With the growth of the population, the municipality is expecting, the new transit hub is designed and made to suit the current modes of transportations and the ways people are traveling.



5.11 Rotterdam Central Station Section. The station provides a shelter for the train platforms and the main level is used as a concourse to connect where people want to go.

5.5 Driverless Car Garages

As mentioned, to facilitate the changes due to the anticipated driverless car movement, city planning and architecture must adapt and accommodate to change. This movement will also make the passengers and the drivers re-think what they actually need from a parking garage. Whether it is just a matter of dropping the cars or the passengers off, and simply paying by an application on the phone, or they still need to park at the closest spot near the work elevator for quick access. (Figure 5.12) Experts also say that the existing structures would need to be retrofitted to suit the new vehicular technology as the transition continues.[76]

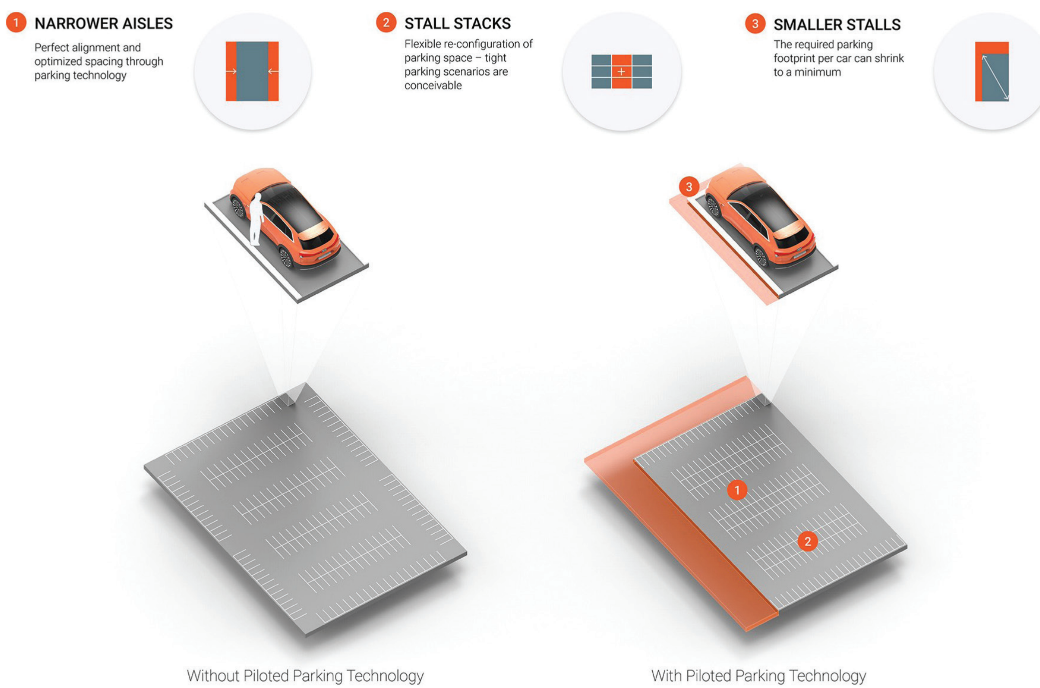
An office park in suburban Nashville was looking to turn the idea of the future to an urban realization project to test out this new idea and create a mock-up project.[77] The developers envisioned this park to have a mixed-use of retail and residential, along with green technology throughout.

"It's not even the clients pushing us, it's the investment group bringing the dollars to the table for the project, and they're saying, 'We need you to take this into consideration,'" said Brian Wright, the founding Principal of Town Planning & Urban Design Collaborative, the company managing the Nashville project.[78]

Although space is not so much of a premium in a suburban environment, the developers still would like to see how much space the technology of driverless cars can save. For example, the city could save space through the standard parking spot, which has a width is 2.5 meters according to Architectural Standards, which allows passengers to get off the cars on both sides.

With the new technology, no person will need to maneuver the vehicle in the parking garage. Therefore, the parking spots could be reduced, saving costs and room for developers and builders while giving back to the society. (Figure 5.13)

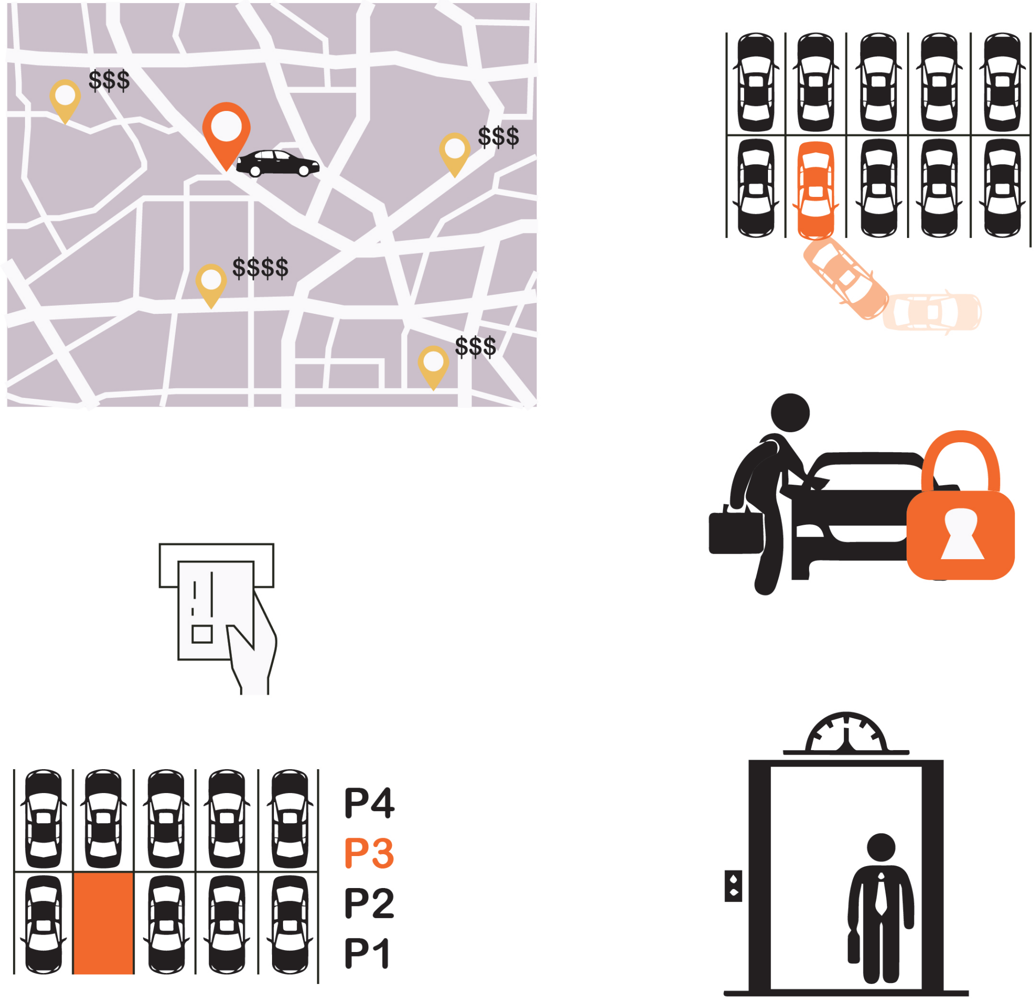
5.12 Proposed Scenario Of Dropping Off And Picking Up Passengers From Audi Urban Future Initiative. This shows a case in the future, people no longer need to go to the parking lot to retrieve their cars. They will be wherever the building entrance and drop off area are.



5.13 Space Saving With Driverless Car Comparing To Normal Garage. Since driverless cars require no driver to park the car, the parking stall can be smaller than the common size.

The sequence of getting around the parking garage today is the following. (Figure 5.14)

Step 1: The driver will need to search for a parking lot in the area, which has a lower cost depending on the stay.
Step 2: Pause at the entrance to get a ticket.
Step 3: Drive up to search for a spot, which may require doing up more levels to find a spot during busier times.
Step 4: Park the car.
Step 5: Leave the car, and make sure the car is locked
Step 6: Find the nearest elevator or stairs to get of the garage.



5.14 Steps of Traditional Parking. This is to show the steps to park the car in a traditional way.

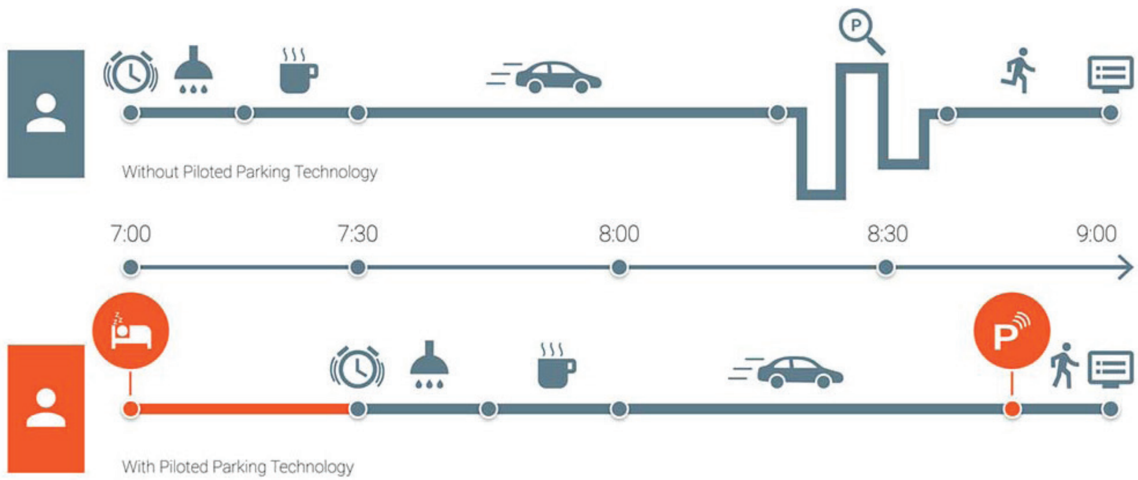
A scenario for the advanced parking includes: (Figure 5.15)

Step 1: Tell the car where the drop-off point is
Step 2: Passenger is dropped off, and the car takes control.
Step 3: The car is being parked itself, and using inductive charging technology to charge the electric car.

5.15 Steps of Driverless Car Parking. This method requires much less effort to park the car comparing to the traditional way on figure 5.14.

The bigger picture is that the only work that one will need to do is to tell the vehicle where to drop you off, and one would only have to get off the car when one arrives at the destination. Driverless car technology not only saved time spent on driving, but gave the passenger more time for other tasks. (Figure 5.16)

In Somerville, Massachusetts, a suburb of Boston situated along the Mystic River, the mayor had a goal to increase the number of residential homes on the new development and at the same time, decrease the land of parking by 60 percent.[79]



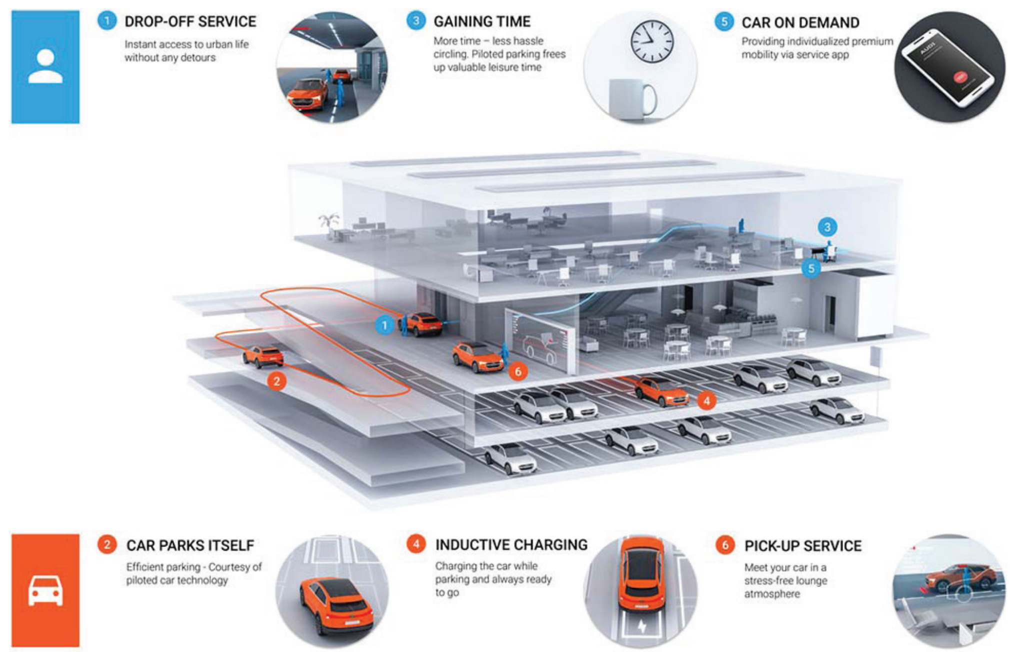
5.16 Advanced Car Vs Normal Car Timeline Showing The Time Passenger Can Save On A Daily Basis. With the driverless car technology, one could save time on searching for the fastest route and on parking on his way to work.

Assembly Row is a mixed-use development across the river that was built on a former brown-field site and where the parking takes up 40 percent of the landscape. (Figure 5.17) Together working with the Federal Realty Investment and Audi's Urban Futures Initiative, a mobility lab was established to monitor and analyze the technologies of driverless cars on how it could reduce the parking footprint. An estimation came out to be a reduction of 26 percent at the preliminary stage of the driverless cars, and as the driverless car technology becomes more reliable, the space reduction could be as much as 62 percent by 2030.[80] (Figure 5.18)

"Parking is not the most sexy thing, but it really is a central piece of architecture,"- Preston.[81]

Although the design of parking garages is often based on quantity over quality, it can also be designed to perform more than just a parking garage. An example would be 1111 Lincoln Road, Miami, US, designed by Herzog & de Meuron. This parking structure was designed with three different floor heights to accommodate various usage, such as retail, and special events. In the future, the need of a permanent parking spot will not as demanding as before since the vehicles can circulate on the road while it is not being occupied. And slowly the need of parking garages will diminish as suggested by the theory from the Audi's Urban Futures Initiative. Therefore, part of the parking garage should be used to host events as needed.

5.17 traditional parking entrance.



5.18 Prototype of Audi's Car Garage. This example is to demonstrate how the driverless car technology can be implemented on a typical office building with a parking lot on lower ground levels.

5.6 Future Predictions

Some say there is no need to build parking lots or garages in the city in the future and that all the cars can parked in the large suburban area periphery. Today's design however, will need to be retrofitted in the future. Some design elements will have to be implemented before the residential or other programs come into play. For example, the garage ceiling would need to be at a certain height to accommodate the future program, such as a minimum eight feet for residential homes.[82] Also, garages in a residential home will soon require a secondary income as car ownership will become a luxury when car sharing becomes popular. Passengers will need to be dropped off instead of driving vehicle into the parking lot and parking. (Figure 5.19) The drop-off zone to a building is now much more critical to the overall design and new scenario. Most of today's site is car-centric, rather than what planners and designers were doing before.

5.19 Future Of A City With Driverless Cars Concept. This sketch illustrates the future town with the technology of driverless cars and how their citizens deal with their everyday lives.

6.

SYNTHESIS & DESIGN INTENT

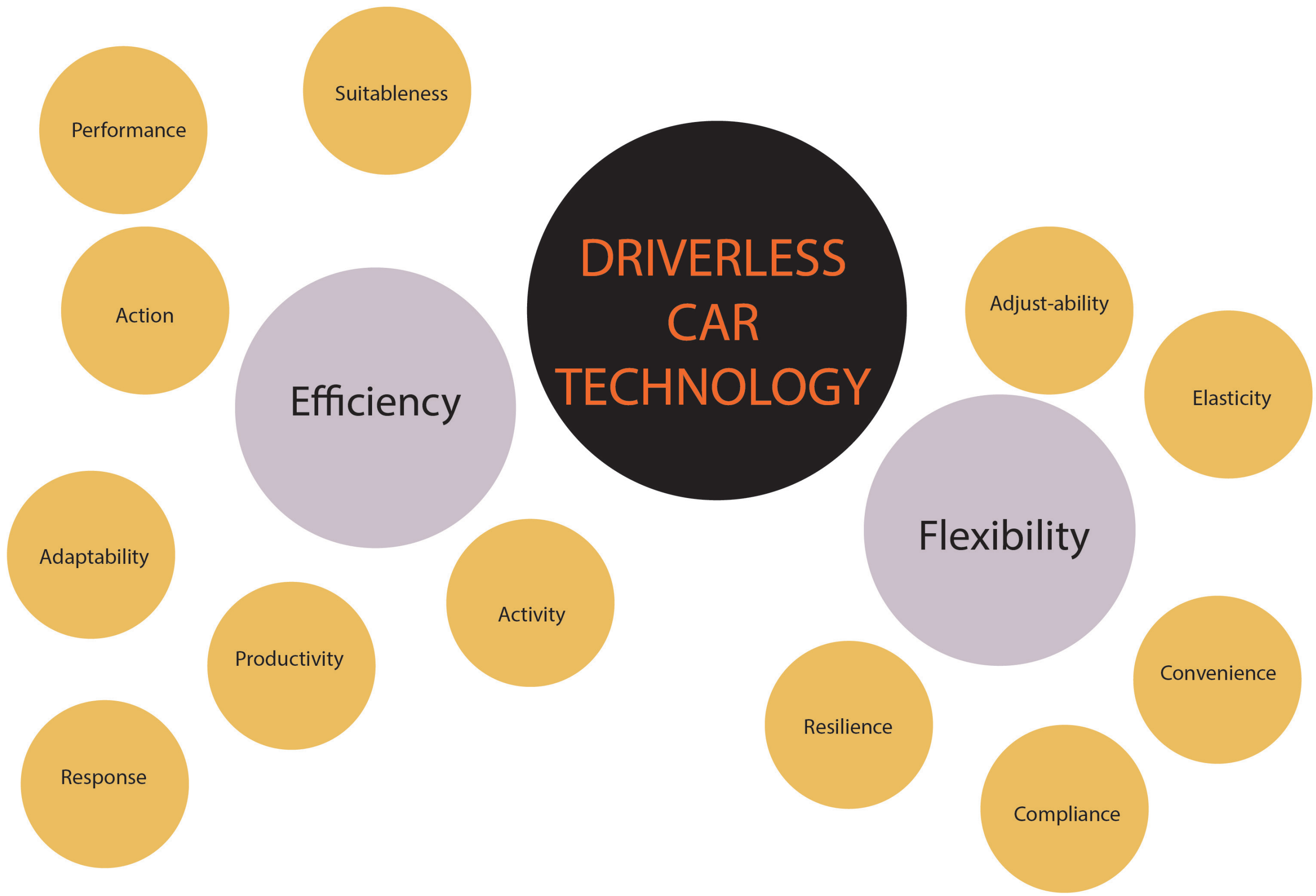
6.1 Synthesis & Design Intent

The issues that were created by our predecessors cannot be changed. We cannot rebuild all of the city to suit new technologies. North Americans have always embraced their automobiles, and especially with Toronto, a city where their citizens do not have much hope in their public transit system. Having access to a car is more like a need than a want. This causes stresses on Toronto's highway and expressway system, earning it a title of Canada's worst highway bottlenecks. The outskirts of Toronto can be busy and people also need to get connected to work in downtown. It becomes a major headache to get people from their home to the nearest public transit stop. With the help of technology and innovation, driverless cars have finally come to a realization and may provide an answer.

Many large companies have been investing and developing the new auto technology and analyzing the benefits advantages that they see. They believe not only that the driverless car can create efficiency and flexibility, but it can also create a safer and less-accidental world for drivers and passengers. In this future, manufacturers and users can benefit from it as the insurance rates would go down, healthcare, with less air pollution would save resources, the size of the parking enforcement would be reduced by a significant amount, and cars would get used more often at least more than 4% of the day.[83]

The geography of the city of Toronto would be an ideal place to test out this innovative infrastructure. The research noted in this work has show the problem, and the need and importance of car-ownership in the GTA. However, as the world is moving forward with driverless car technology, almost all car manufacturers are putting their investment into it, simply because they believe this is what their clients want in the future. This change is not only about the initiative from car manufactures, but also the users. The residents would also have to be ready for this change. In a way that the car companies are doing is to promote this technology in phases, from the baby steps of implementing the technology in lane departure, to the fully automated car fleet.

This revolution is also a learning path for the users. Planners and designers also need to foresee the vision together and bring a new genre of building to facilitate the change, while maintaining and improving the efficiency of existing systems. They are the starters who need to expect this movement to construct the new architectural standard.



6.1 Mind Map Of Driverless Car Technology. The technology of driverless car will bring efficiency and flexibility into people's lives, improving the quality of the daily basis.

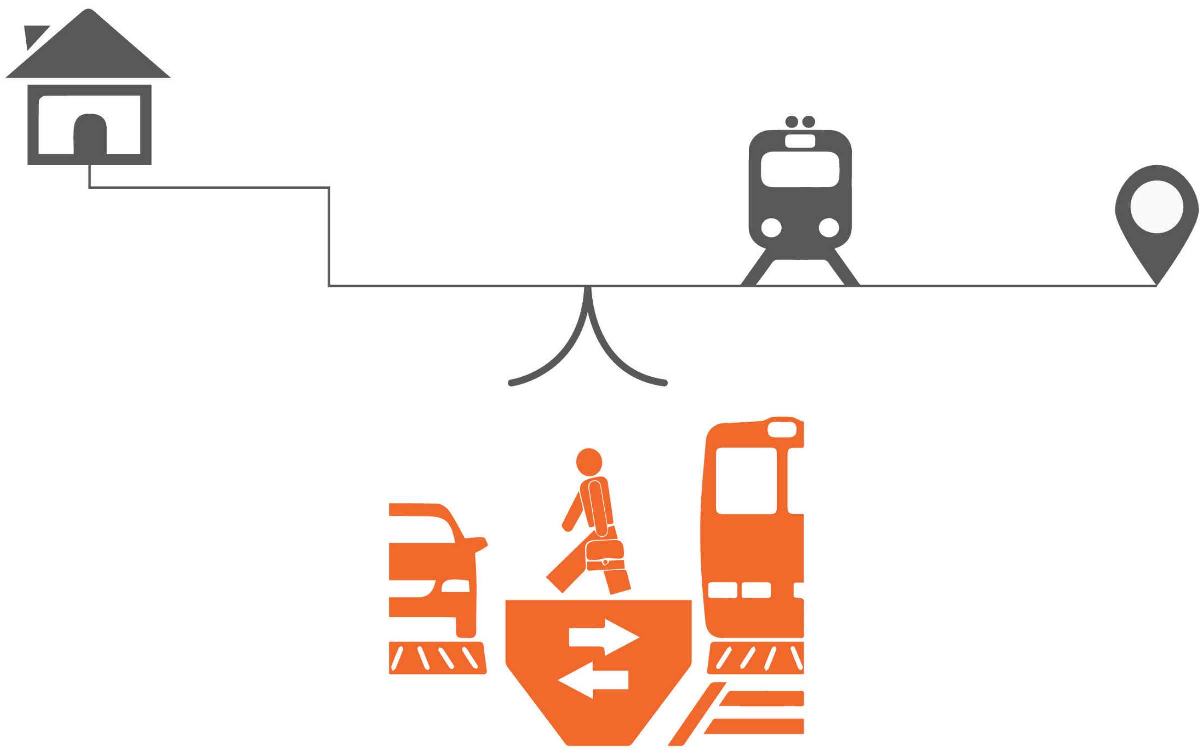
6.1.1 Design Intent

Based on the research and prediction on driverless car operation 20 to 30 years in the future, the design proposal seeks to address the following three fundamental issues: (Figure 6.2)

1.) The efficiency of the arrival of the driverless car and the dropping-off logistics. How do the elements in the proposal allow the process of dropping-off to run smoothly through the transition through various speeds, such as driving speed and walking speed?

2.) The public transit system connection after the passenger is being dropped off. With the help from the proposals under Metrolinx, how could we ensure the passengers to get connected to the desired transit system?

3.) Space planning and program response due to the nature of car roadways working differently compared to a building that is truly designed for human beings. How can space planning collaborate with a human-scale while providing services to automobile, and in the future, the response on the evolution of the parking garage itself.



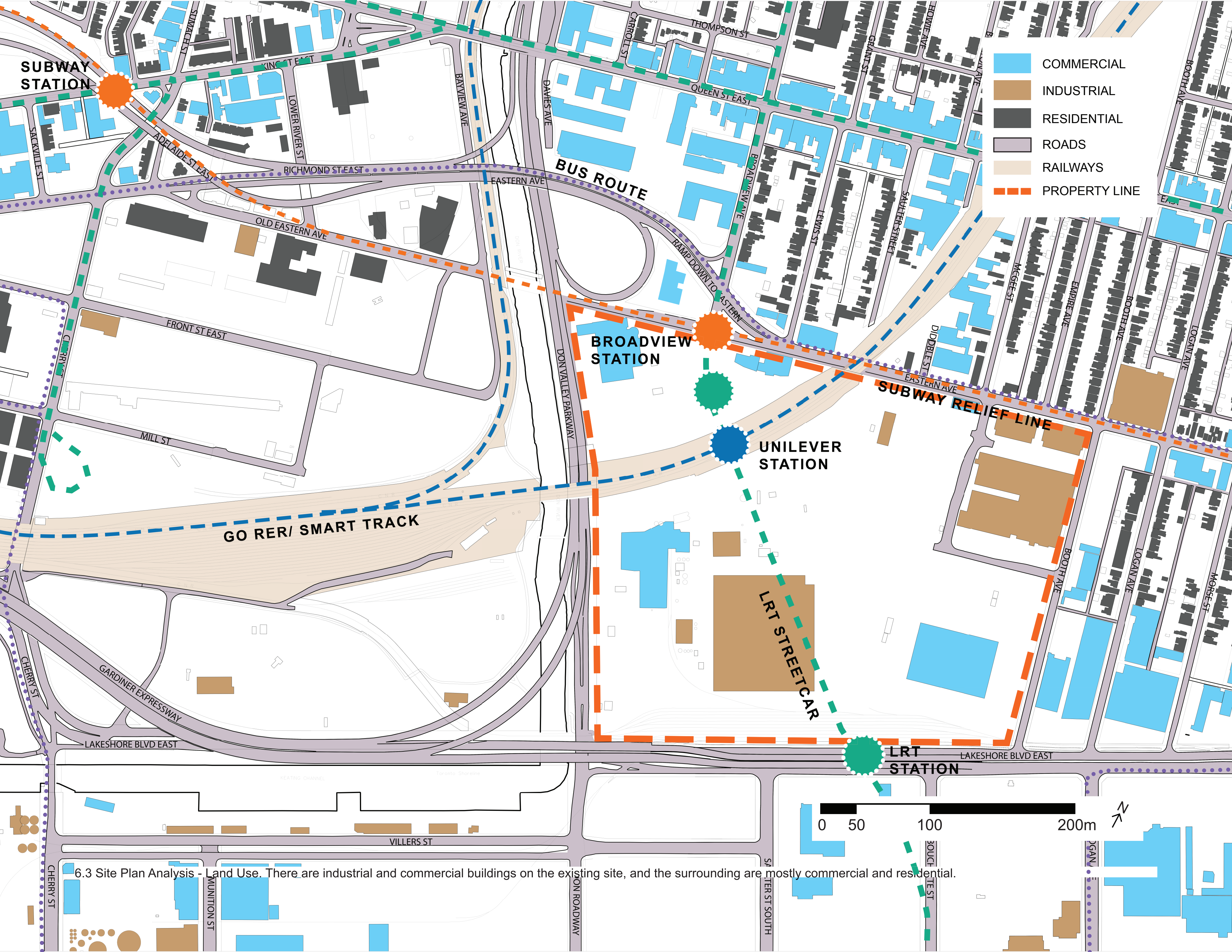
6.2 Parti Of This Thesis. The transit hub acts as a transfer point from home to the hub, and making the transition to the public transit seamless.

6.2 Site

The site will need to be close to where traffic congestion is located, and with multi-modal transit systems crossing. The design thesis site is located at the intersection of the Gardiner Expressway and DVP, on ground level at Eastern Ave., and the Don Roadway. The reason why the project has been proposed at the highway intersection is that having a direct connection to the highways is key to get the cars onto the highways without interrupting the local streets. This location is also an underdeveloped land.

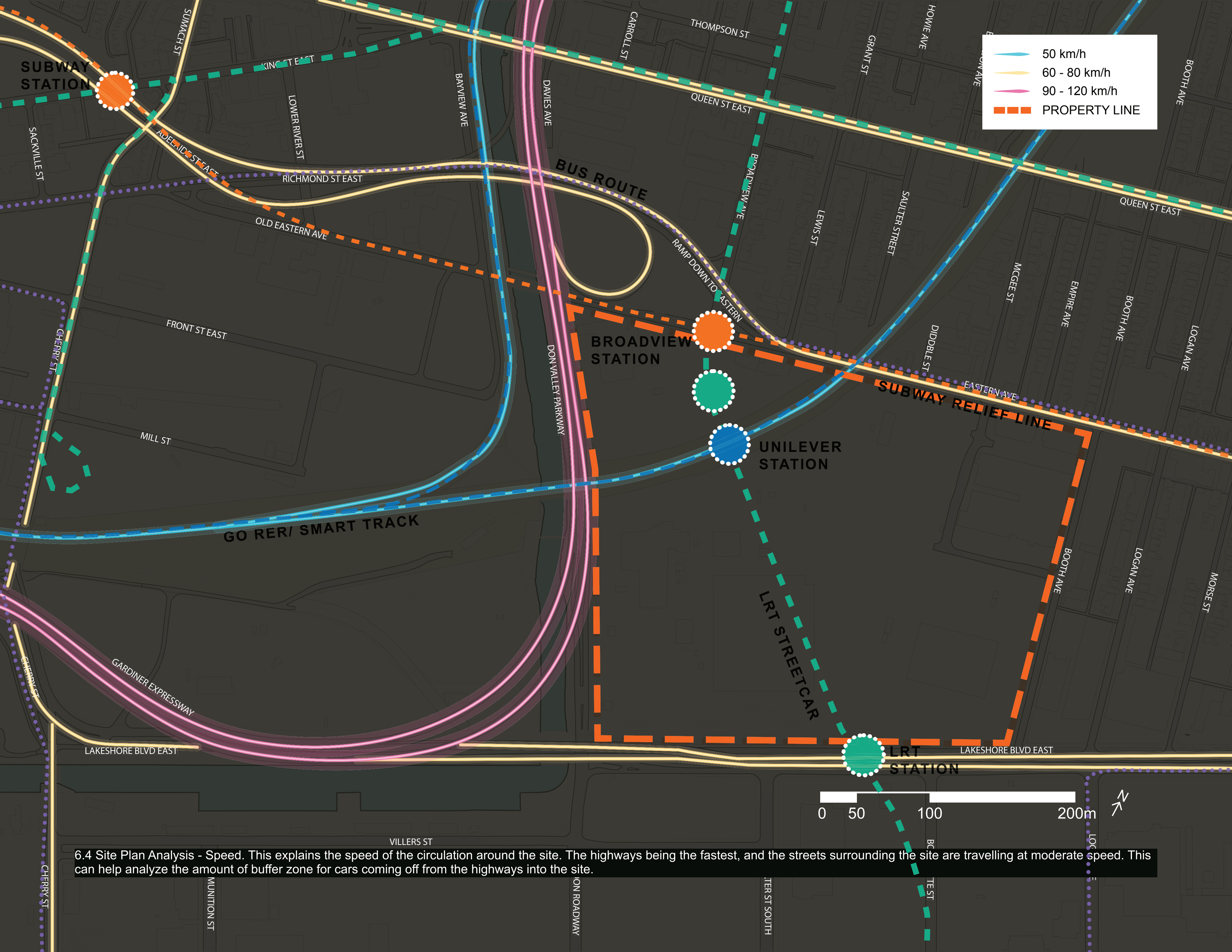
The proposal can take advantage of the large footprint and use it to experiment with a mass transit hub in a city. With support from Metrolinx and the City of Toronto, a new subway line, a new LRT and also the GO Smart Track system have all been selected to be in that location.[84] The proposed transit system also gives an excellent opportunity to allow designers to create city life around it and proposes a mixed-use development.

6.3 The site within the context of commercial and industrial buildings, and is surrounded by residential buildings and small commercial spaces to the north.



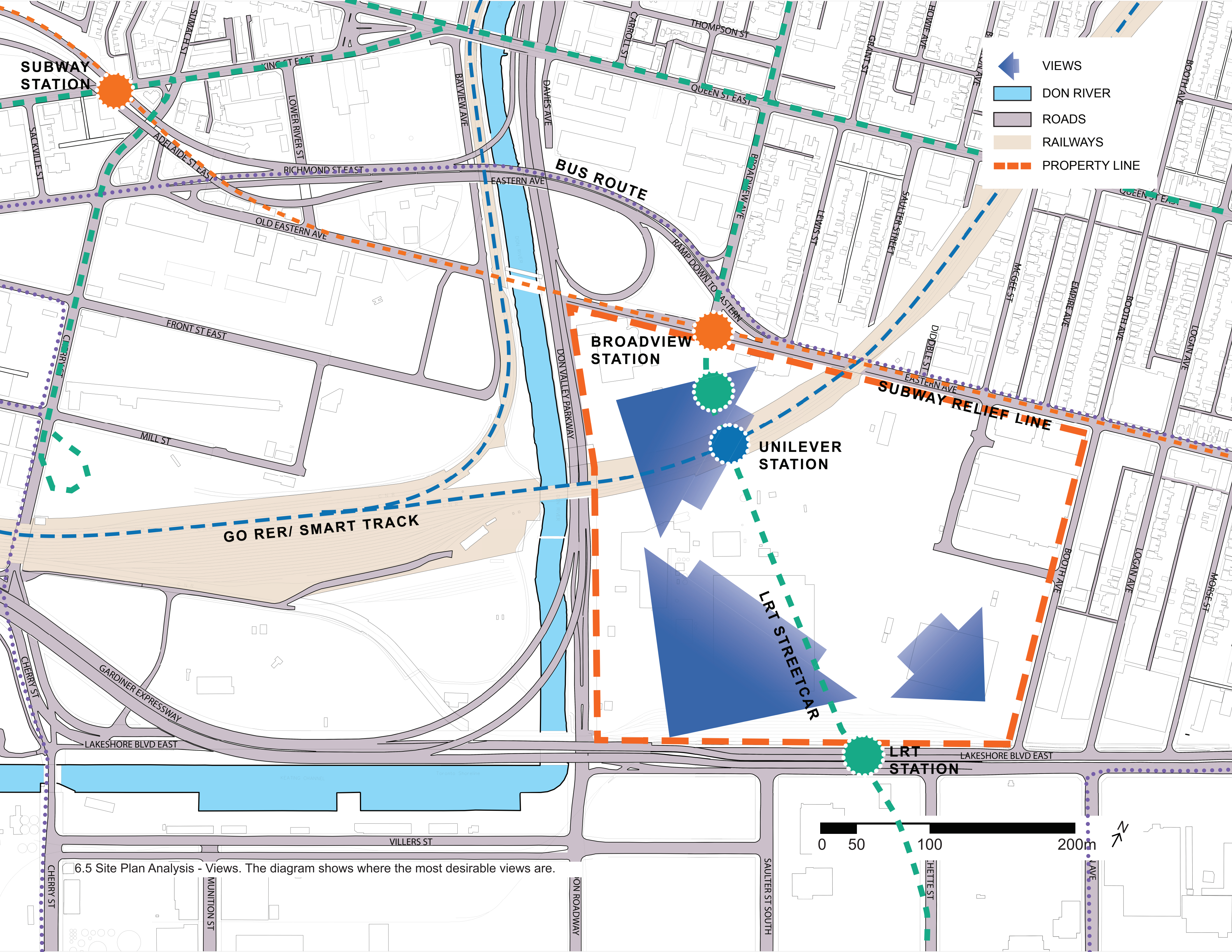
6.3 Site Plan Analysis - Land Use. There are industrial and commercial buildings on the existing site, and the surrounding are mostly commercial and residential.

6.4 The site is located on the east of Don Valley Parkway and Gardiner Expressway intersect. Vehicles coming off from the highway travel at a fast and variable speeds during normal hours.



6.4 Site Plan Analysis - Speed. This explains the speed of the circulation around the site. The highways being the fastest, and the streets surrounding the site are travelling at moderate speed. This can help analyze the amount of buffer zone for cars coming off from the highways into the site.

6.5 This site offers an open view to the Don- lands and the water-front on the south, and a view to the city center towards the west.



6.5 Site Plan Analysis - Views. The diagram shows where the most desirable views are.

6.6 There are parks and green spaces surrounding the area of the site. Two major parks are nearby: one is Corktown Common, and one is McCleary Park.

6.6 Site Plan Analysis - Green Space. There are many green spaces around the site comparing to other site in the downtown has to offered.

7.

THESIS DESIGN PROPOSAL

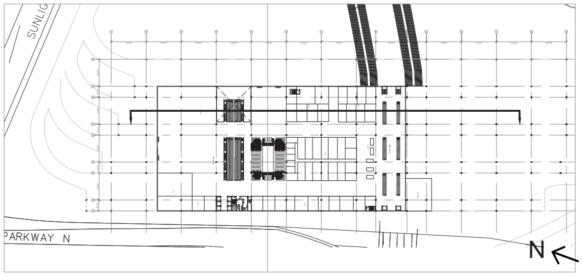
7.1 Design Proposal

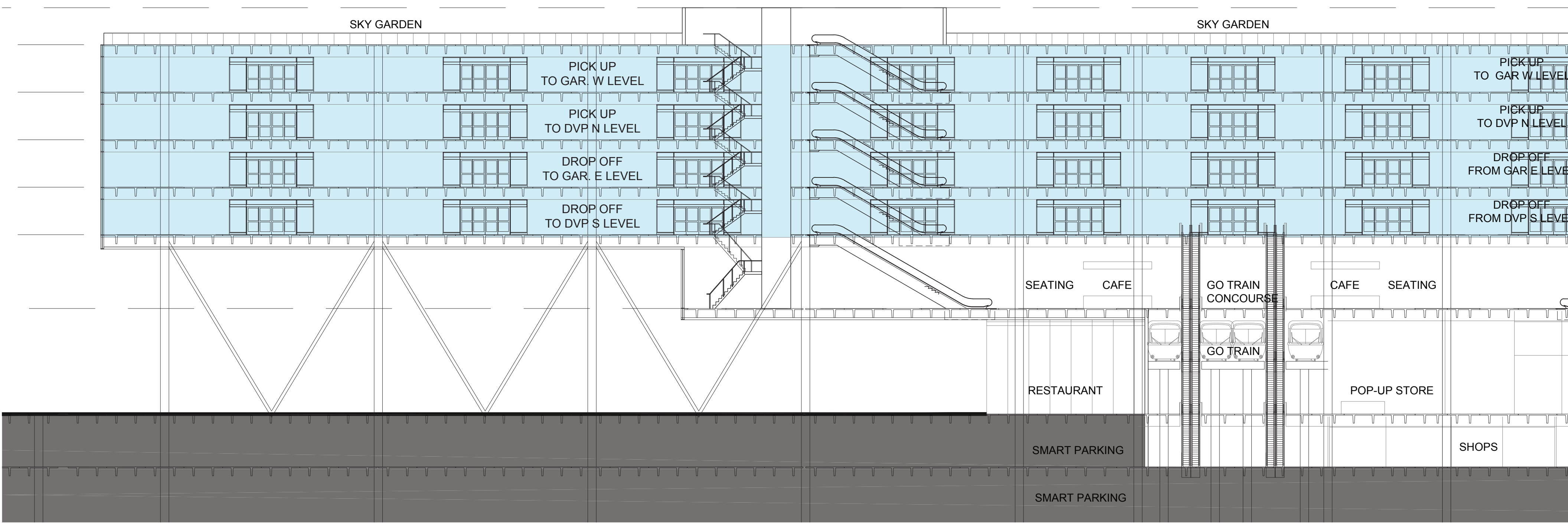
This design proposal is set in the near future. Imagine that in 20 to 30 years from now when the technology and by-laws of the driverless cars mature, what the city will look like. The thesis aims to posit how driverless cars can improve the quality of commuting by re-organizing the transit nodes and the sequence of travelling to perform daily tasks, and demonstrate the prototype of the driverless car garage. Designers can learn from this early sample and adapt it to other appropriate sites.

7.2 No more Parking- Drop off & Pick Up zones

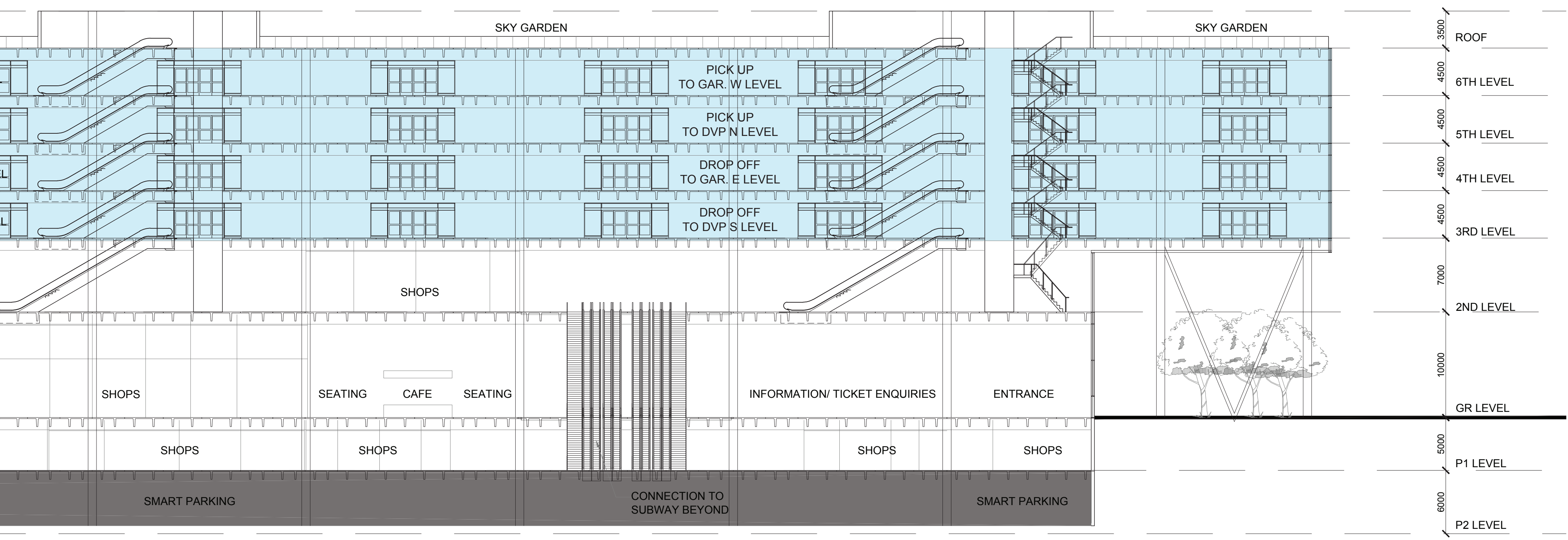
When thinking about designing a garage in a transit hub in the future with the use of driverless cars technology, one must reflect on the access points. How it needs to movw traffic at a safe speed while having the flexibility for cars to go fast or slow as they needed to be. To determine where the car does take control can also affect the communication between the building and the car. Diagrams are going to help with explaining the reasons above. (Figure 7.1)

7.1 Perspective Of The Drop Off And Pick Up Location. This shows the passengers will arrive to their assigned drop off area, and they will then get connected to the concourse level via the tube.



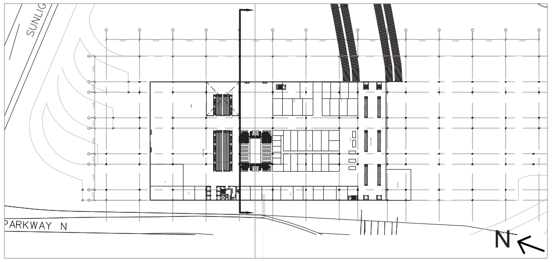


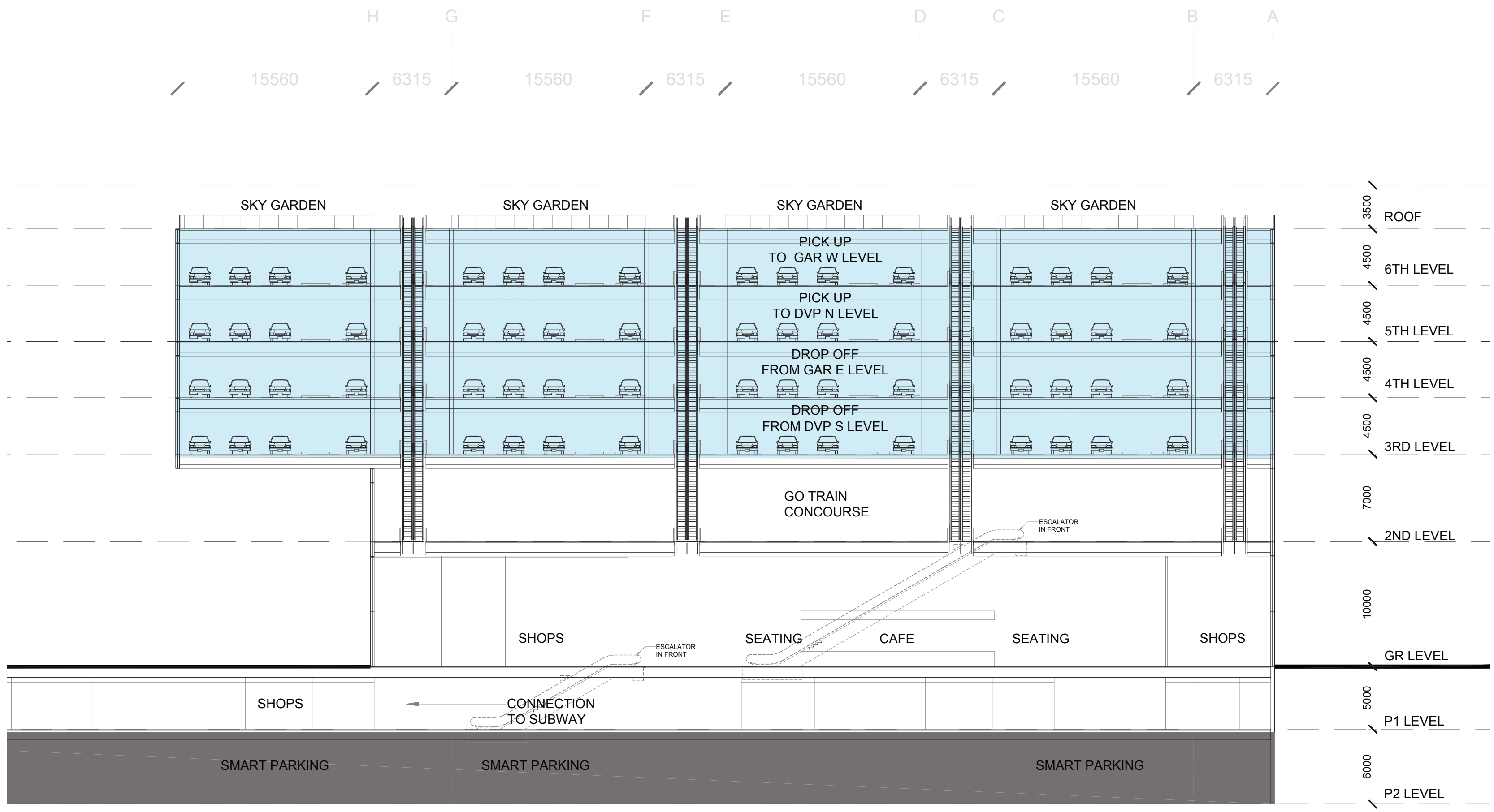
7.2 E-W Section. This section shows the 3rd to 6th floors are dedicated to drop off and pick up from or to the highways, and the passengers will connect to the transit they wish.


SKY GARDEN
SKY GARDEN
PICK UP
TO GAR. W LEVEL
PICK UP
TO DVP N LEVEL
DROP OFF
TO GAR. E LEVEL
DROP OFF
TO DVP S LEVEL
SHOPS
SHOPS
SEATING
CAFE
SEATING
INFORMATION/ TICKET ENQUIRIES
ENTRANCE
SHOPS
SHOPS
SHOPS
SHOPS
SMART PARKING
CONNECTION TO
SUBWAY BEYOND
SMART PARKING
3500
ROOF
4500
6TH LEVEL
4500
5TH LEVEL
4500
4TH LEVEL
4500
3RD LEVEL
7000
2ND LEVEL
10000
GR LEVEL
5000
P1 LEVEL
6000
P2 LEVEL

Many predictions from the researchers have found that the future garage would only have drop-off zones and pick-up. In this driverless car garage, there will be a parking program that is only accessible for driverless cars, and where no human beings are allowed to enter except for maintenance purpose. By designing the massive structure this way, it will truly bring out the advantage of driverless car. To work only with drop-off zones, the connections provide a to-and-from the four directions from the DVP and Gardiner Expressway. Each of the directions will occupy one level of the structure. The drop-off will occupy the first two levels above the concourse, and the following two upper levels will be used as the pick-up zone. The reason why the drop-off is planned to be closer to the concourse is that in the morning, the commuters are usually going to work in a rush. To incorporate with the Metrolinx system, the Presto card will be embedded into the smart phones, and using them as a device to pay. By planning it this way, the commuters can get the public transit in a shorter amount of time. (Figure 7.2-7.8)

7.3 The building consists of eight levels. The ground floor, mezzanine and P1 level are for public transit transfers, and the floors above the second floor are the drop off and pick-up areas for the driverless cars travelling to and from the highways.

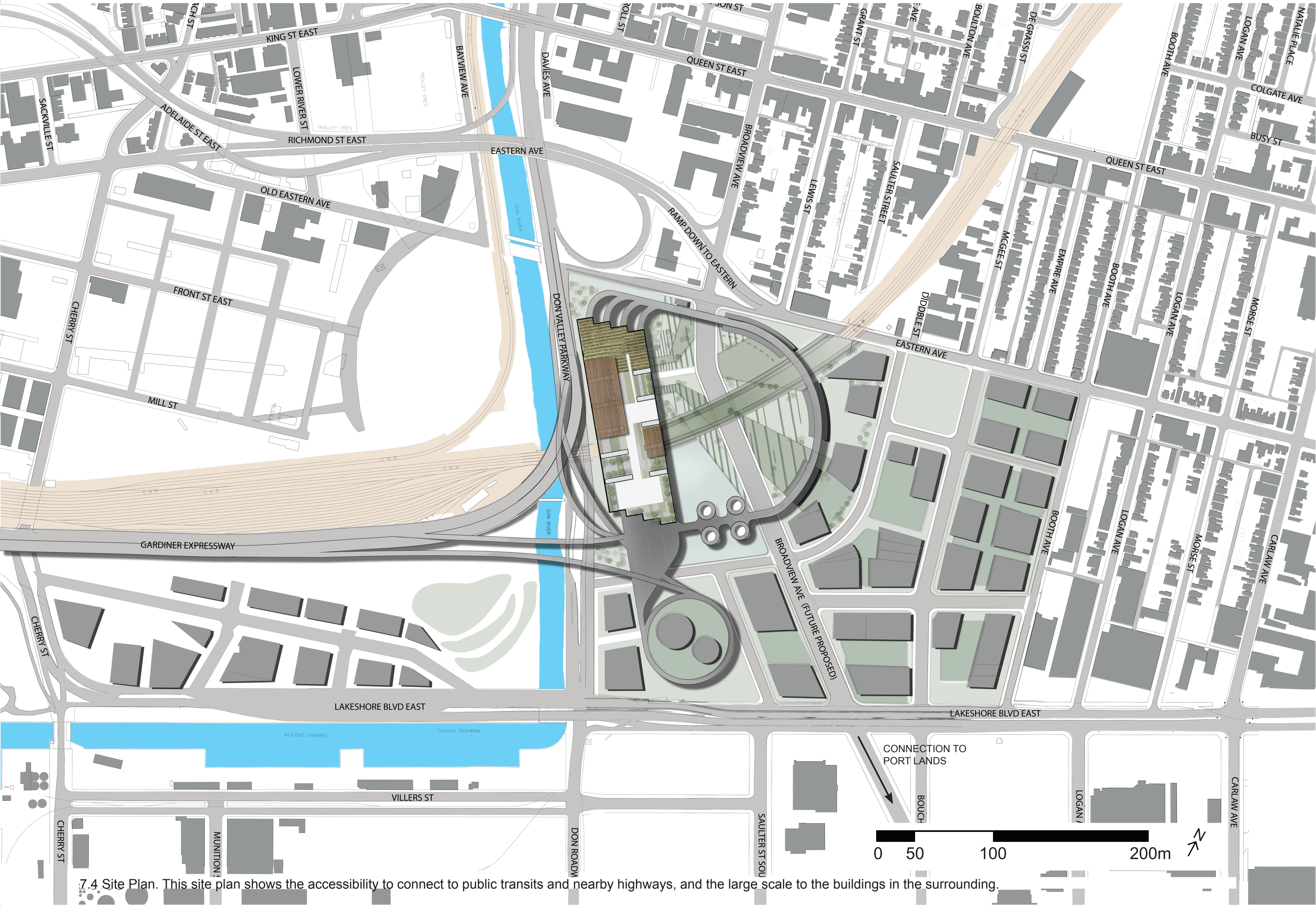




7.3 N-S Section. There are 4 lanes on the drop off/ pick up levels, and the lower levels will be utilized for smart parking.

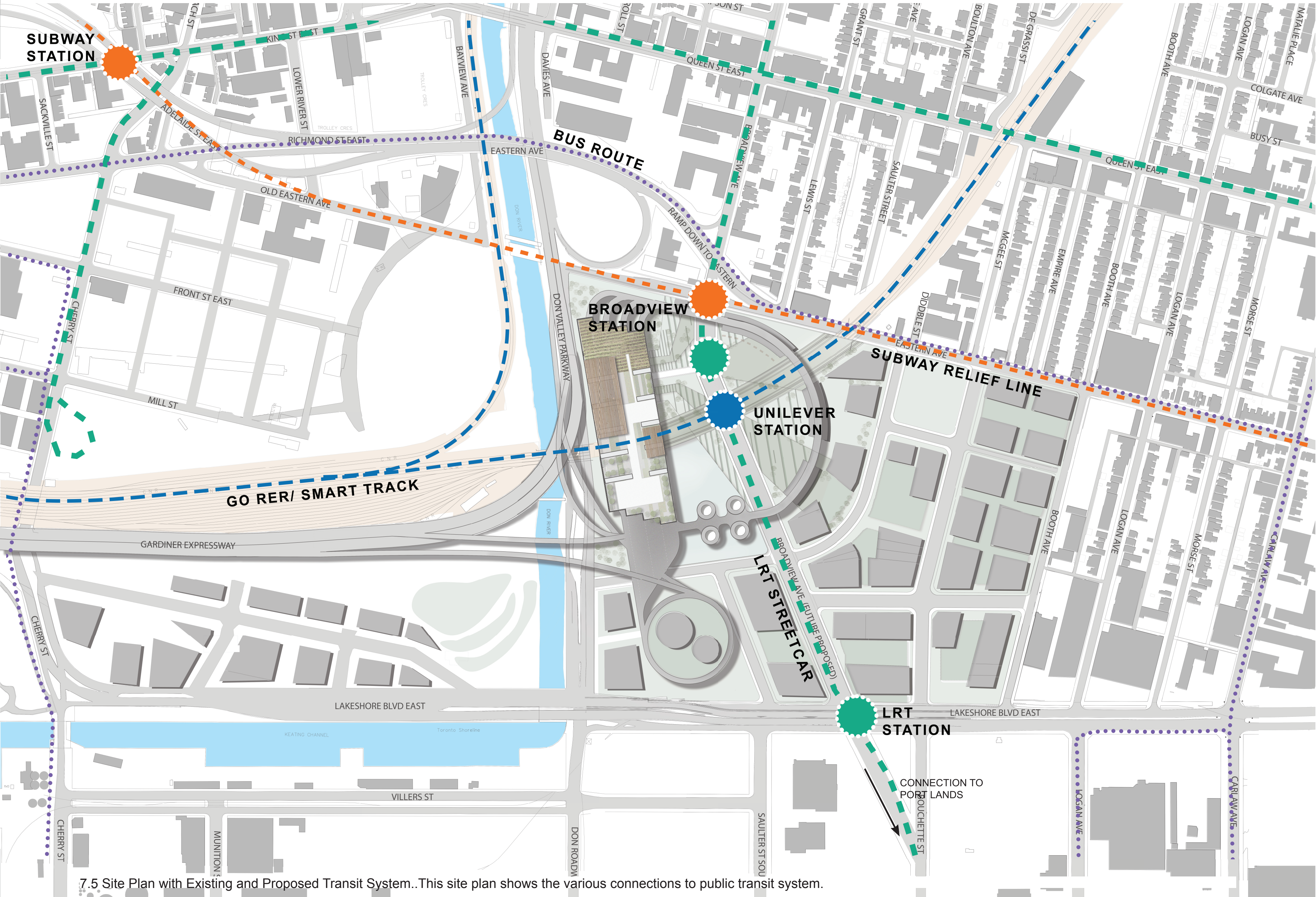
This site has two major highways next to it. There are many current public transportation system lines and under construction projects from Metrolinx. (Figure 7.4) A total of three modes of public transit are provided through this transit hub. Trains will use the railway lines to go through the mezzanine level and provide stops. The future plan of Metrolinx will have the streetcars going through a new proposed Broadview Ave to provide service to connect to the Lakeshore Ave LRT. The future Broadview station will be located on the P2 level of the transit hub. A boardwalk will be covering the train tracks and provide an open space for the artists to host large social events. The roof terrace will be used as a local market, pop-up stores, amphitheater, lunch hand-out spots for future commercial buildings in the surrounding area.

7.4 Site Plan. This site plan shows the accessibility to connect to public transits and nearby highways, and the large scale to the buildings in the surrounding area.

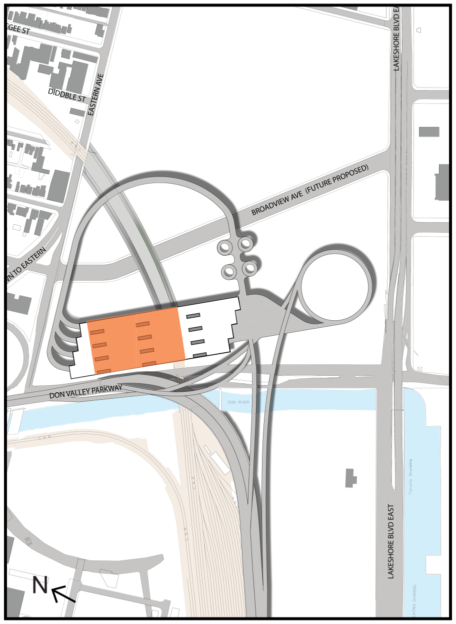


7.4 Site Plan. This site plan shows the accessibility to connect to public transits and nearby highways, and the large scale to the buildings in the surrounding.

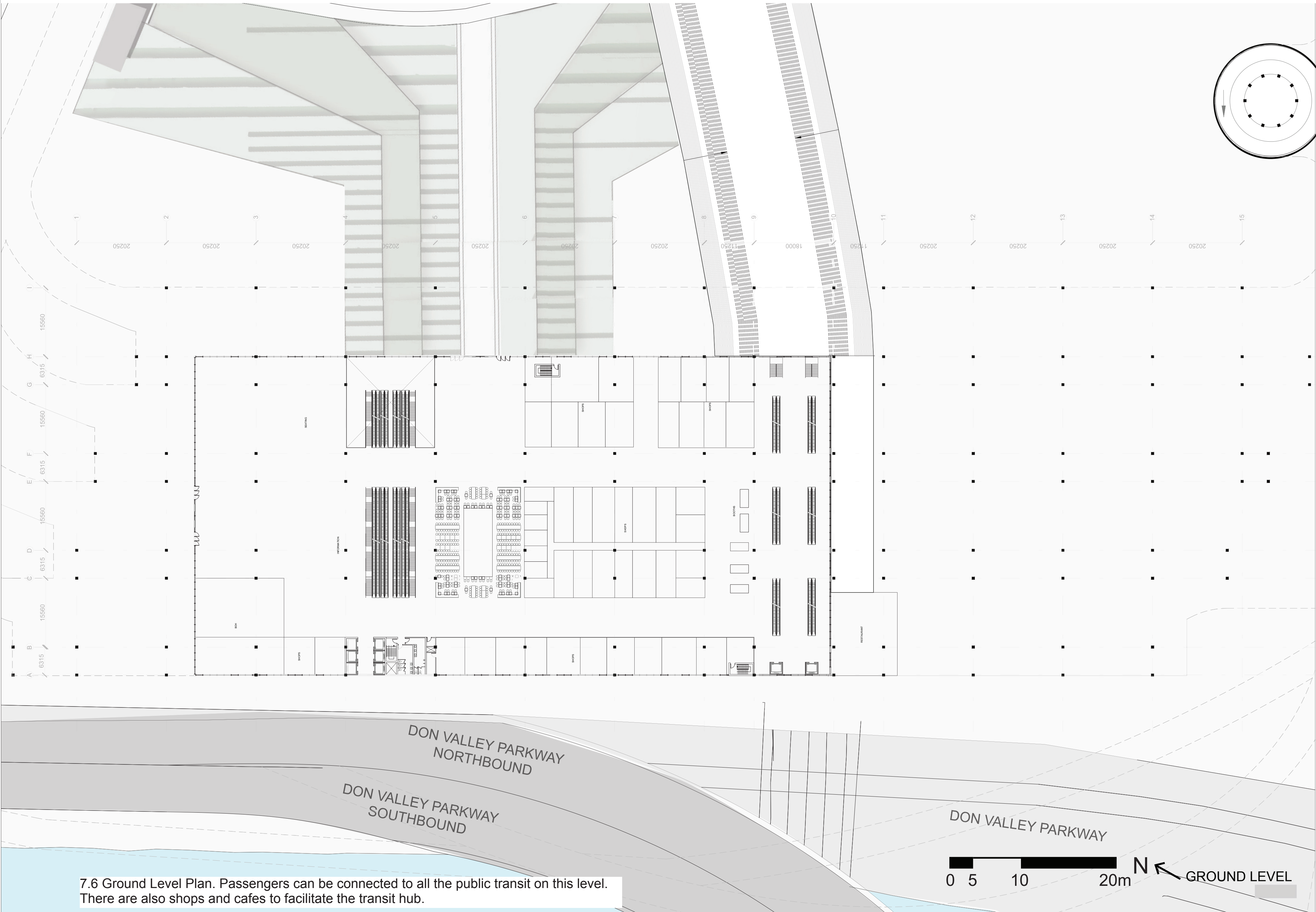
7.5 Site Plan with Existing and Proposed Transit System. This site plan shows the accessibility to connect to public transits and nearby highways, and the large scale to the buildings in the surrounding area.



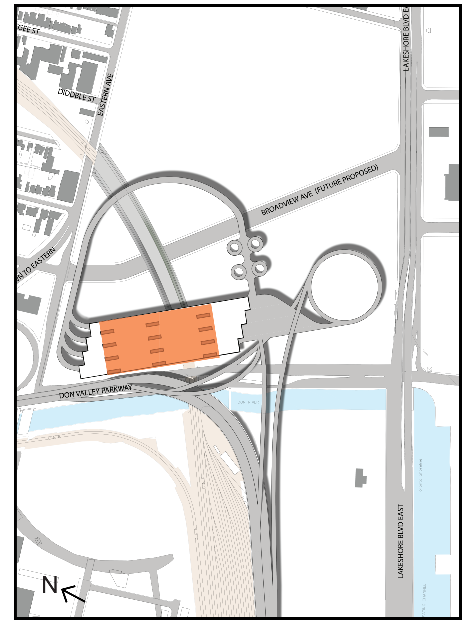
7.5 Site Plan with Existing and Proposed Transit System..This site plan shows the various connections to public transit system.



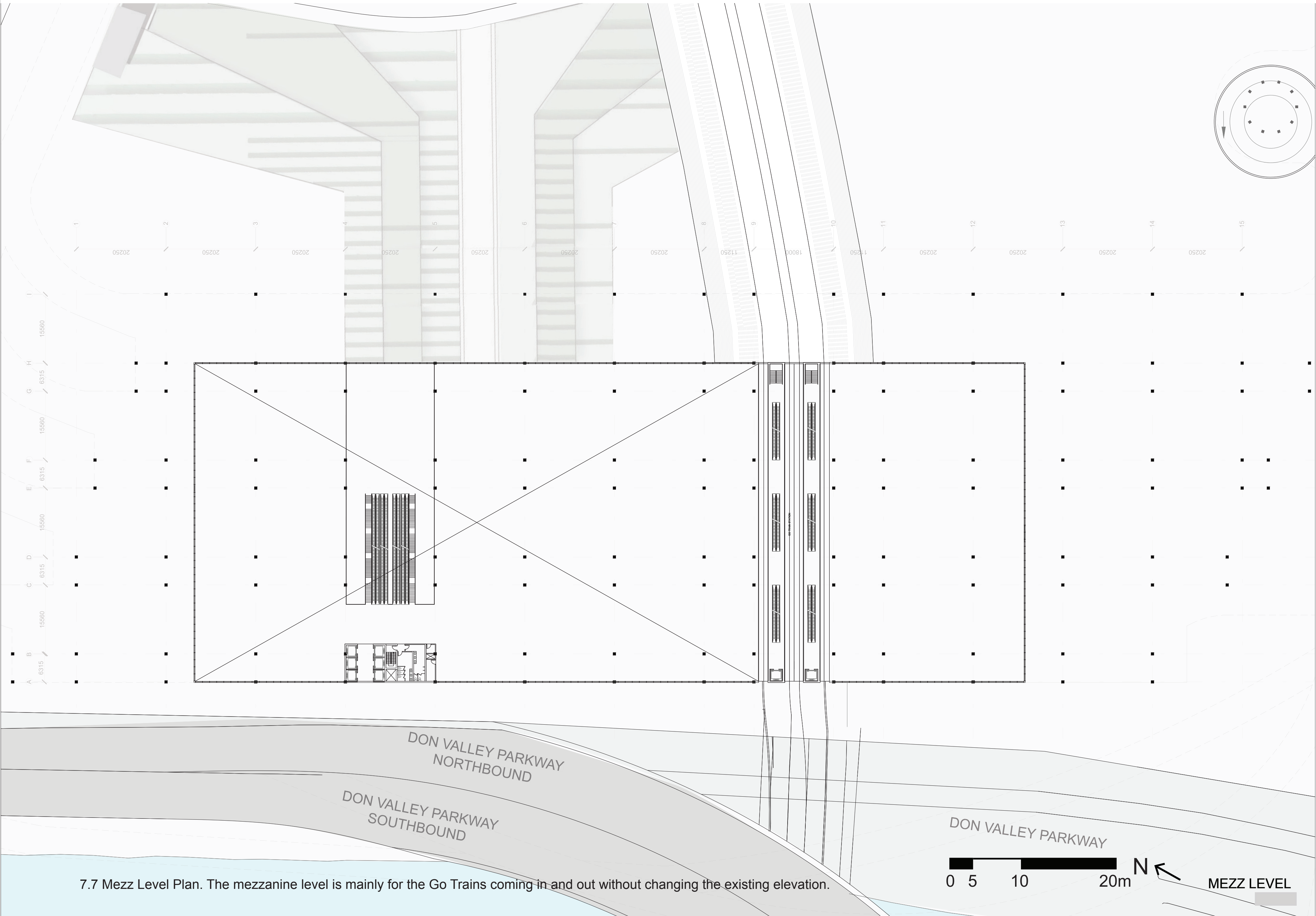
7.6 On the ground floor, commuters can use vertical connections such as escalators to get to GO Trains, subway, and streetcars are to be provided to sustain the operation of the transit hub.



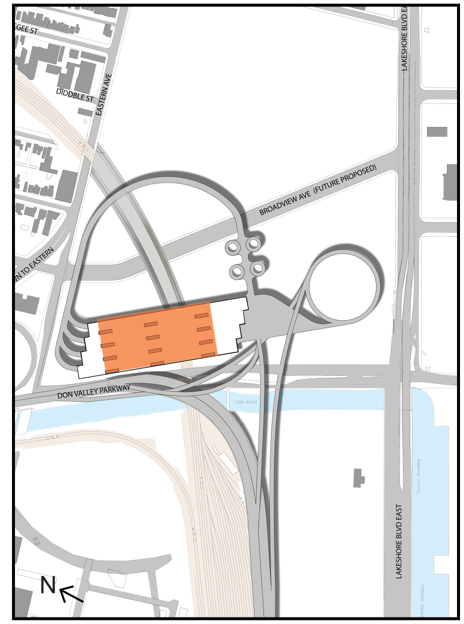
7.6 Ground Level Plan. Passengers can be connected to all the public transit on this level.
There are also shops and cafes to facilitate the transit hub.



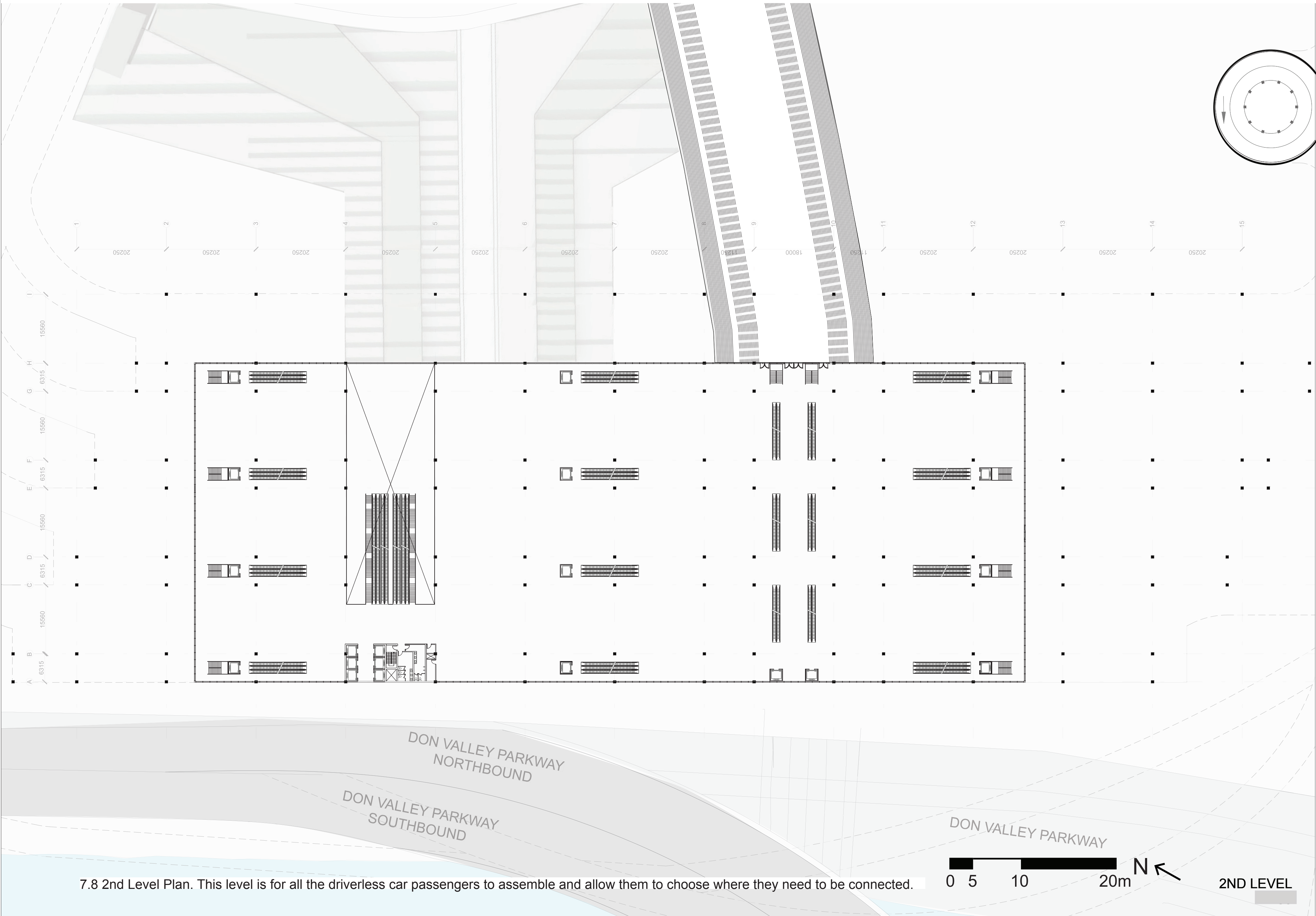
7.7 On the mezzanine level, the southern portion of the complex is the GO Train concourse. The commuters can get to the mezzanine level from the ground floor and the second floor.



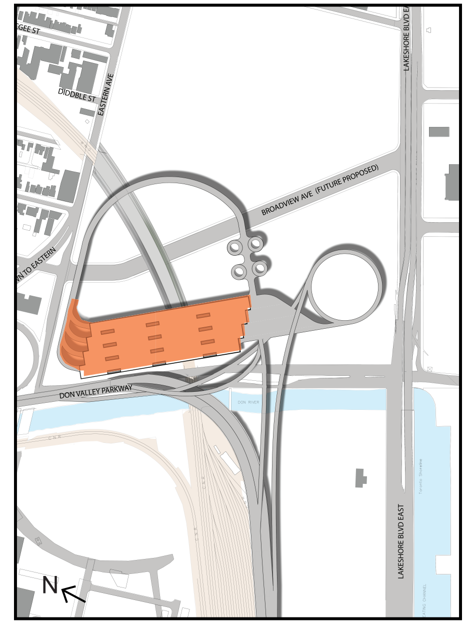
7.7 Mezz Level Plan. The mezzanine level is mainly for the Go Trains coming in and out without changing the existing elevation.



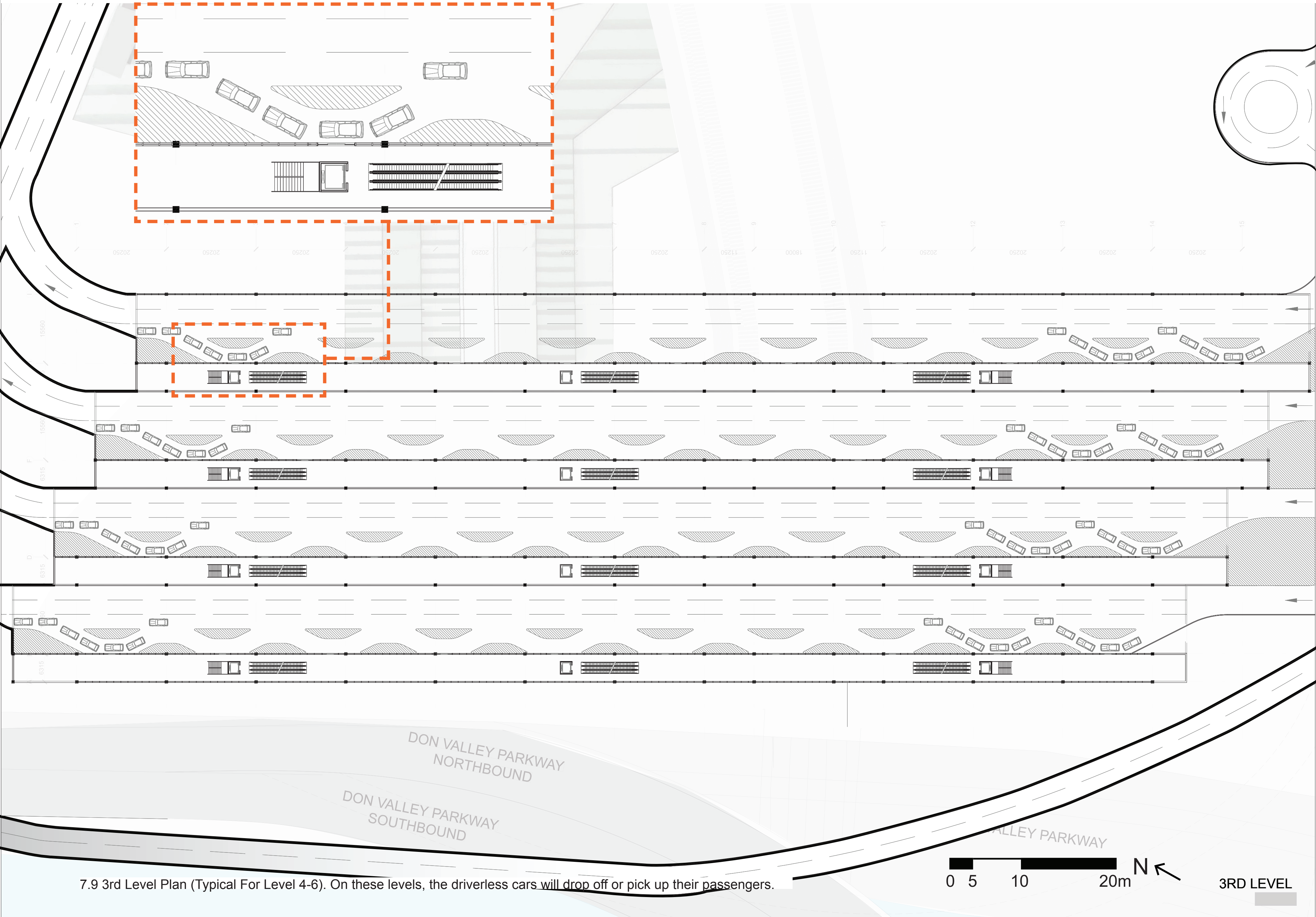
7.8 The second floor brings all the commuters form the drop-off and pick-up together. This level acts as a concourse for driver-less car passengers to come to a common place and allow the commuters to connect to other levels.



7.8 2nd Level Plan. This level is for all the driverless car passengers to assemble and allow them to choose where they need to be connected.



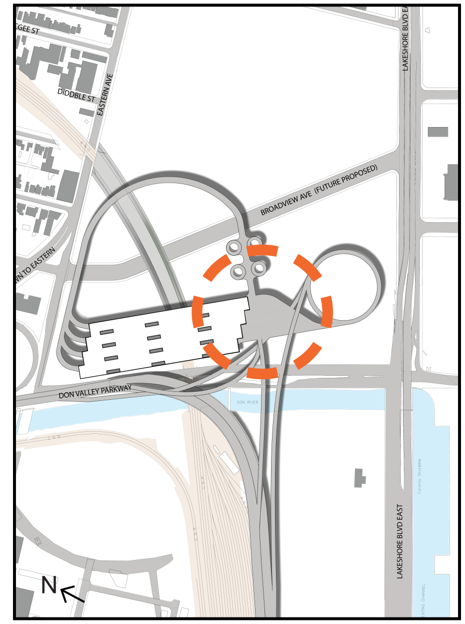
7.9 This is a typical floorplan for 3rd - 6th floors. These 3rd and 4th floors are the drop-off levels from the highways; and the 5th and 6th floors are the pick up levels from the transit hub.



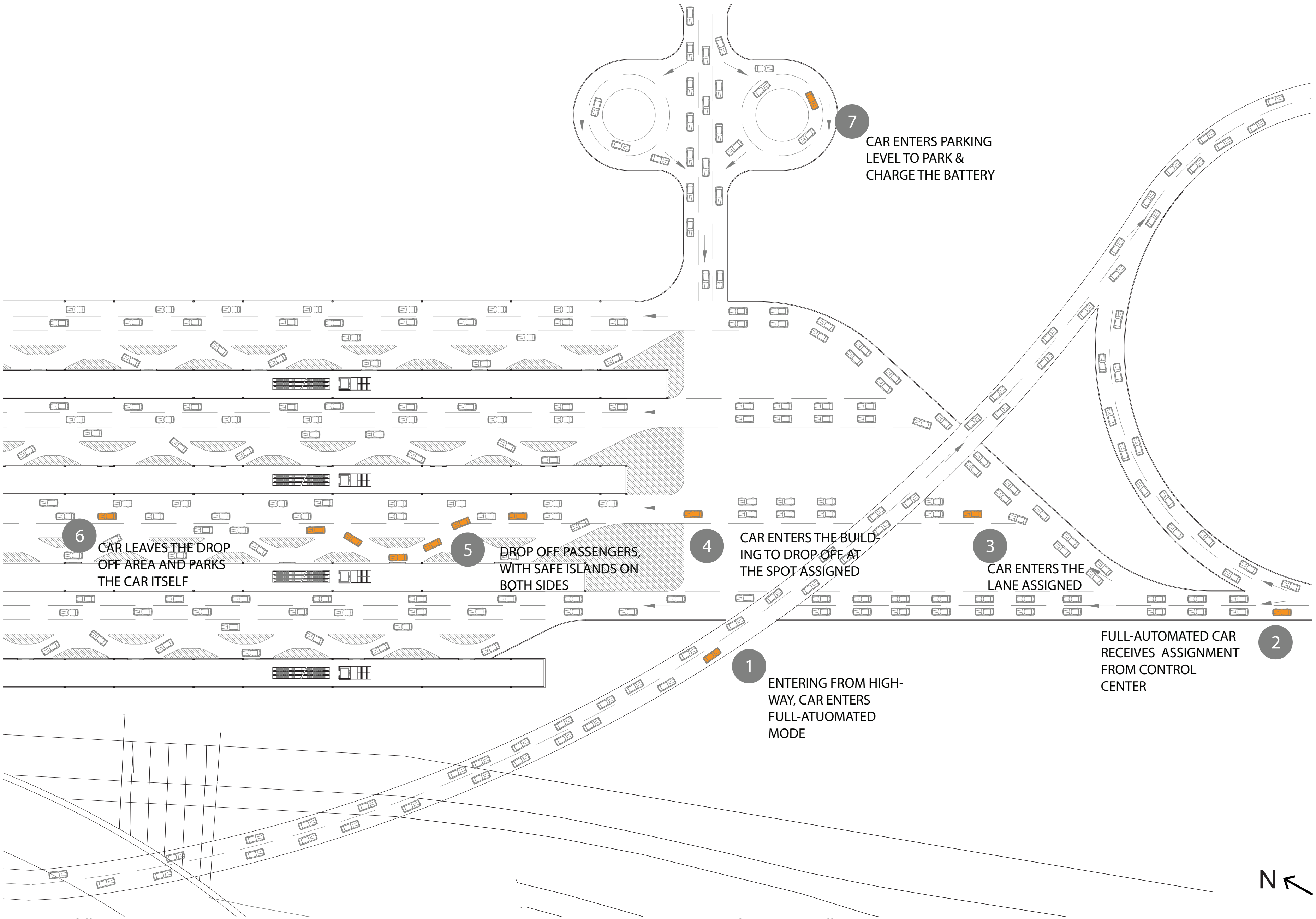
7.9 3rd Level Plan (Typical For Level 4-6). On these levels, the driverless cars will drop off or pick up their passengers.

7.10 The driverless cars use the ramp to get connected from the highway to the building. By providing the direct connection, this can make the transition from the road to the complex much more efficient and smoothly.

7.10 Perspective from DVP Southbound Into The Complex. This is a view looking towards the DVP southbound. Driverless cars will use the direct ramp provided to get into the complex.

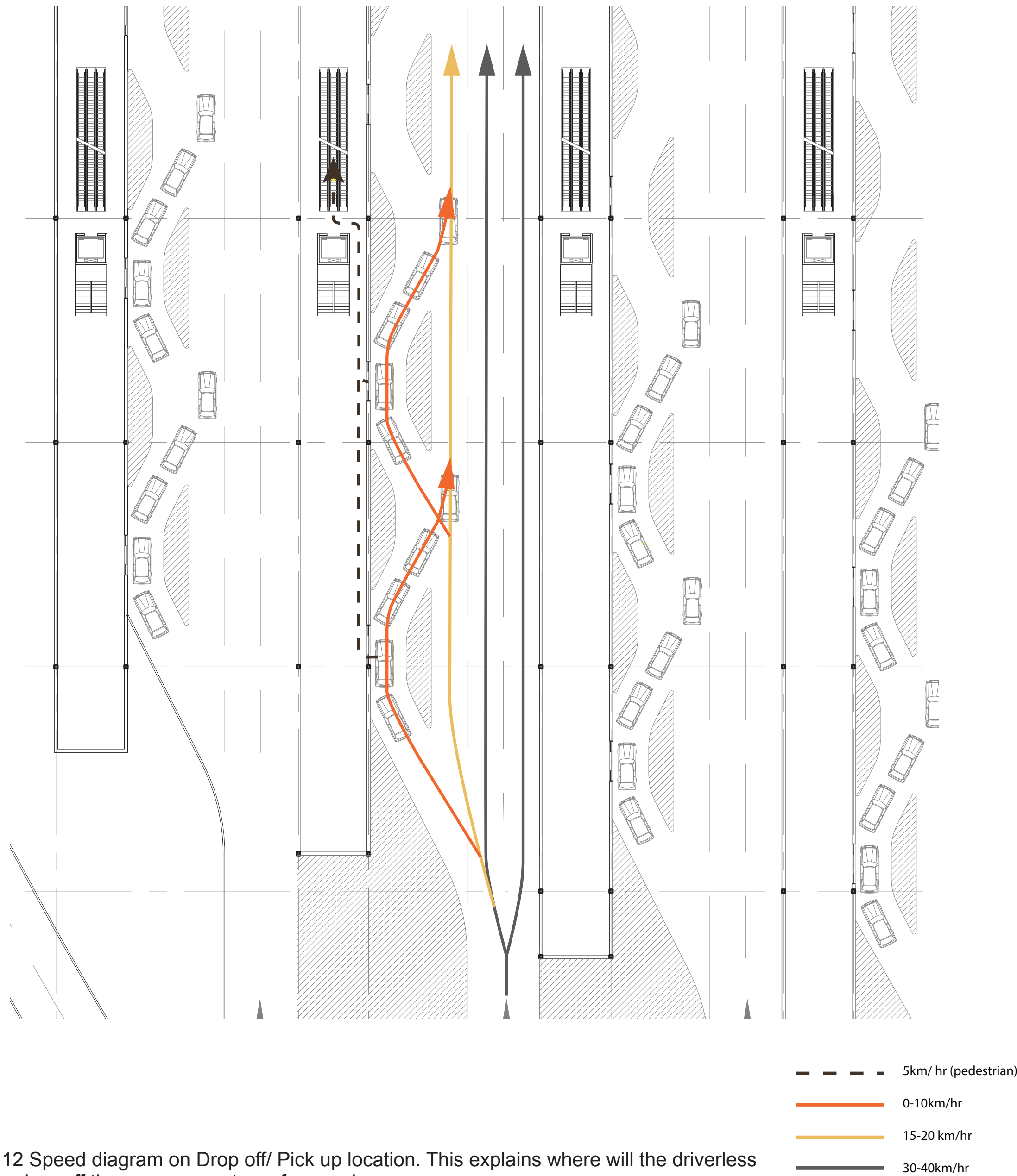


A question that is going to be a challenge to this ambitious undertaking is why not having the drop-off zone proposed at the entrance? Many futurists have speculated that the drop-off zone would be in front of the building. However, to think about how this building is going to collect 50% of the current traffic going through the DVP & the Gardiner each day, this will create another chaos and more traffic jam. The proposal has four ramps coming in and out to the highways. The four ramps each enter to each of the levels, and from there, cars will be communicated and assigned to enter to the right aisle (the drop-off area). During the pickup session, the individual will receive a notification on their smart phone, and they could go to the assigned location and pick up the car. (Figure 7.11)



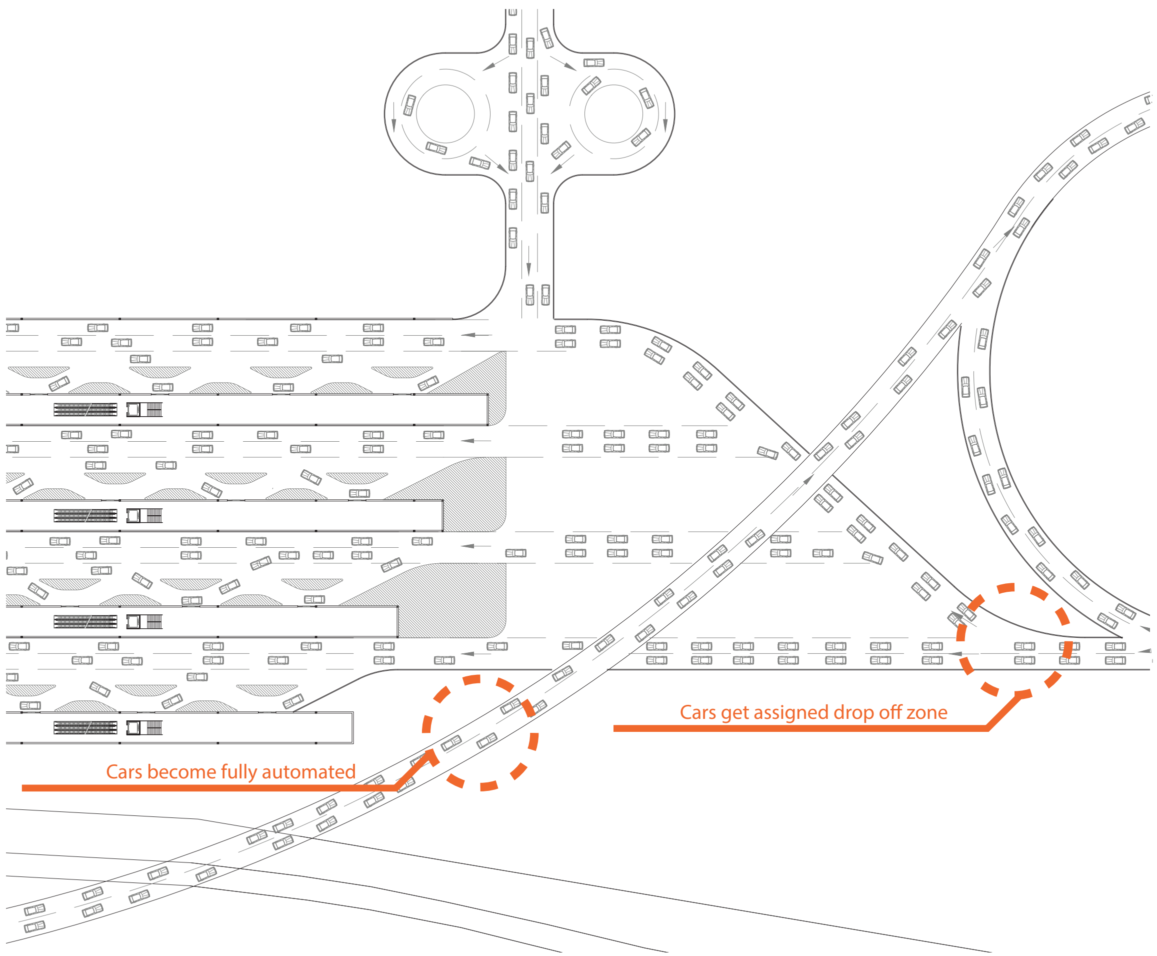
7.11 Drop Off Process. This diagram explains step by step how does a driverless car enters and park the car after it drops off a passenger.

In order to have the car accelerate from 0km/h to 20+ km/h, the routes within the each drop-off zones must be thought through clearly. This project proposes once the car enters from the ramp into the aisle, the computer system will communicate to the car and ask it to go to the assigned spot to drop off the passengers. On each of the level, there will be four lanes beside each aisle. The four lanes are operated by a come and stop traffic on the first lane from the left, with an island at every drop off zone to ensure the passengers would have ample amount of space to get off the car safely; the second one from the left will operate at a speed of 5-10km/h. This logistic allows the car from the drop off lane to easily accelerate to a constant speed, while not having other cars on the second lane to break immediately. The third lane operates at 10-20 km/h in which the cars from the second lane could start to change lane instead of at the fork. The fourth lane is always at a constant speed to allow cars to get through without stopping. (Figure 7.12) After the cars have passed the aisle and gateway, they will go into a two-lane system to go to where they need to be. It would either be entering the parking garage or to where the car's next destination need to be at as the cars could be a shared vehicle similar to Uber, but subtracting the driver.



7.12 Speed diagram on Drop off/ Pick up location. This explains where will the driverless car drop off the passenger at a safe speed.

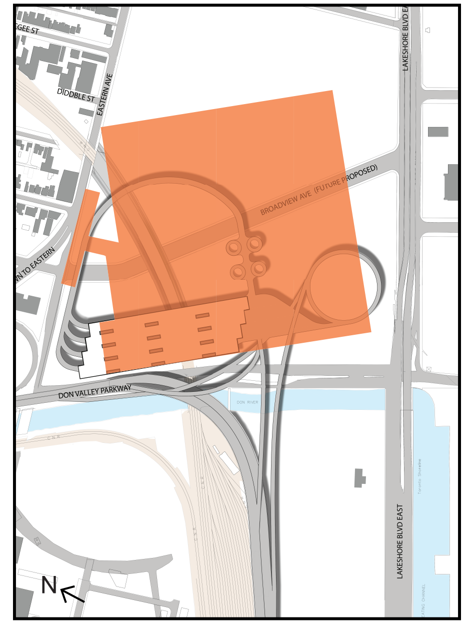
When managing if the driverless car should become automatic or controlled by a person, careful considerations must be made. To order cars to travel safely without human error, the building must operate in full control of the driverless car system. This way the building, the drop-off zones, and the car can communicate together in accordance to allow the drop-off process smoothly. To get the most advantage out of the driverless car technology, each car that enters the infrastructure will be assigned and have a chance to communicate with the infrastructure which could keep track of which spot will be available when the car gets there. (Figure 7.13) Although no one can control how fast the passengers get out of the car (whether they need to get their bag from the back seat or they forgot some articles that they need to bring with them) a penalty will be put on them if they failed to get out of the car with a certain amount of time, such as one minute allowance during the rush hours. Therefore, the transit hub does not become another congested zone and allowing passengers to move from one place to another quickly. Moreover, when the drop-off zones fill up with cars and a car that does not get assigned with a drop off location, the car will go in a loop system until it can find a spot to drop off their passenger.



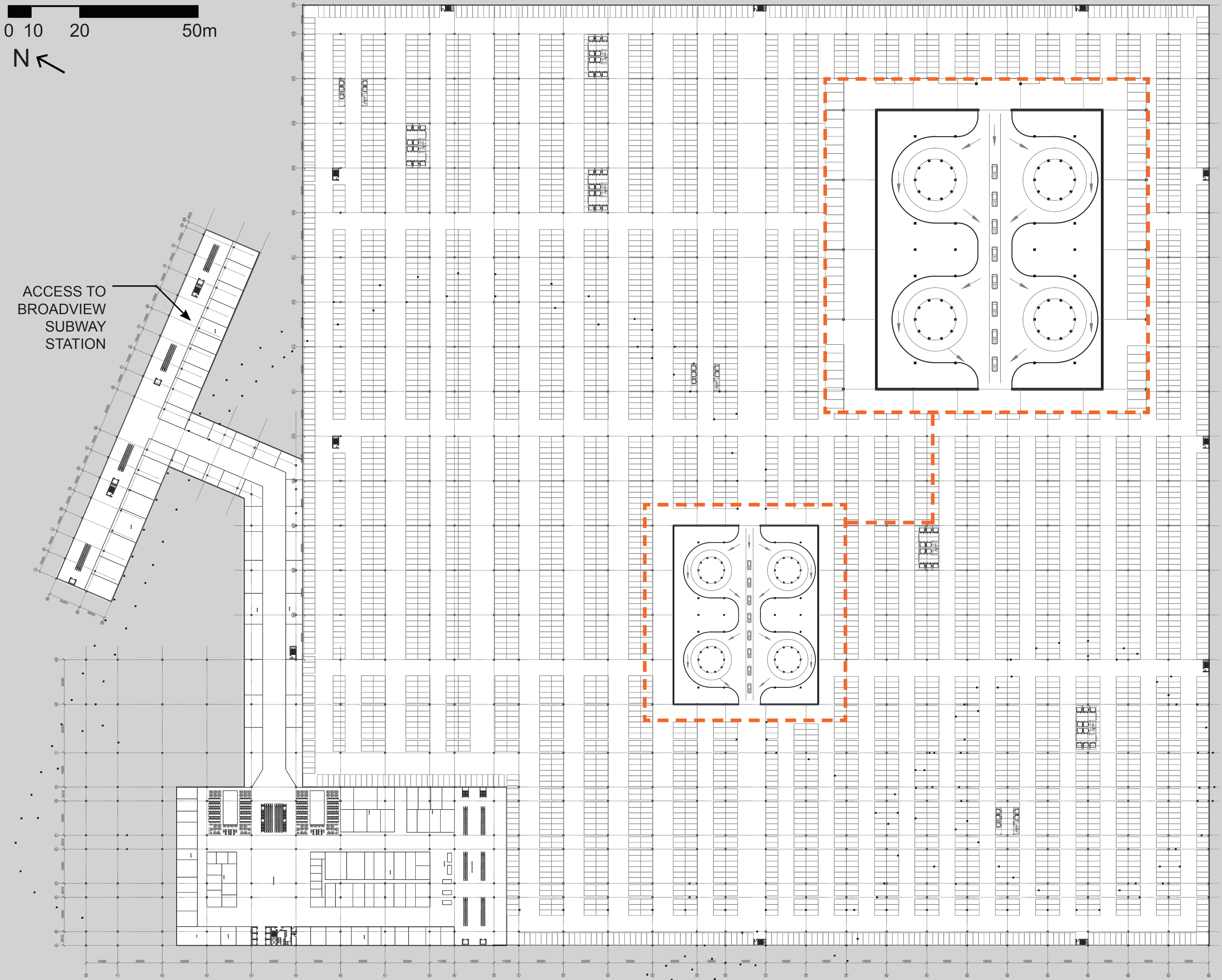
7.13 Control Points. This explains where will the vehicle becomes fully automated and the transit hub will assign a drop off area for the passenger.

7.14 The passengers will receive a notification of when and where the driverless car will arrive. The passengers will then go to the designated area to hop onto the vehicle.

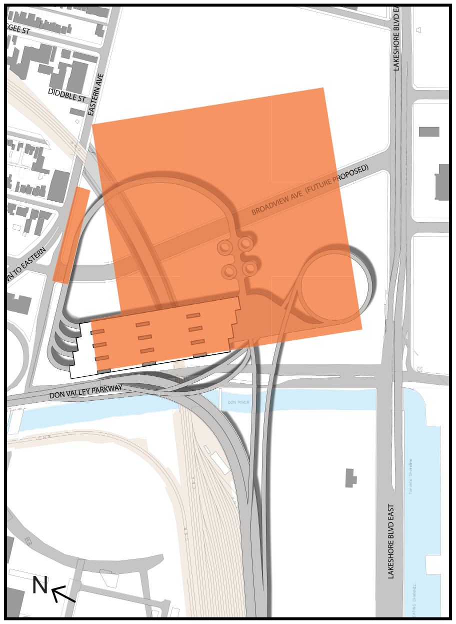
7.14 Perspective Within The Pick Up Area. This perspective shows an scenario which a passenger is waiting for their car to arrive as it sends a notification to the phone.



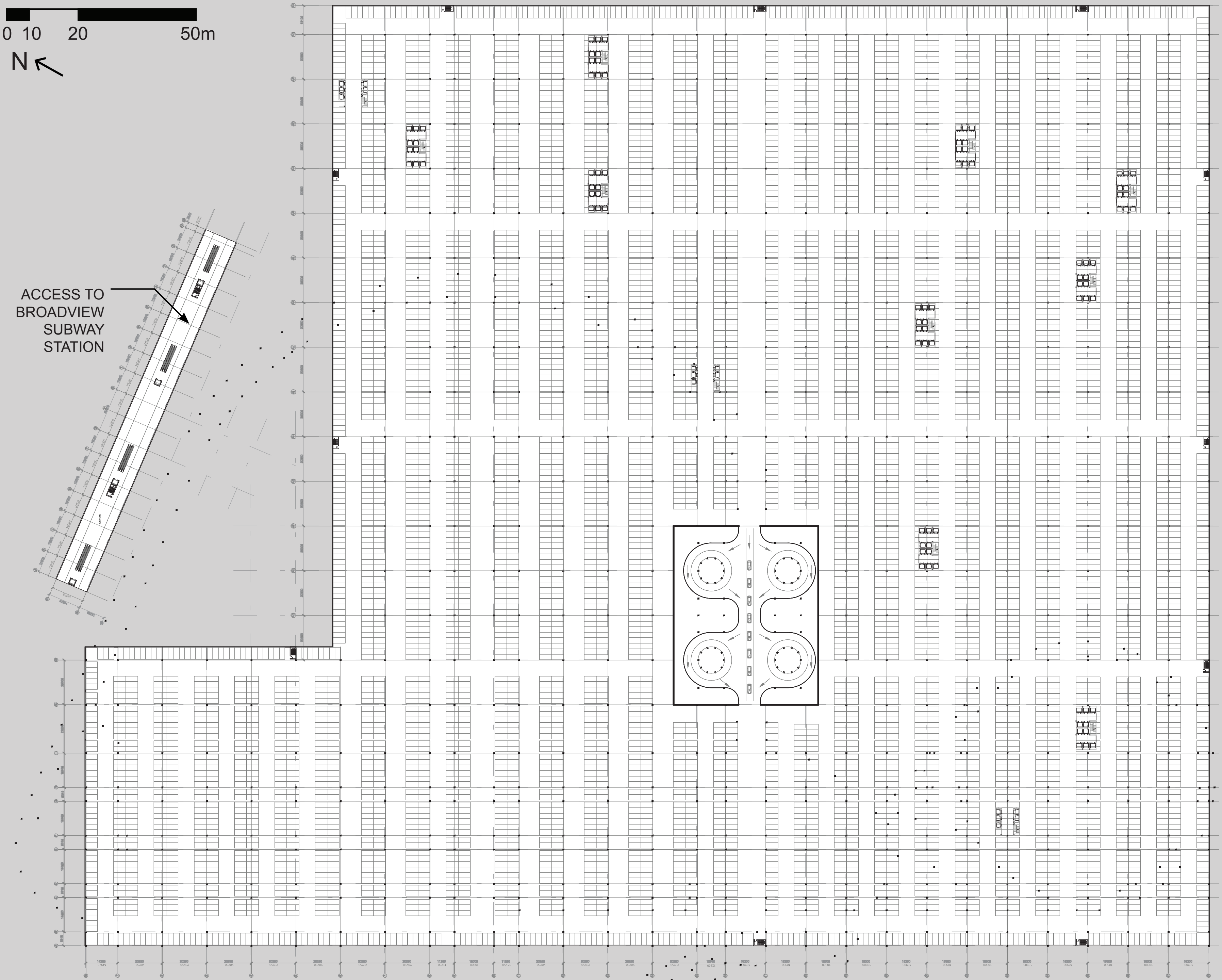
7.15 The P1 Level serves as a connection level from the ground floor to the subway level. Along the walkway to the subway station escalators, there are shops on both sides. The rest of the underground portion are parking garage.



7.15 P1 Level Plan. This level shows the connection to the subway concourse and the parking garage underground.



7.16 The P2 Level is solely for subway access from P1 level and for parking garage. It has a 5m ceiling height to allow future transformation of the space, such as offices or retail spaces when driverless technology is all automated and advanced in future years.

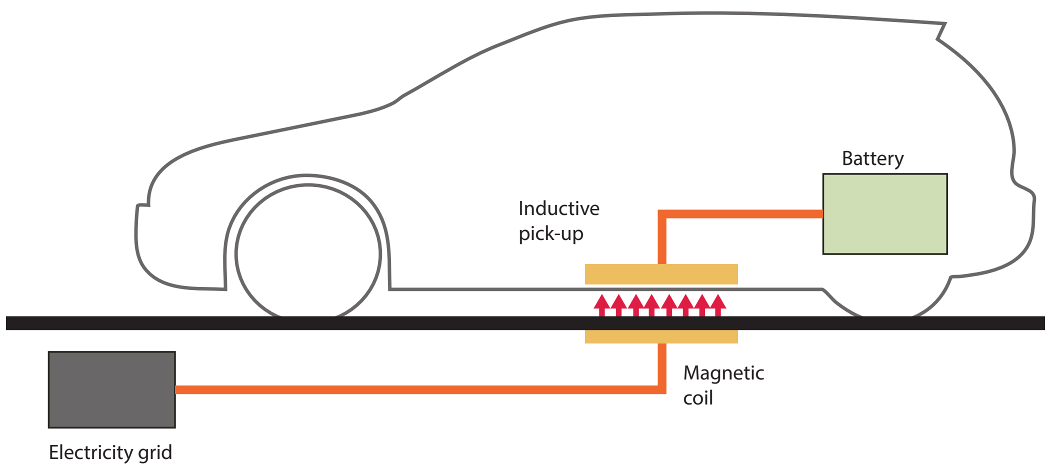


7.16 P2 Level Plan. This explain the majority of P2 level is for parking, and part of it is for subway access.

7.3 Self-parking cars

In order to accommodate 50 percent of the traffic coming from the highways each day, and accumulating with the growth of Toronto, a massive garage system will need to be designed. The two levels underground garage can accommodate 14,700 cars. (Figure 7.14, 7.15) Also, in the early phases, the garage will accommodate electric and non-electric cars as engineers and developers are still creating the technology of fully electric vehicles. On each of the parking spot, there will be an inductive charging pad for the electric car when it is parked stationary. (Figure 7.17) The customer can decide whether they would like to recieve this service with a surcharge. In the later phases of this garage, it will be available for electric vehicles only. By proposing the system this way, it can promote sustainability and largely reduce the volume of emissions from car to improve the air quality in the area.

This garage will incorporate sensors to direct cars to park in the designated spot. This way the building is always communicating with the car and to prevent manual control with human errors. Moreover, because the garage is a smart garage, making it much more efficient and accident-free. For instance, in today's world, if a person was to drive through the aisle, they would need to be very conscious when they drive because cars may be coming from all sort of directions, cars backing out, cars coming through the blind spot, etc. With the communications between cars, they can move with an eye that could anticipate mistakes. The car will receive a message from the owner or the client when and where they would like to retrieve their vehicle. Then the car will leave the garage from P1 or P2 back to the 5th and 6th floor. The vehi-

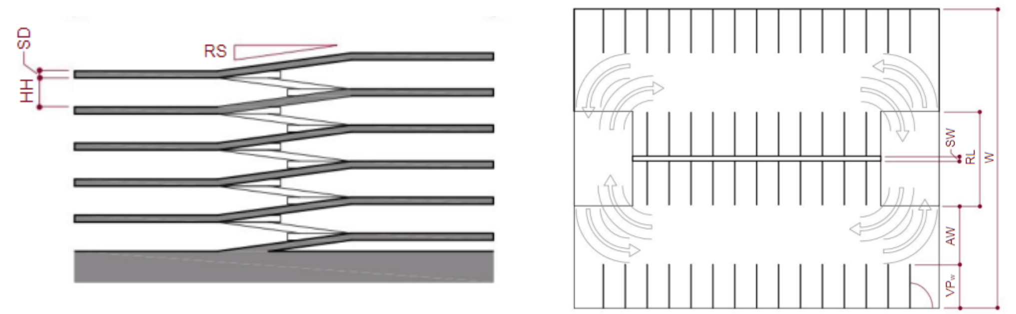


7.17 Inductive Charging. This diagram explains how a car can be charged without the help from people.

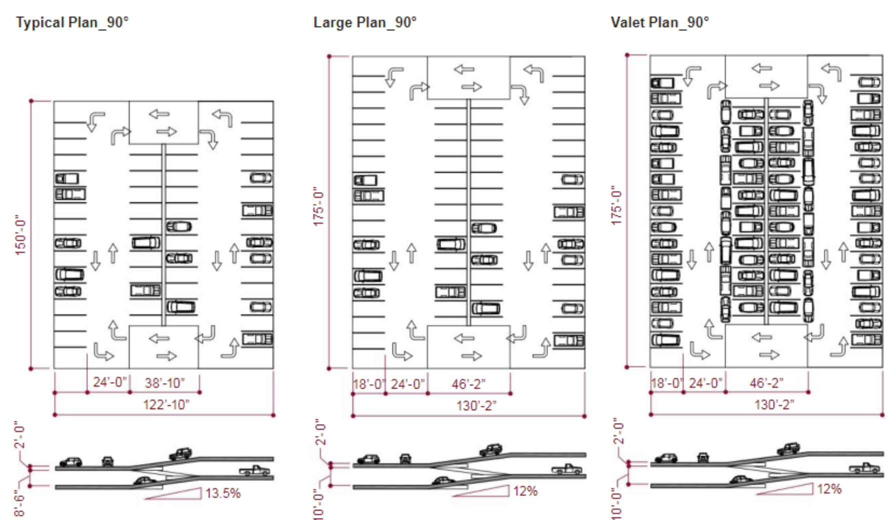
cle will then arrive to the designated spot at the pickup floor, and allow the passenger to get into the car. Similar to a system that we have for the drop-off zone, the passenger will be penalized at a cost if they are spending too much time getting on the car.

To design this garage, it would not be very different from designing a traditional garage, where the column grids are dictated by the size of the parking spot. Due to the technology of the driverless car, the traditional space for passengers to get out of the car can be saved. Regarding to planning, the designer could have the same span that they would propose in a traditional design but with more cars in the structure. (Figure 7.18)

As these studies predict, cars would no longer need to be close to the workplace or the shopping malls because the driverless car could simply pick a person up as long as they place an order on the phone. To encourage people to take the public transit after being dropped off by a driverless car, charges can be implemented by the City of Toronto similar to the Congestion Charges in London, UK which apply to cars driving into the city center during peak hours. The need of garage in city center became a question for the future. Why would the developers still want to build garages when they could make more money out of them by building homes or retail location? This statement makes sense when every car is a driverless car in the city. However, in the early stages of this infrastructure, a garage is still needed. This is why when designing the garage, the designers need to accommodate future designs. For example, the garage should not be designed just to the height of the cars, but rather designing a space with a minimum 15 feet high ceiling for retail purposes in the future.



	STALL ANGLE	STALL DEPTH	AISLE WIDTH	STRUCTURAL WIDTH	STRUCTURAL DEPTH	HEAD HEIGHT	RAMP SLOPE	WIDTH
(PLAN SIZE)	(SA) (DEGREE)	(VP^{w}) (FT)	MINIMUM (AW) (FT)	(Sw) (FT)	(SD) (FT)	(HH) (FT)	(RS) (%)	(W) (FT)
MINIMUM	90	18.0	24.0	2.0	2.0	7.0	15.0	122.0
TYPICAL	90	18.0	24.0	2.0	2.0	8.5	13.5	122.8
LARGE	90	18.0	24.0	2.0	2.0	10.0	12.0	130.2



7.18 Architectural Standard From Architectural Record - Parking Lot Dimensions. These are the design guidelines when designing for spaces in the garage.

“Two years from now the bus that commuters take to their nearest TTC station may be missing a familiar feature — a driver. The report suggests autonomous shuttles could provide a solution to the so-called “last mile” problem, a term used to describe the difficulty of finding efficient ways to transport people between their homes and transit stations in areas where ridership demand doesn’t meet the threshold that would necessitate conventional transit service. Successful public transit systems need to offer safe and accessible connections to transit stops and stations ... Closing the gap between a person’s home and the nearest transit stop could be addressed in a variety of ways — emerging technologies is one way including ride-sharing, demand-responsive transit and, possibly depending on the results of our pilot, autonomous vehicles.”[85] - Ben Spurr, Transportation Reporter at The Star.

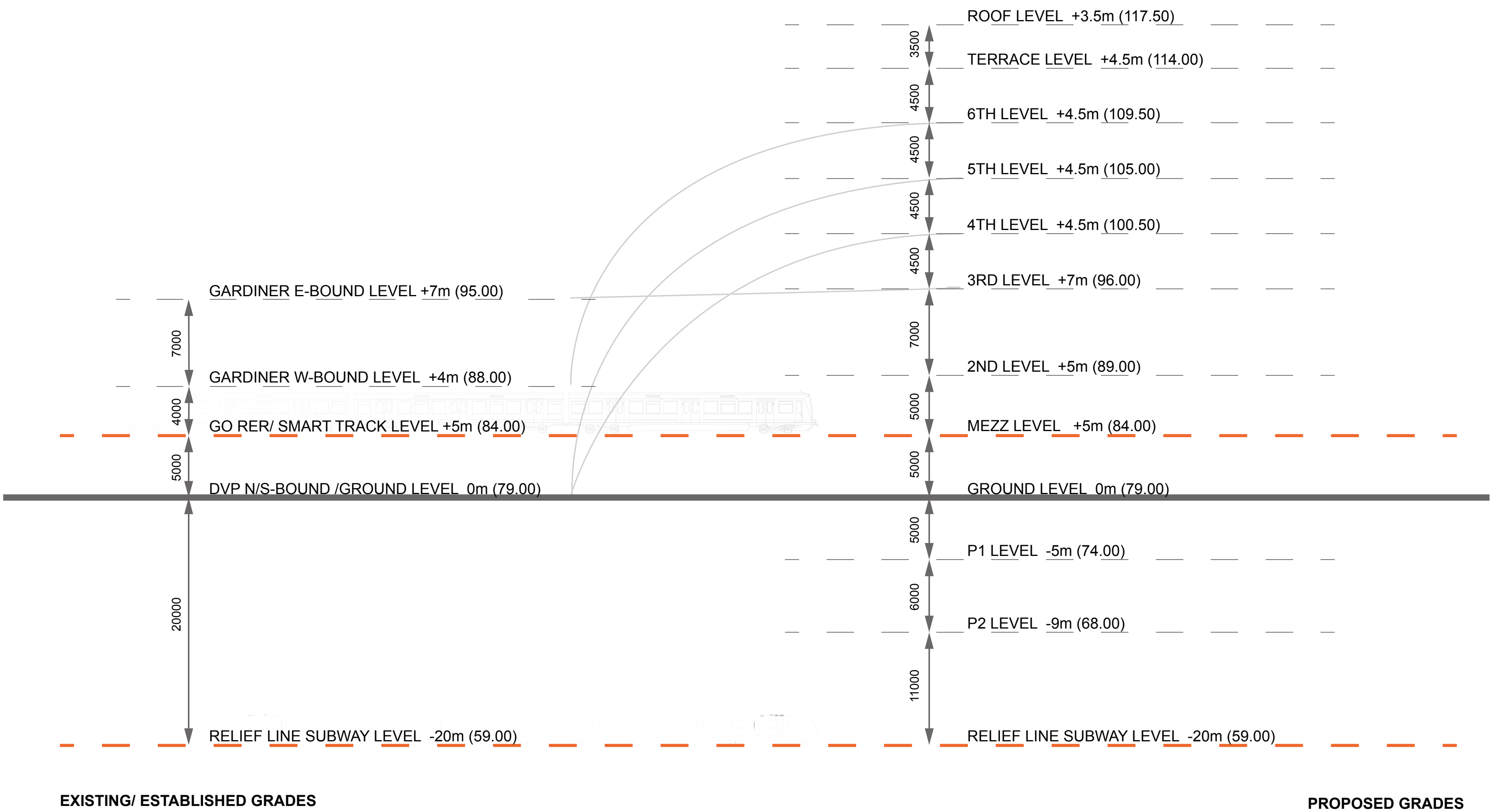
7.19 Exterior Perspective Looking Towards Streetcar Broadview Station. This perspective shows the transit hub in use during the day time. After the commuters get dropped off and picked up by the driverless cars, the cars will park in the underground garage or go to the next destination, and some commuters will transfer to the ground level to connect to the TTC streetcar service.

7.4 Connection to Public Transit

In the beginning, this proposal sought to examine the prototype on a site next to the highway and have a close proximity to the city core. The proposed location is situated at the intersection of the DVP & Gardiner and the 427 & Gardiner. The reason why the DVP & Gardiner site was chosen is mainly because of the close proximity to the city center where the traffic is more severe.

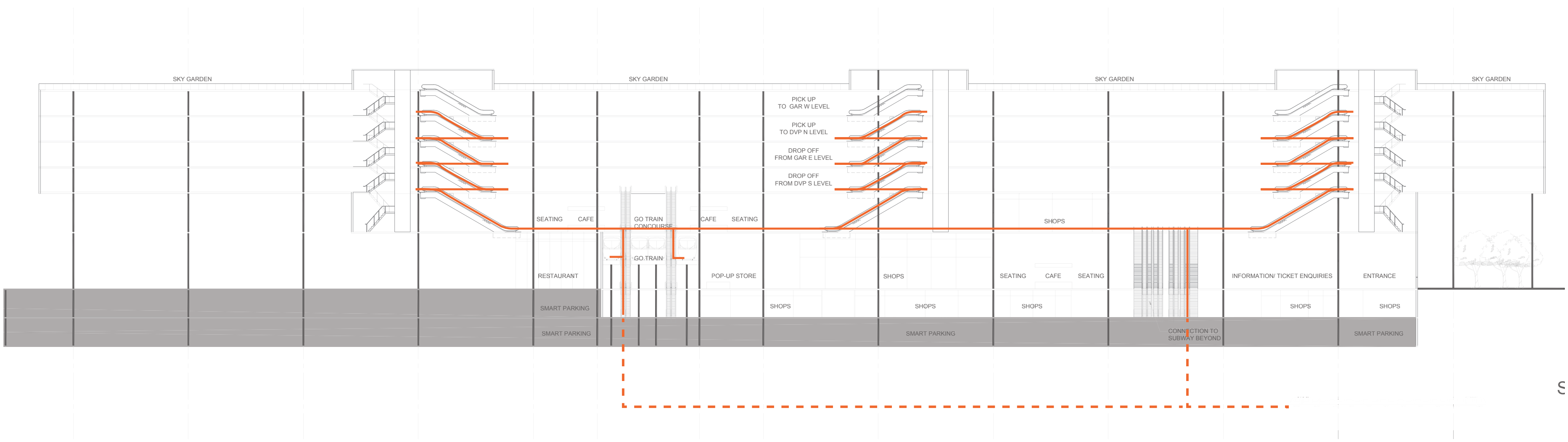
The site is located in downtown Toronto, which is currently being underused due to the characteristics of the site. The City of Toronto and Metrolinx have proposed new transit locations and expansions to existing public transit. There will have be a new relief line that connects the downtown Toronto (King, Union, Jarvis) to the Bloor-Danforth subway. Moreover, along with the subway relief line, the Go RER, Smart Track, and also the new LRT line are all going to be developed on one site.

There is also another challenge in this project: due to the various number of public transit vehicles going through the site, the proposal will have interaction with various public transit systems at different points. For example, the new relief line will require 20 meters down from Earth, while GO RER raised as of existing, with 5 meters above the Ground level. These level differences became a crucial design factor that will need to accommodate the sequence and logistic from where the people have been dropped off, and where they should go to get connected to public transit. Also, it highly became a design guide to place floors and divided them into the appropriate levels. Moreover, the on and off-ramp from each of the highways have a different grade to start. (Figure 7.20) For example, the DVP is also at grade to the ground level of the complex, and the Gardiner Expressway is seven meters above the ground level. The complex has allocated the drop off zones on the second floor for cars coming from the DVP, and the third floor for Gardiner to allow cars to come in from both directions.



7.20 Cross-Section Of Different Levels Of Grade. This diagram helps to understand there will not be a difference in level when the trains, subway and streetscar come in.

Vertical circulation will be provided to get to the public transportation from the drop-off zones. (Figure 7.21) It explains where in each of the levels the public transit intersects, as well as how long would it take to get to the appropriate destination. For instance, if a person is being dropped off at 4th floor, they would first exit from the Gardiner Expressway. From there, they can use the escalator to get to the concourse level (2nd floor), and if they decide they want to be connected to the GO RER, then they could go to the mezzanine level. To go to the LRT streetcar, they could go to the ground level. If they want or if they want to be connected to Subway, they could go to P2 level. (Figure 7.22)



7.21 Circulation Diagram. This diagram explains how one can be connected after being dropped off/ picked up.

7.22 This is the main hall where the commuters can get connected to their preferred public transportation and on the same level, there are cafes where they can pick up their breakfast order that they ordered through phone.

7.22 Perspective Of The Main Hall. This shows the multi-modal transportation in this image.

Due to the size of the massive infrastructure, the design must be filled with programs to get the users to feel more integrated and not only using it as a passage. This is when the designer needs to think and experience the infrastructure from the user's point of view. When a person is being dropped off, they want to get to concourse level as soon as possible, and then they could decide where they would like to go from there. Whether one gets to the concourse levels or the ground floor, there are retail and cafés to serve the morning craving for breakfast. Also, to avoid long line ups, there could be a connected app where the commuter could order ahead and pick up the warm muffin and coffee on the way to the public transit. Alternatively, if they have already eaten their breakfast during their ride in the driverless car, they can simply get to the waiting stations. This complex can get intense and busy during rush hours, though there would also be non-peak hours. This vast infrastructure will act as a mall with a mix of retail and restaurants to keep this place eventful. Also, with the help of the driverless technology, the mall will be much more client-oriented rather than car-oriented similar to the typical malls we have in North America, where the parking lot became a boundary of the mall landscape. There is a rooftop park where restaurants, patios, driverless food trucks and events could be hosted. Moreover, in the future of expansion, more residential and commercial master-planning could utilize the space as a communal space. (Figure 7.23)

7.23 Perspective of The Master Planning In The Future. There will be more and more commercial buildings coming into this area, as Toronto is going through a stage of densification within the city.

8.

CONCLUSION

The invention of transportation is to provide people with better efficiency to get from one place to another. The same concept applies to driverless car, which is to provide a more enjoyable and stress free commute. This thesis is a prototype to integrate the emergence of driverless cars in the future and inherit the use of the existing public transit system and road networks we have in the city.

"Autonomous vehicles will bit the market by 2020." [86] – Raj Nair, Product Development of Ford.

"Uber's fleet to be driverless by 2030."[87] – Travis Kalanick, CEO of Uber.

Driverless cars technology will not only revolutionize the way to travel every day, but it will have a large impact on infrastructure, built environment and landscape. Thinking about how inefficiently people use their cars and realizing that cars nowadays are only being used 4 percent a day on average, there will be some drastic infrastructural changes. To see the benefits of the driverless cars, including buying people more time and helping people work more efficiently with a greater flexibility are truly what matters in improving people's life.

The thesis intends to investigate to possibilities of creating a prototype of a driverless car transit hub when the technology of driverless car becomes fully realized. It seeks to explore how driverless cars work with existing and proposed public transit.

The design proposal is not meant to be a complete solution to all the problems and uncertainties that driverless car technology still presents, but places it into a perfect scenario where the infrastructure around it can be fully realized. It will require extensive modelling from traffic engineers on the amount of vehicles coming into this transit hub during rush hours. This prototype can be implemented where the highways intersect, for example, where the Gardiner meets Highway 427 on the western end of the city. The proposal attempts to create a development to improve the efficiency and flexibility of people's commute with the help of the driverless car technology and transition to the transit hub.

The challenges arise on the transit hub, where all the structures will need to be approved by the engineering team. Also, because where the proposed infrastructure is situated, having a preliminary anti-flooding plan is very important, but also when the future expansion of new commercial and residential components come in, it will need to be looked at very carefully. The number of cars in the transit hub that will be stored and going in are calculations as per current prediction from the researched scholars. If in the future, the number grew exponentially, more facilities will be required. North America has always known as the country that depends on cars, but how come we are always the follower on the technology side?

This thesis proposes to take advantage of the fast growing automobile and public transit industries. More developments are happening in downtown Toronto, as well as across North American suburbs. To put it into context, these investments could allow developers, planners, and architects to improve infrastructure without a full redevelopment. This transit hub allows North Americans to re-think their city environments once again and ask urban planning questions. Is it necessary to have vast amount of land of parking surrounding a mall? Is it worthwhile to invest ground level development on parking where with the new technology people would just need to be dropped off in front of the building? This revolution is a chance to have architects and planners to step up to the challenge, be leaders of the future, and design for the city of tomorrow.

8.1 Reserving The Seat In Future Scenario. In the future, one can reserve a seat in a ride share program run by driverless car, and before one gets into the car, the seat is already set to your last seat memory.

8.2 Performing Task In A Driverless Car. A car will no longer be a transportation from point A to point B. It is your home, your workplace, and your life.

Endnotes

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