Reimagining Rail Travel in the United States

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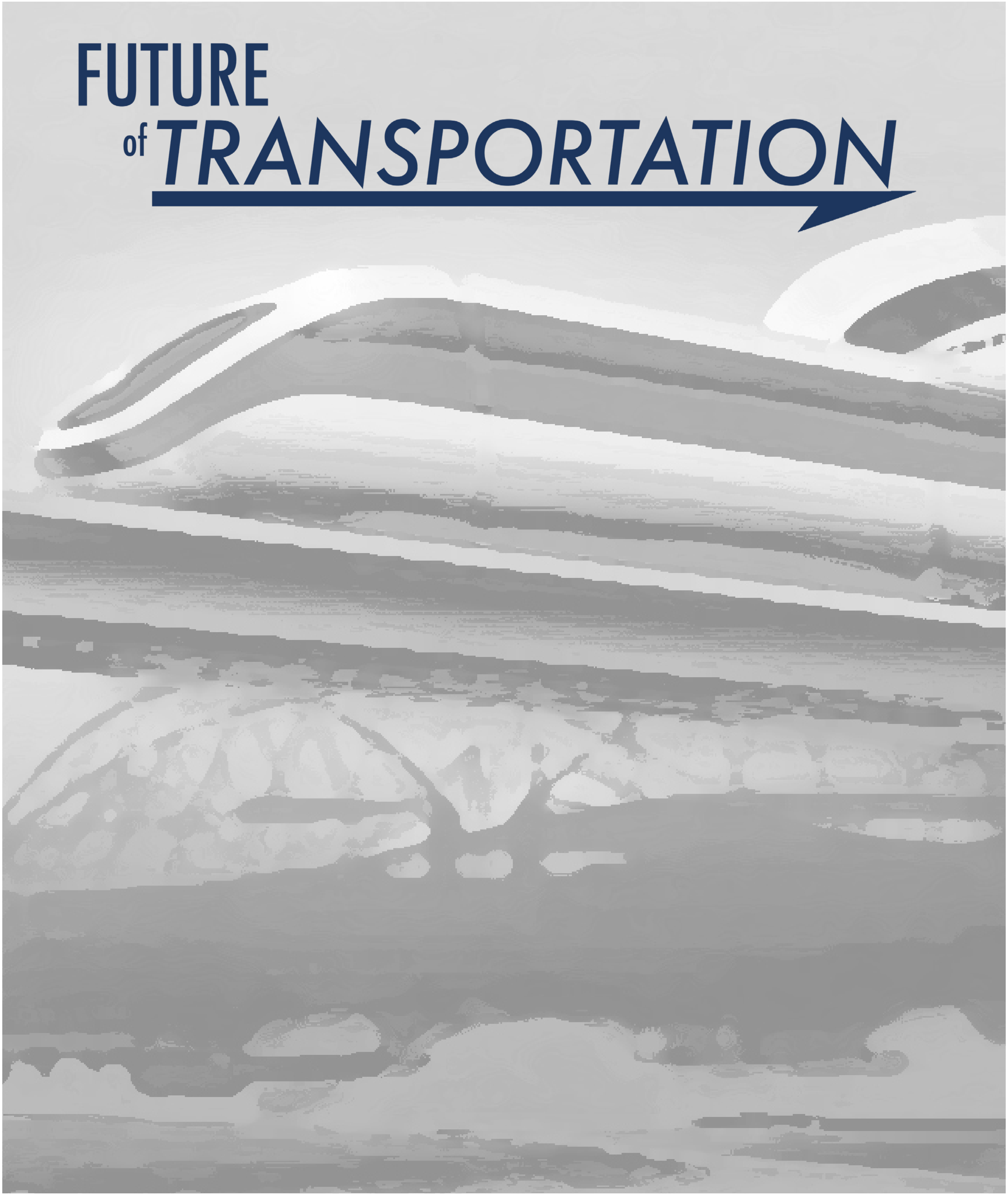
FUTURE of TRANSPORTATION



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REIMAGINING RAIL TRAVEL IN THE UNITED STATES

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ABSTRACT

The increase of congestion in American cities is creating a slower and more expensive commute for the average American passenger in major cities. Convenience and speed are incredibly important to the average American citizen. While research is being done on ways to increase the efficiency of automotive and air transportation, one of the quickest payoffs will be the re-introduction of mass passenger rail systems throughout the United States. The new types of Magnetic Levitation and Hyperloop technology allow for the speed of these new rail lines to travel at speeds close to and exceeding the average commercial airliner. By combining these new types of transportation systems with our existing infrastructure and other smaller scale transportation systems, there is an opportunity in America to revolutionize the transportation for the twenty-first century. Transportation hubs will form the human connection with these transport systems and an entirely new system will allow us to reinvent the transit hub of tomorrow. By analyzing American rail hubs such as Cincinnati's Union Terminal, New York's Pennsylvania Station, one can learn from the past to help influence the design and systems in these next generation of hubs. Modern day equivalents such as San Francisco's new Transbay Transit Center and foreign examples such as Berlin's Hauptbahnhof Station will help influence how these hubs interact with modern inner-city transit systems. Transit hubs create the human connection to the mechanical network of rail, automobile, and air transportation systems. They are often gateways to the region in which they reside, and the first and last place a person see's as they travel from one city to another. Designing the next-generation of transit hubs is key to how we as a society interact and experience our travel.

REIMAGINGING RAIL TRAVEL IN THE UNITED STATES

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INTRODUCTION

The Roman Empire conquered the Mediterranean with their endless stretches of road just as in the 19th and 20th centuries the United States would stretch from sea to sea on a network of railways. As the United States progresses into the twenty-first century, we are required to look at the next generation of transportation systems and find a way to incorporate them into our existing infrastructure efficiently. How will the mass transit hub of the future work? How will it fit into our current transit systems? What systems can be replaced with more fuel efficient and cost-effective means of mass transportation? Magnetic Levitation, high-speed rail, and the Hyperloop system will have a significant impact on how we as a society will communicate and trade with one another. They are poised to completely change the landscape of mass transportation throughout the United States. This paper considers how the next generation of systems will interact with each other on both a macro, inter-city scale and a micro, inner-city scale. Transportation has always been essential to human civilization. Efficient examples of the past such as the Cincinnati Union Terminal and the modern equivalents such as San Francisco's Transbay Transit Center will be used as a blueprint for the future of transportation hubs that will connect the next-generation of systems and Americans to one another. First-hand research of existing examples of past and present train stations and airports will be used in combination with researched data and interviews with industry professionals to help paint a picture of the future of American rail transportation.

HISTORY OF RAIL IN THE UNITED STATES

To fully understand how rail systems can once again become a mainstream option for American travel, we must first explore how it reached the peak of transporting 98% of all travelers in the country.

EARLY RAIL TRAVEL

The modern revolution of transportation started in the early nineteenth century. Since the formation of the United States, transcontinental travel has been continuously sought after. The famous Lewis and Clark expedition set out to find a new waterway across the Northwestern United States. Instead what the explorers saw was an almost impregnable wall of mountains that stretched for thousands of miles in either direction and was at points over 300 miles wide.[1] While the expedition of Lewis and Clark failed to find the fabled Northwest Passage, the country nevertheless pressed on with western

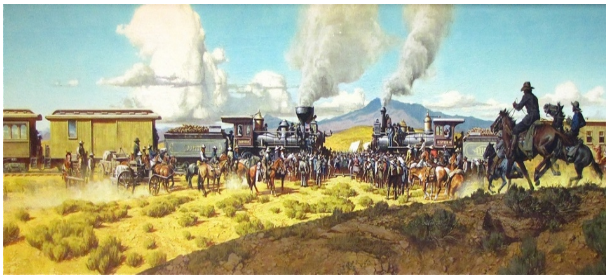

Figure 1: Transcontinental Railroad

expansion. Early settlers made the incredibly treacherous journey in wagon trains that comprised of up to 100 Conestoga wagons, also known as prairie schooners.[2] Following the discovery of gold in the territory of California in 1849 the expansion westward exploded as everyone rushed to strike it rich. Steam Trains, which had first been introduced to the United States in 1830, already had significant track work in place throughout the eastern states. Soon the federal government hosted a competition between the Central Pacific Railroad Company and the Union Pacific Railroad to complete what was to be known as the Transcontinental Railroad. After grueling years of labor, the two companies finally met up in Promontory Summit, in modern day Utah on May 10, 1869. The two halves of the country were for the first time connected by a mode of mass transportation.[3]

RISE AND FALL RAIL

The railroad network in the United States continued to rapidly expand throughout the rest of the nineteenth century, eventually reaching its peak in the early twentieth century in what became known as the 'Golden Age of Railroading.' Railroads suffered almost no competition for overland transportation until the break out of World War I. According to the University of Iowa's exhibit on the Golden Age of Railways, "In 1916 railroads carried about 77% of all intercity freight and 98% of all intercity passenger business."[4] Train travel was essential for the booming economy of the United States during the 'Roaring Twenties.' Following the First World War, rail travel began a steady decline; the advent of commercially available automobiles and trucks, the invention

TABLE 8.5

DISTRIBUTION OF INTERCITY FREIGHT TRAFFIC IN THE UNITED STATES

(BILLIONS OF FREIGHT TON-MILES AND PERCENTAGE OF TOTAL)

Year	Railroads	Percentage	Inland Waterways	Percentage	Truck	Percentage	Pipeline	Percentage	Air	Percentage	Total
1916	367	77.2	88	18.4	...	...	21	4.4	...	...	476
1930	390	74.3	86	16.5	20	3.9	28	5.3	...	...	524
1940	379	61.3	118	19.1	62	10.0	59	9.6	.01	...	618
1945	690	67.3	143	13.9	67	6.5	127	12.3	.09	...	1,027
1950	597	56.2	163	15.4	173	16.3	129	12.1	.32	...	1,062
1955	631	49.4	217	17.0	226	17.7	203	15.9	.48	...	1,278

Figure 2: Distribution of Intercity Passengers

of the airplane, and the opening of the Panama Canal all contributed to the end of the golden age of rail transportation. The rise of the personal automobiles and safe commercial airline flights during the post-World War II boom led to the end of almost all passenger-based rail travel in the United States. From the years of 1916 to 1960 the percentage of passenger travel accommodated by rail travel plummeted by 71% and the total number of railroads fell by 50%. Following the Second World War, President Eisenhower signed in to law the Federal-Aid Highway Act of 1956, effectively creating the interstate highway system that we know today. This system revolutionized road transportation in the United States and allowed private and commercial automobile travel to reach every corner of the continental United States.[5] The age of mass transit inter-city railway systems had effectively ended.

Railway freight transportation, by contrast, fared much better than passenger travel. While the percentage of goods moved over rail declined by 33%. The total number of lines for freight transportation grew around 50%.[6] As Americans demanded more goods, train travel became the most efficient form of overland mass commercial transportation.[7] Freight travel was revolutionized in the late 1960's and 70's with the advent of the standardized intermodal container design. Allowing containers packed with almost any commercial good to quickly be transferred from ship to rail to truck allowed the freight rail industry experienced a boom. It has since become the

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(BILLIONS OF FREIGHT TON-MILES AND PERCENTAGE OF TOTAL)

ar	Rail-roads	Per-cent-age	Inland Water-ways	Per-cent-age	Truck	Per-cent-age	Pipe-line	Per-cent-age	Air	Per-cent-age	T
16	367	77.2	88	18.4	...	...	21	4.4	...	...	
30	390	74.3	86	16.5	20	3.9	28	5.3	...	...	
40	379	61.3	118	19.1	62	10.0	59	9.6	.01	...	
45	690	67.3	143	13.9	67	6.5	127	12.3	.09	...	1,
50	597	56.2	163	15.4	173	16.3	129	12.1	.32	...	1,
55	631	49.4	217	17.0	226	17.7	203	15.9	.48	...	1,

Figure 3: Distribution of Intercity Freight

fastest growing segment of the freight rail industry since 1980.[8] As of 2010, the rail industry constitutes around 40% of all freight moved in the United States, of which 91% is comprised of bulk commodities such as agricultural products, automobiles, and raw materials.

MODERN RAIL

Today, passenger rail travel is experiencing a slight increase in traffic. Climate change is continuing to become more of an issue, and fuel efficiency is becoming more critical than ever. Current model Amtrak trains are on average 17% more efficient than commercial airlines and automobiles and are often powered by electrical systems rather than fossil fuels. Freight travel is even more efficient, producing 75% fewer greenhouse emissions and averaging 400% efficiency over truck transportation. "Transitioning just 5% of cargo moved by trucks to rail transport would save about 800 million gallons of fuel per year".[9] The next generation of rail transit will require even more efficiency. Magnetic Levitation and Hyperloop systems will be essential to help reduce the carbon footprint of our mass transit. Today the transportation sector is the second highest contributor to CO2 emissions (27%) in the country.[10] The rail industry is poised to help reduce this percentage with the introduction of high speed and high-efficiency systems that can replace automotive and air travel.

RESEARCH

To know how to design the future of transit hubs in the United States it is important to understand what is not working about the current systems in place, and what systems are poised to replace and enhance our travel experience.

AIR TRAVEL

Today, air travel is the quickest option for most intercity travel throughout the United States. While the flights are often quick, anyone who has taken a commercial flight will know that a majority of time is not spent in the air. The logistics, locations, and security at today's airports cause a bottleneck in the system that can take longer than simply driving to your destination via a car or bus. While time spent at airports has begun to decrease, airlines

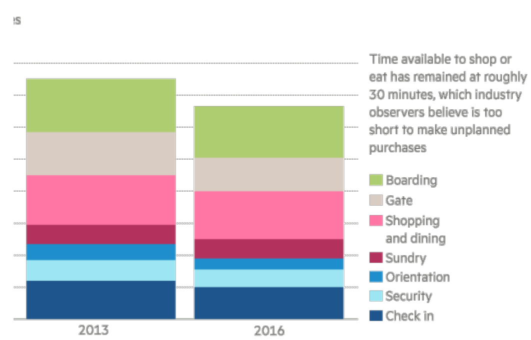

Figure 4: Time Spent at the Airport

continue to recommend passengers arriving at the airport two hours ahead of domestic travel and time spent at the airport continues to reflect more than two hours on average.[11] There are roughly 5,000 aircraft in the skies of the United States at any given time, and on average the FAA handles more than 42,000 flights per day amounting to over 25,000,000 passengers traveling through U.S. airports on an average day. The sheer number of people flying within the United States is staggering. While flying itself is not much of a chore, traveling to and from your destination to the airport and at the airport, itself can often be an incredible hassle. Once inside the airport, travelers are often powerless to the delays, reroutes, and cancelations that can ruin an entire trip on a moment's notice. The Federal Aviation Administration (FAA) reported that over a span from 2012 to 2016 the nation's

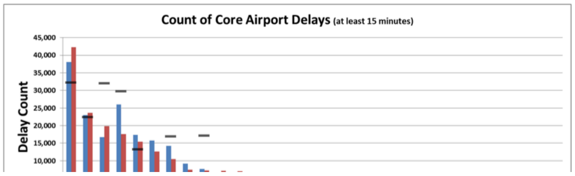

Figure 5: Airport Delays

largest 30 airports experienced over 210,000 delays of 15 minutes or greater and a yearly average of 136,000 cancelations. Over the same span of time, these airports reported an average of 17,000 diversions, where a plane is rerouted to a different airport in the region.[12] These numbers are all too real for those of us who frequently travel via airplanes. These delays are costly for both the passengers and the airlines themselves. According to the FAA, the total cost of these delay's averaged over 20 billion dollars a year from 2012 to 2016 (10 billion dollars of which is a cost to the passengers of the airlines).

Even with all of the current problems facing domestic air travel, the future is not bright for this industry. Capacity has become a major issue as more people began to fly than ever before. Since the late 1970's the number of air passengers commuting globally on commercial airlines has increased by over 725% to a staggering 3.7 billion people in 2016. At its current rate, the global air travel is set to double over the next 20 years to 7.8 billion passengers annually.[13] The United States is expected to spend an estimated $75.7 billion in infrastructure improvements before the year 2019 to keep up with the ever-growing demand for airports. For many U.S. airports, improvements are difficult and incredibly damaging to the environment. New York's LaGuardia airport, already overextended, continues to set new records for total passengers. With very few locations to expand runways and terminals, the airport would require projects to fill in the surrounding Jamaica Bay causing potentially devasting impacts on the surrounding environment. Airports throughout the United States will continue to struggle into the foreseeable future as capacity remains stagnant and population continues to increase.

MAGNETIC LEVITATION

Magnetic Levitation trains, also known as mag-lev, have been commercially operationally since 2003. These trains use the basic

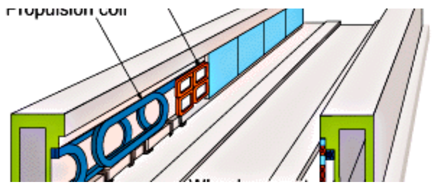

Figure 6:Mag-Lev Diagram

principles of magnets to create a train that in essences floats a few inches above the tracks and reduces the friction of the steel train wheel on a track system.[14] This system does not require the traditional engine that has been used to pull trains since their inception. Instead using a system of coils to create a magnetic field that allows the train to levitate between 0.25 - 4.0 inches over the guide rails. This allows for the trains to travel at much higher speeds than a traditional rail system, speeds in excess of 310 miles per hour. By comparison, the typical Boeing 777 commercial airliner travels at 562 miles per hour. These trains have been implemented successfully in countries like Japan, Germany, and China. They offer an incredibly sustainable mass transit option over the fossil fuel powered rail systems. Unfortunately for this systems implementation in the United States, they are very cost prohibitive. Today in the United States, California is currently implementing one of the country's first true high-speed rail systems to connect the cities of San Francisco to Los Angeles. At a distance of roughly 520 miles, the project's cost has inflated since its inception and is expected to reach a final cost of around $98.1 billion, roughly $188 million per mile of track.[15] By comparison the Chūō Shinkansen mag-lev line in Japan between Tokyo and Nagoya is estimated to cost roughly $51 billion for a distance of 178 miles, which comes out to roughly $286 million per mile of track.[16] Mag-lev trains in the United States are projected to cost even more, with a proposed mag-lev route to connect Washington D.C. and Baltimore, Maryland estimated to cost roughly $15 billion, or roughly $420 million per mile.[17] These cost are truly astronomical. Fortunately, there is an ability to recoup some of these costs over the long project life of these systems. "Mag-lev operating cost will be only 3 cents per passenger mile and 7 cents per ton mile, compared to the 15 cents per passenger mile for airplanes and 30 cents per mile for intercity trucks".[18] Another positive for these systems is the fact that guideways can last for at least 50 years with minimal maintenance because there is no mechanical contact or wear. Using the statistics for the new Avelia Liberty high-speed train coming online for the New York to Washington D.C. route, we can expect that the California high-speed train will service roughly 400 passengers per trainset.[19] It is projected that by the year 2022 the annual ridership of the CalTrain will be roughly 11.3 million passengers and increase to 33.1 million by the year 2040.[20] Using these numbers it can be calculated that over a 50 year period a mag-lev system would cost almost 1/2 a billion dollars less to operate than a traditional high speed rail and offer speeds of almost double the advertised top speed of the CalTrain.

HYPERLOOP TRANSPORTATION

Another promising mass transit that is just beginning the testing stage is the Hyperloop system that has been advertised by entrepreneur and engineer Elon Musk.[21] The Hyperloop system takes the basic principles that make mag-lev transportation so effective, namely the reduction of friction, a step further. "At its core, Hyperloop is all about removing the two things that slow down regular vehicles: friction and air resistance. To do away with the former, you make the pod hover above its tracks, like a magnetic levitation train… As for air resistance, that's where the tube comes in. The tubes enclose the space through which the pods move, so you can use vacuums to hoover out nearly all the air – leaving so little that the physics are like being at an altitude of 200,00 feet. And so, like a cruising airplane, a Hyperloop needs only a little bit of energy to maintain the pods' speed."[22] The Hyperloop systems have just begun testing, but the outlook is promising for this new technology, the mag-lev technology and the frictionless vacuum environment allows the trains to travel at speeds over 700 miles per hour.[23] Musk has also made claims that the Hyperloop system would be far cheaper than the high-speed rail

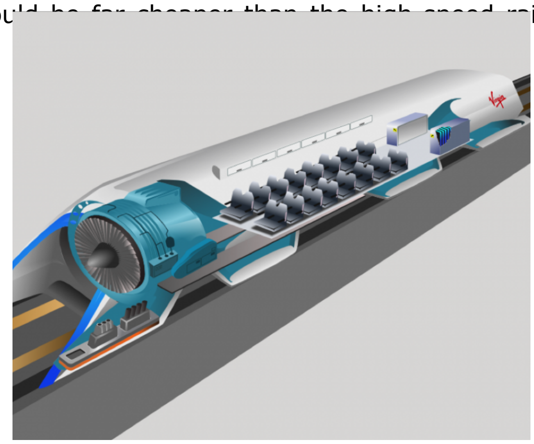

Figure 7: Hyperloop Passenger Pod

Table 8. Total cost of the Hyperloop passenger transportation system.

Component	Cost (million USD)
Capsule	**54** (40 capsules)
Capsule Structure & Doors	9.8
Interior & Seats	10.2
Compressor & Plumbing	11
Batteries & Electronics	6
Propulsion	5
Suspension & Air Bearings	8
Components Assembly	4
Tube	**5,410**
Tube Construction	650
Pylon Construction	2,550
Tunnel Construction	600
Propulsion	140
Solar Panels & Batteries	210
Station & Vacuum Pumps	260
Permits & Land	1,000
Cost Margin	**536**
Total	**6,000**

Figure 8: Hyperloop Cost Estimates

equivalent. He projected a cost for the San Francisco to Los Angeles route to cost roughly $6 billion, or $11.5 million per mile.[24] This has been refuted by many sources including the company Hyperloop On. They are currently attempting to make Hyperloop a reality in the San Francisco Bay Area. Hyperloop One's estimations land the cost of a 107-mile Bay Area project to be between $9 billion to $13 billion, or $84 million to $121 million per mile.[25] The Hyperloop system offers a potentially viable replacement for domestic passenger air travel. At estimated speeds that

Figure 9: Hyperloop Commercial Pod

commercial airlines, the Hyperloop offers a quick and extremely more fuel-efficient system than the average passenger flight. The Hyperloop system also offers a more efficient system than even the current mag-lev trains. While mag-lev trains require power along the entire length of track, Hyperloop systems will only require energy to a portion of the track to push the train along in a frictionless environment.[26] Hyperloop systems will also offer the ability to work with the current intermodal shipping industry. Creating pods that are specifically designed to handle the standard shipping containers of today, the Hyperloop system has the potential to become the most efficient means of commercial shipping.

These systems, however, are only as effective as their stations allow them to be.[27] The most significant bottleneck to any rail operation is the transfer point in which passenger embark and disembark from the trains. Looking at historical precedents and recent case studies will be crucial to creating a transit hub that can effectively balance both the current transit systems and the next generation of transportation.

SOLUTIONS

The speed of the Hyperloop and Magnetic Levitation systems offer a variety of solutions to the current problems of mass transit. These include connecting existing infrastructure to help reduce congestion and replacing systems altogether.

MEGA-AIRPORT

The ability to connect two airports to one another is a promising small-scale use of a hyperloop and mag-lev train systems. Connecting two airports within a distance of roughly 50 miles allows for more efficient use of a city's airport hubs. New York and Washington D.C. are prime examples of cities that could benefit from this strategy. Allowing New York to balance travel between LaGuardia, JFK, and Newark airport will help reduce the need for expansion and increase the versatility of the airports themselves. According to research done by Virgin Hyperloop One, "Linking airports together to create a mega-airport not only create greater capacity and maximizes the use of existing assets, but very importantly can either defer or significantly reduce capital investment spending needed to develop new or existing airports. In addition, grouping airport assets would create a ripple of benefits for airlines, passengers, and the regional economy."[28] This strategy also allows for the expansion of existing airports that are landlocked within a city to more rural areas that are cheaper to build, less intrusive for construction, and allow for a reduction of noise pollution in populated areas. New York's LaGuardia airport would be able to expand it runway network without paving over Rikers Island or Jamaica Bay causing much less harm to the environment.

REPLACING DOMESTIC AIR TRAVEL

A more extreme solution to the problems of domestic air travel is simply replacing it all together. As discussed earlier in the sections on the Hyperloop and Magnetic Levitation systems, speed and efficiency are key to these new types of rail transportation. Mag-lev systems, while slower than the average commercial airliner, would allow for passengers to make up most of the time they currently spend in airports themselves. Even a slight reduction in these times would allow for the mag-lev systems to quickly surpass most intermediate domestic flights in terms of total transportation time. The Hyperloop system would allow for travel quicker than the average passenger airline. While rail travel was once the dominant means of long-distance transportation in the United States, it has become almost non-existent in today's society. One of the problems facing domestic rail travel is that a majority of the tracks themselves are not owned by passenger travel services but instead freight companies that lease use of the tracks to passenger rail on the side. This causes passenger travel to experience delays and stoppages often as the freight trains are given priority to the passenger trains. Creating a network of Hyperloop tubes or mag-lev lines would ensure that the domestic passenger rail travel is given priority on its system allowing the United States to become quicker and more efficient in everyday rail travel. Railway stations were once the main hubs of transportation within the United States and are often romanticized today in books, cinema, and pop culture. A return to these hubs as the gateway and connection of our cities could go a long way to help to reduce the stress and tediousness found in today's air travel.

CASE STUDIES

UNION TERMINAL

CINCINNATI, OH

Cincinnati's Union Terminal, a "Temple to Transportation," built in the 1930's is one of the great transportation hubs of the twentieth century. The station was designed and constructed to fix the chaos that was the Cincinnati rail stations. At the turn of the nineteenth century the railways were scattered across the city at five major stations, none of which had a natural connection to one another, creating a logistical nightmare for passengers passing through Cincinnati. This masterpiece of art deco architecture created one of the most successful railway hubs in the country. At its peak during World War II, the station, designed to handle 216 trains with roughly 17,000 passengers traveling through was handling over 34,000 passengers each day.[29] Unfortunately for the Union Terminal, like all passenger rail throughout the United States, a major declined occurred in the rail travel following the Second World War. By 1970, the once bustling station was only servicing two trains a day. In 1972, the Union Terminal closed its doors as a passenger rail station. After the railyard was purchased by a freight transport company to use an expanded railyard, the city worked to protect the station from demolition but was unable to save the terminal concourse, which was destroyed to allow for intermodal container freight cars that were too tall to fit under the existing concourse.

Figure 10: Cincinnati Union Terminal

Designed by architects Alfred T. Fellheimer, Steward Wagner, Paul Philippe Cret, Roland Wank, the Cincinnati Union Terminal is arguably one of the most significant pieces of art deco architecture.[30] It was built sparing no expense and has been estimated to be valued at well over half a billion dollars according to the construction cost of the last few years. The original tea room is adorned from floor to ceiling with now priceless Rookwood pottery. While the building was extravagant in its

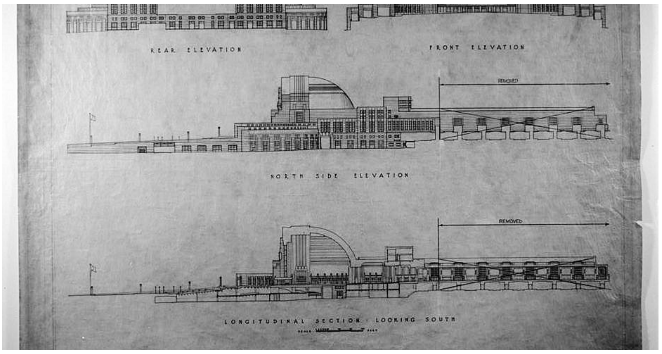

Figure 12: Union Terminal Section

materials, it was also incredibly thorough in the subtlety of design. The station was designed to focus on the compression and decompression involved in train travel. For travelers entering the station, they began their experience by leaving the metal tube of the passenger cars. From there the passengers would enter in the concourse, the terminal, the rotunda, and the exterior each of which grew in size from the previous spatial experience and allow the passenger to slowly acclimate to and from the space and into the city of Cincinnati.

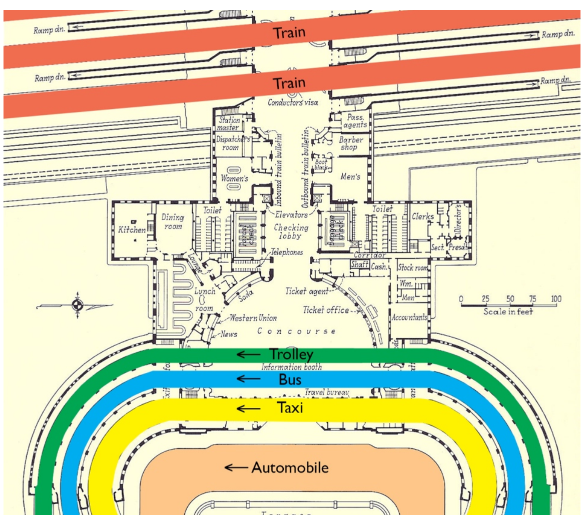

Figure 13: Union Terminal Multi-Modal System

While the Union Terminal was designed to be a railway hub for the city of Cincinnati, it also was incredibly efficient at utilizing all types of transportation. The Union Terminal presents one of the most important precedents for my thesis because it combines all the modern transportation types of its age into an incredibly efficient system that could handle capacity well over its designed limits. By ferrying passengers to and from local, city, and statewide transportation it successfully merges small, medium, and large-scale transportation types into a seamless cohesion.[31] I have had the pleasure of intensely studying this building inside and out over the years and continued to be inspired and in awe of every visit.

PENNSYLVANIA STATION

NEW YORK CITY, NY

Figure 14: Penn Station Interior

The original Pennsylvania Station in New York City was built to be the grand entrance to one of the great metropolitan cities of the world.[32] Designed in the early twentieth century by architectural firm McKim, Mead & White, Pennsylvania Station was modeled after the Roman Baths of Caracalla, Diocletian, and Titus and incorporated 84 granite Doric columns based on the Acropolis, the Brandenburg Gate, St Peter's Basilica, and the Bank of England.[33] The station truly made everyone who passed through feel a sense of importance for both themselves and the city they were entering. Pennsylvania Station is widely considered to be one of the great Beaux Art masterpieces of architecture. Certainly, one of the most intrinsically beautiful transportation hubs ever constructed. Unfortunately, its beauty was not to last. Following the collapse of the rail industry in the United States, Pennsylvania Station proved to be too much for the struggling railroad to support and was sold off. On October 29, 1963, demolition began on one of the great American architectural landmarks. The New York Times ran a front-page article stating, "Pennsylvania Station, a grimy monument to an age of expansive elegance, suffered the fate of an anachronism yesterday."[34] The station that replaced Pennsylvania Station has since become a tragedy of modern architecture; an irreplaceable building was torn down to create one of the most hated sites in New York City.

Figure 15: Penn Station Current Interior

Current day Penn Station is arguably the busiest transportation hub in the western world, handling over 650,000 people daily.[35] While the glorious station above was demolished, the concourse and track system below remained in place while Madison Square Garden was built above. What remained was a cramped labyrinth of corridors and platforms that have confused passengers for decades.[36] Comparing the original Pennsylvania Station with the current Penn Station, the Yale architectural historian Vincent Scully describes, "One entered the city like a god; one scuttles in now like a rat."[37] The complete absence of natural light and exterior views removes the travels from any sense of their location in space and time. The low ceiling hallways confine the rider in a never-ending stressful

Figure 16: Penn Station Proposed Interior

experience full of advertisements, conflicting signage, and massive crowds. The passengers who travel through this station are suffocated in a sarcophagus of the once proud landmark.

Pennsylvania Station has a legacy that hopefully has not yet been completed. There is renewed hope for a restoration of a new terminal built in honor of its predecessor. The city of New York has had enough of the current iteration of the station that is desperately overcrowded and undersized for what is needed in modern day New York City. The design of this proposed station will need to be built to outlast its predecessors. Currently, there is a major proposal to renovate the existing station and repurpose the adjacent post office (also designed by McKim, Mead & White).[38] However, the city of New York has an opportunity to create both a true replacement to Pennsylvania Station and truly the station for the future of mass transit in the United States. Currently, there is a growing movement that hopes to see a rebuilding of Pennsylvania Station.[39] However, simply rebuilding this station is not an option in our ever-changing modern society. By implementing new technologies that are beginning to come online in mass transit the station, combining the artistic nature of the original style, and creating a frame that can handle the future direction of infrastructure the station can easily create a new gateway into the great Western metropolis of New York City.

HAUPTBAHNHOF TERMINAL

BERLIN, GERMANY

Opened in 2006 on the previous site of one of Berlins largest rail stations, the Berlin Hauptbahnhof or Berlin Central Station is the culmination of an effort to relink East and West

Figure 17: Hauptbahnhof Terminal

Berlin and modernize the city with a state of the art rail network. The station was designed by Meinhard von Gerkan of the architectural firm Gerkan, Marg, and Partners. The building itself focus on function over form, combining

Figure 18: Hauptbahnhof Section

two sets of tracks perpendicular to one another that cross above and below one another. The lower platform consists of eight tracks and is located below ground to allow for connection to other subterranean lines in Berlin. The upper track consists of six tracks and connects to the elevated rail network that runs throughout Berlin. The upper tracks are housed in a glass archway that spans a distance of over 150 feet and a height that reaches 50 feet above the platforms.[40] The upper platforms are intersected by two glass towers that house 470,000 square feet of commercial space. These towers allow the station to abstractly resemble the previous station that was heavily damaged during World War II. The station itself is very efficient at transferring passengers between the multiple sets of trains that cross at this point. When the station was built in 2006, it was designed to house 14 train tracks with an expansion capacity of 4 additional tracks.[41] It connected itself to the smaller inner-city transit systems through a bus and taxi drop off location. In 2010 it was also connected to the Berlin tram system to give even more integration within the city.

The Berlin Central Station is a prime example of a modern regional transit hub build to connect multiple tracks that are coming into the station from multiple directions. The design of the station allows it to increase its longevity by creating a space for future expansion sites.

This will be crucial for new transit hubs as we continue to see the exponential growth of populations and passengers of inner and inter-city rail travel. The design of the station echoes the station of the past without binding itself to these classical forms. The towers flanking either side of the main entry vaguely mimic the original structure, and there is a sense of familiarity with the design of the upper platforms. These subtle moves are important to respecting the past design of the stations without sacrificing modern design and methodology.

TRANSBAY TRANSIT CENTER

The Transbay Transit Center is a modern-day transportation hub built for current mass transit in the city of San Francisco. The center was first proposed in the early 2000's to replace an aging and overcrowded transit system and allow for commuters to easily transfer between the primary mass transit systems of the bay area. The transit center combines eleven different transit systems under one roof to create the 'Grand Central Station of the West,' these include Amtrak, CalTrain, BART, Greyhound Bus, and the under-construction high-speed rail between San Francisco and Los Angeles. The Transbay center is expected to handle 100,000 passengers per day and over 45 million a year.[42] The Transbay Transit Center under

Figure 19: Transbay Transit Center Section

construction now is being built to replace the original transit center constructed in the late 1930's. Similar to the history of Cincinnati's Union Terminal the station saw its peak usage during World War II, only to see a steady decline until the city of San Francisco dismantled its Key light rail system the station was converted just to handle bus traffic and steadily declined in usage. This new transit hub will reinvigorate the spirit of the original center and reconnect the San Francisco city center to the primary California rail lines, just as its predecessor had done 80 years prior.

The station is being constructed as a LEED Gold facility and is expected to be one of the defining locations in the city.[43] The architects,

Figure 20: Transbay Transit Center

Pelli Clarke Pelli, used an undulating façade with a geometric pattern designed by mathematical physicist, Dr. Roger Penrose. The building, taking advantage of a vertical space uses light wells to get natural light into the lowest levels of the center which avoids the dark and inhuman aspects that are often attributed to New York City's Penn Station.

The Transbay Transit Center, true to the green thumb of San Francisco helps to offset the large parcel of land it takes up by adding in a new 5.4-acre city park onto the roof of the center.[44] Seen in the adjacent image is an artist rendition of the city garden and the protruding tops of the light wells.[45] Overall the Transbay center provides an excellent design for the modern-day transit hub. However, with the recent advances in technology in the world of transportation, there is some risk that the current modes of transportation it was designed for could be going out of use, and we could see a similarly short lifespan to the original Transbay Center and the Union Terminal.

CONCLUSION

One of the most critical aspects of modern human civilization is our ability to travel and communicate. Finding ways cheaper and more efficient ways to interact and trade is becoming essential in the new age of globalization. The Hyperloop and Magnetic Levitation systems that are currently in development and under construction offer one of the most efficient ways to move large quantities of people and products across long distance at the highest speed possible. Finding a way to create transportation hubs that are both long-lasting and efficient at integrating people and transit into a smooth flowing system will be the key to creating a pleasant and usable transit system well into the future. As we begin a renewed focus on infrastructure in the United States, we should take this opportunity to create the systems that will last a lifetime. Iconic transportation centers such as New York's Grand Central Station continue to be the gateways for major cities long after their construction, and we as a society should strive to recreate this level of system for the future. For these new systems to be successful, we will need to create a new generation of transportation hubs that will offer a solution for our current transportation issues.

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Reimagining Rail Travel in the United States

JOSHUA PEDOTO
Miami University

POST ESSAY ADDENDUM

Following the completion of my thesis position paper I focused on the means and method of producing a transit hub that could be used as a model for future Hyperloop expansion. I narrowed down the locations for this terminal to Washington DC, Chicago, and Cincinnati. Initially my thoughts and process focused on Chicago, as a major midwestern hub it would be a logical point to bridge the Eastern and Western parts of the country. However, Chicago was soon abandoned due to the complexity of the site master planning and the massive size that would be required for this transit hub. Instead I focused my attention on Cincinnati, Ohio. This mid-sized midwestern city would be a perfect location for a region hub and the size of project I was looking to tackle. I quickly settled on a project site located in the cities West End neighborhood. The historical rail center of the city and a neighborhood that has scene constant turnover since it was split in two by the construction of Interstate 75. This neighborhood is also located around some of the city’s most prominent buildings; including the Cincinnati Union Terminal, Music Hall, and the under-construction FC Cincinnati Stadium. The Union Terminal as one of the preeminent design examples of Art Deco architecture provided one of the most challenging buildings to work with in the nearby location.

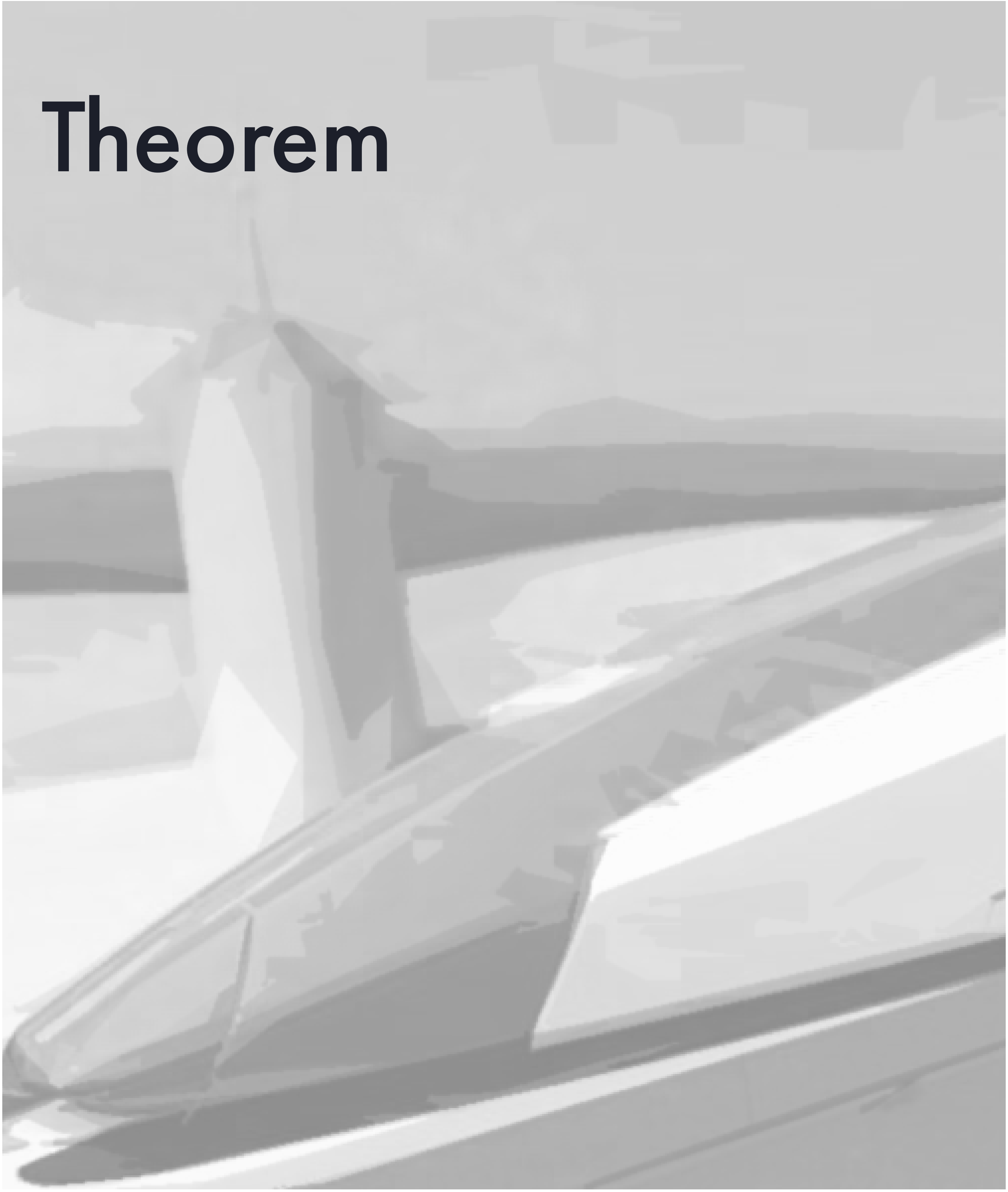
POST WORK ADDENDUM

With my thesis presentation and work complete I am able to reflect on the work of the project and the next steps I would like to complete. My final presentation focused on the construction of a self-sustaining hyperloop terminal in Cincinnati, Ohio. This building would host at least 4 million people each year in a transit system that would span the country. The hyperloop terminal would be positioned above Ezzard Charles Drive and would directly communicate with the Cincinnati Union Terminal in a newly planned axis that would connect the two buildings as the past and future of rail transit. While I was criticized in my presentation for placing a futuristic terminal in a present day city, I would argue that this is in fact where the terminal is needed most. Replacing domestic air travel is a huge step in fighting climate change, and one that has not been given enough precedent in current studies and while it is fun to imagine a future where personal vehicles are not present, I would argue this is a dangerous assumption that pushes a project like this further out of reality.

One of the biggest shortcomings for my thesis project was a lack of understanding and investigation of a country wide system and how these tracks might connect cities across the country and the cost that would be associated with this. I started out with a grand idea to build a true system but was forced to cut this from my project as my ambition exceeded the time I had for the project. Another aspect lacking in my project is the true environmental cost associated with air travel, and how a system like this could benefit the United States as we look to push toward a greener future.

As a whole, I set out on this thesis process with the goal to create an image of what a hyperloop terminal may look like in just a few decades and how this technology is poised to replace domestic air travel for domestic intercity passenger transportation. I am very satisfied with the work I was able to achieve and feel that it is still an important idea that should be researched further.

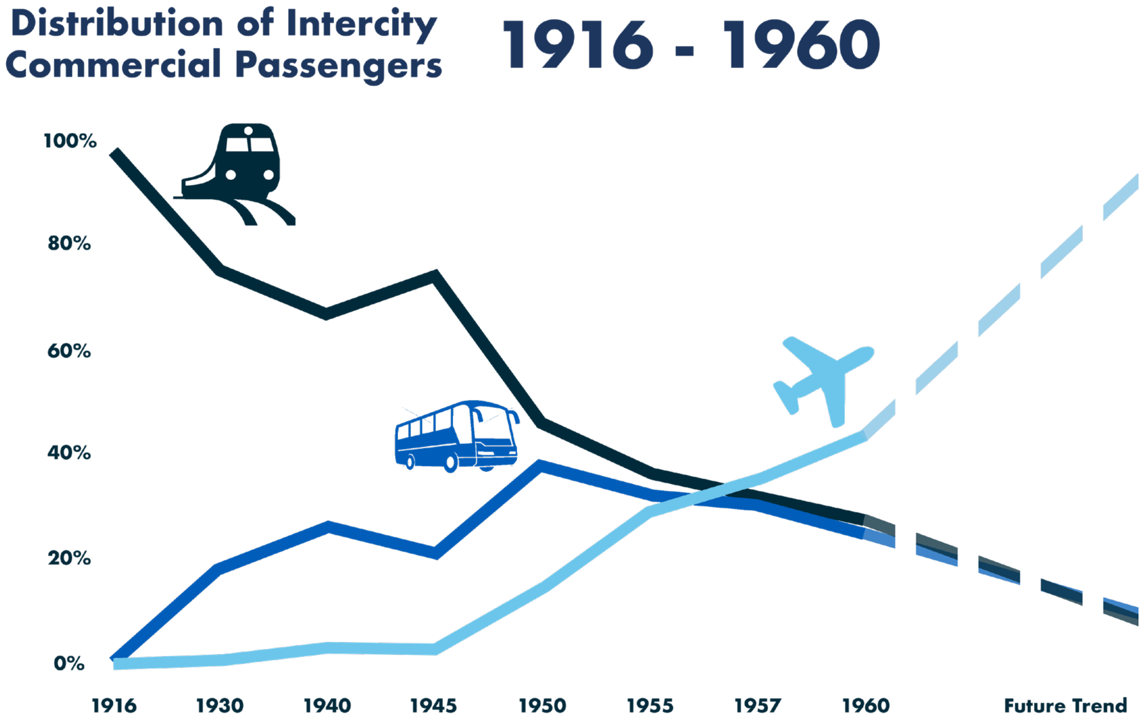
Theorem



Theorem

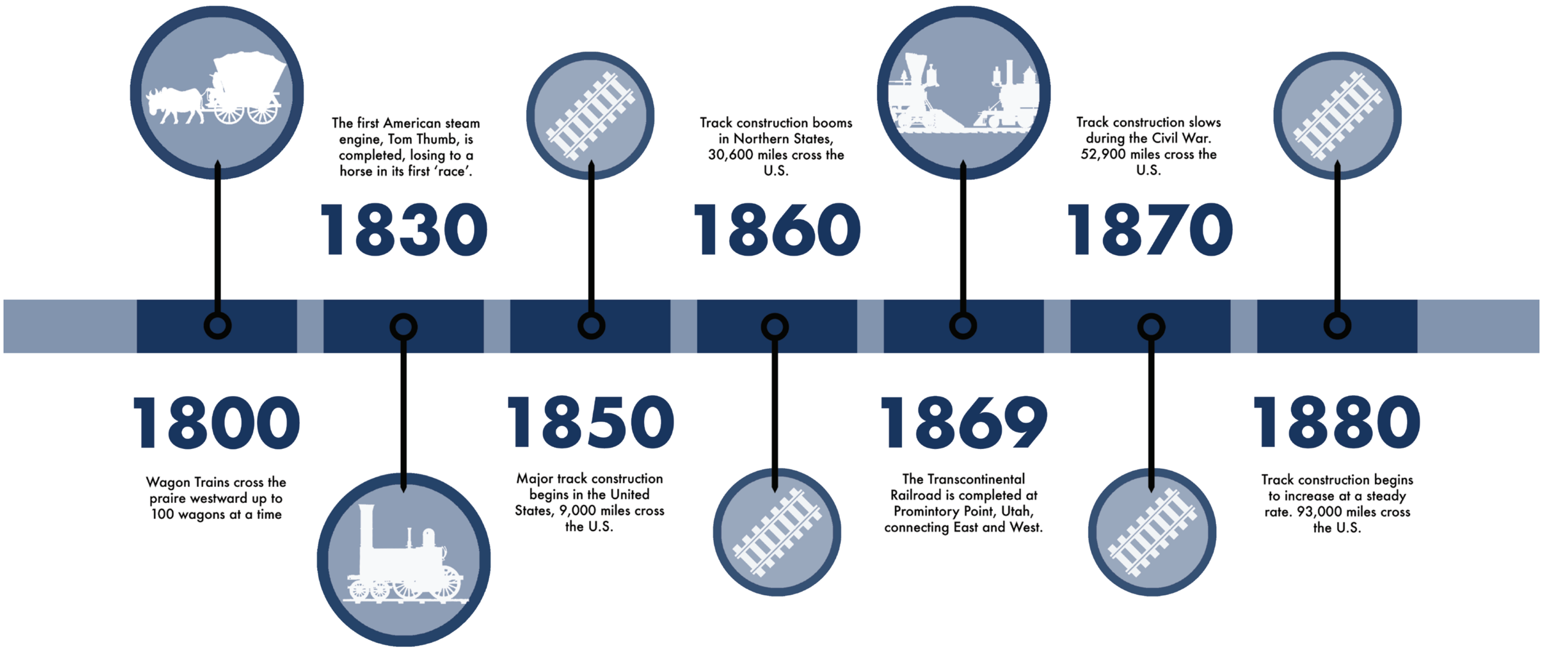
History of U.S. Intercity Travel

The basis of my thesis focuses on the modern day intercity travel in the United States. Today, roughly 90% of all commercial intercity travel is done via the air industry, which is incredibly environmentally inefficient for short distance traveling. Looking at the past, present, and future rail travel I will attempt to replace air travel.

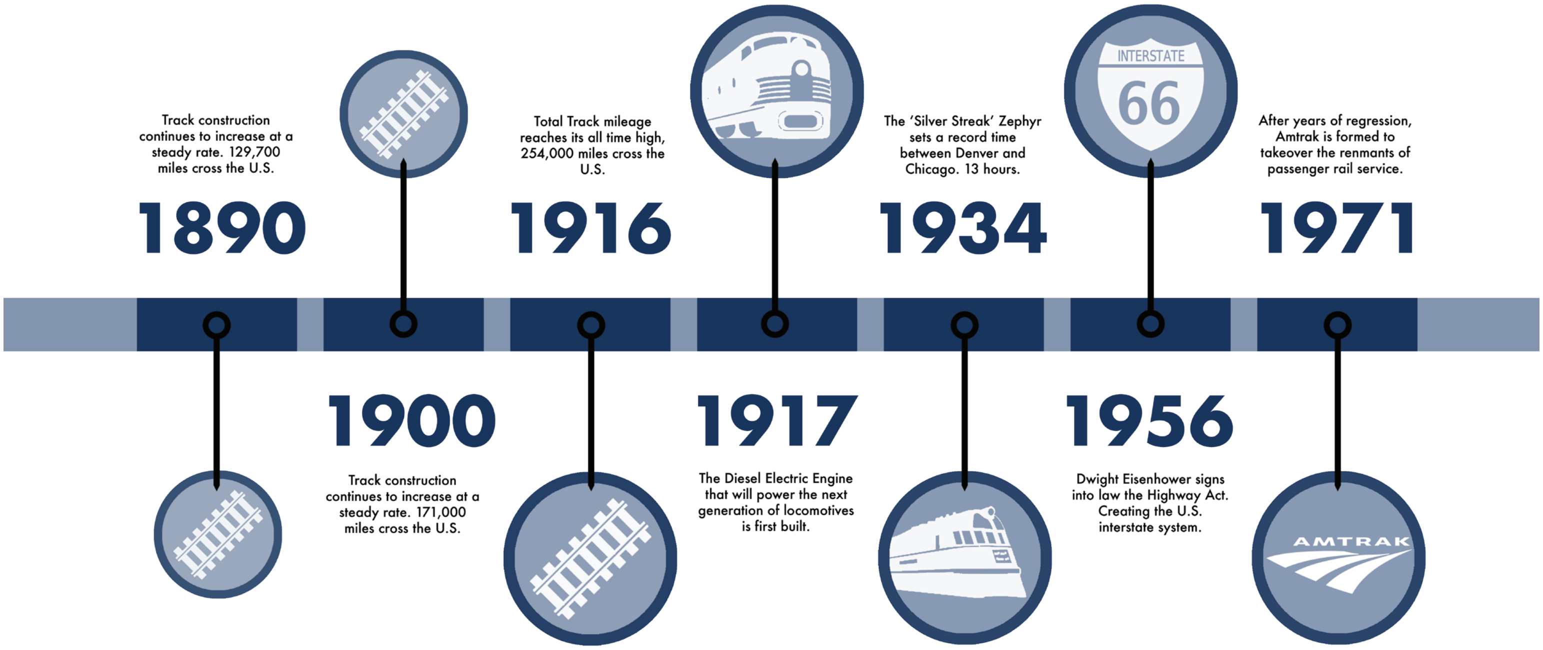


Theorem

History of U.S. Intercity Travel



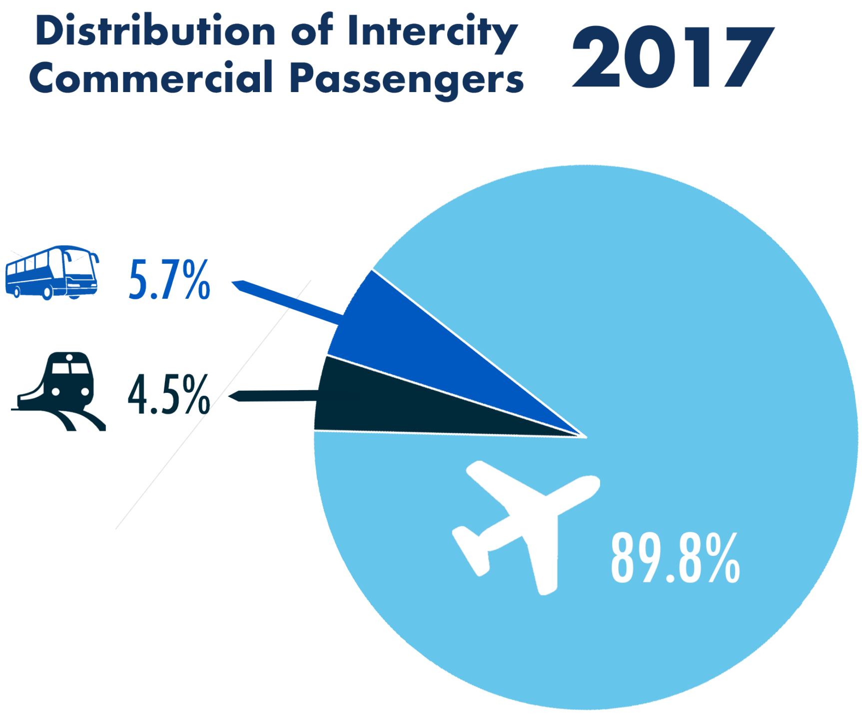
Timeline | 1800 - 1880



Timeline | 1890 - 1956

Theorem

History of U.S. Intercity Travel

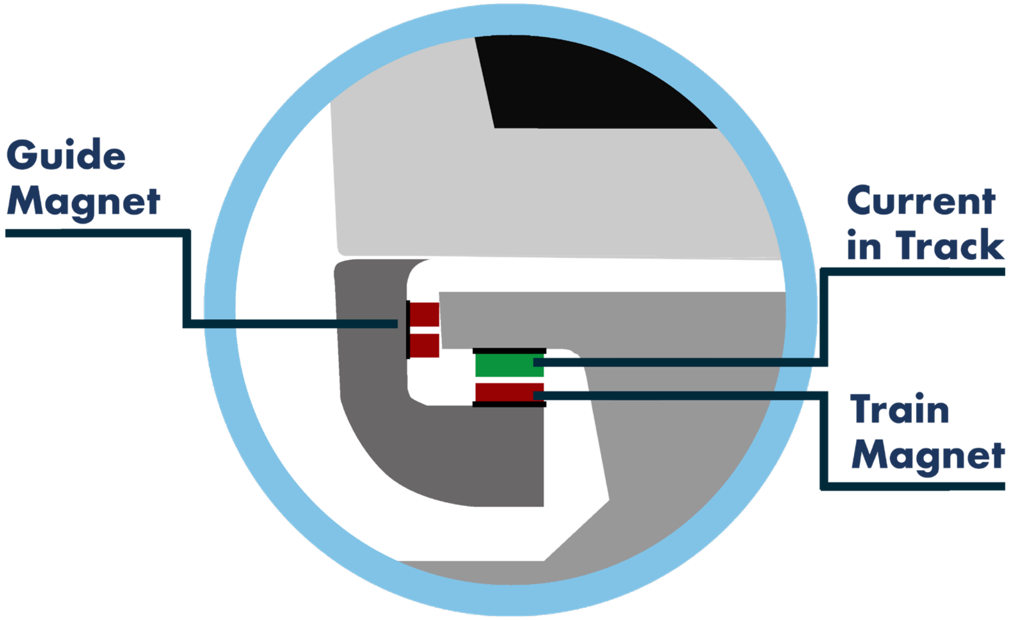


Cincinnati - Chicago Travel Time

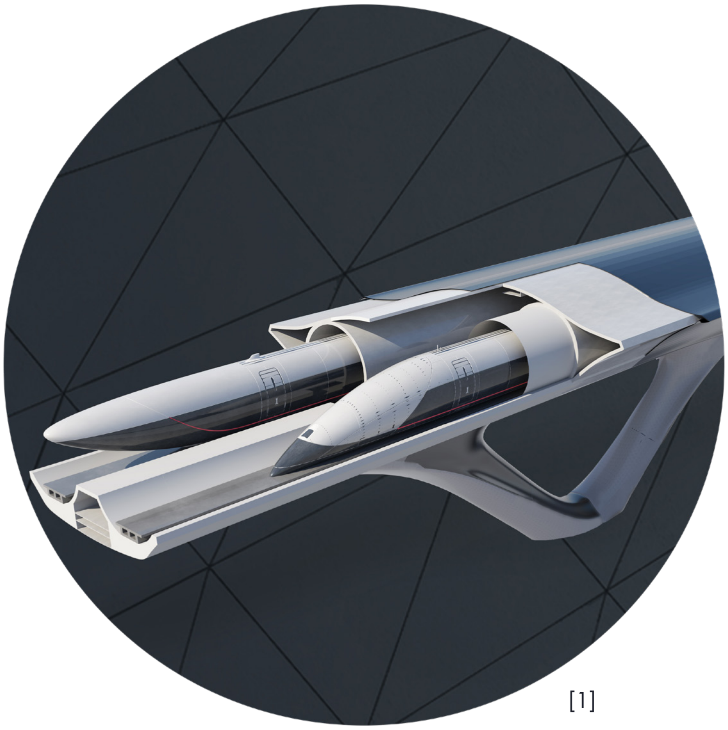
Theorem

Hyperloop Concept

The hyperloop systems that are being researched today offer an incredibly promising alternative to the commercial air industry we have today in the United States. By using the concepts of Magnetic Levitation, Hyperloop systems add a vacuum tube around the train to create a frictionless system capable of surpassing an airline in speed.



Mag-Lev Technology



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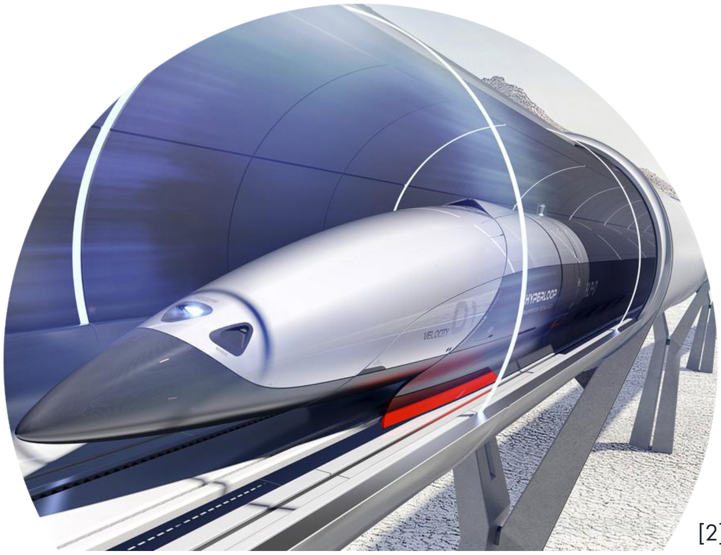

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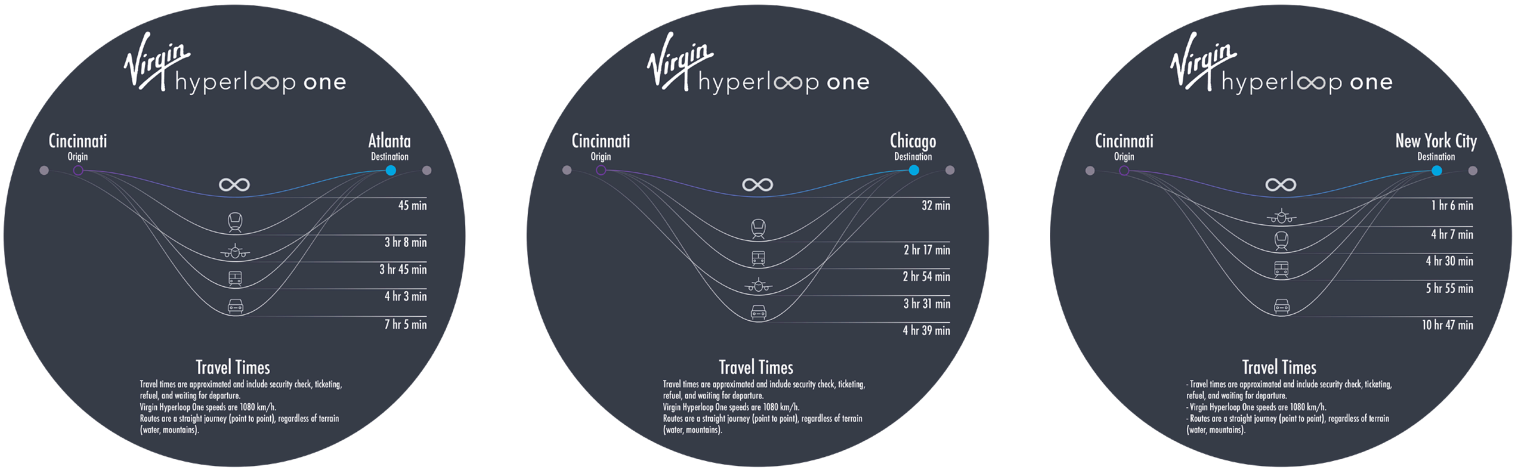
Hyperloop Conceptual Images

Theorem

Hyperloop Concept



Hyperloop Theoretical Times

Hyperloop Theoretical Routes

Site Analysis

Site Analysis

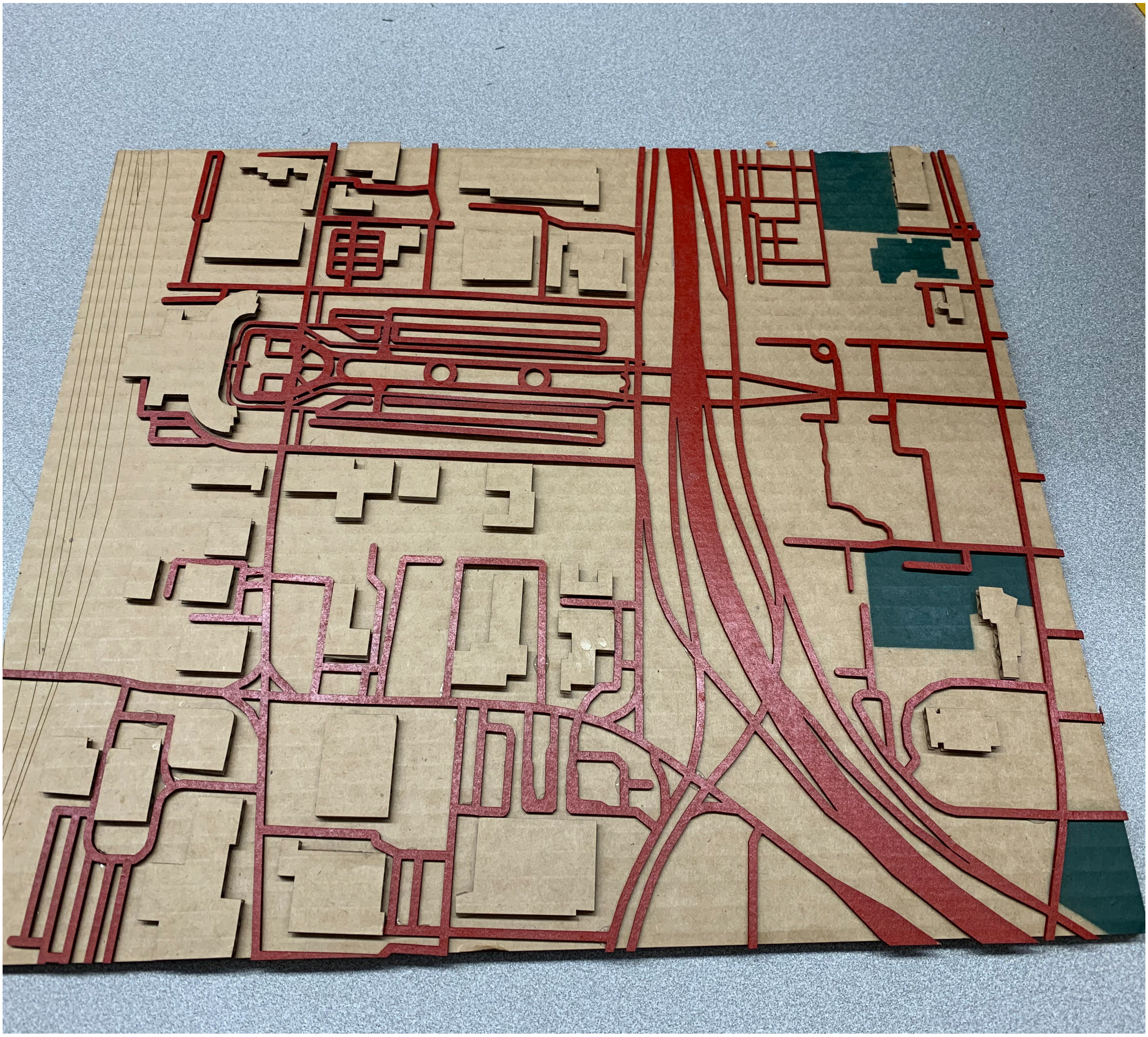
Cincinnati | Ohio

- Population of 301,000 (est. 2017)
- Population of 2,100,000 in Greater Metro Area (2010 Census)
- 28th Largest Metropolitan Area in the United States
- Fastest Economic Growth in the Midwest (2016)
- Within a 1 day drive of 2/3rds of US Population
- Long History of Rail Travel

West End Context Map

Site Analysis

Cincinnati | Ohio

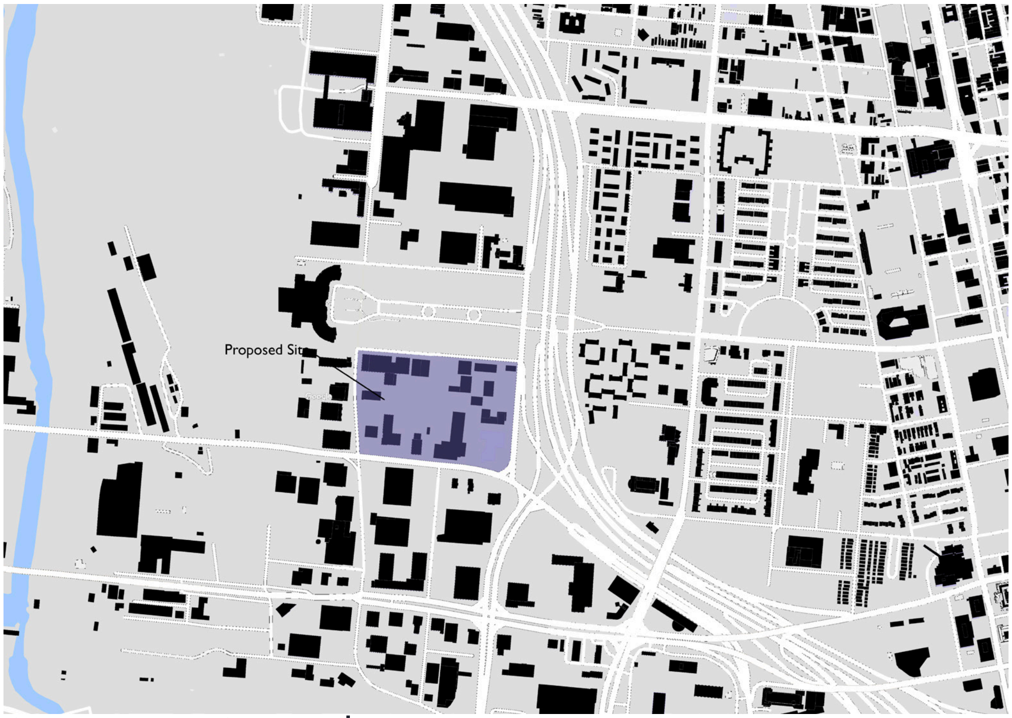


West End Context Model

Site Analysis

Cincinnati | Ohio

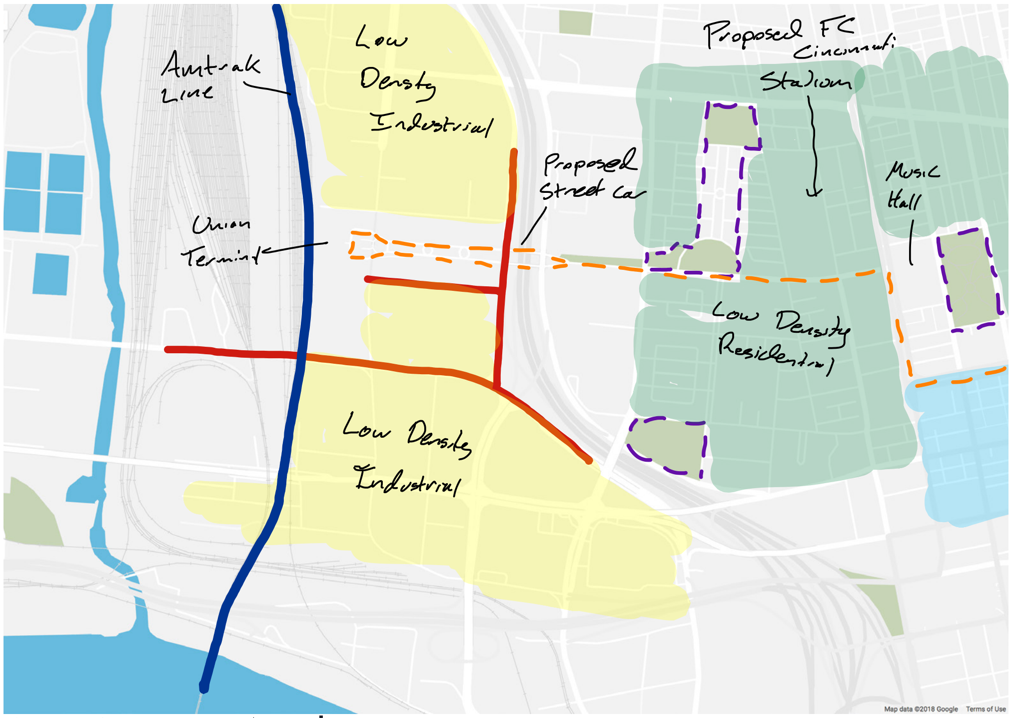
Initial Site Aerials



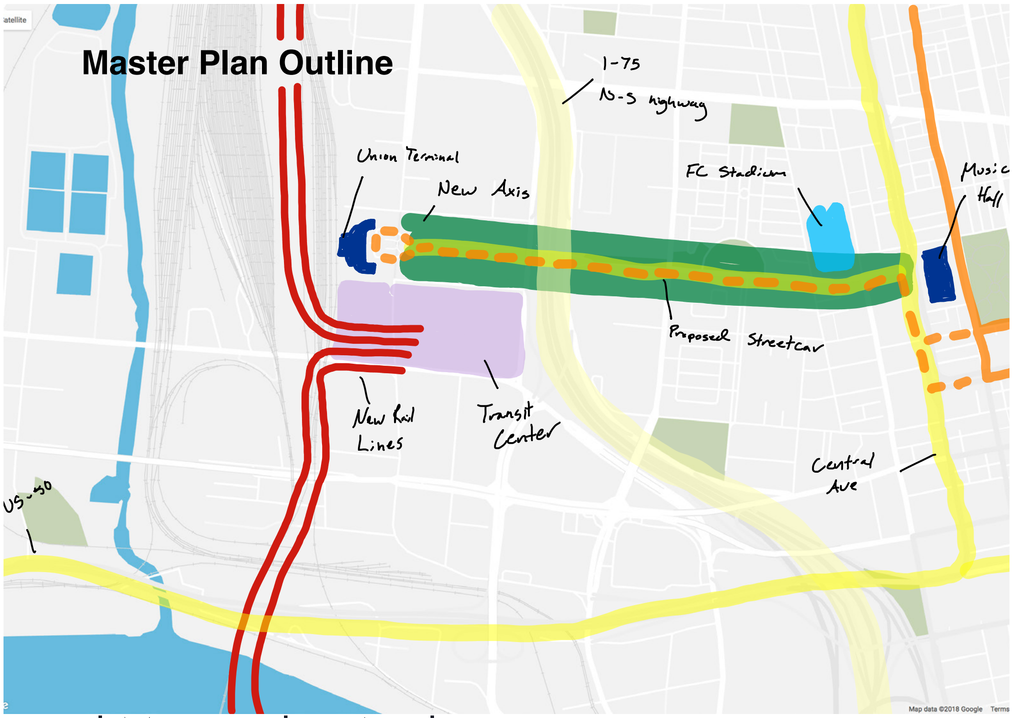
Site Figure Ground

Site Analysis

Cincinnati | Ohio



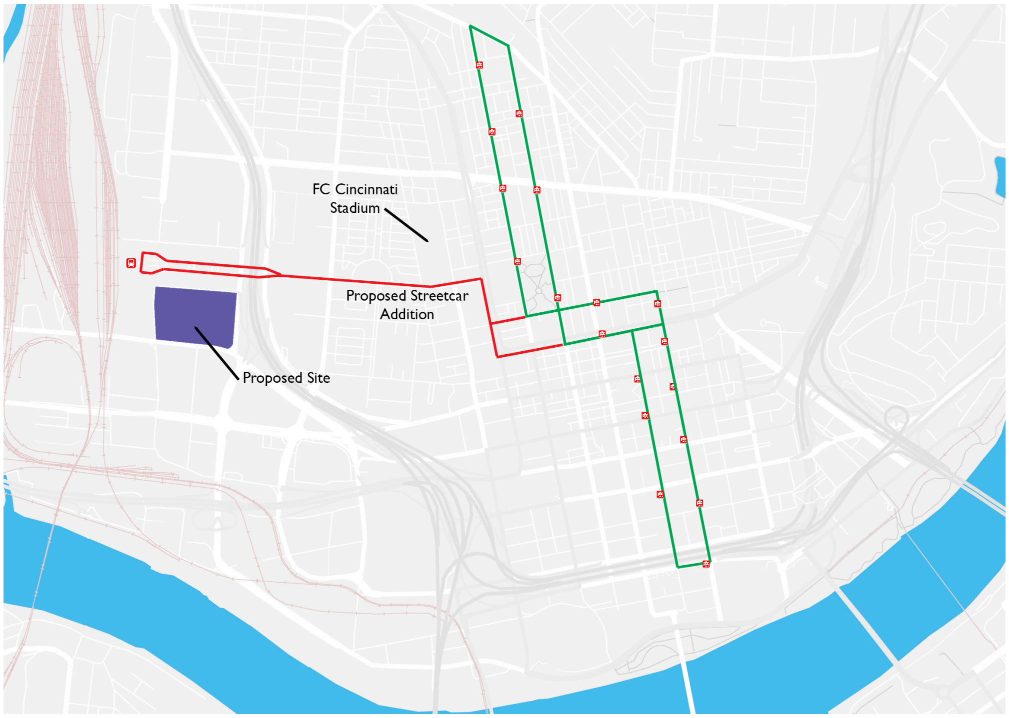
Site Context Analysis



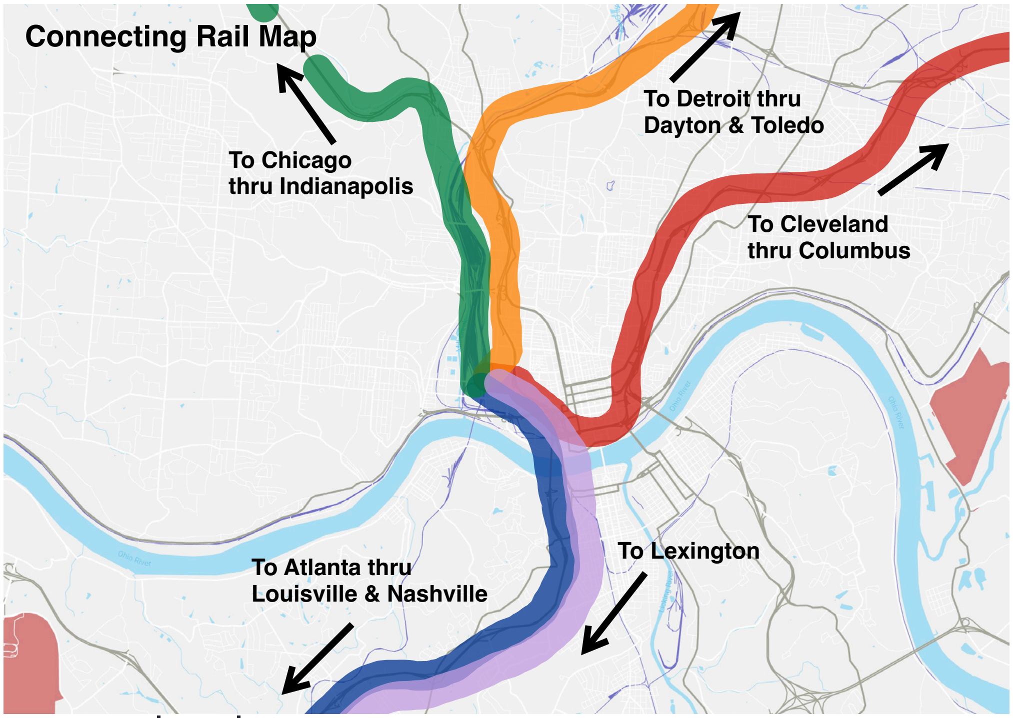
Initial Master Plan Analysis

Site Analysis

Cincinnati | Ohio



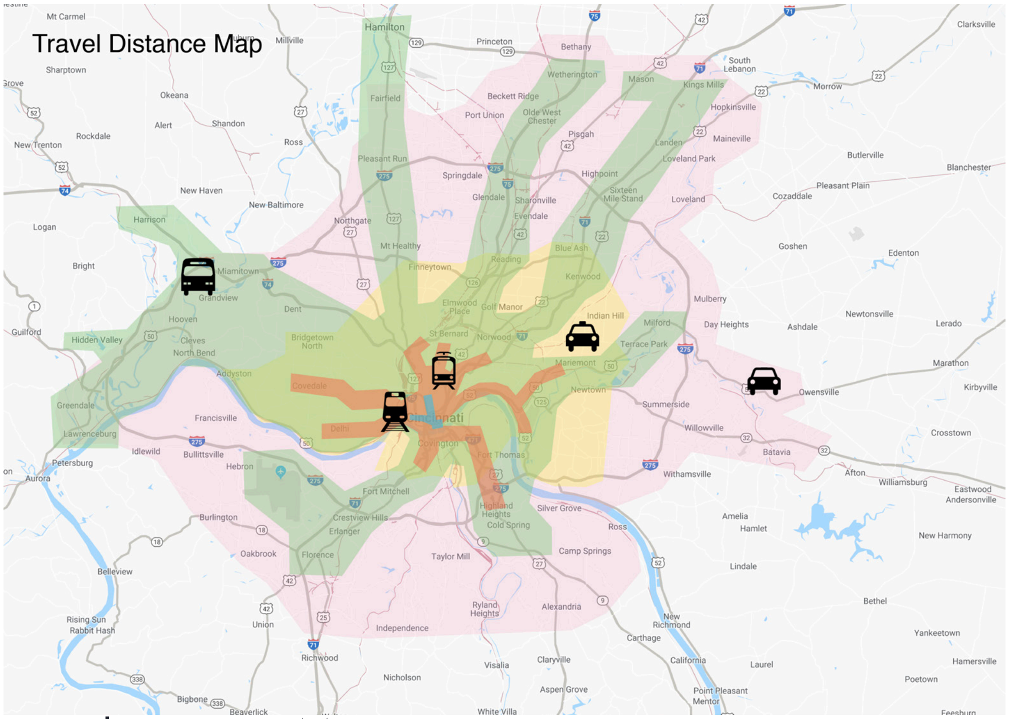
Downtown Cincinnati Streetcar



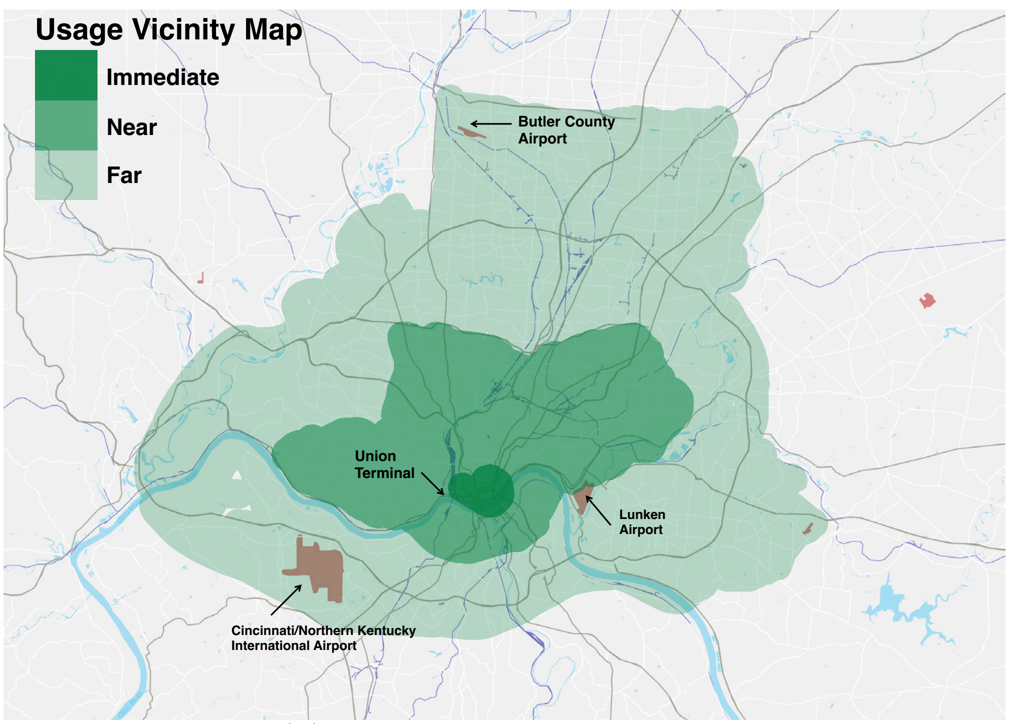
Potential Rail Connection

Site Analysis

Cincinnati | Ohio



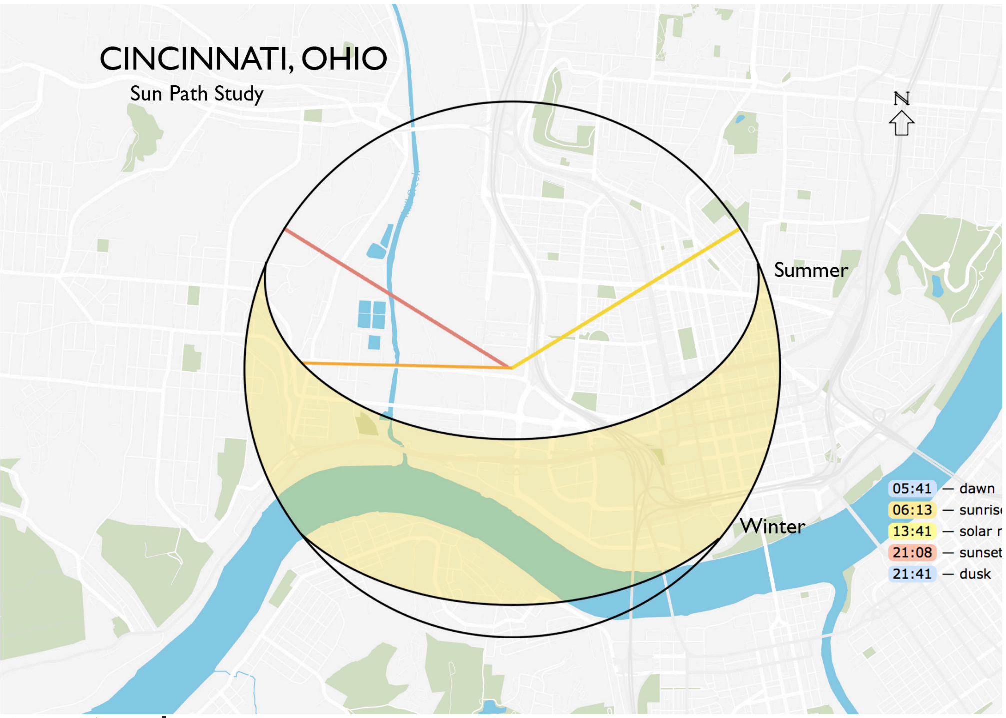
Travel Distance Map



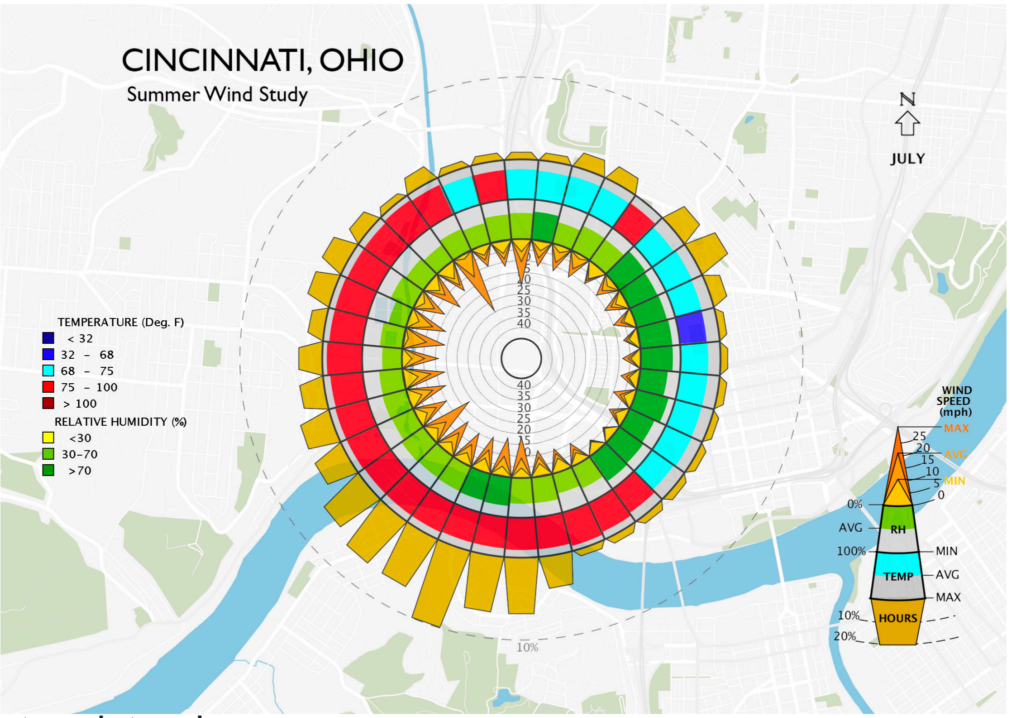
Usage Vicinity Map

Site Analysis

Cincinnati | Ohio



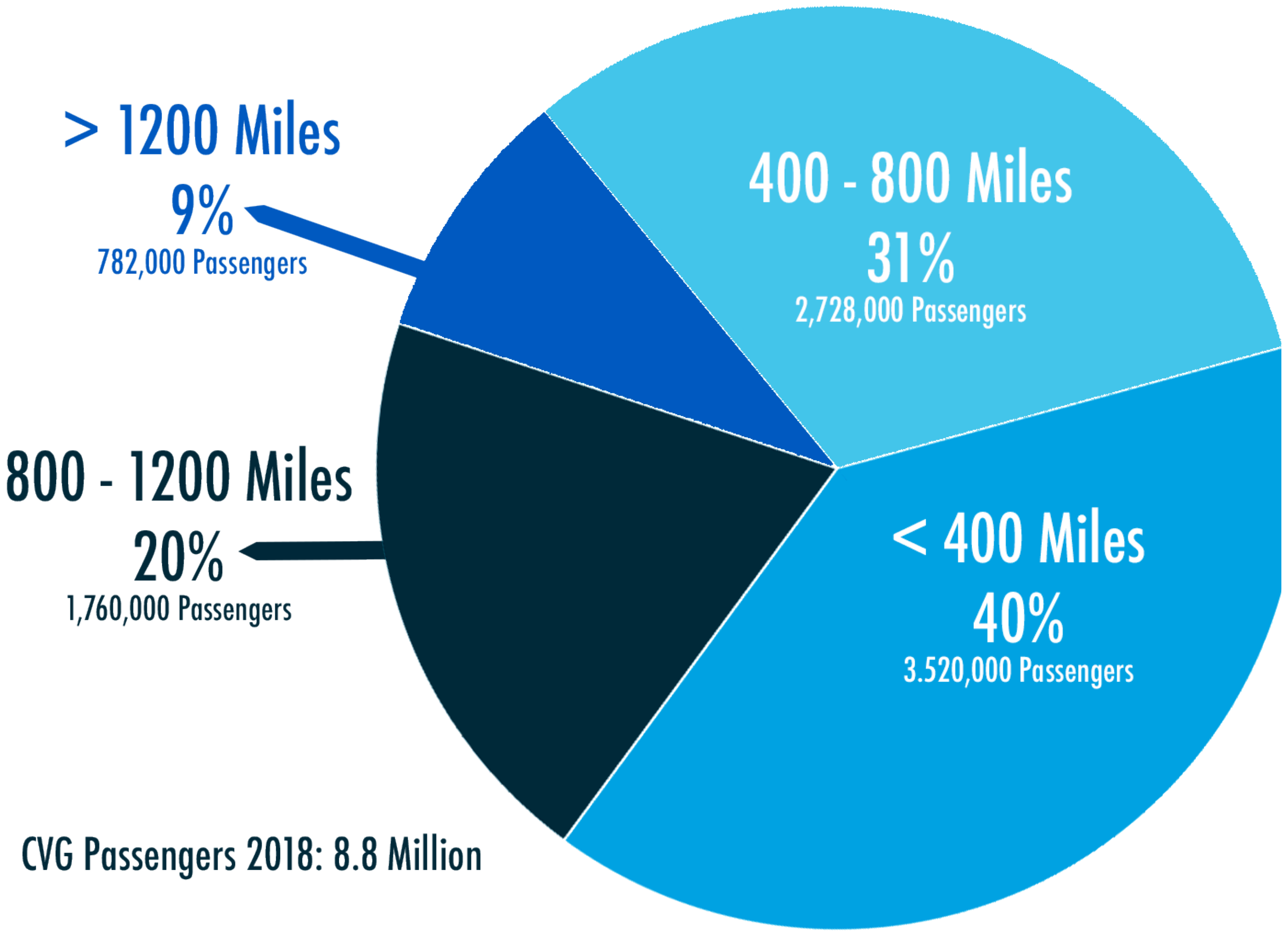
Sun Angle Diagram



Wind Analysis Diagram

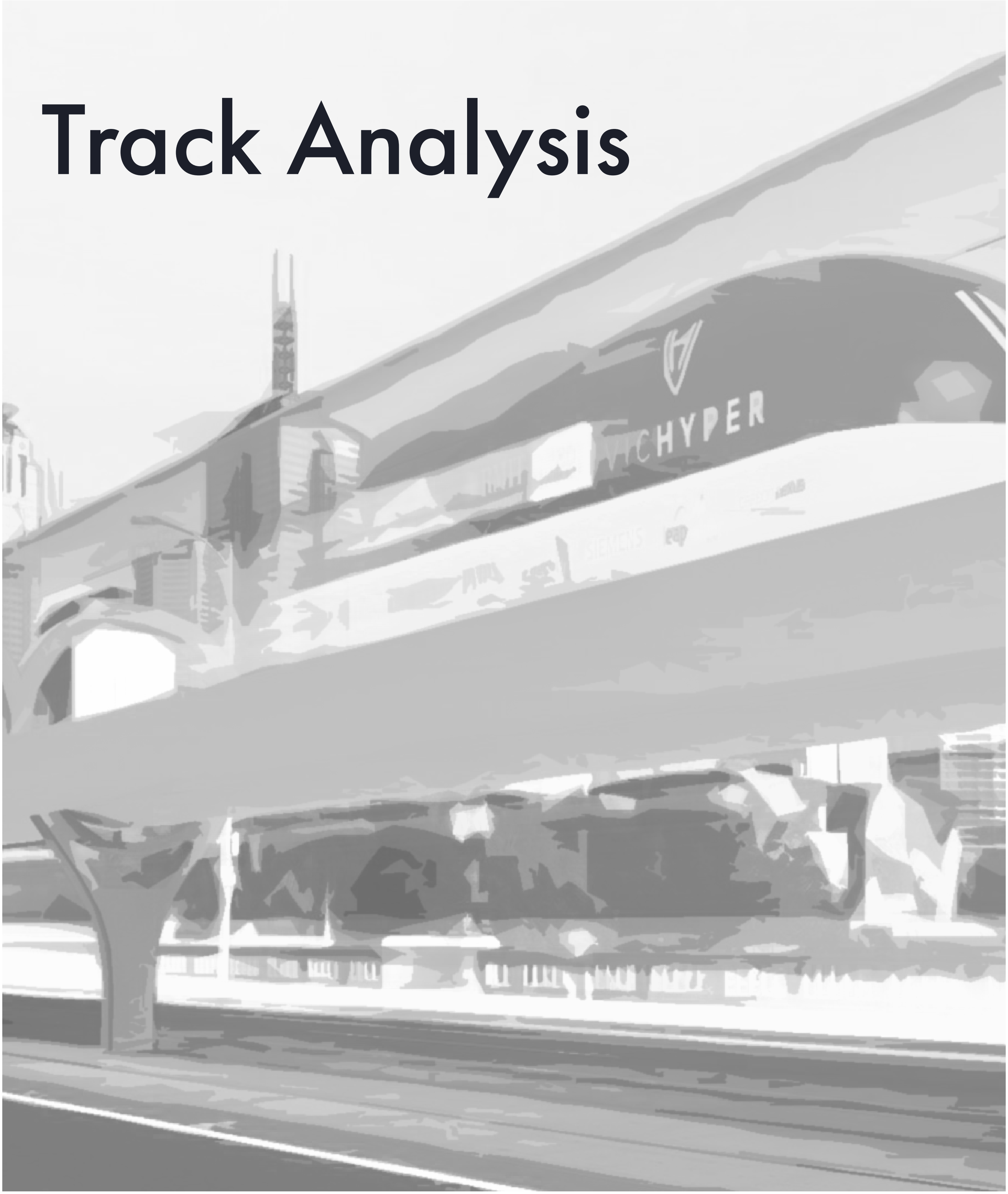
Site Analysis

Cincinnati | Ohio



CVG Flight Breakdown

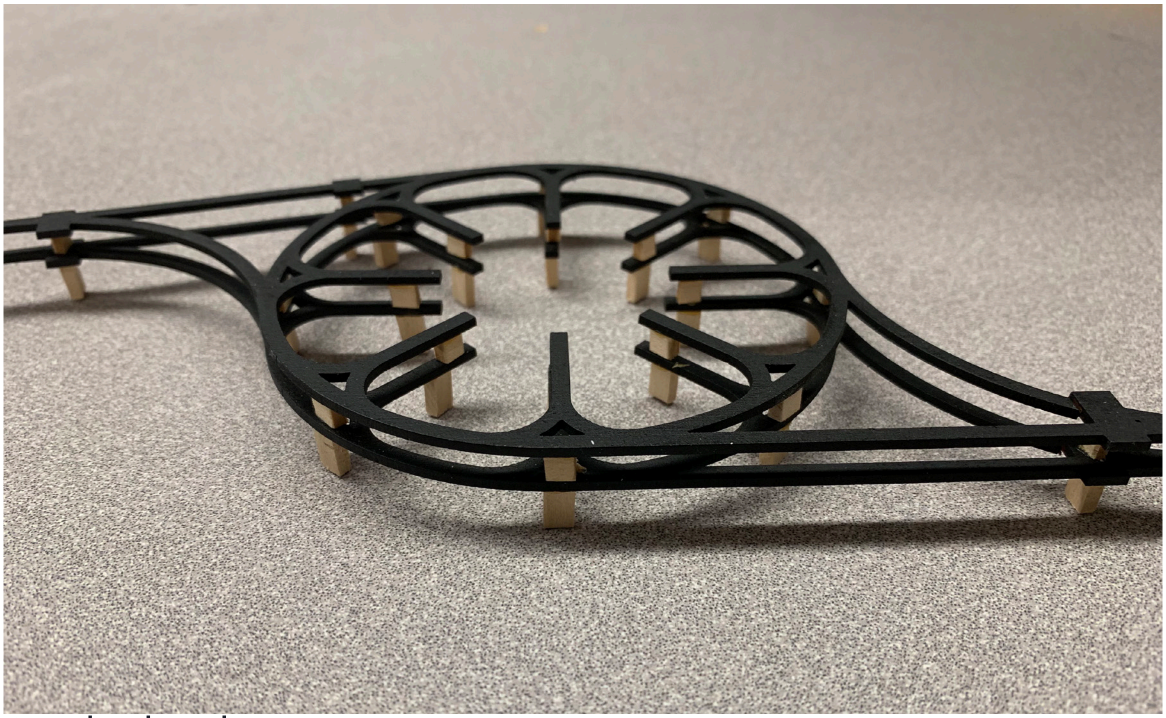
Track Analysis



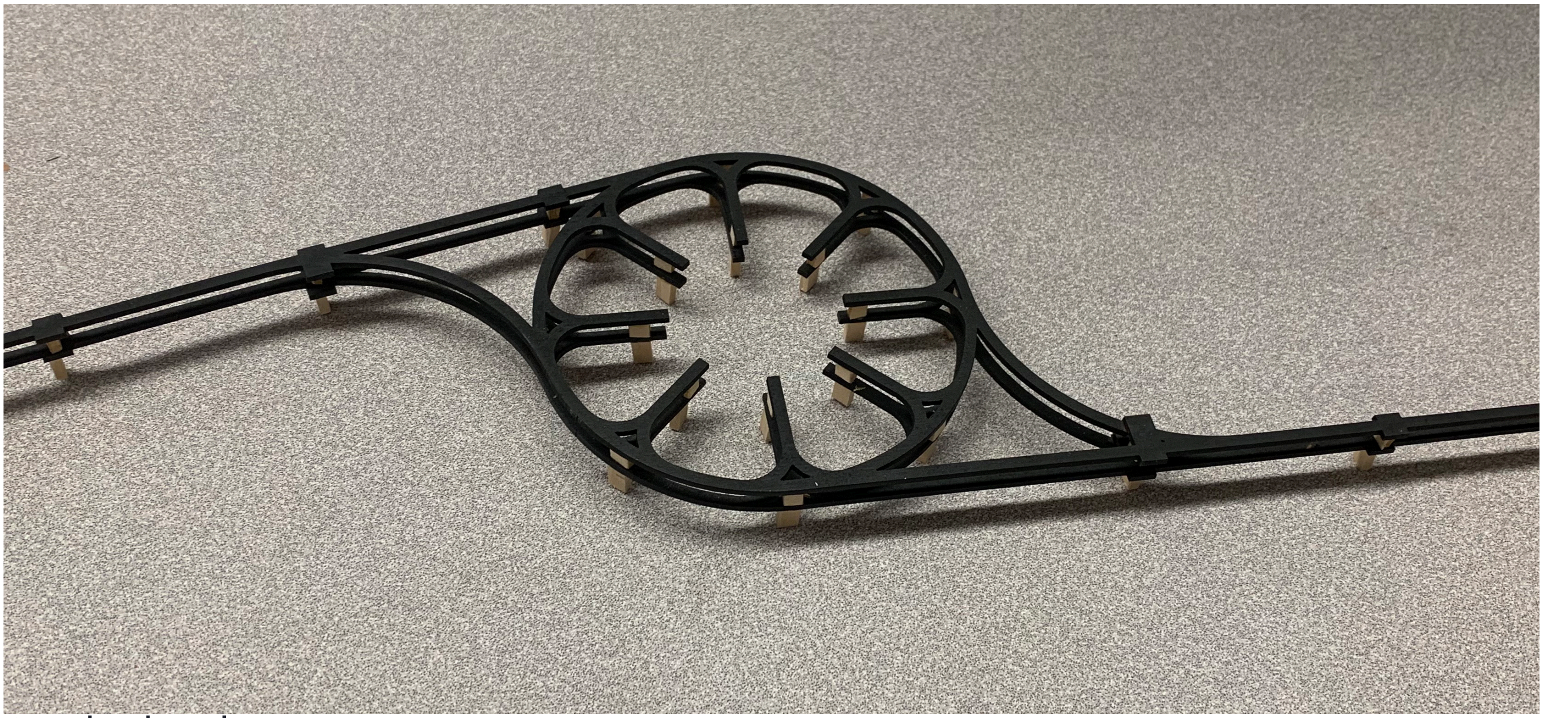
Track Analysis

Track Sketch Models

By researching conceptual Hyperloop systems in the United States, Mexico, and Europe I found a promising new style of track layout in the helix layout. Extrapolating this for a Hub station using a spoke and wheel concept I created multiple possibilities for track layouts.



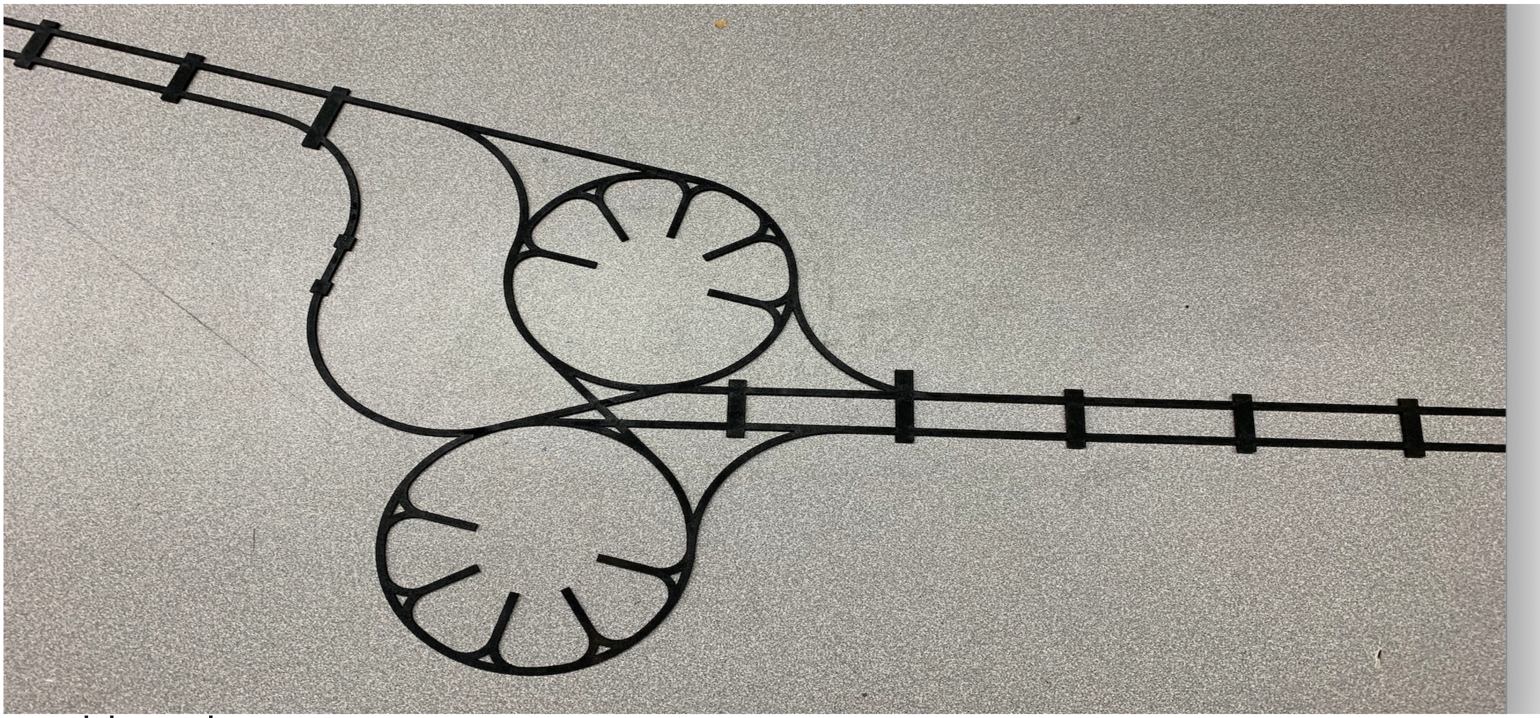
Stacked Helix



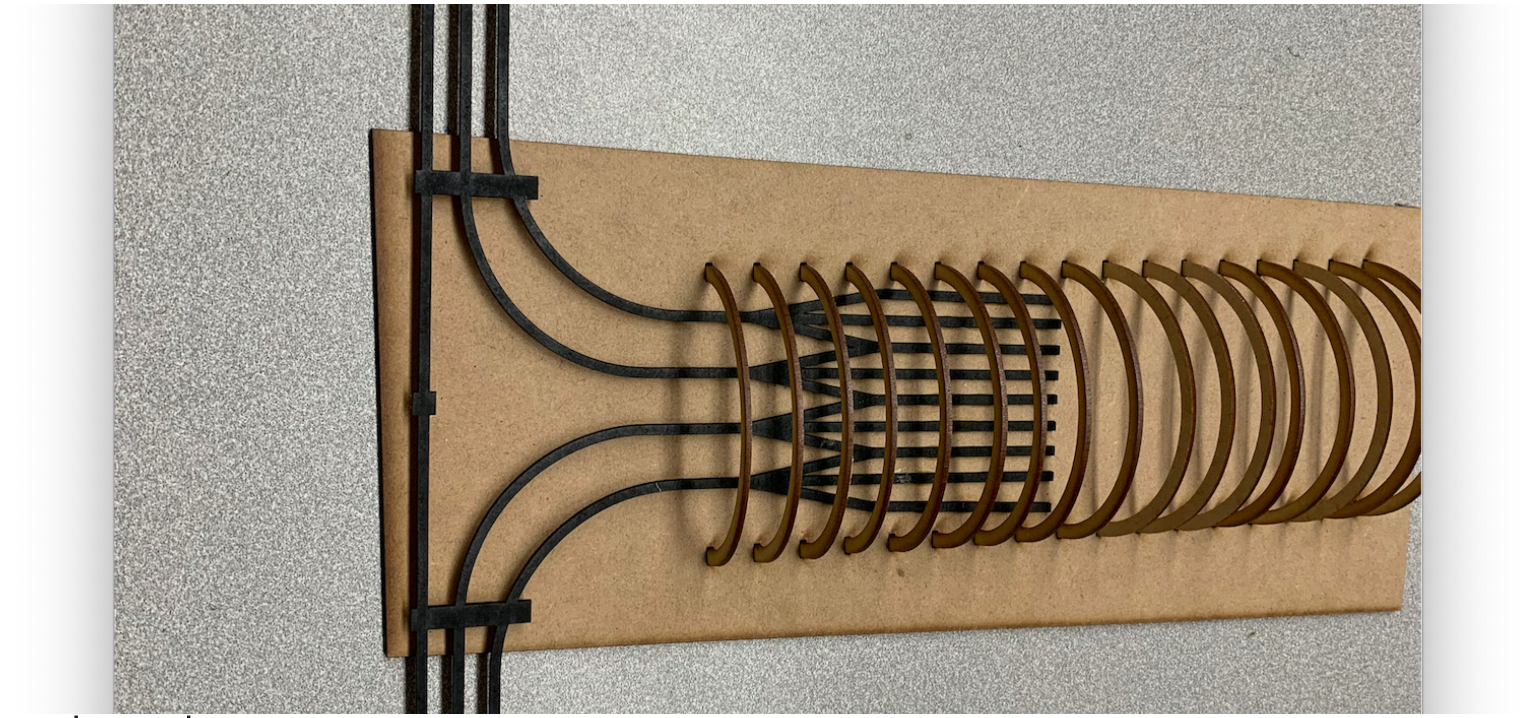
Stacked Helix

Track Analysis

Track Sketch Models

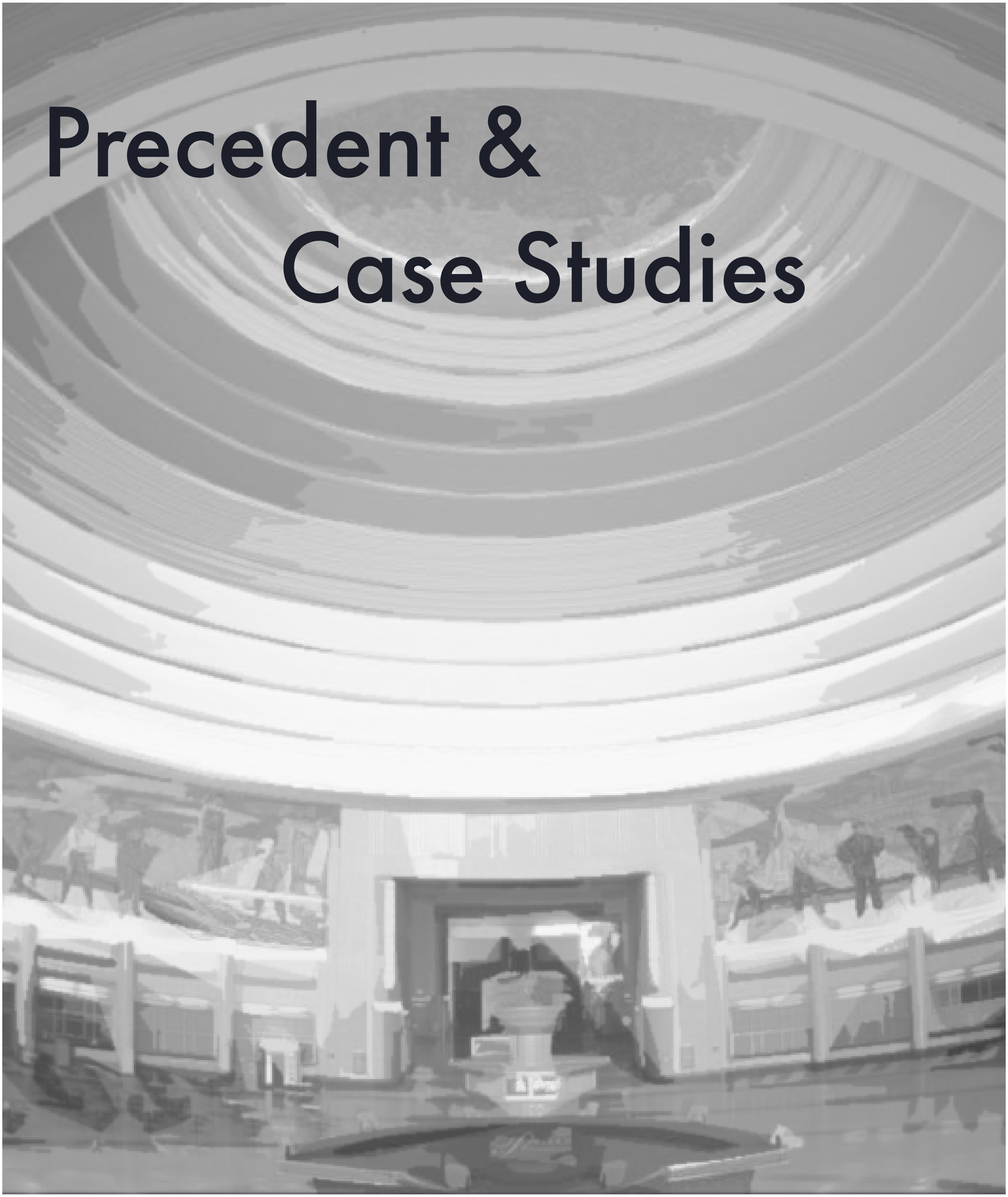


Double Helix Concept



Traditional Concept

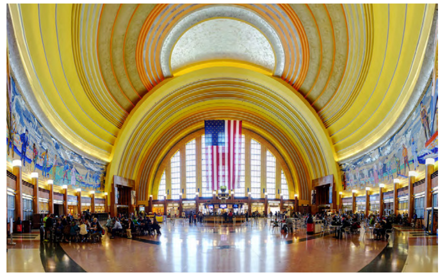
Precedent & Case Studies

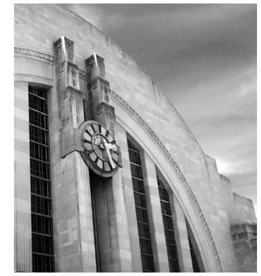


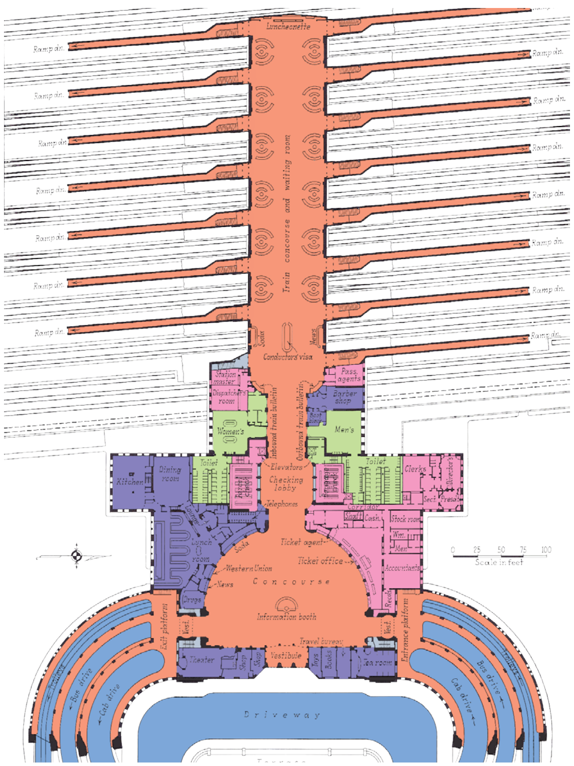
Precedents and Case Studies

Cincinnati Union Terminal

Architect | Alfred Fellheimer & Stewart Wagner

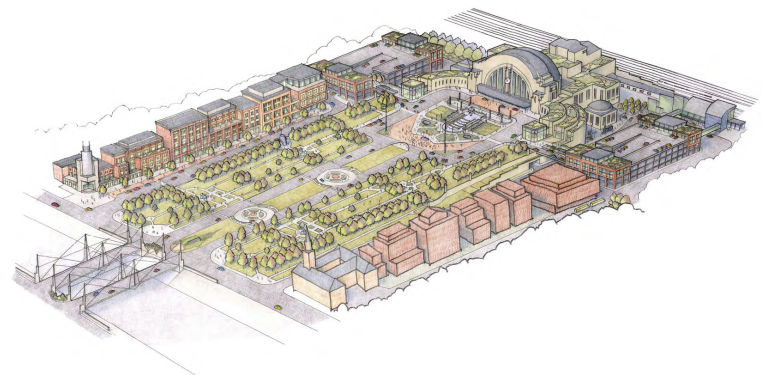



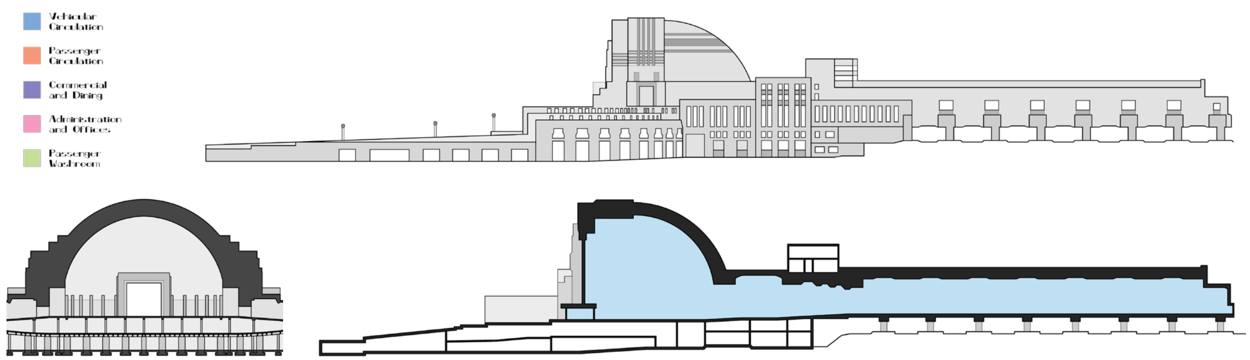




Built in 1933 the Cincinnati Union Terminal exhibits all of the aspects I hope to accomplish in my new transit hub, directly adajecent to this building. Today the station has been reworked into the Museum Center for the city of Cincinnati and can no longer function as a high capacity rail station.

The Terminal exhibits an intermodal transit system between the rail, the streetcar, the bus system, and the private and commercial car services. It also creates an effective compression and decompression space between the city of Cincinnati and the rail car.

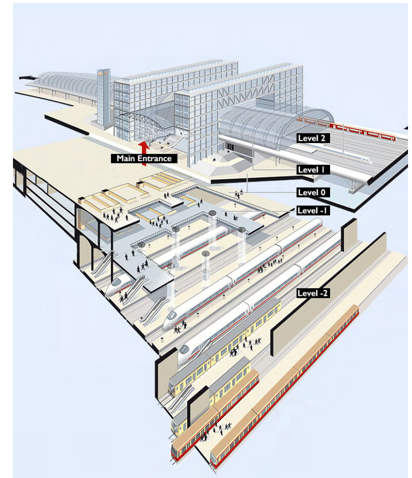




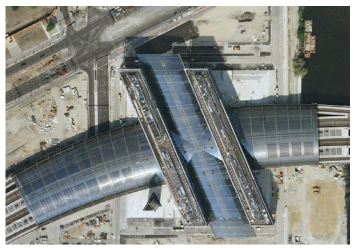
Precedents and Case Studies

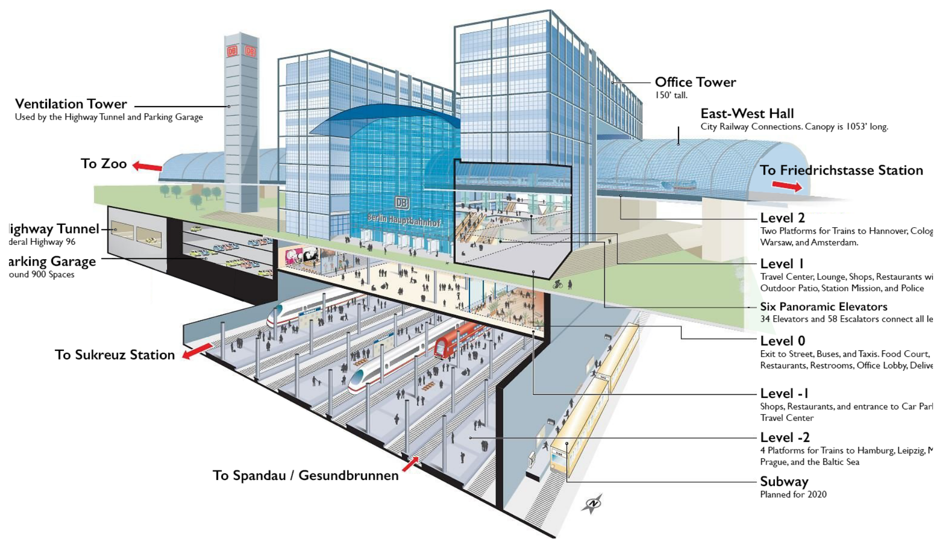
Berlin Hauptbahnhof Terminal

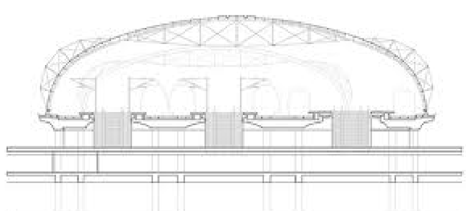
Architect | Gerkan, Marg, & Partners

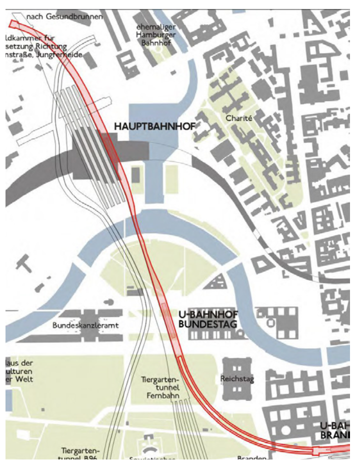


Berlin Hauptbahnhof Terminal built in 2006 was part of an effort in Berlin to reunify the cities infrastructure after decades split apart by the Berlin wall. The Terminal combines inter and inner city rail and street car systems. The station was built on the site of the original 19th century station destroyed in WWII. It nods to this original without pandering to its design





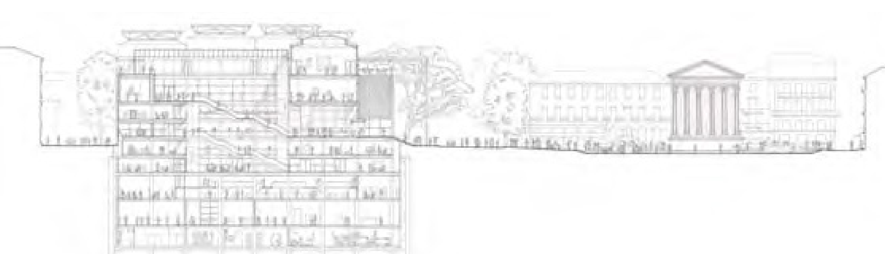


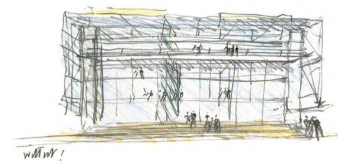


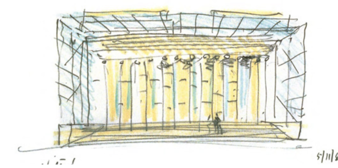
Precedents and Case Studies

Carré d’ Art - Nimes

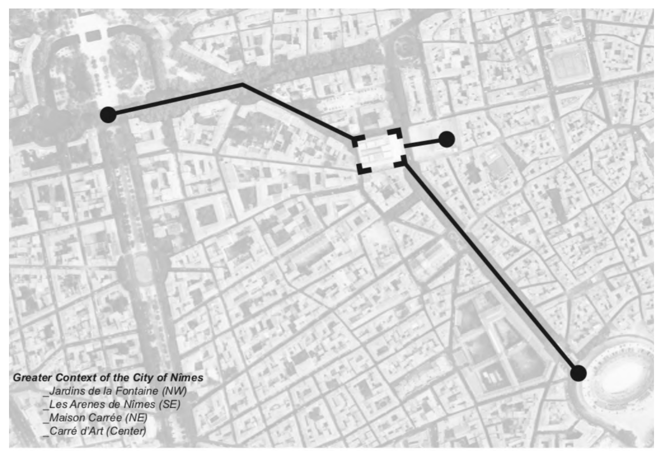
Architect | Foster + Partners



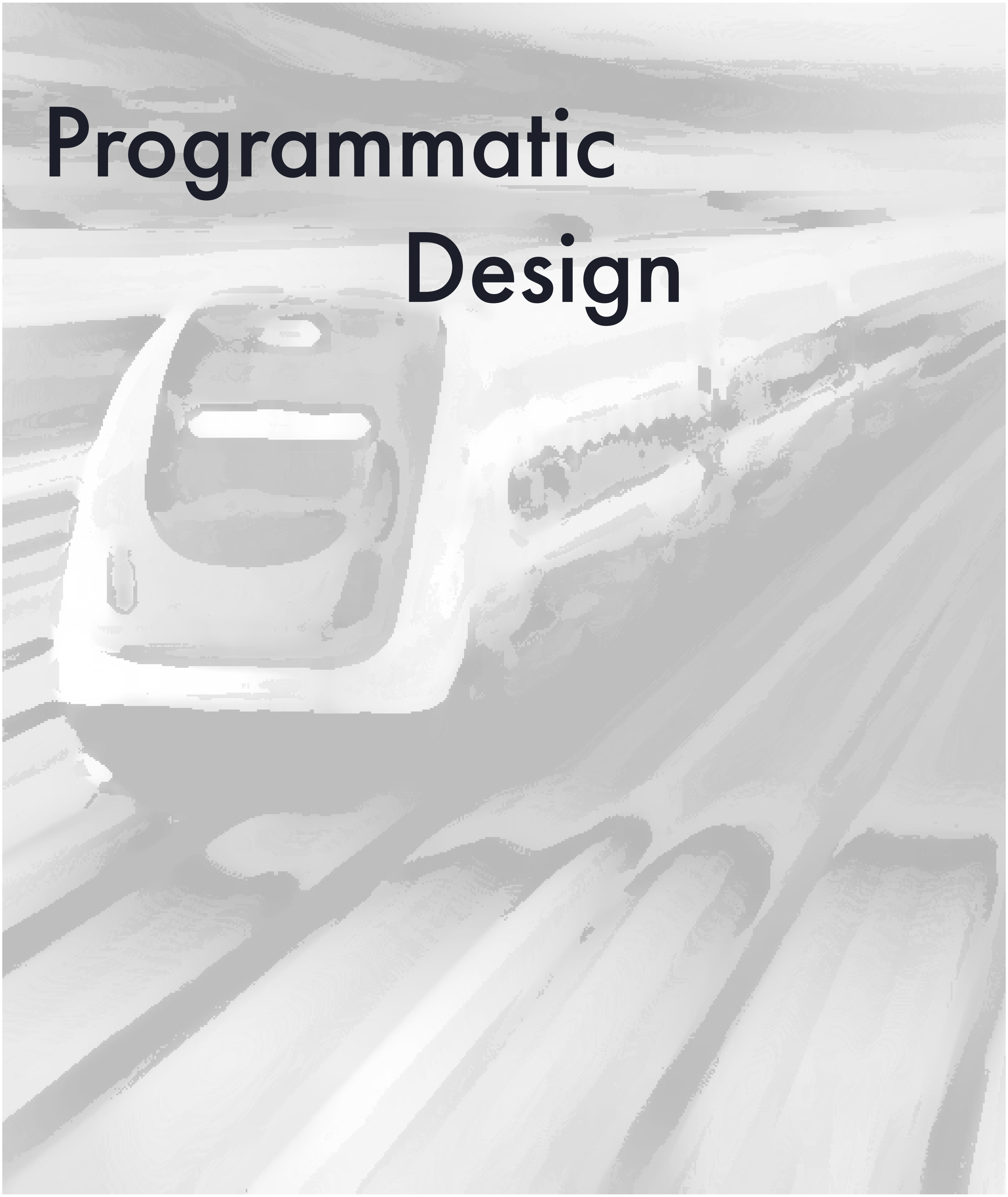




The Carré d’Art by Norman Foster is a modern museum built adjacent to the Roman Temple Maison Carrée. The museum balances the architecture of the past with the modern stylings. Foster does not rely on past forms to integrate new construction into existing contexts. Instead, he uses modern materials to create an abstract but classically inspired building.



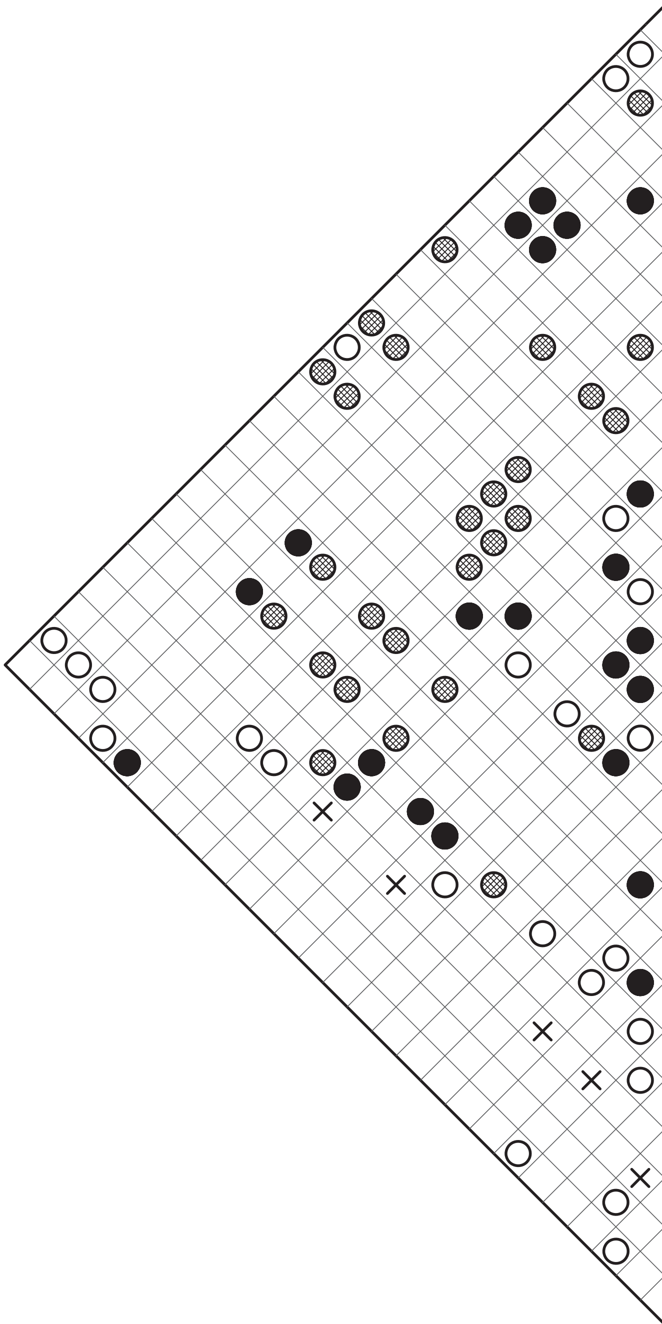
Programmatic Design



Programmatic Design

Programming Matrix

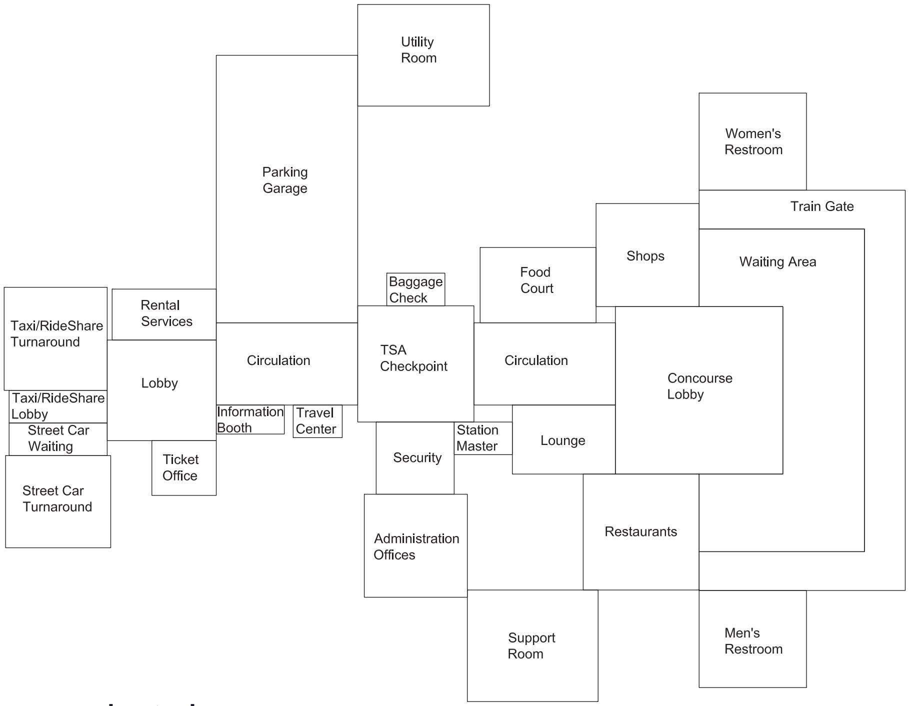
●	Immediately Adjacency
◍	Important Adjacency
○	Reasonably Convenient
	Unimportant
×	Remote



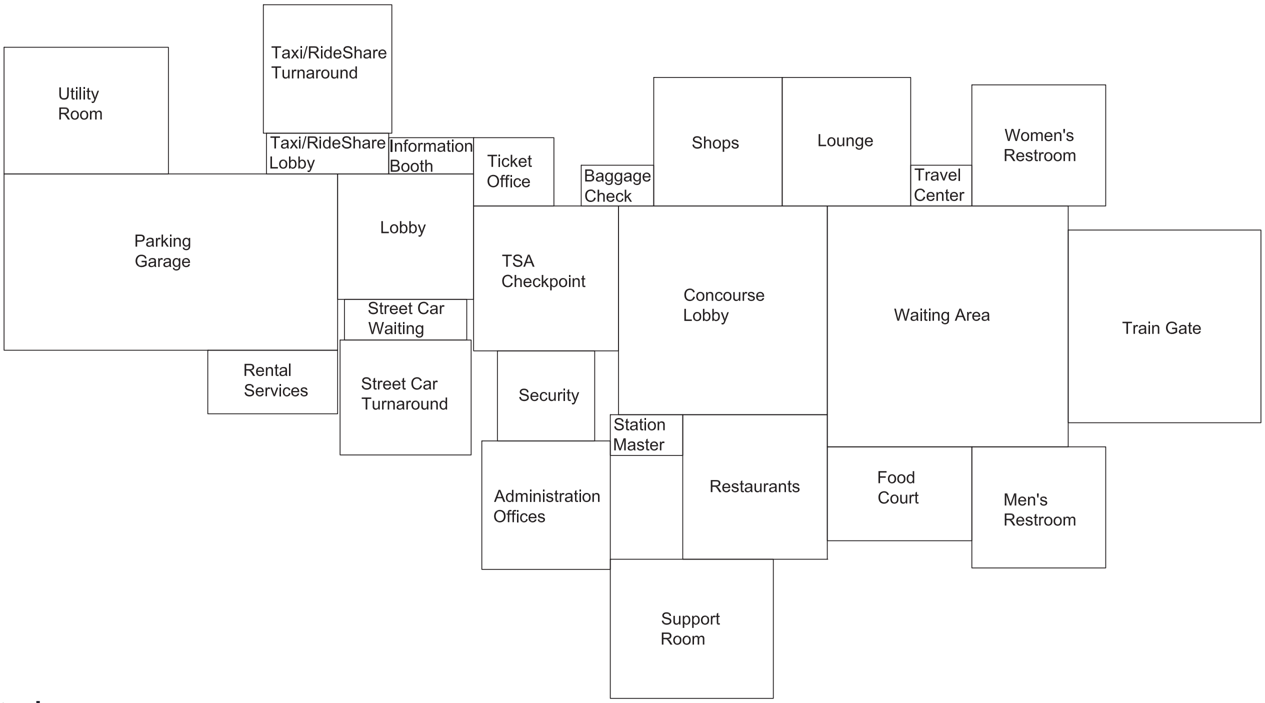
1	Shops
2	Restaurants
3	Food Court
4	Travel Center
5	Rental Services
6	Circulation
7	Men's Restroom
8	Women's Restroom
9	Station Master
10	Lobby
11	Information Booth
12	Baggage Check
13	Concourse Lobby
14	Lounge
15	Waiting Area
16	Ticket Office
17	Train Gate
18	Street Car Turnaround
19	Street Car Waiting
20	Taxi/RideShare Turnaround
21	Taxi/RideShare Lobby
22	TSA Checkpoint
23	Security
24	Administration Offices
25	Utility Room
26	Support Room
27	Parking Garage

Programmatic Design

Adjacency Diagram



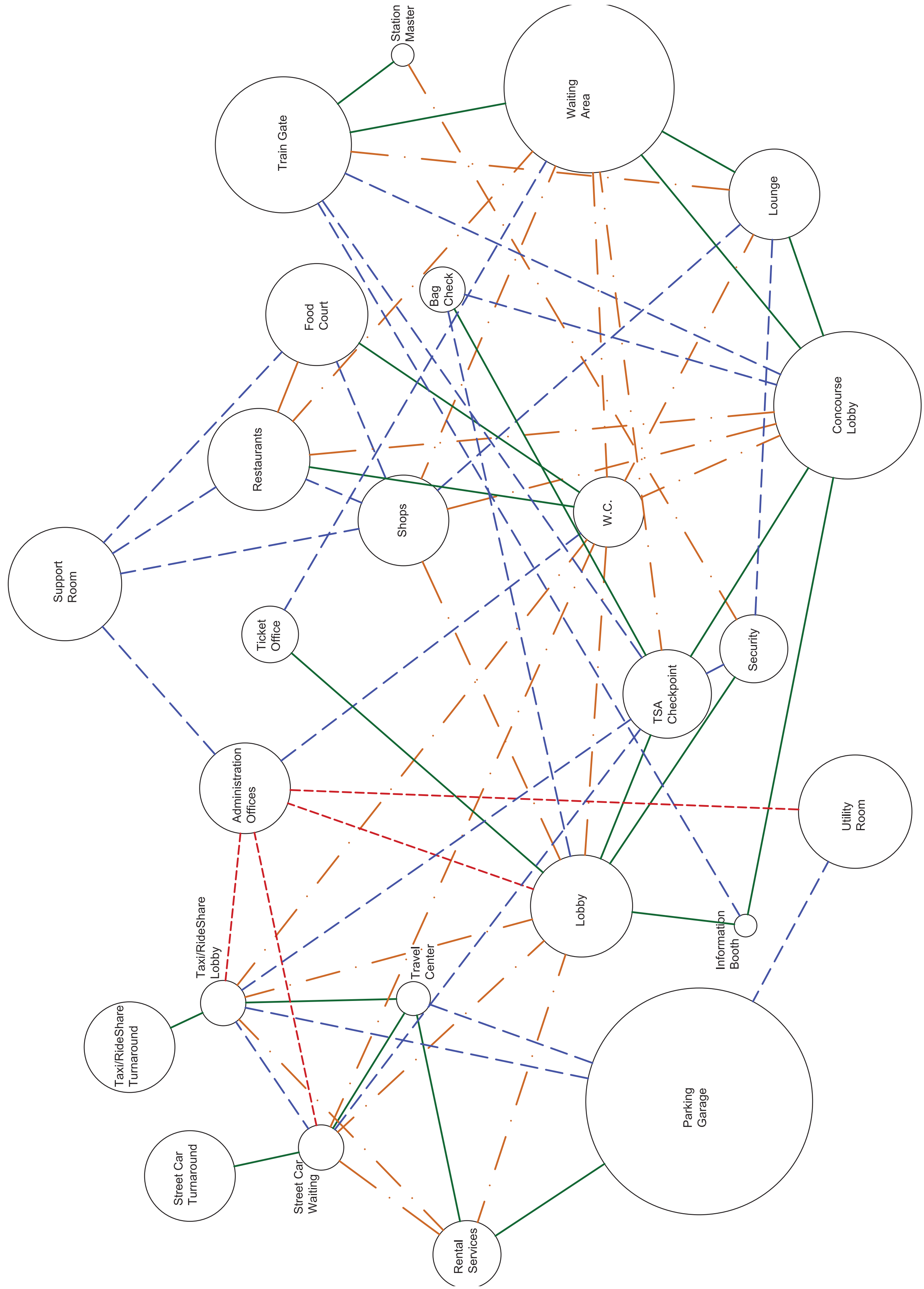
Two Hub Adjacency Diagram



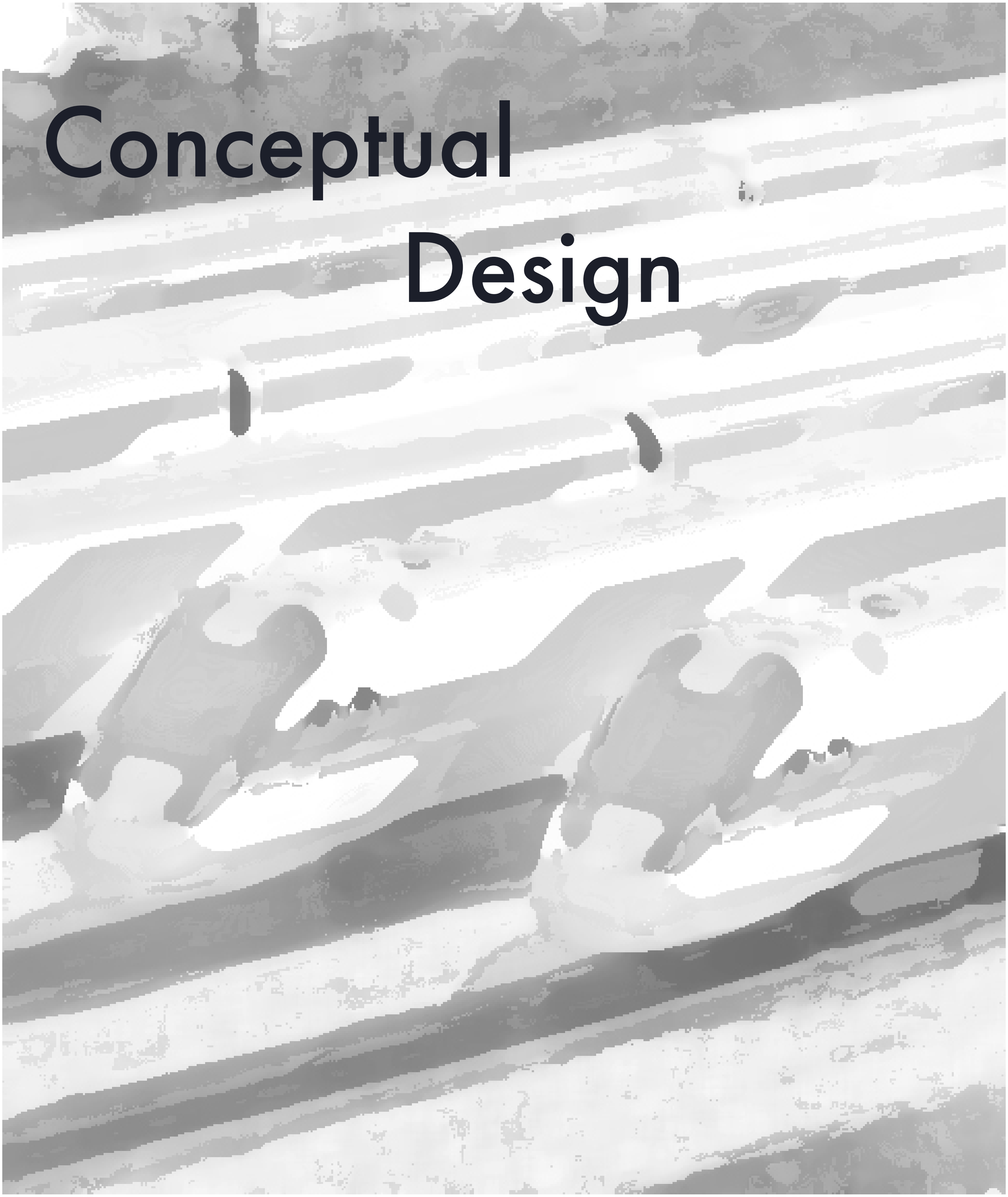
Linear Adjacency Diagram

Programmatic Design

Adjacency Bubble Diagram



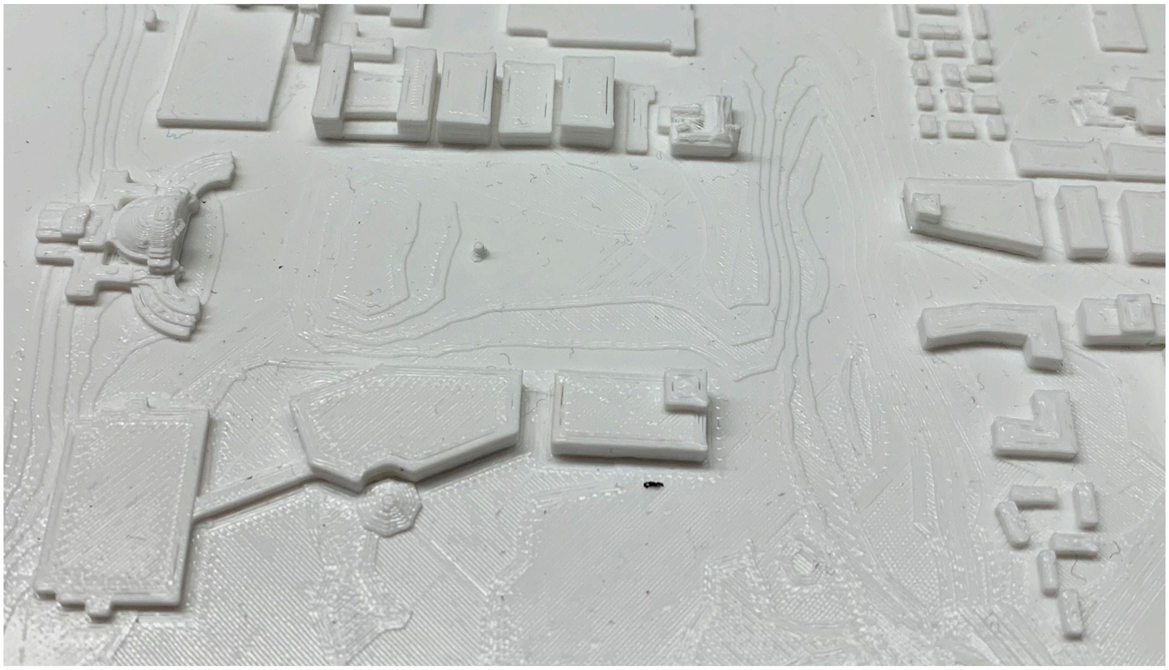
Conceptual Design



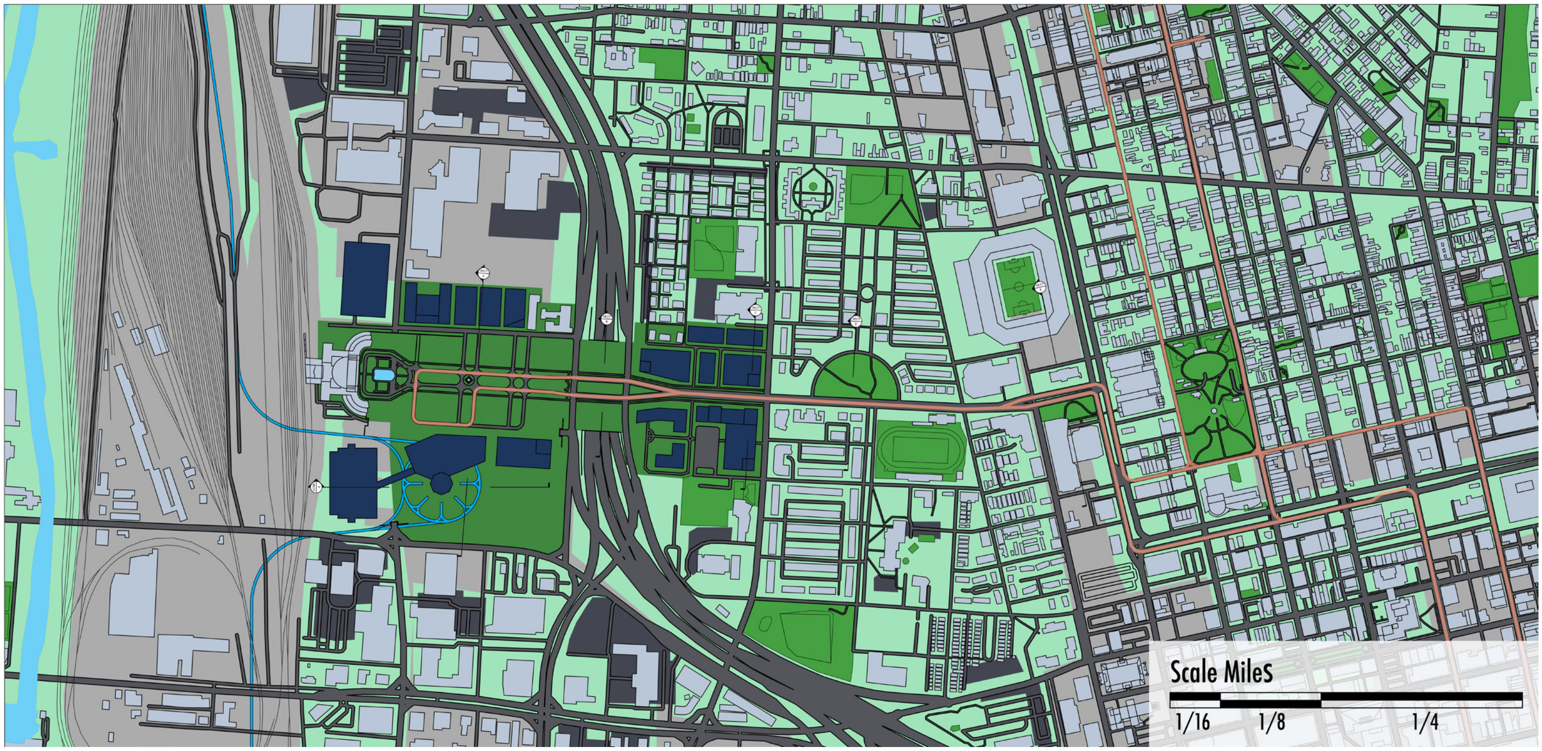
Conceptual Design

Initial Terminal Concept

Initially I started looking to place my new hyperloop almost completely underground and as close to the Cincinnati Union Terminal as possible. This design pulled all the major elements of the building below ground utilizing a large atrium to help bring light into the lower levels.



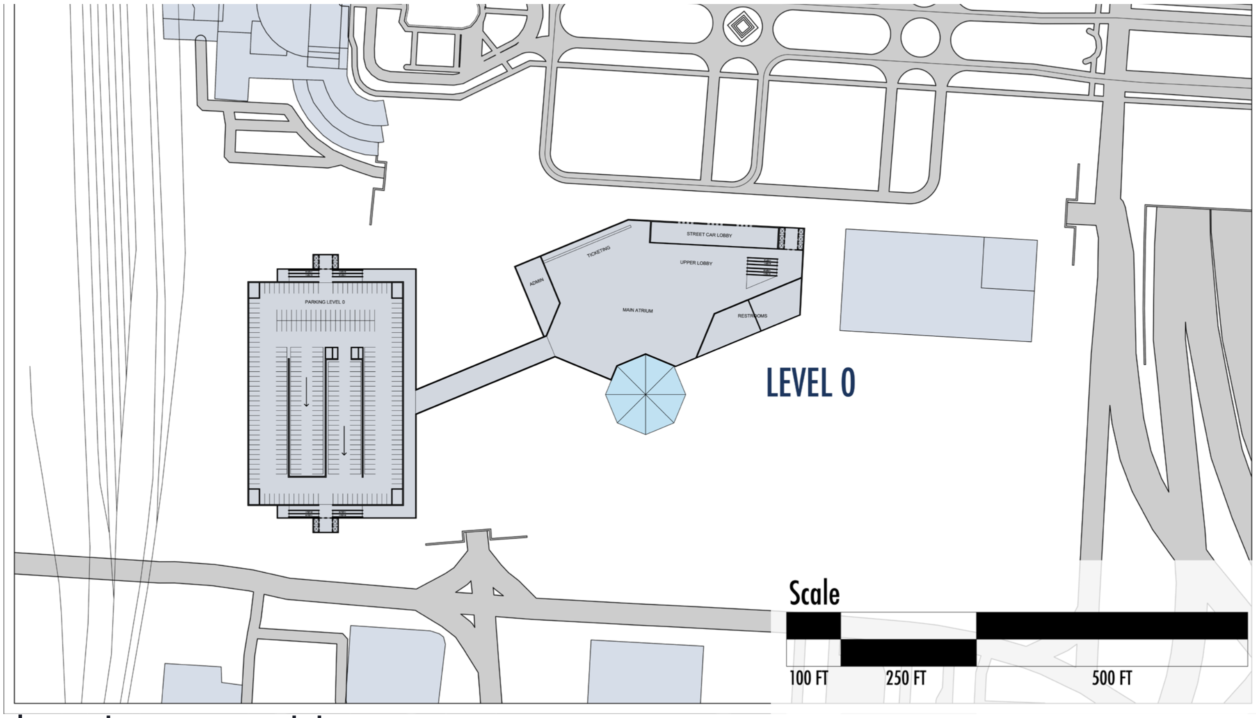
3D Print Site Plan



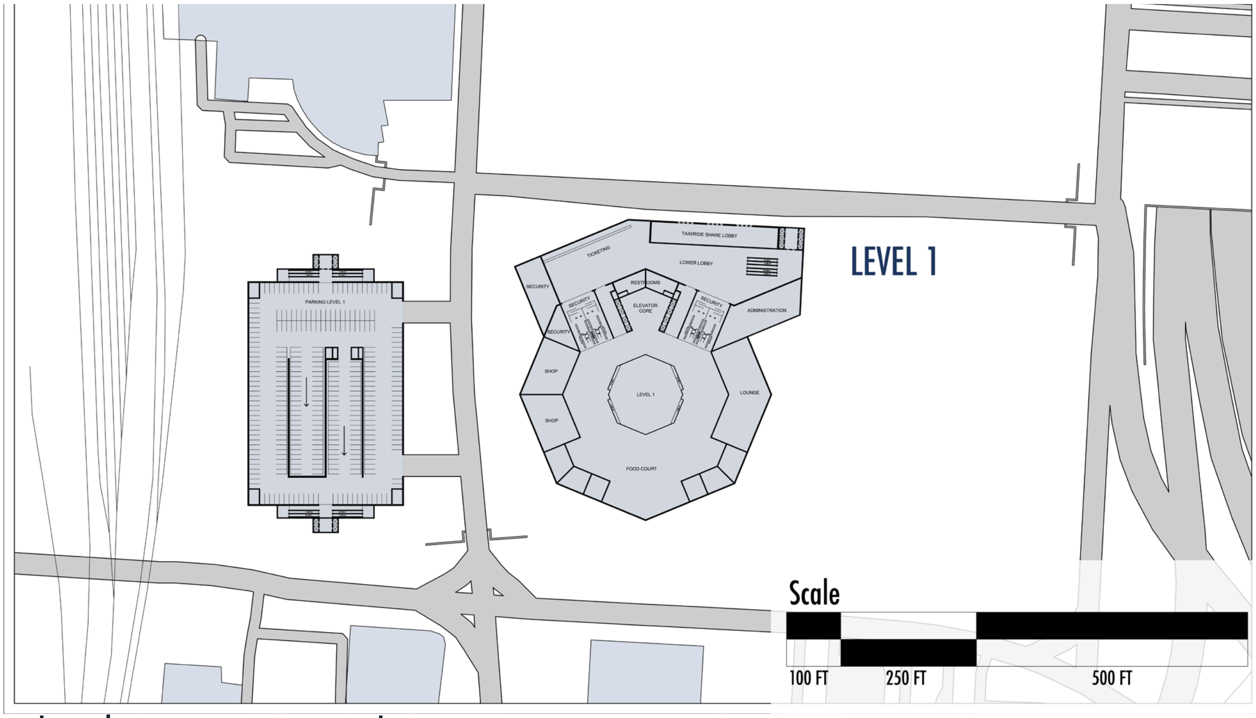
Master Plan

Conceptual Design

Initial Terminal Concept



Level 1 | Pedestrian Lobby

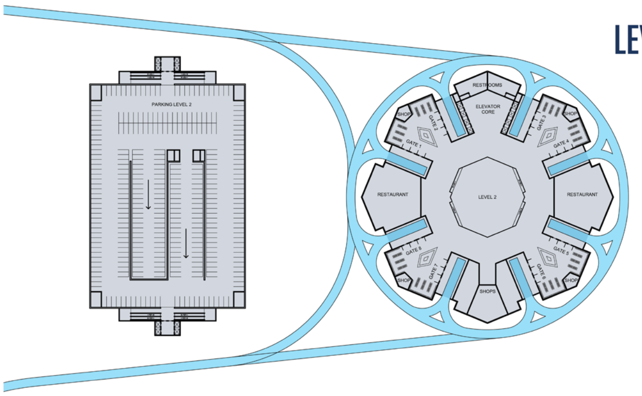


Sub-Level 1 | Security Level

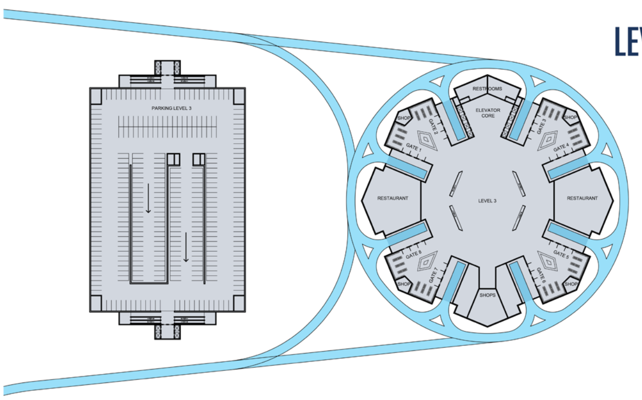
Conceptual Design

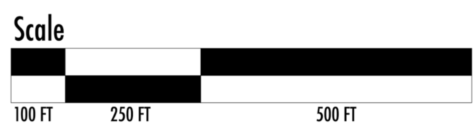
Initial Terminal Concept

LEVEL 2



LEVEL 3



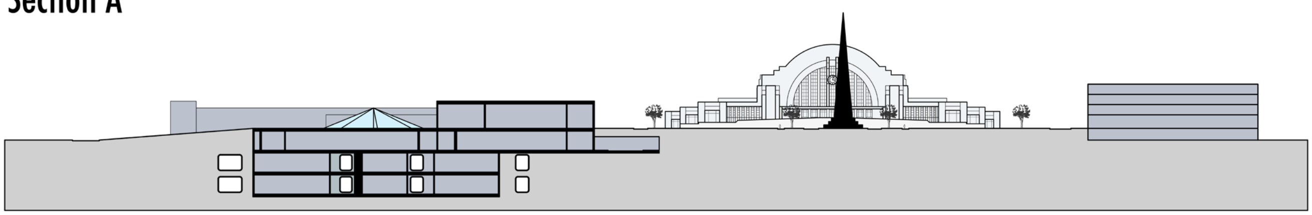


Sub-Level 2-3 | Terminal Level

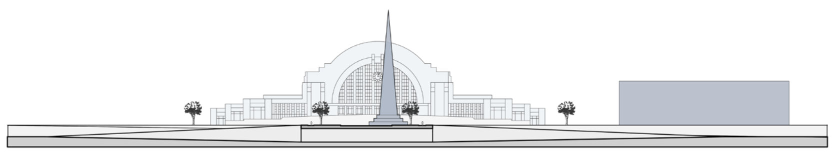
Conceptual Design

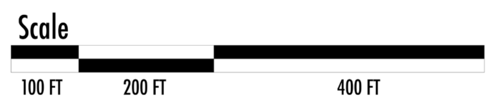
Initial Terminal Concept

Section A



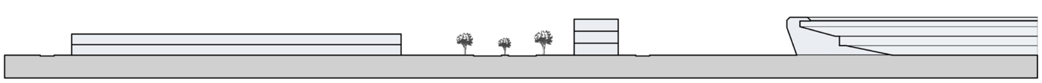
Section B



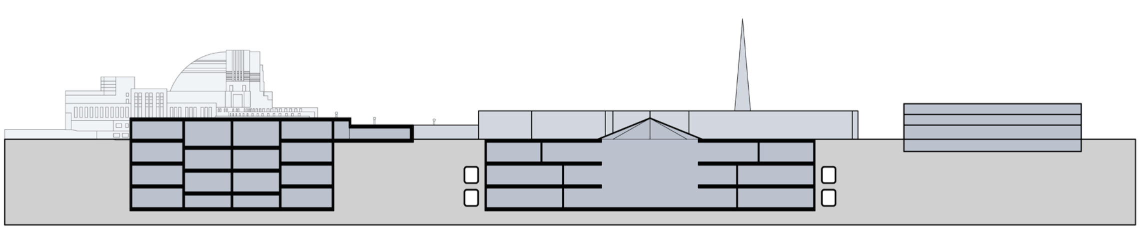


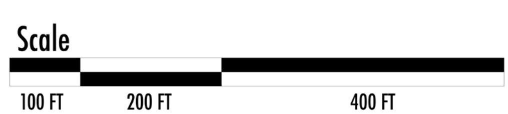
Site Sections

Section E



Section F





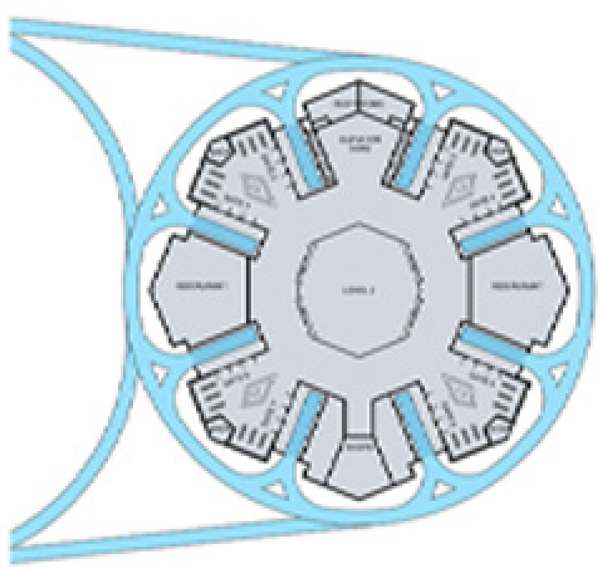
Site Sections

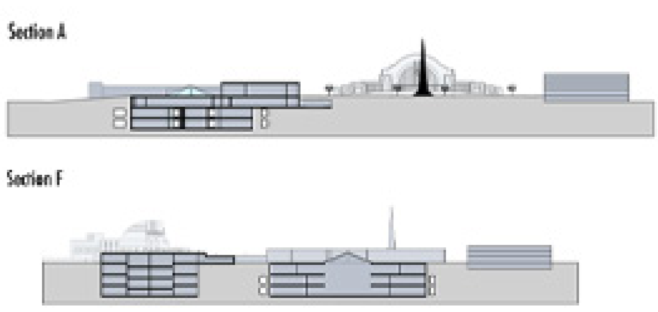
Conceptual Design

Identifying Concepts to Advance

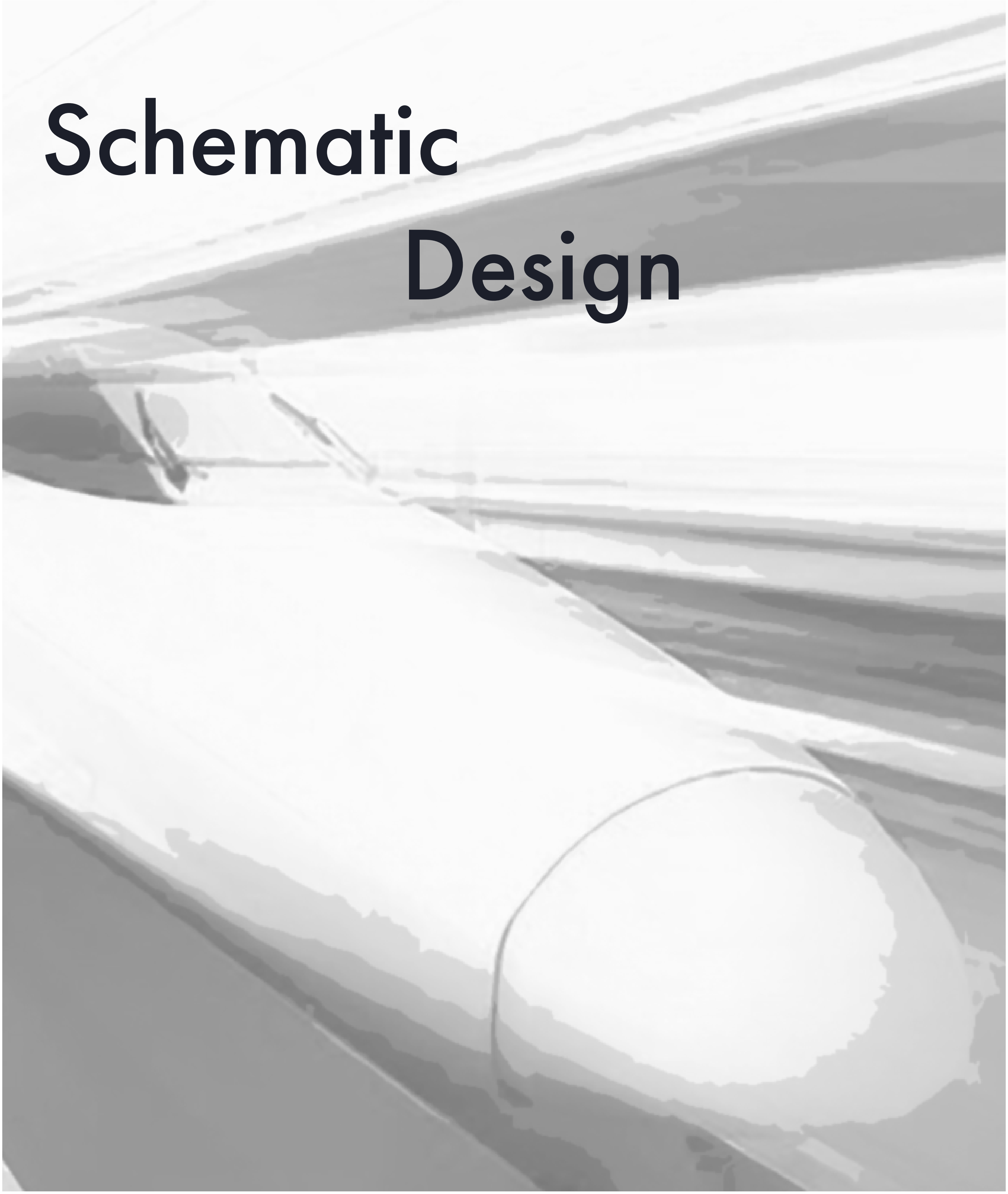
While the initial concept design was ultimately a failure, it was able to provide me with some very important ideas and concepts. The monumental axis created in front of the Cincinnati Union Terminal was determined to be the ideal place for this new structure.

The flower design used for the terminal levels of this design would also go on to influence how I laid out future stations and concepts.





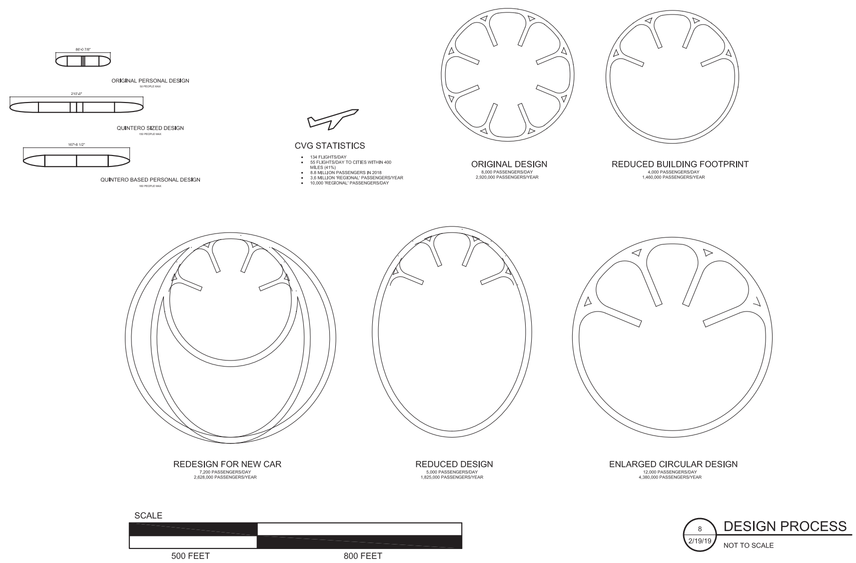
Schematic Design



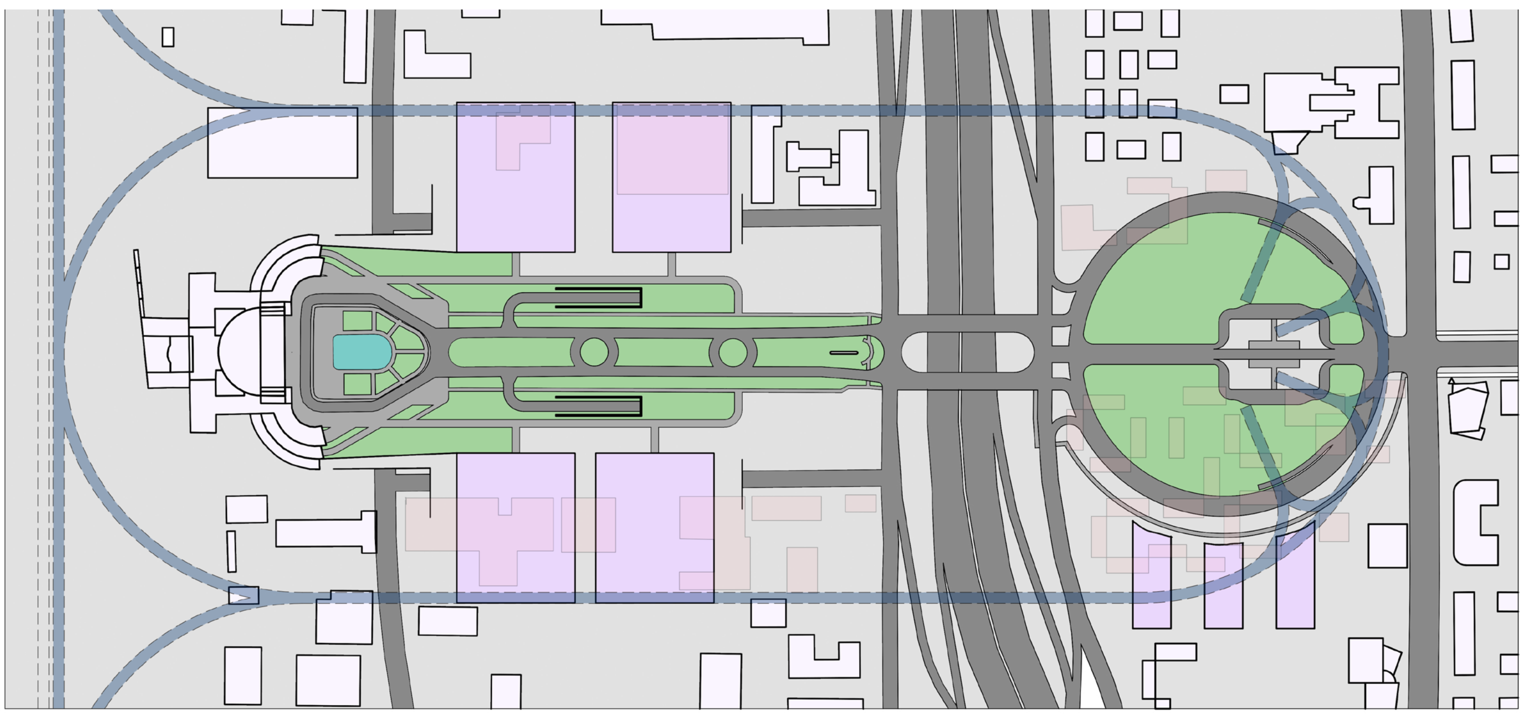
Schematic Design

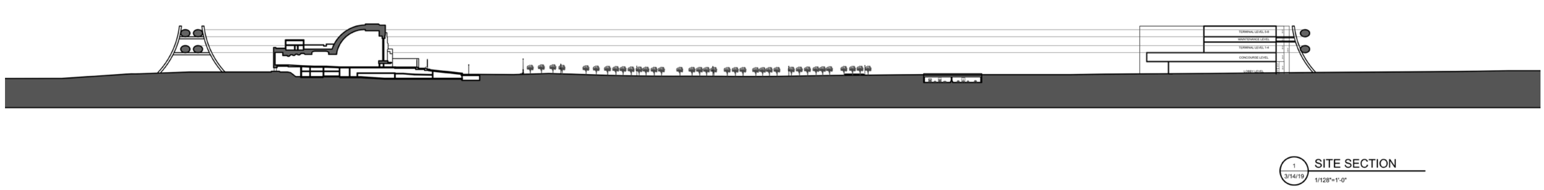
Initial Schematic Design

By focusing on the track design and advancements in the hyperloop vehicle design I adjusted the track concepts from earlier to try and find the most efficient design for passenger movement. Determining that this was a 4 track design with a large radius to accommodate larger vehicles I began to design using the half-circle as a base.



Site Sections

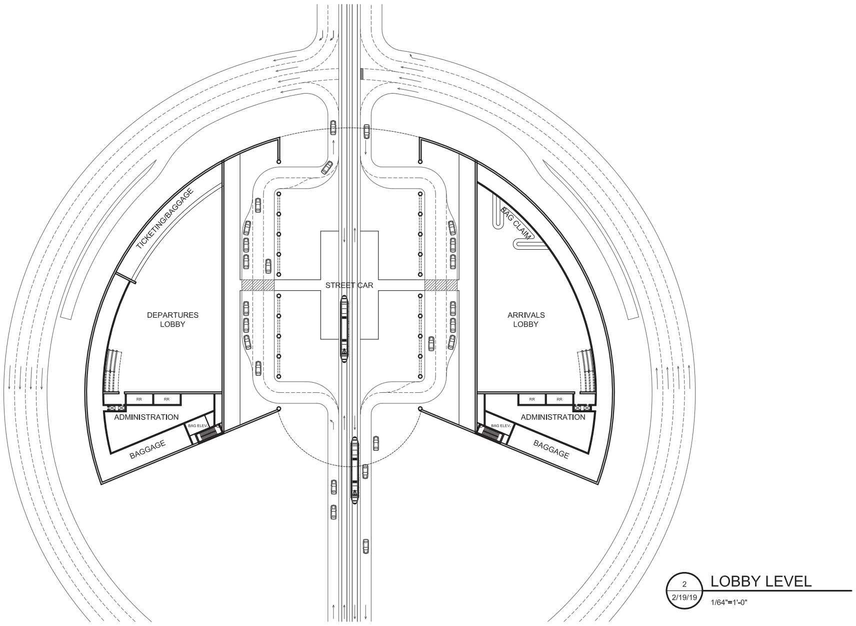




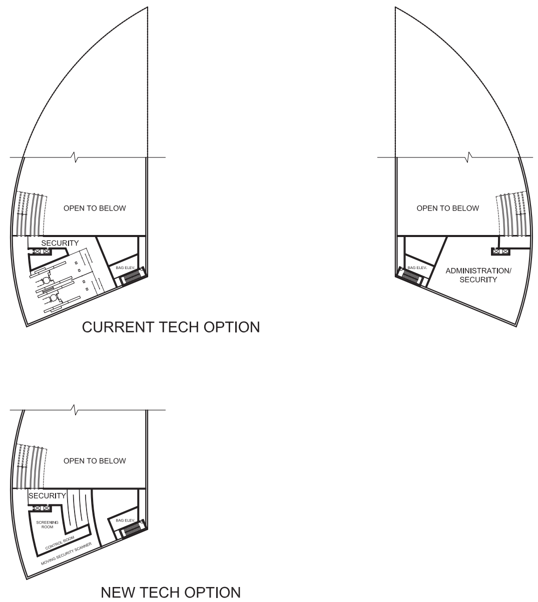
Site Masterplan & Section

Schematic Design

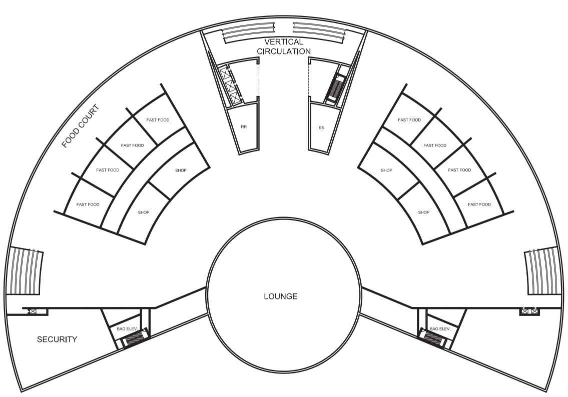
Initial Schematic Design



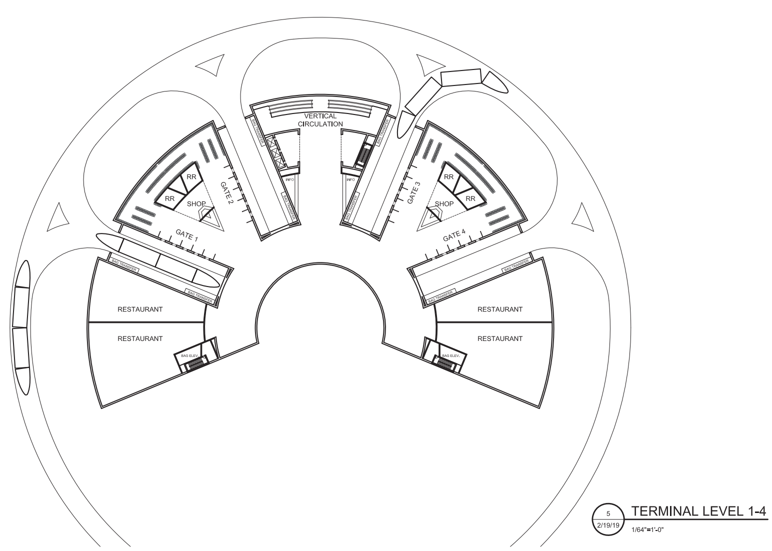
Lobby Level



Security Level



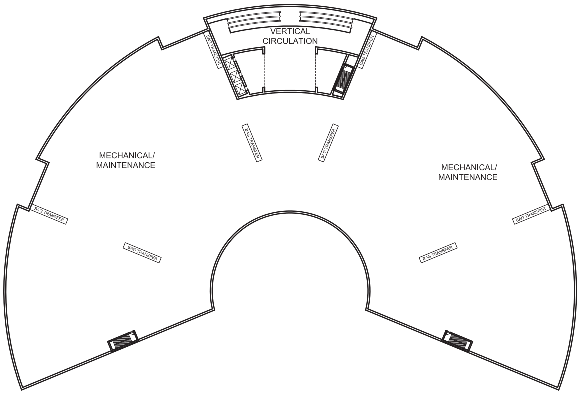
Concourse Level

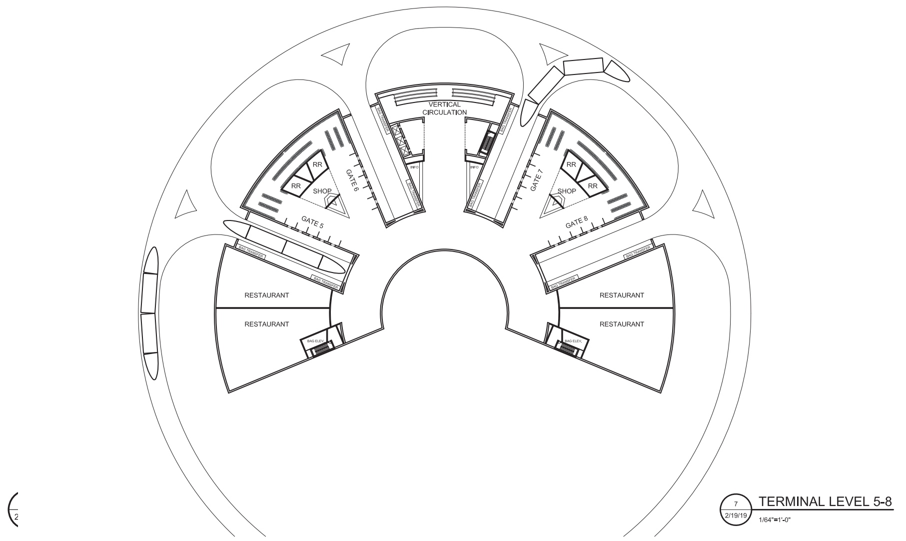


Terminal Level 1-4

Schematic Design

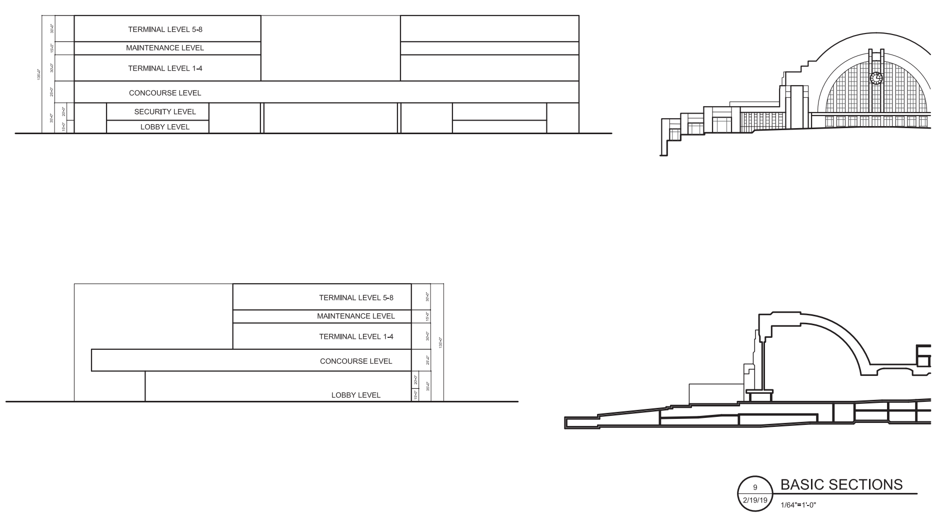
Initial Schematic Design





Concourse Level

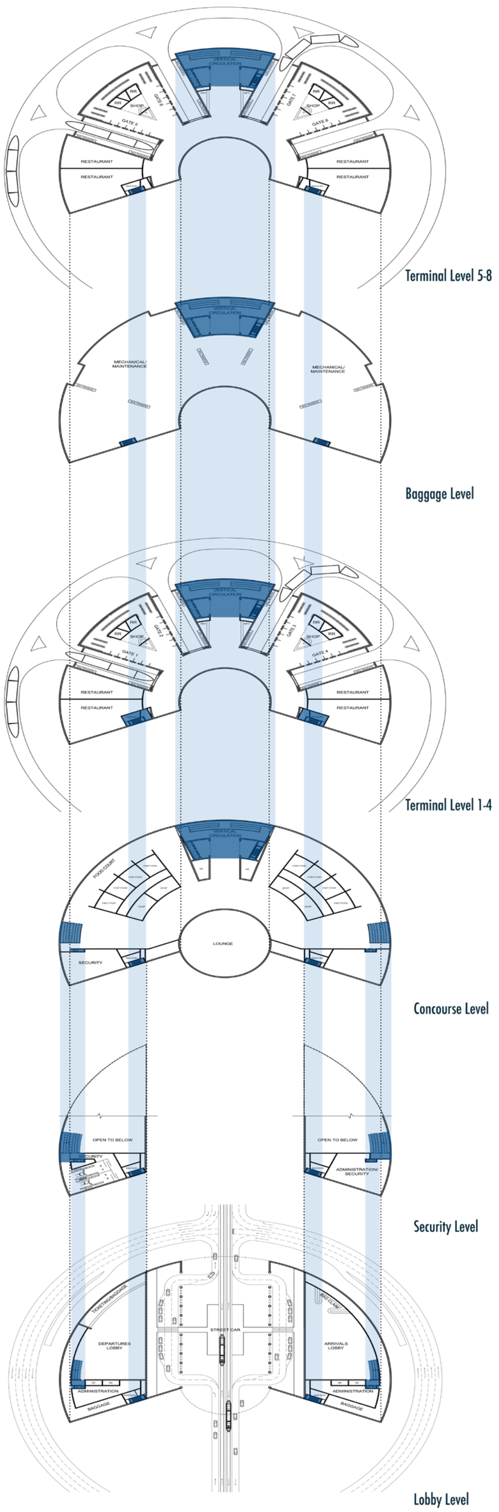
Terminal Level 1-4



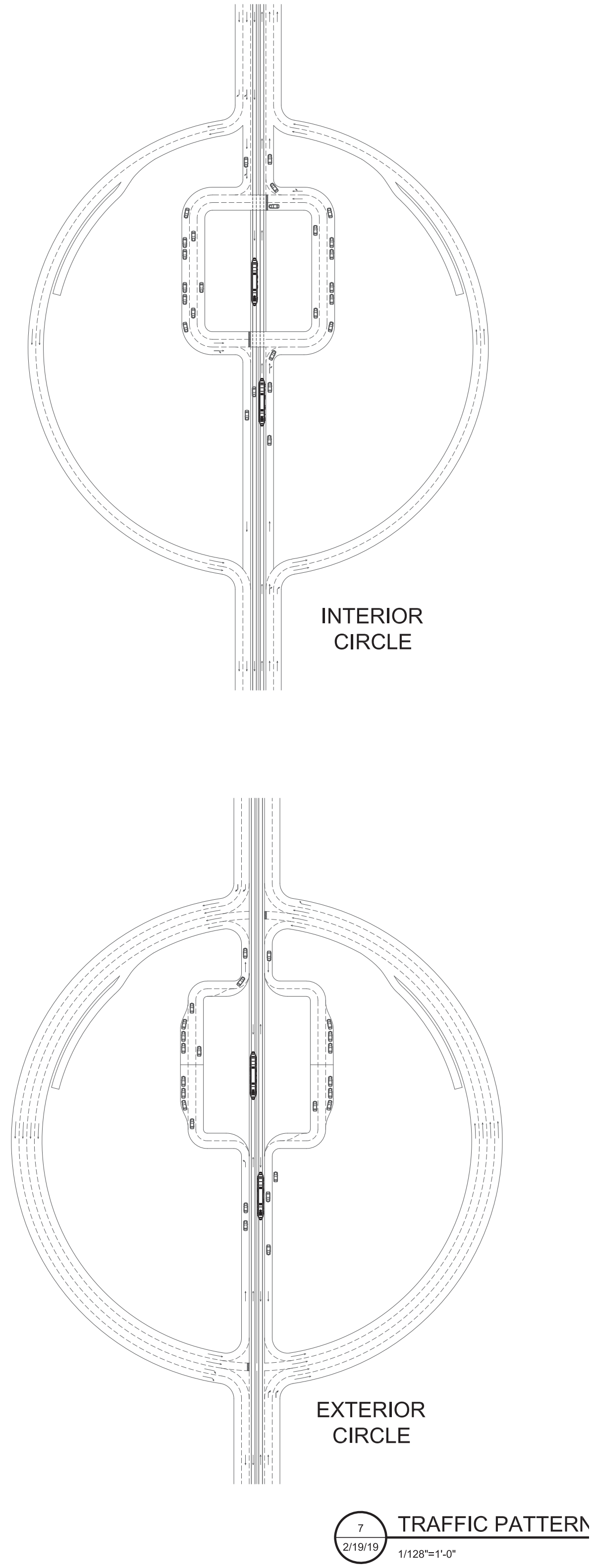
Section & Context

Schematic Design

Initial Schematic Design

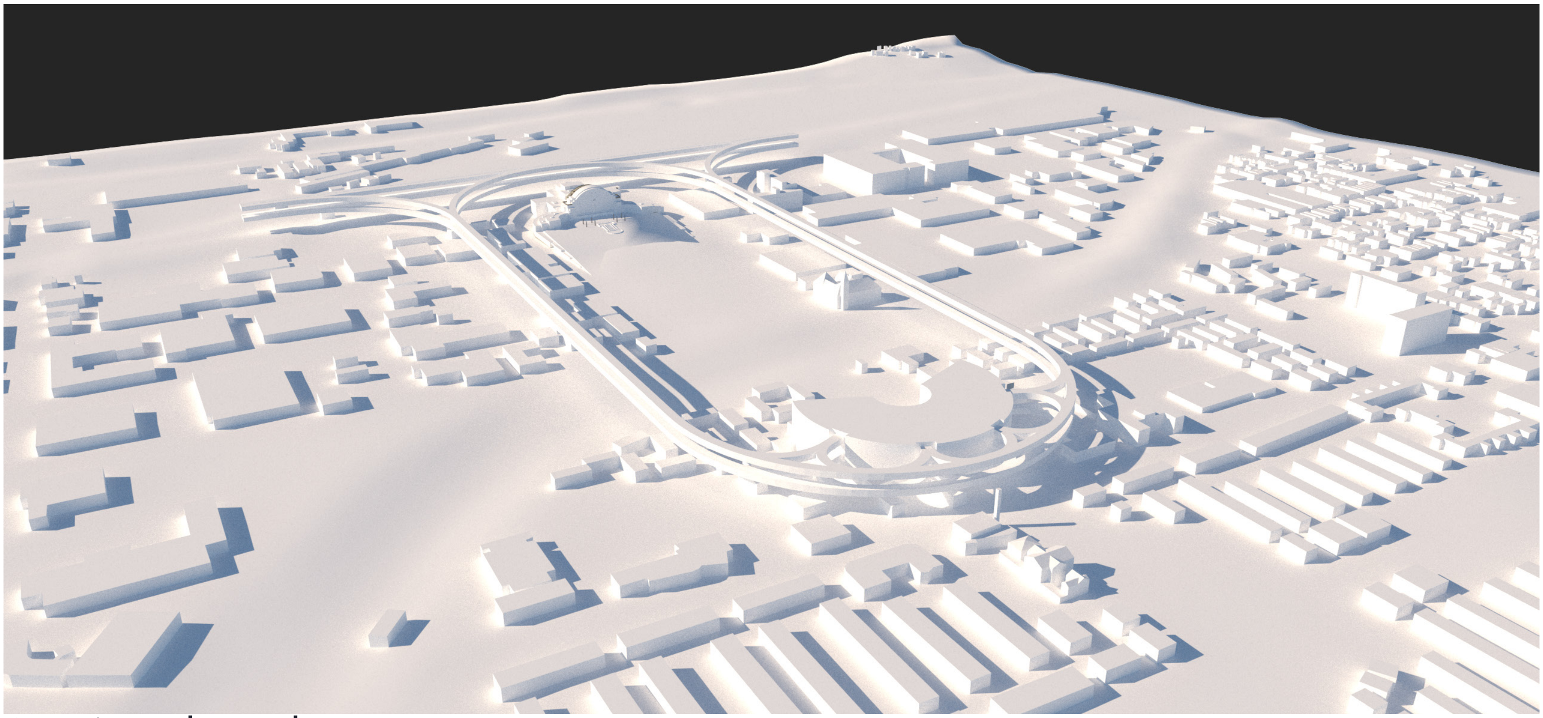


Circulation Diagram

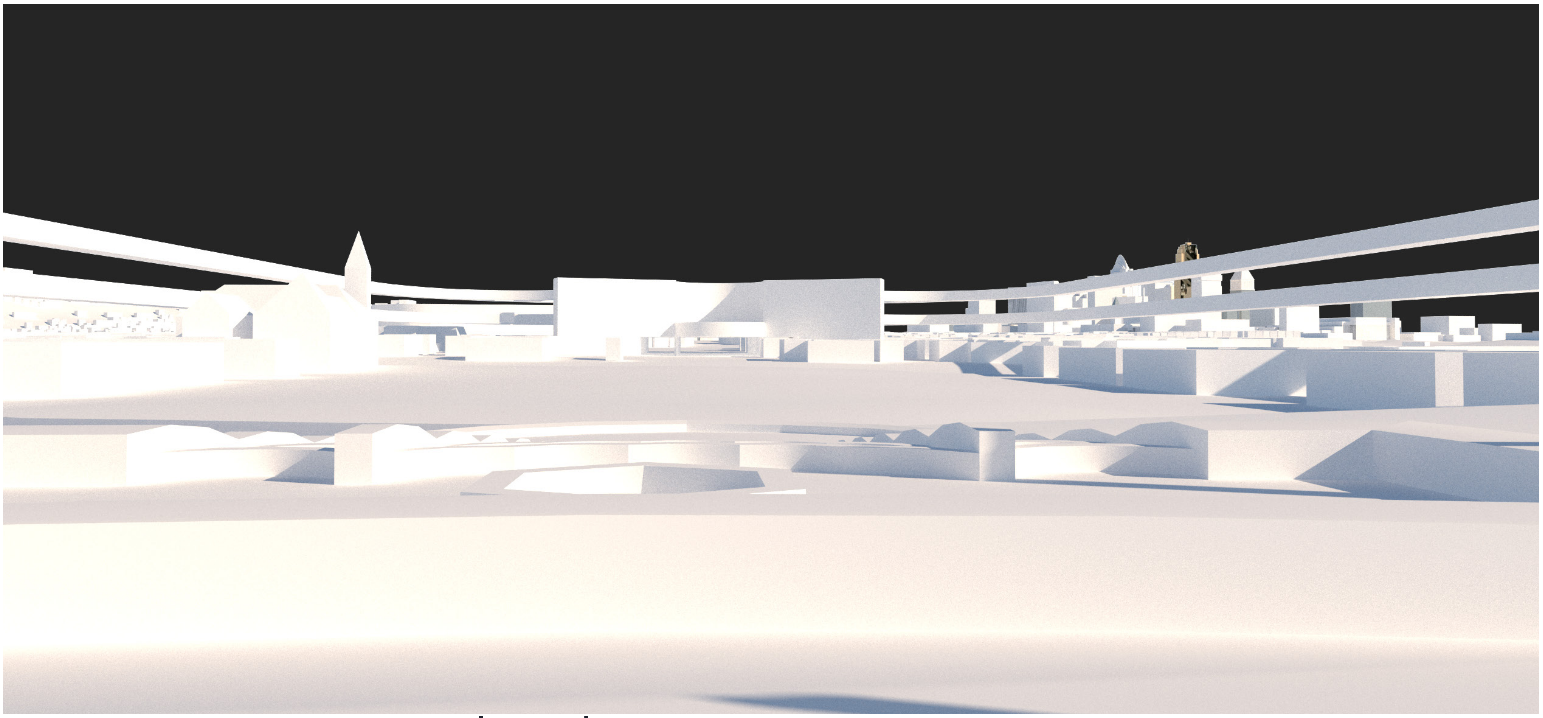


Traffic Pattern Options

Initial Schematic Design

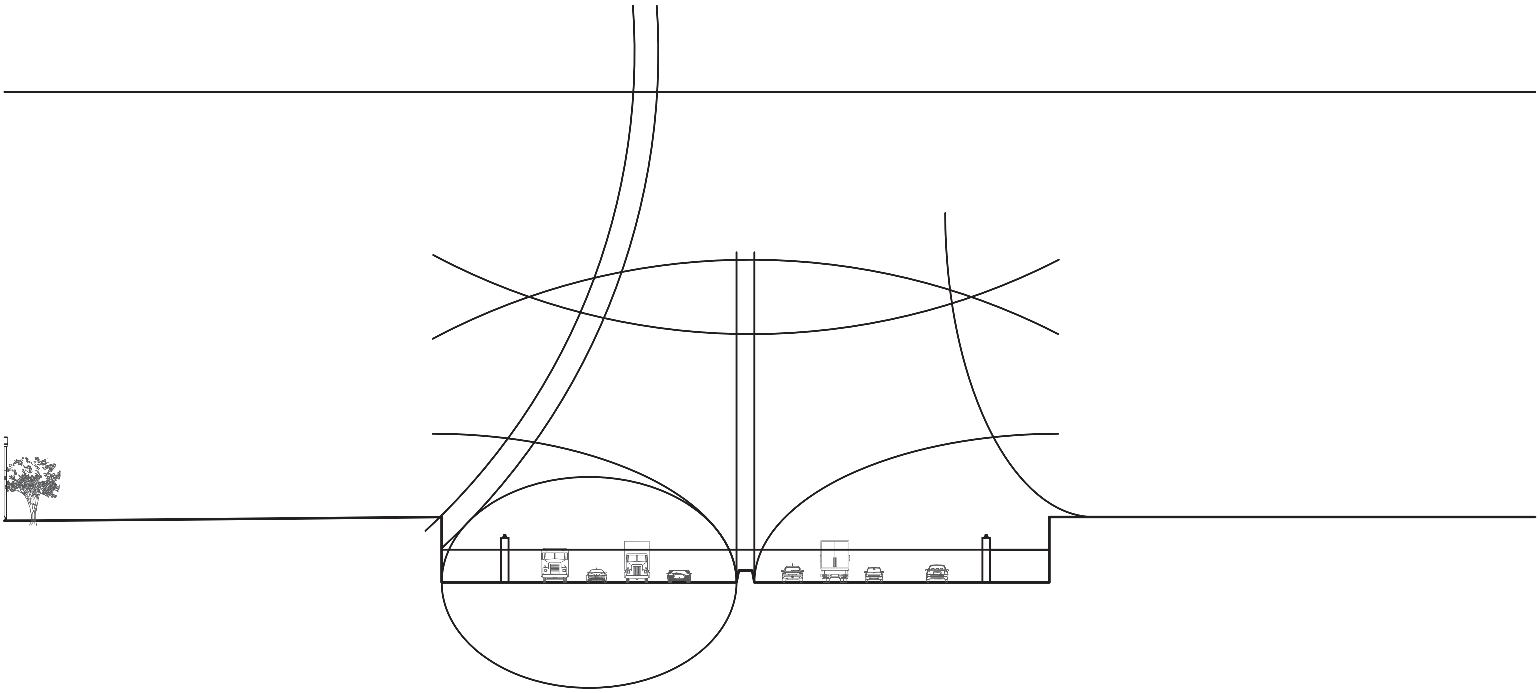


Site Aerial Render

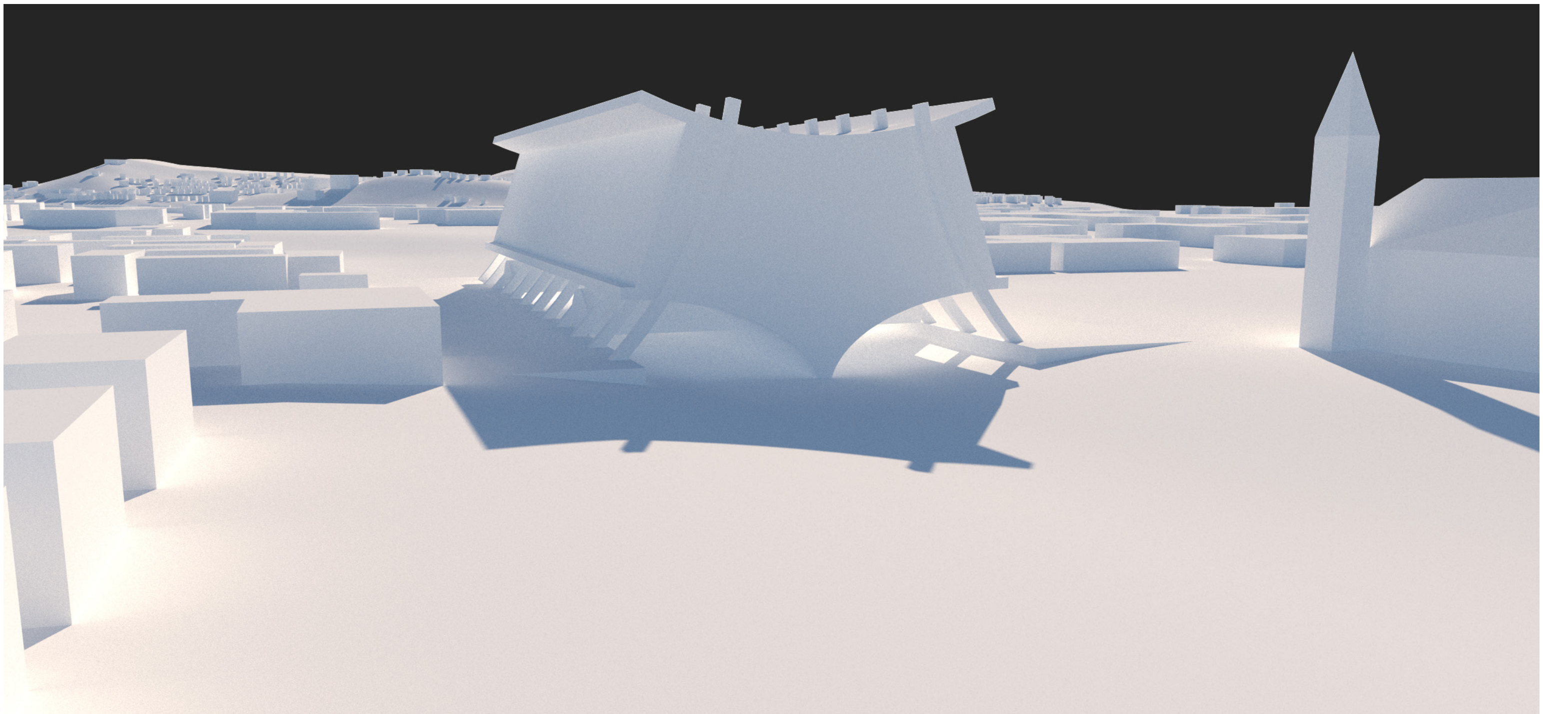


View From Union Terminal Render

Parametric Design Research | 'Dulles'

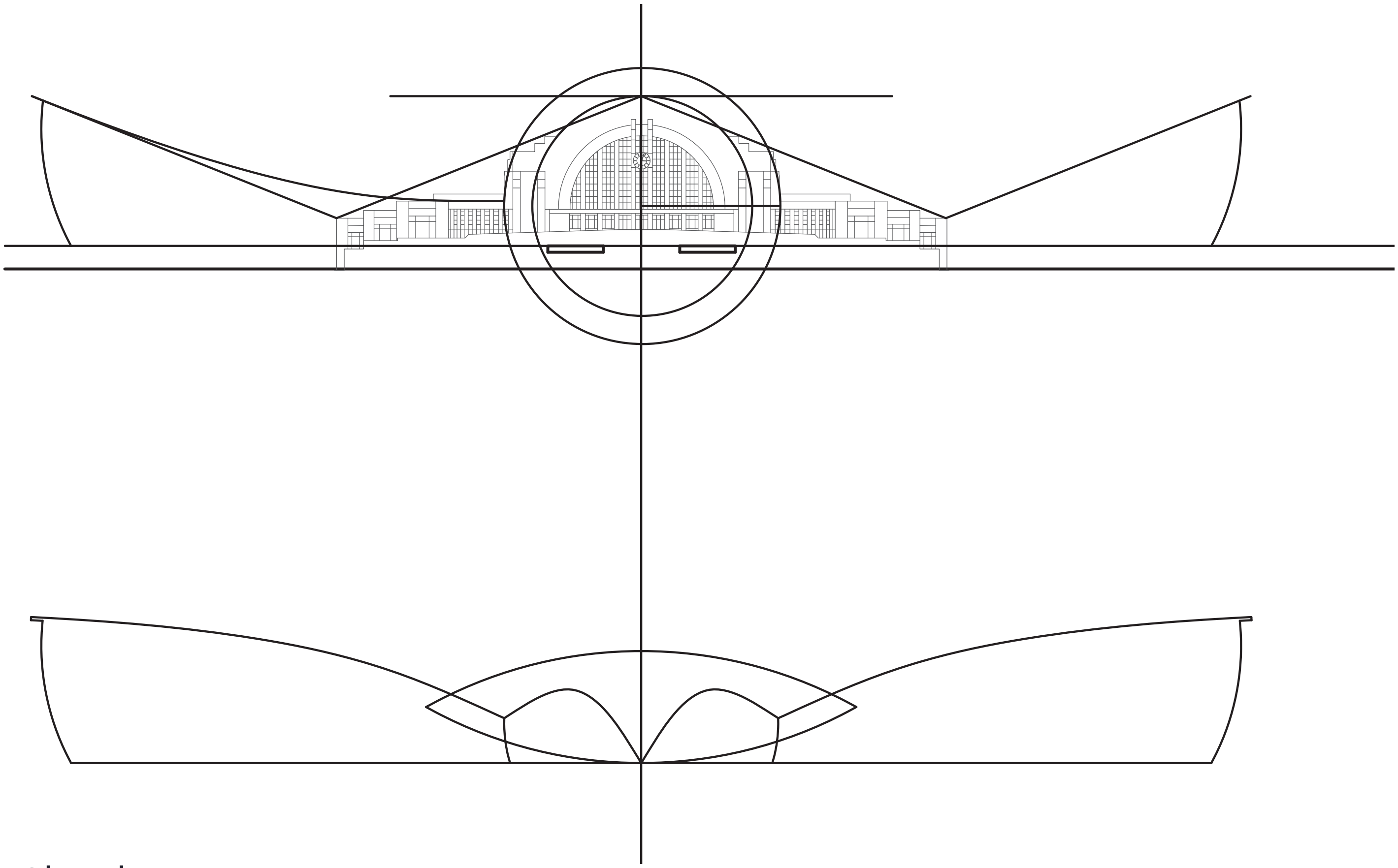


Building Form Diagram

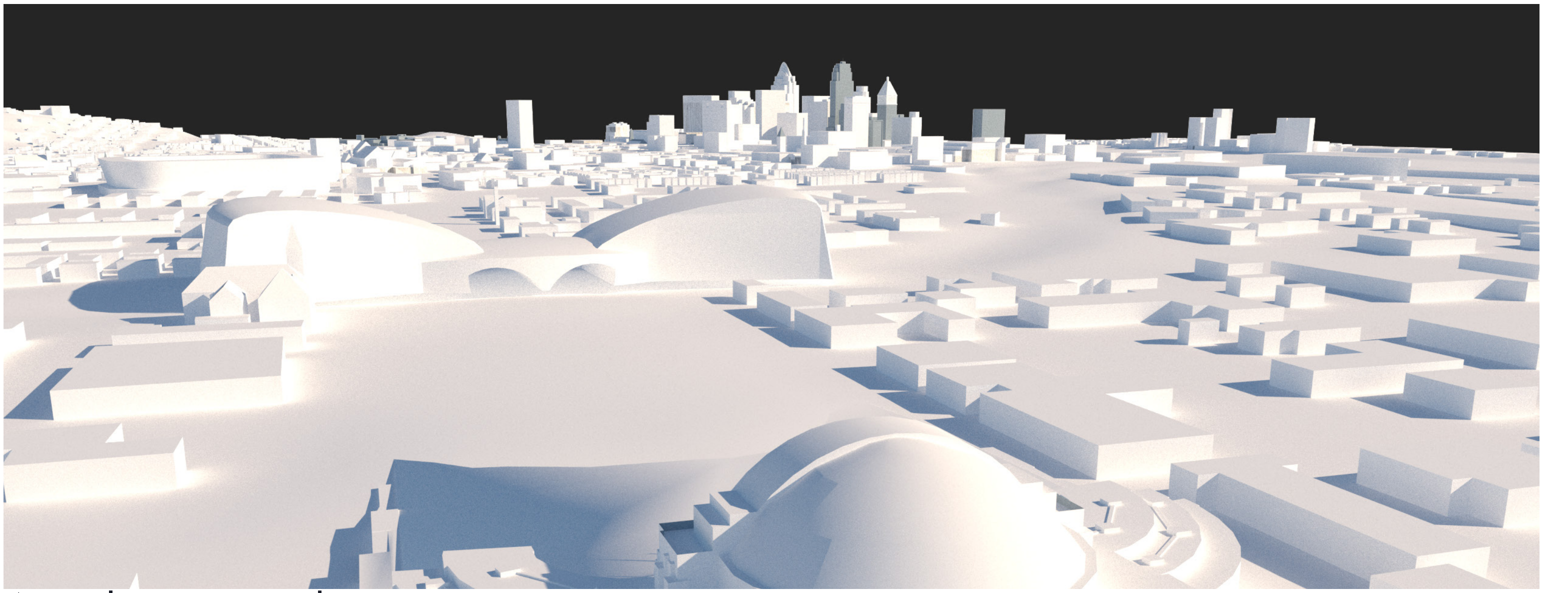


Side View Render

Parametric Design Research | 'TWA'



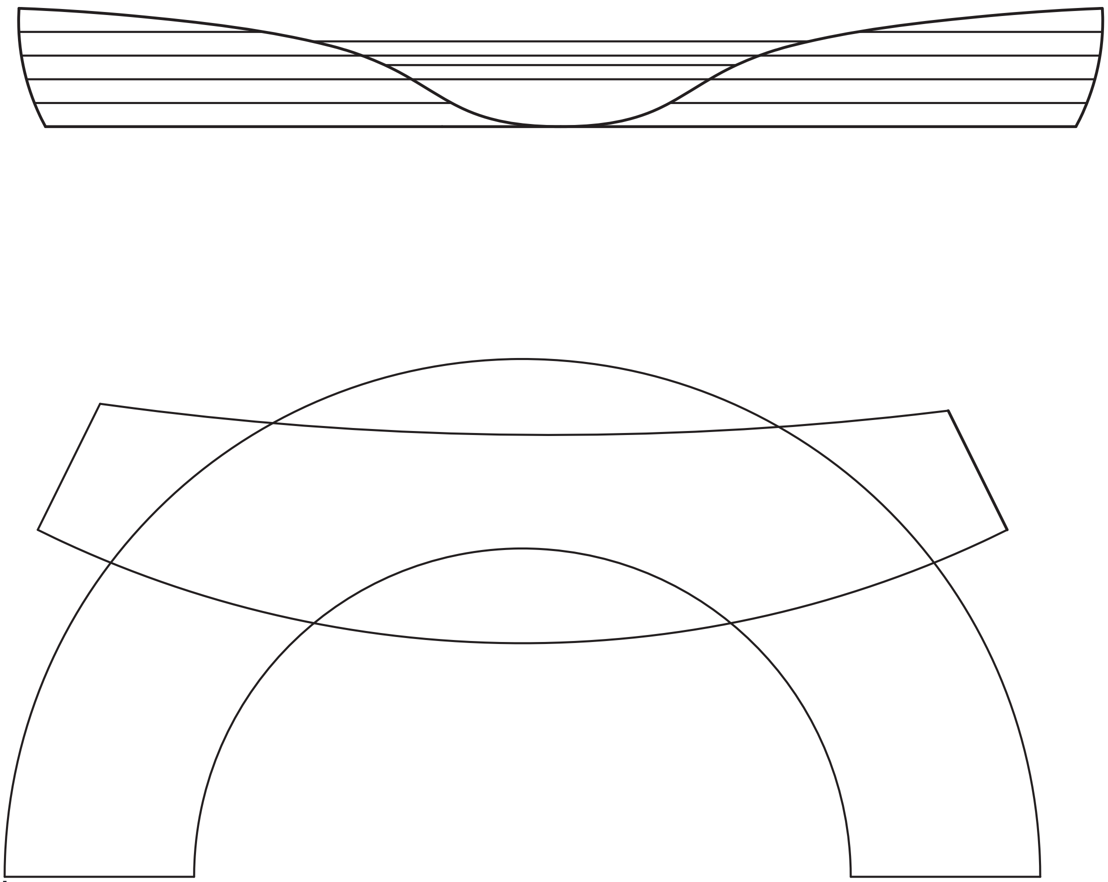
Design Sketch



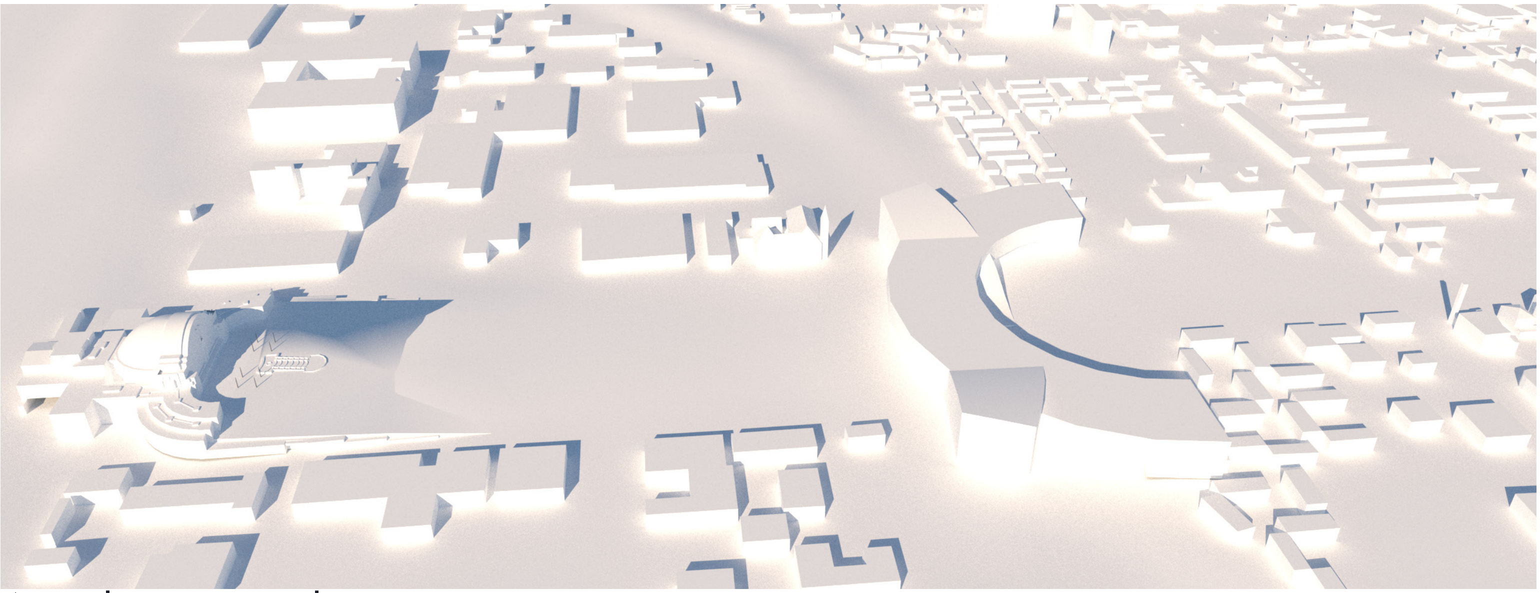
Aerial View Render

Schematic Design

Parametric Design Research | 'Hybrid'



Design Sketch



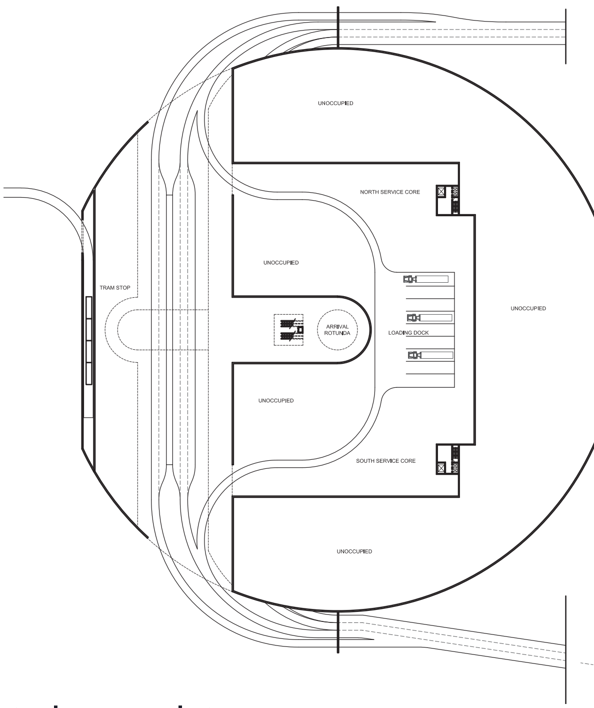
Aerial View Render

Design Development

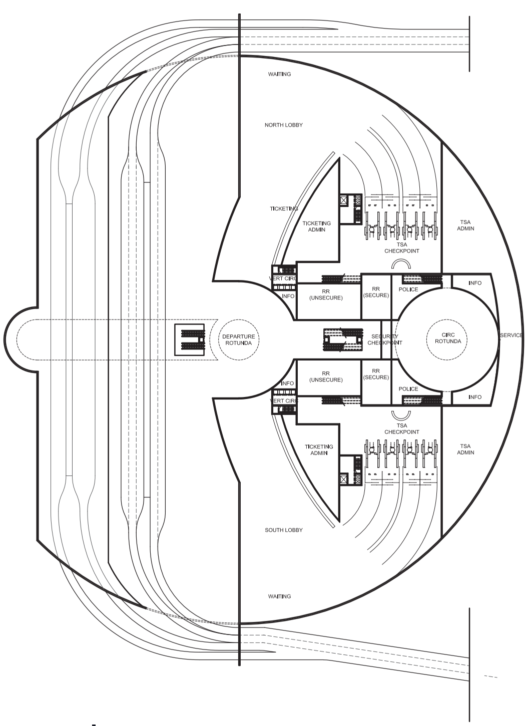
Design Development

Finalized Design Development

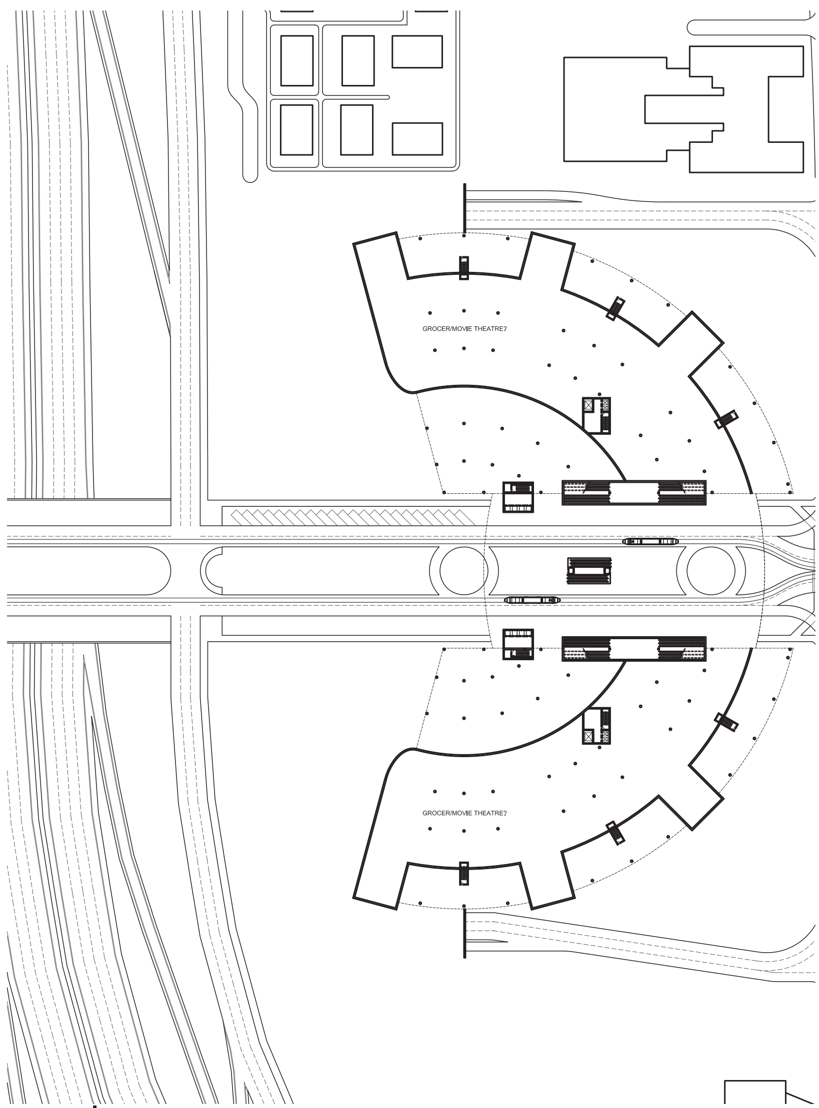
After a brief, but informative dive into parametric design, I determined that the most effective design was an adjustment and redesign of my initial schematic design building. Utilizing some the principles learned in my schematic design process I separated the building and bridge the area over the road with a glass atrium to lighten the structure and allow the building to impose less mass over Ezzard Charles.



Sub-Level 2
Pick-Off & Service Level



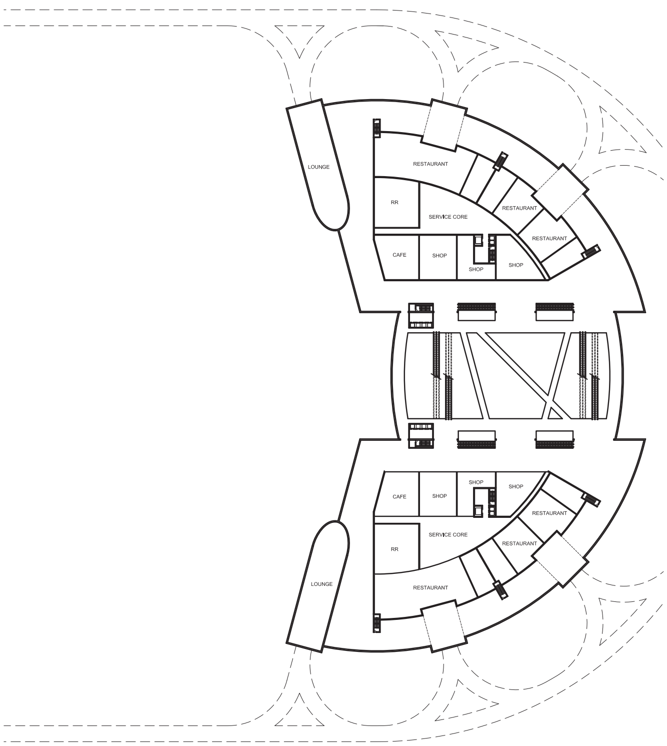
Sub-Level 1
Drop-Off, Lobby, & Security Level



Level 1
Public Commercial Level

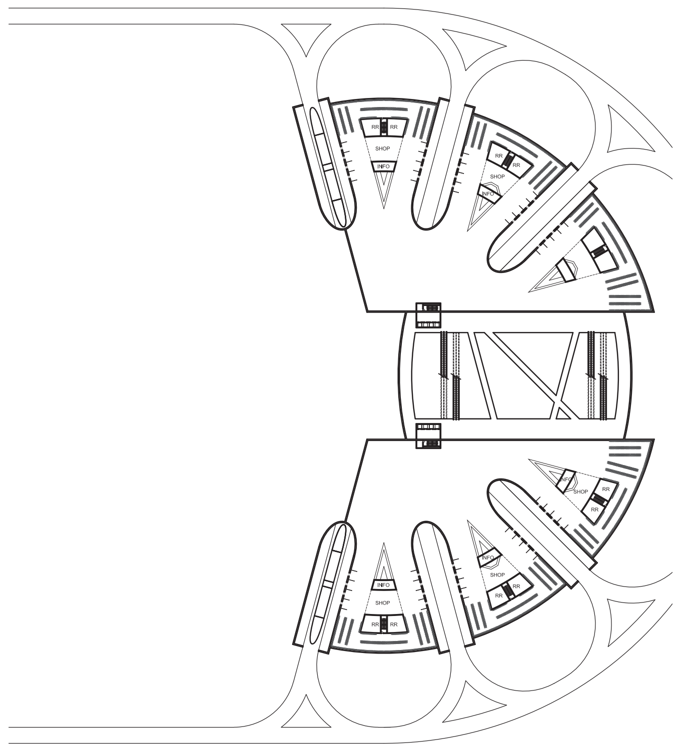
Design Development

Finalized Design Development



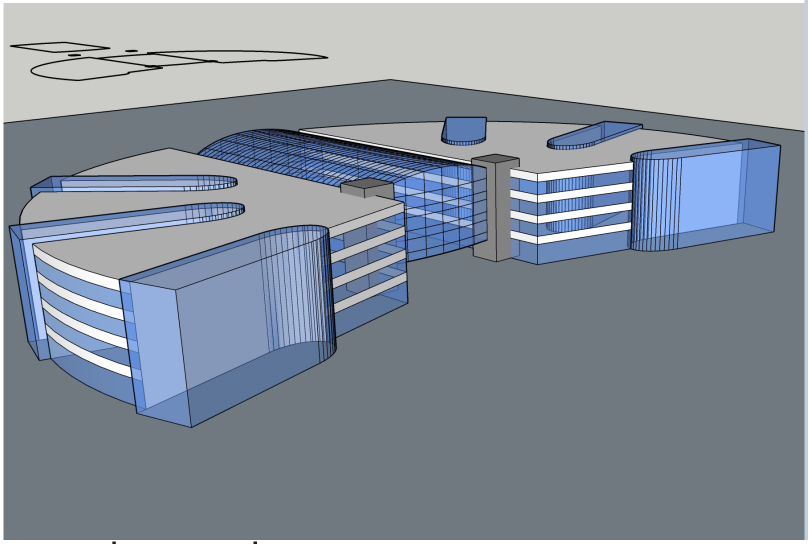
Level 2

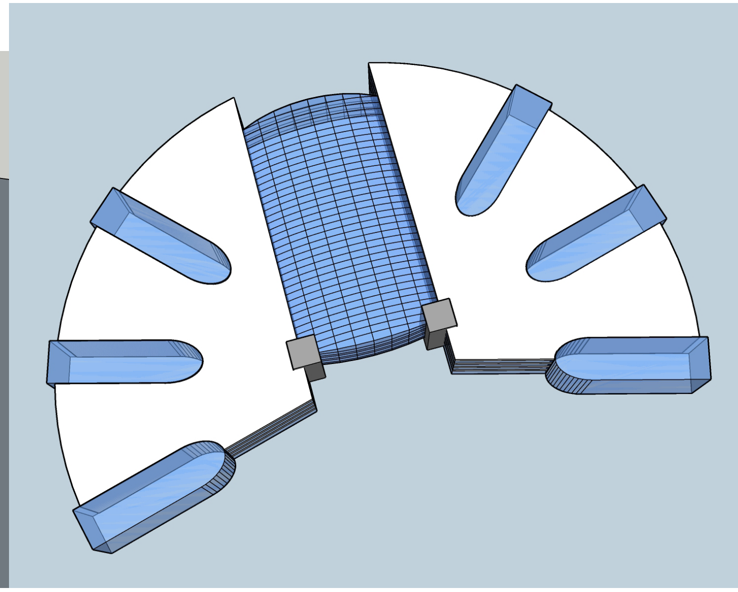
Concourse Level



Level 3 & 4

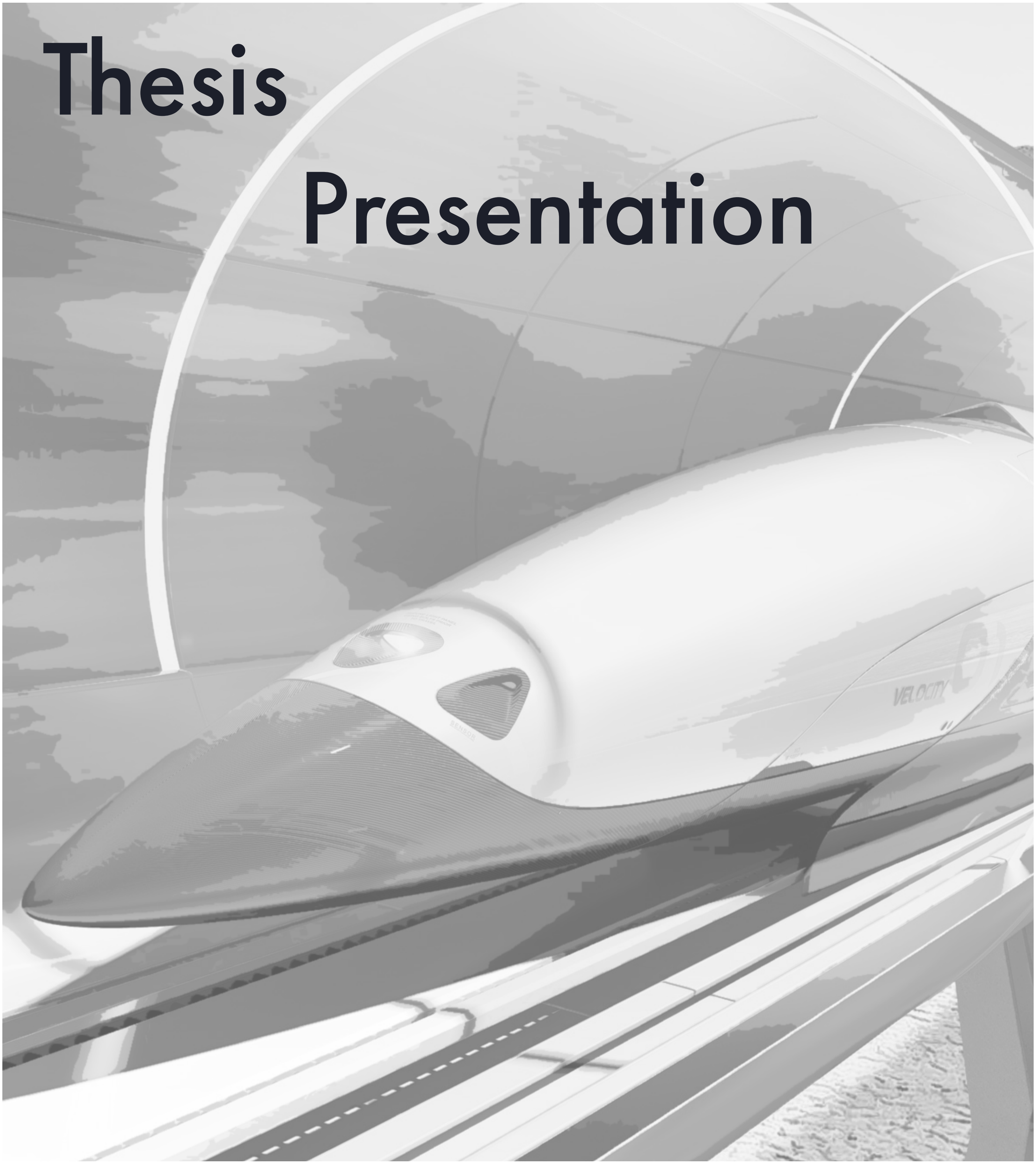
Terminal Levels



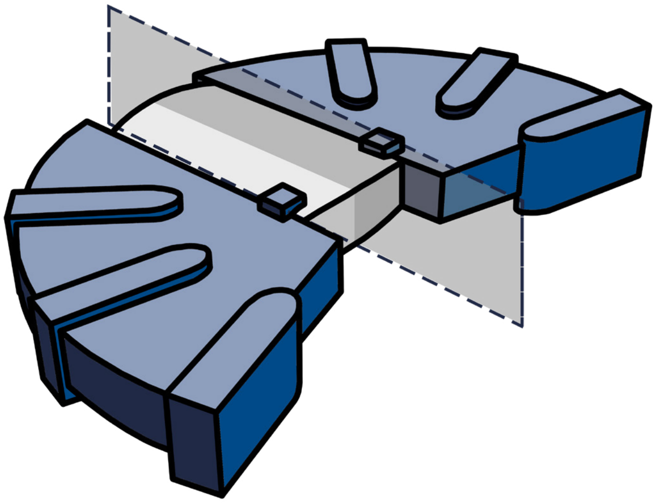


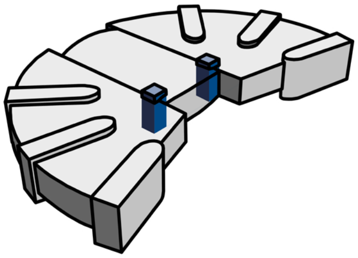
Facade Development

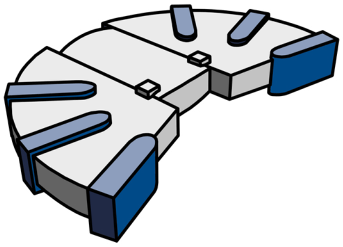
Thesis Presentation

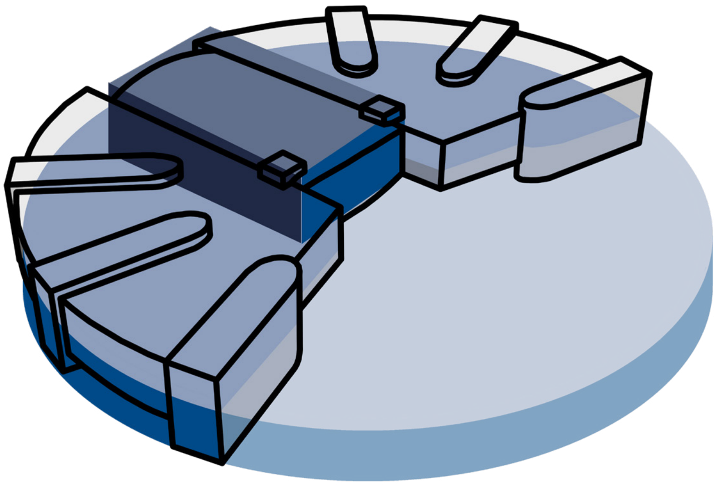


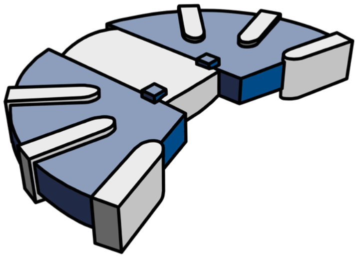
Building Diagrams

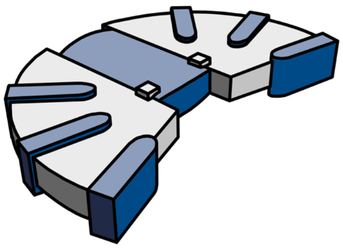

Symmetry


Core


Train Terminal


Geometry


Solid


Void

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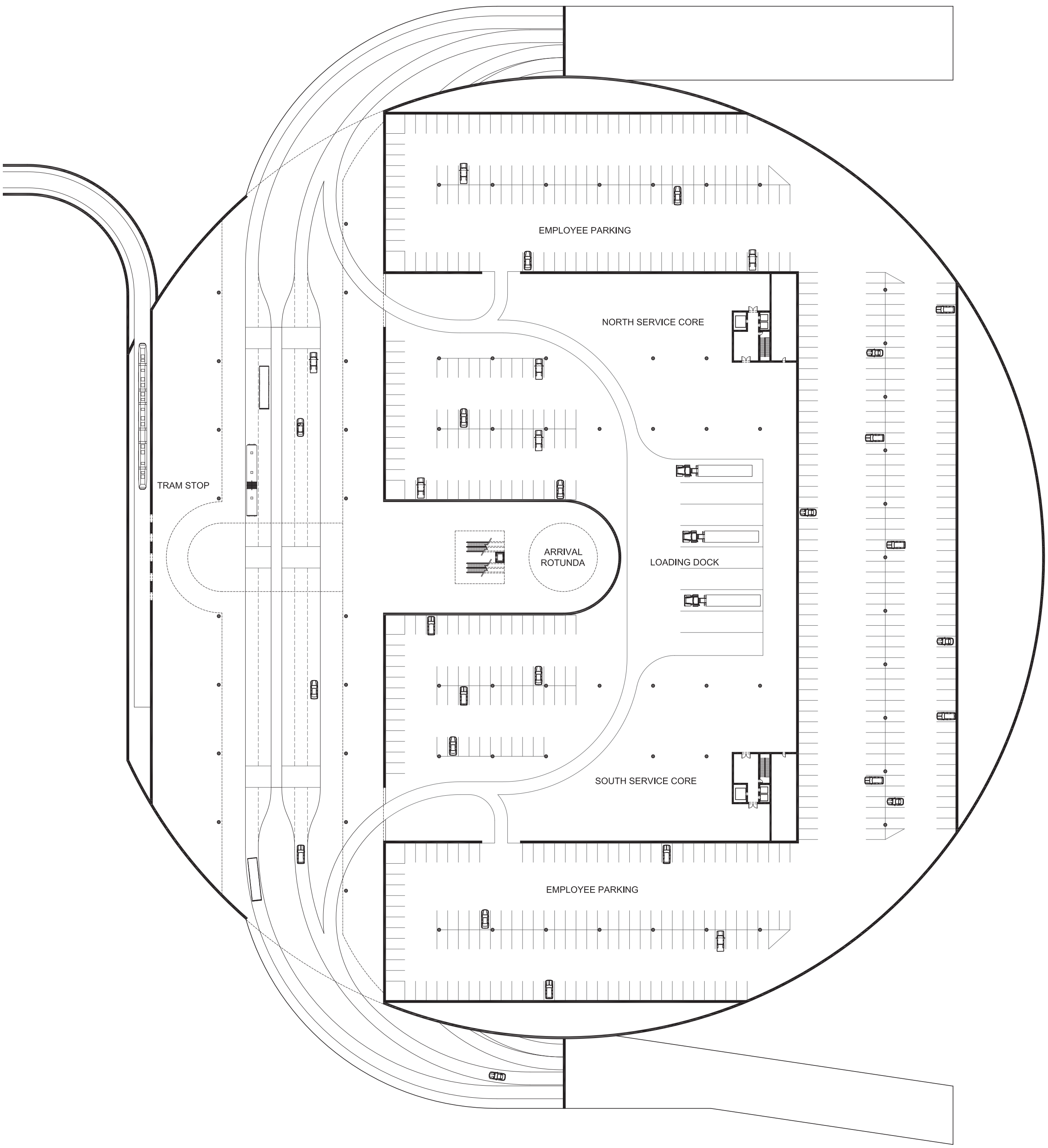
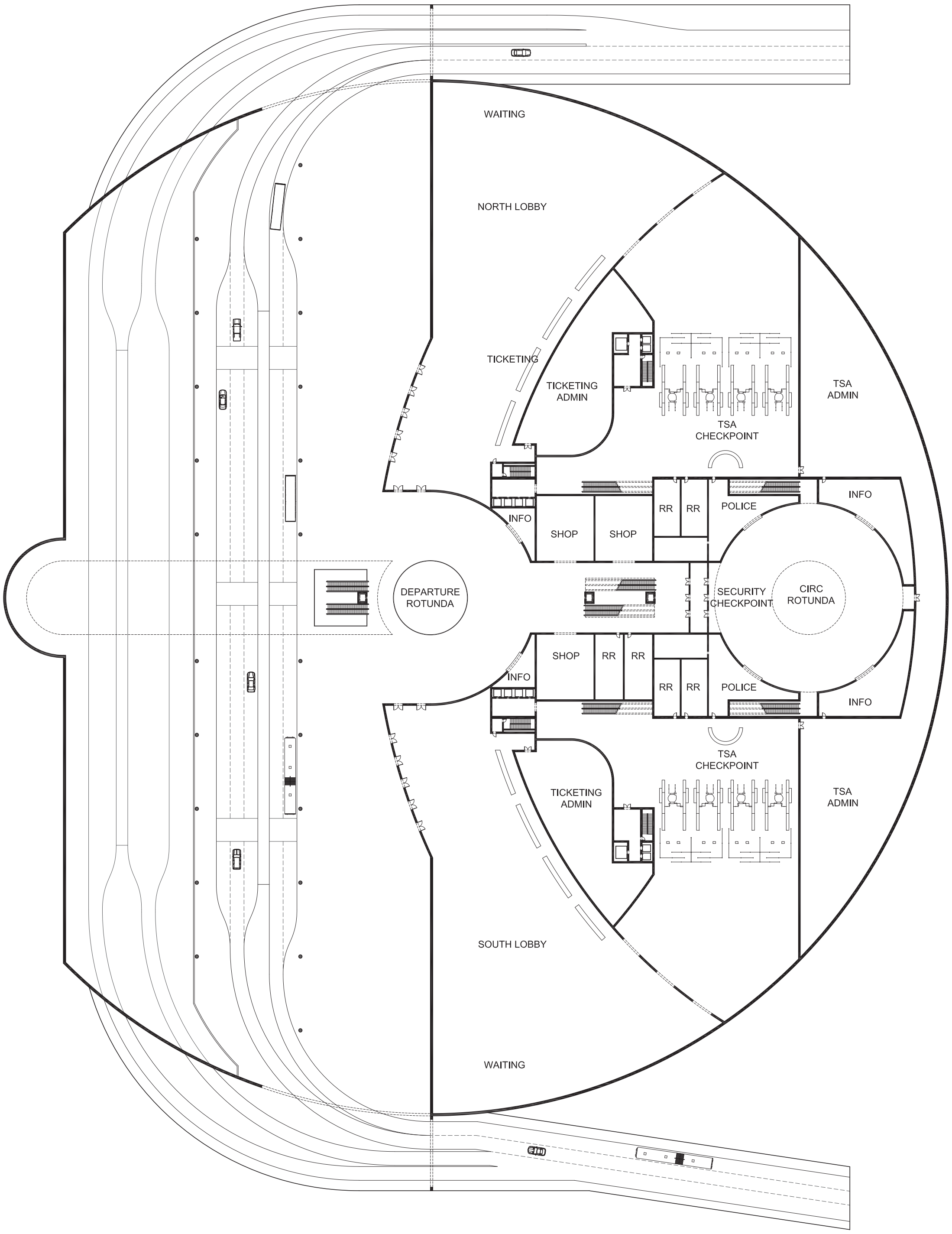
Terminal Floor Plans



Sub-Level 2
Pick-Up, Service, Parking Level

Thesis Presentation

Terminal Floor Plans



Sub-Level 1

Drop-Off, Lobby, & Security Level

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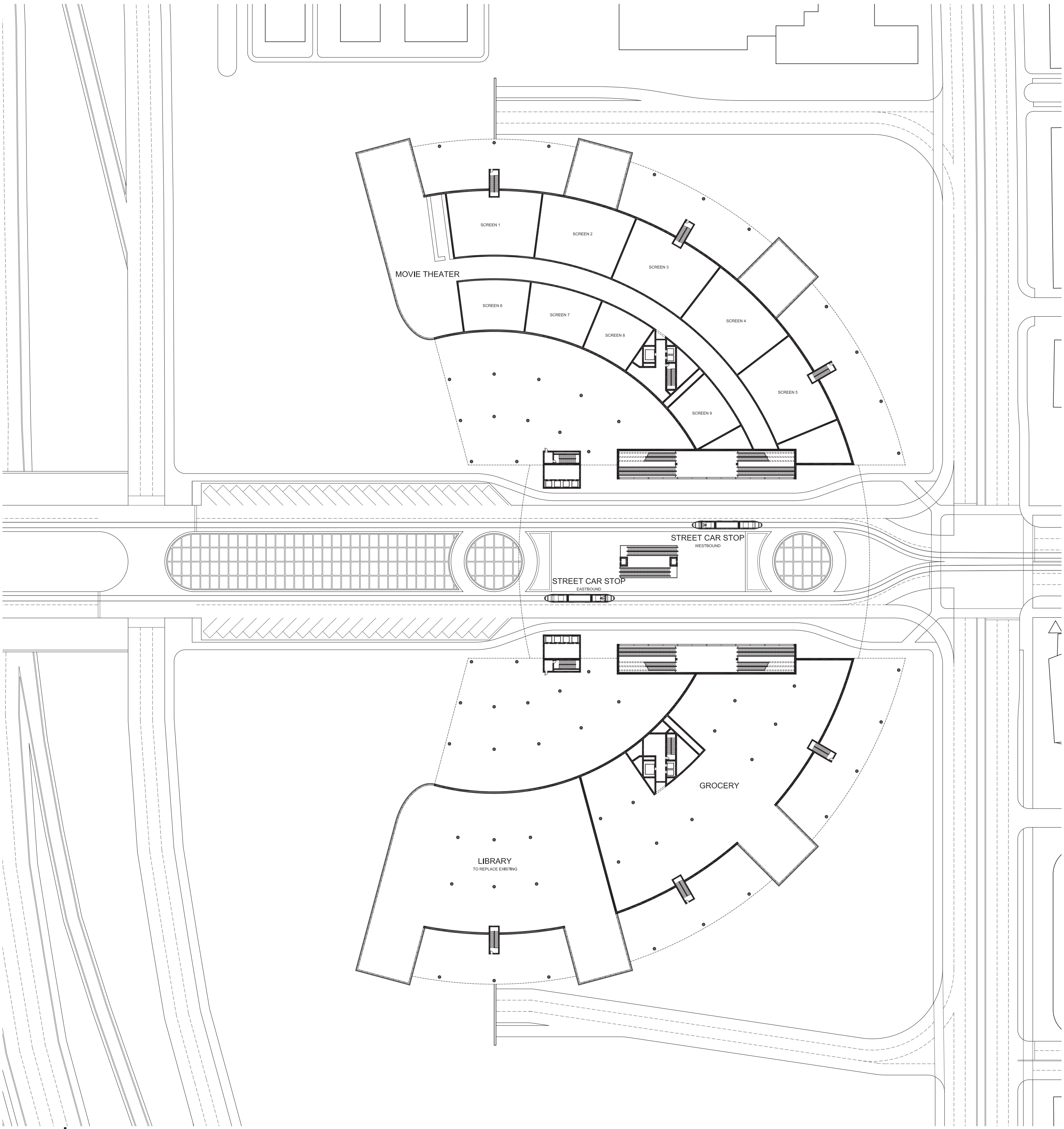
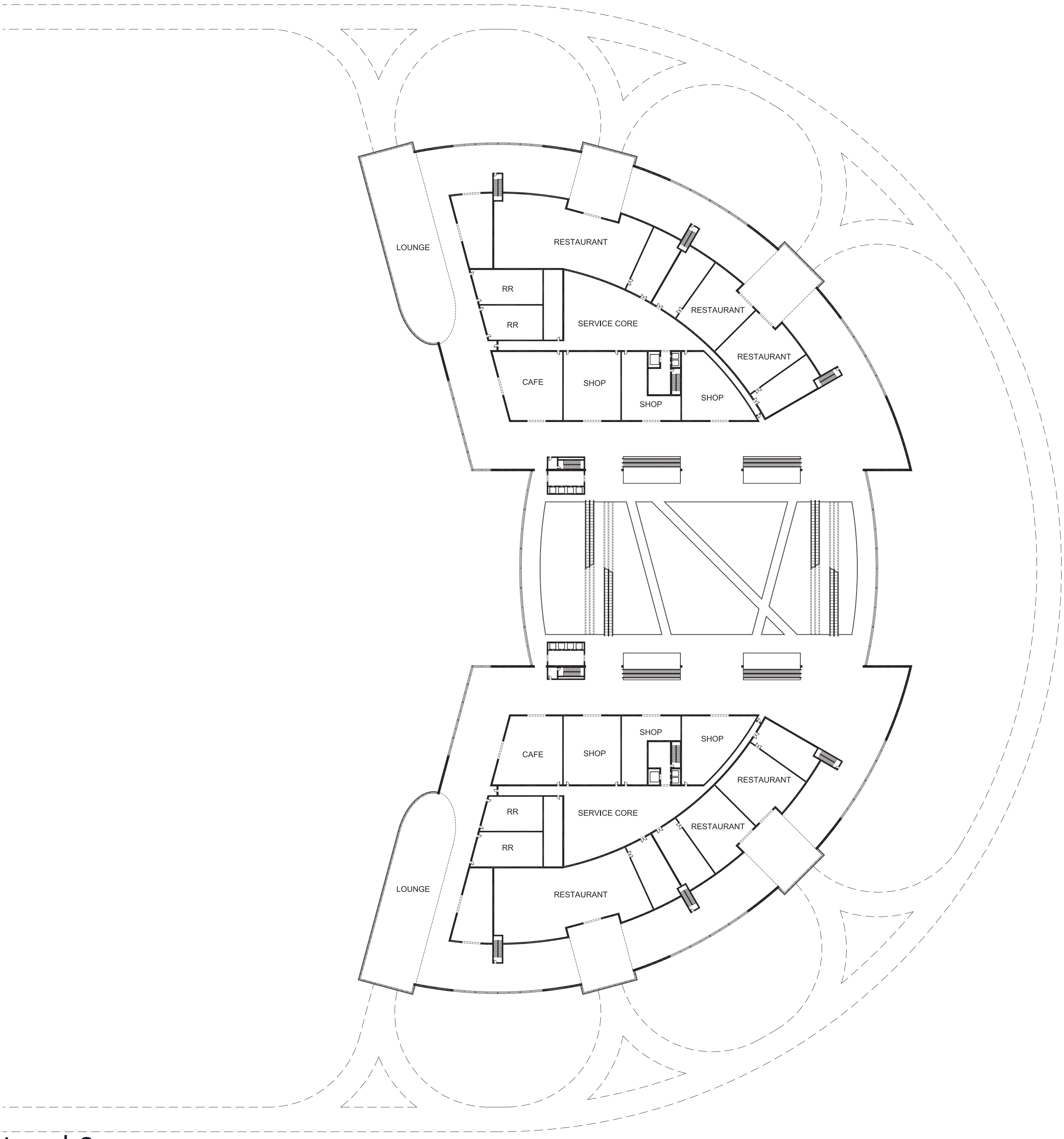
Terminal Floor Plans



Level 1

Public Retail Level

Terminal Floor Plans



Level 2
Concourse Level

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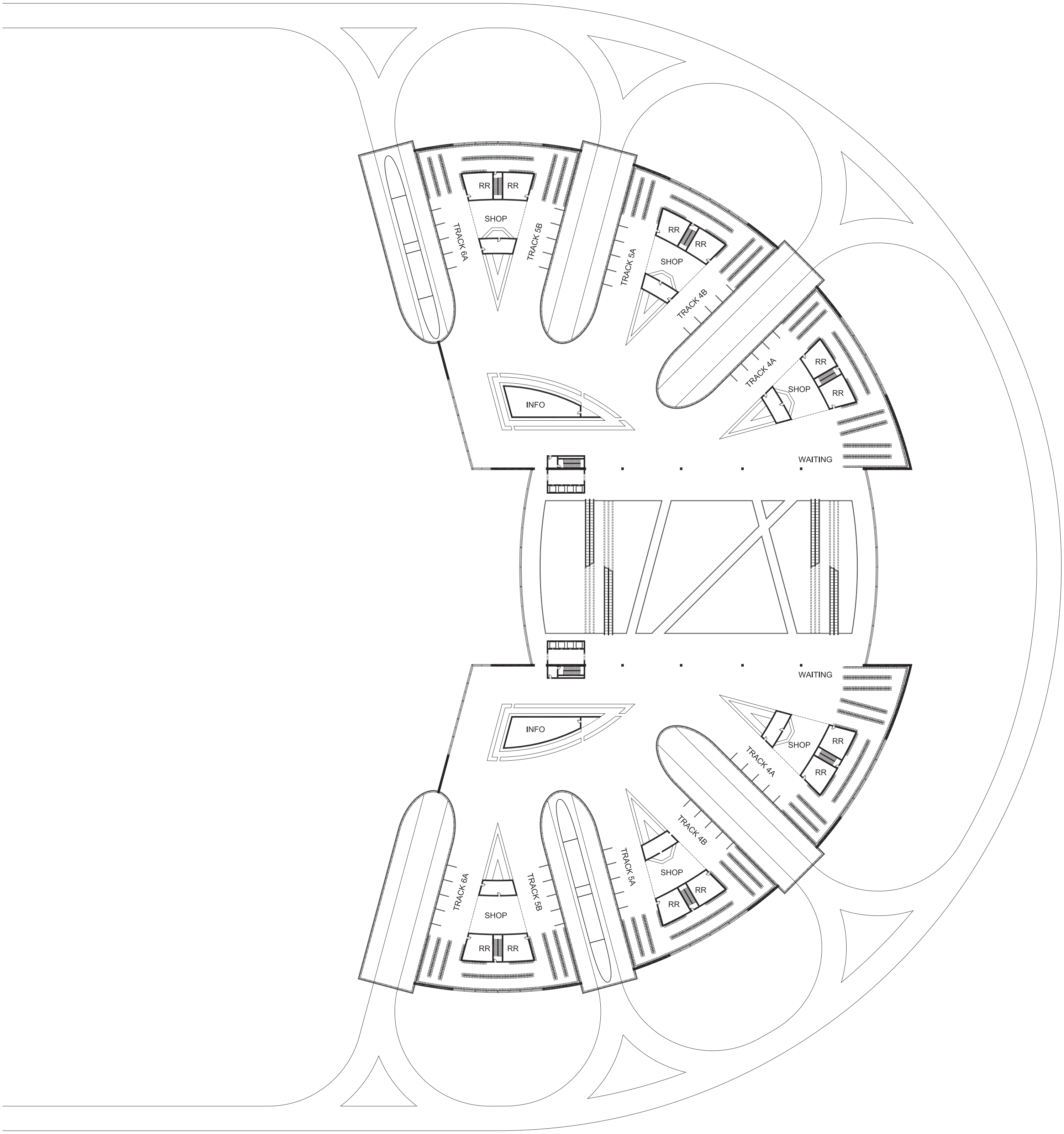
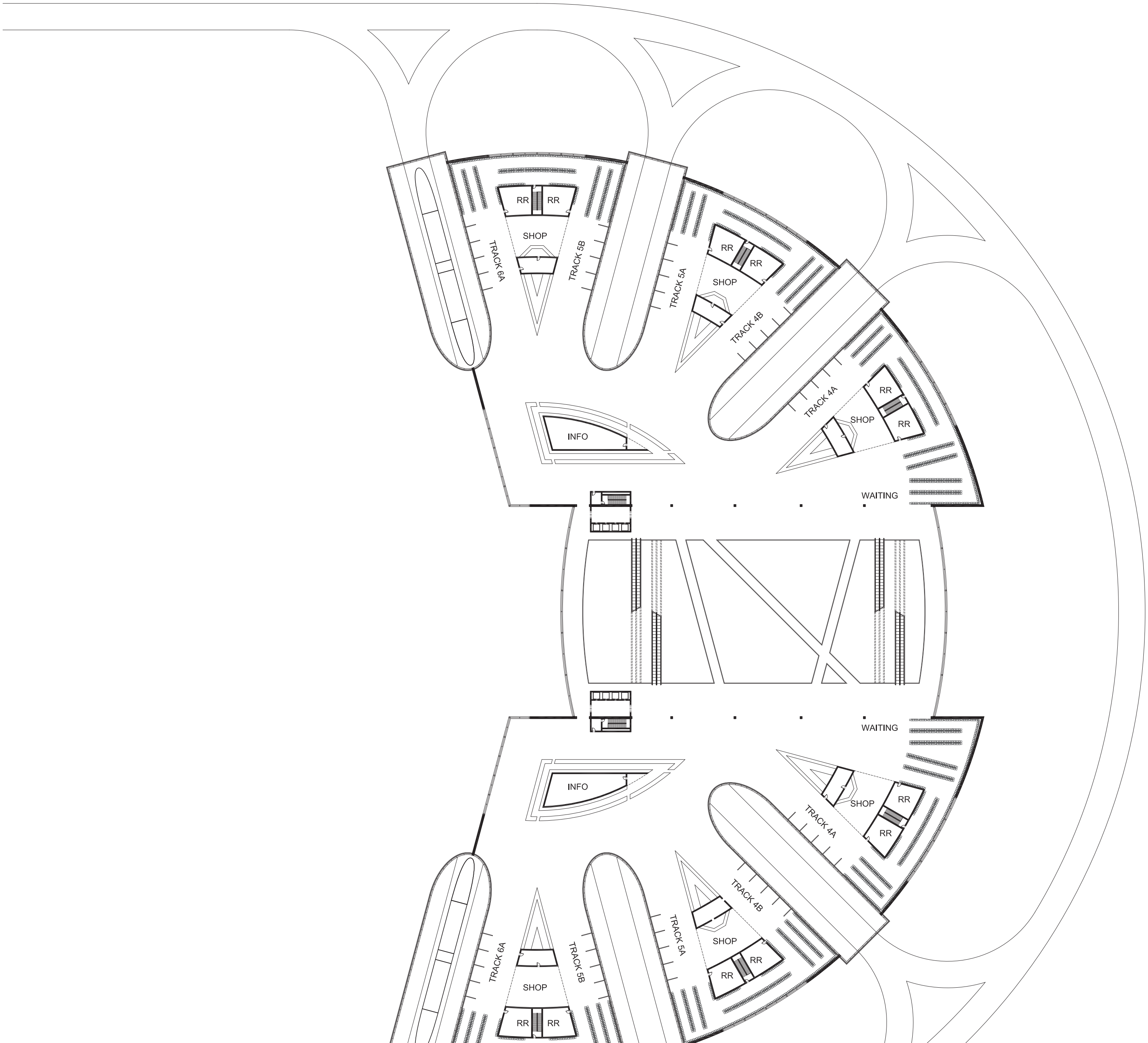
Terminal Floor Plans



Level 3
Terminal Level

Terminal Floor Plans



Level 4
Terminal Level

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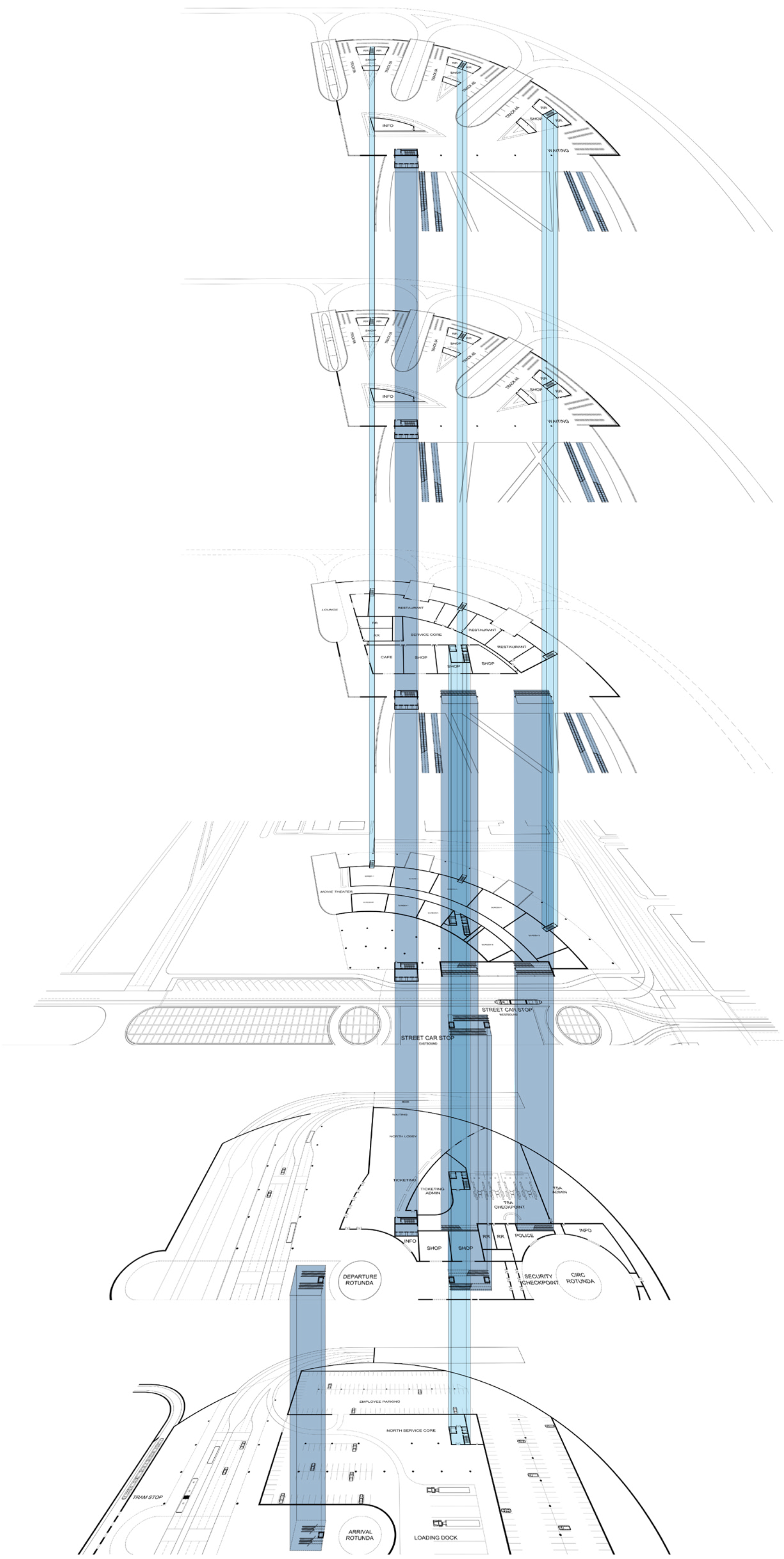
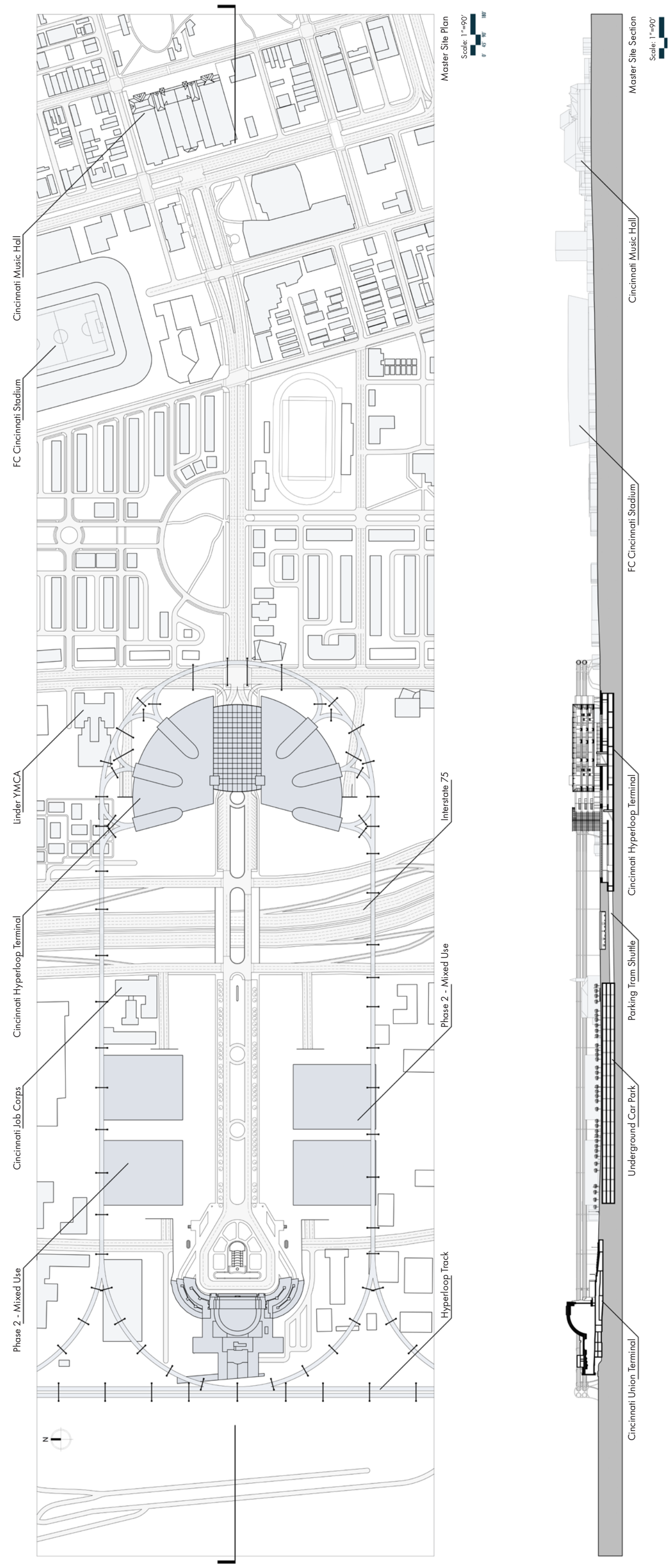
Terminal Circulation and Site



Vertical Circulation Diagram



Master Plan & Section

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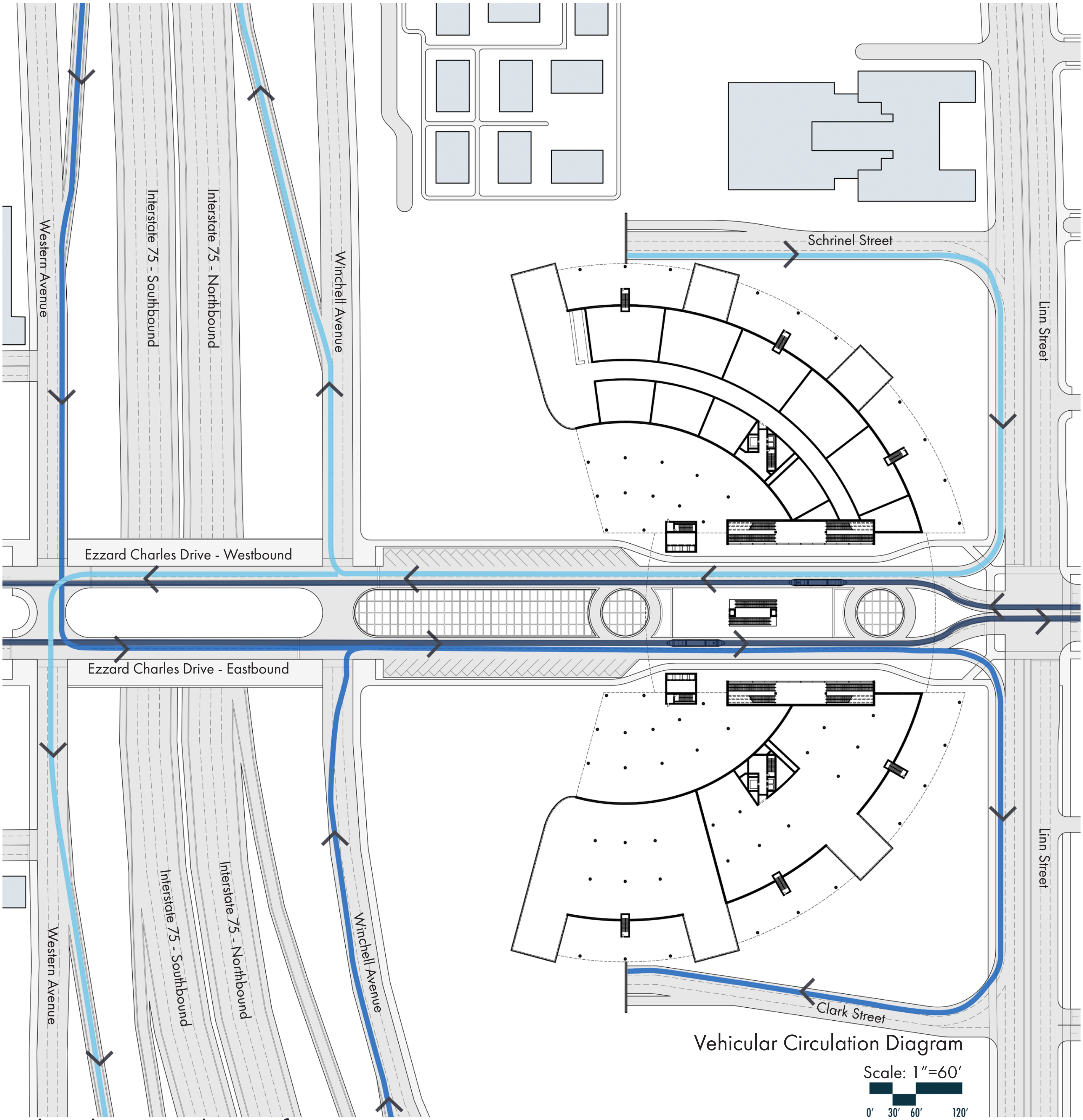
Site Context



Vehicular Circulation from I-75

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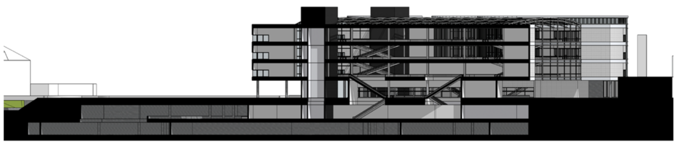
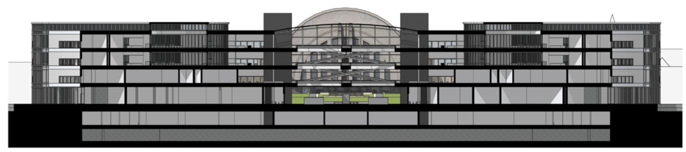
Elevations

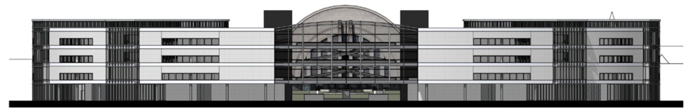


South Section



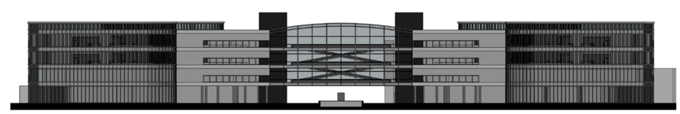
East Section

South Elevation



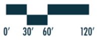
East Elevation

North Elevation

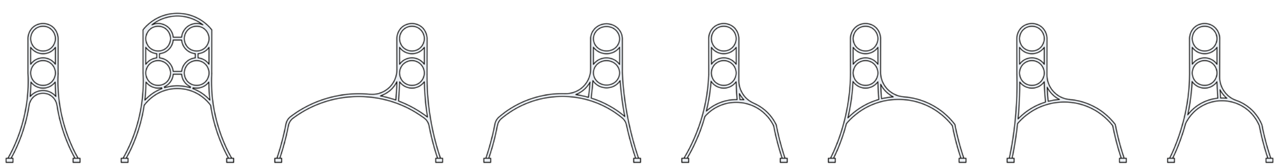


West Elevation

Scale: 1″=60′



Building Sections & Elevations



Hyperloop Track Supports

Scale: 1″=30′

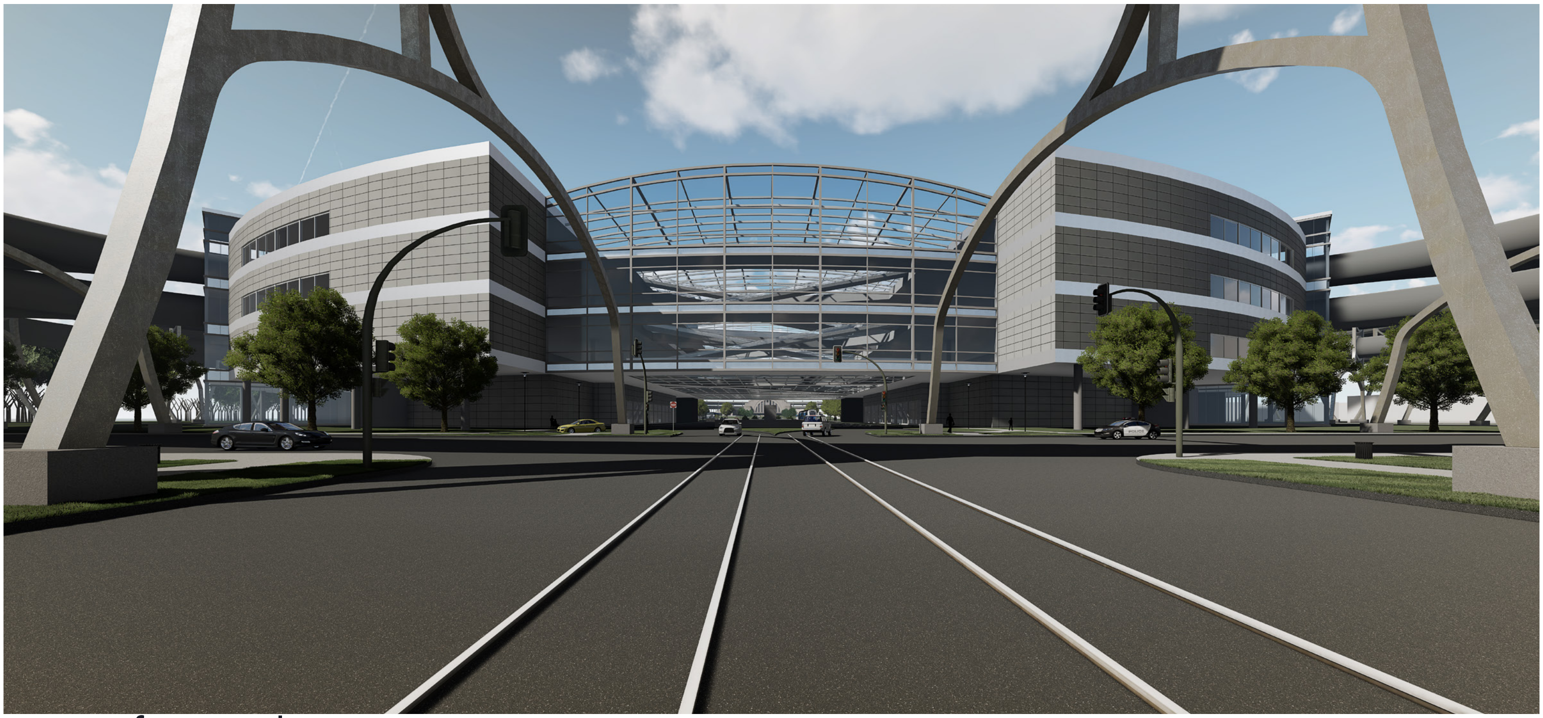
0' 15' 30' 60'

Track Structure Elevations

Thesis Presentation

Renderings

View of Front Elevation



View of Rear Elevation

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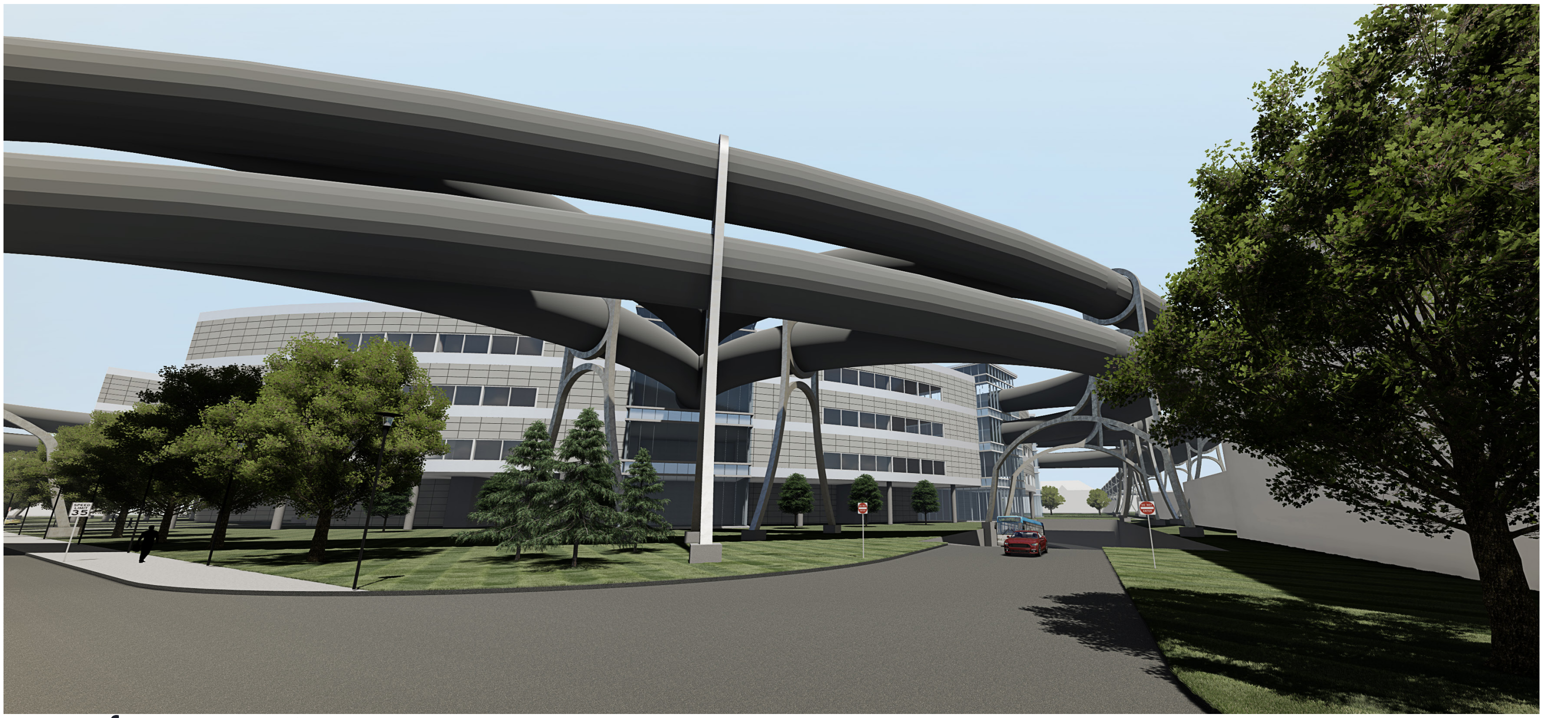
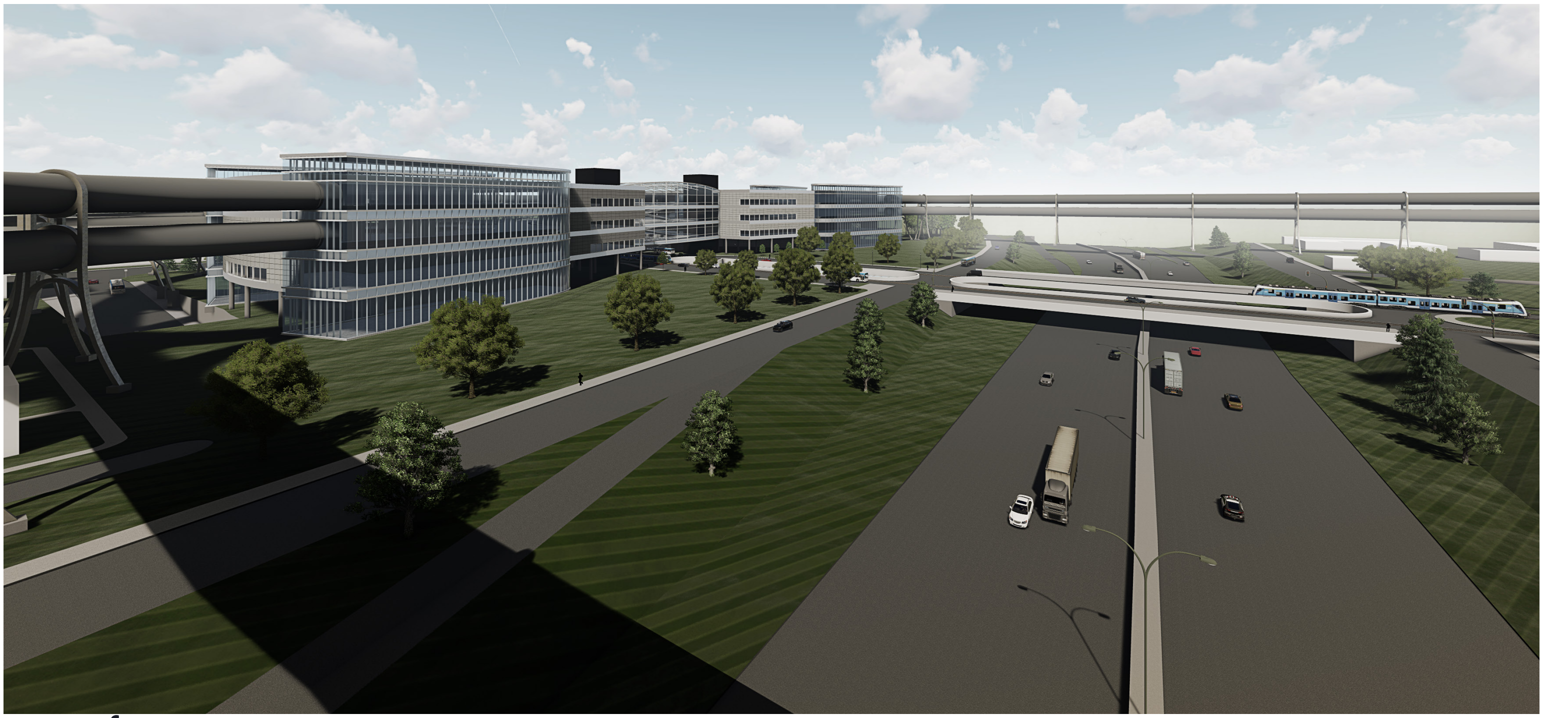
Renderings

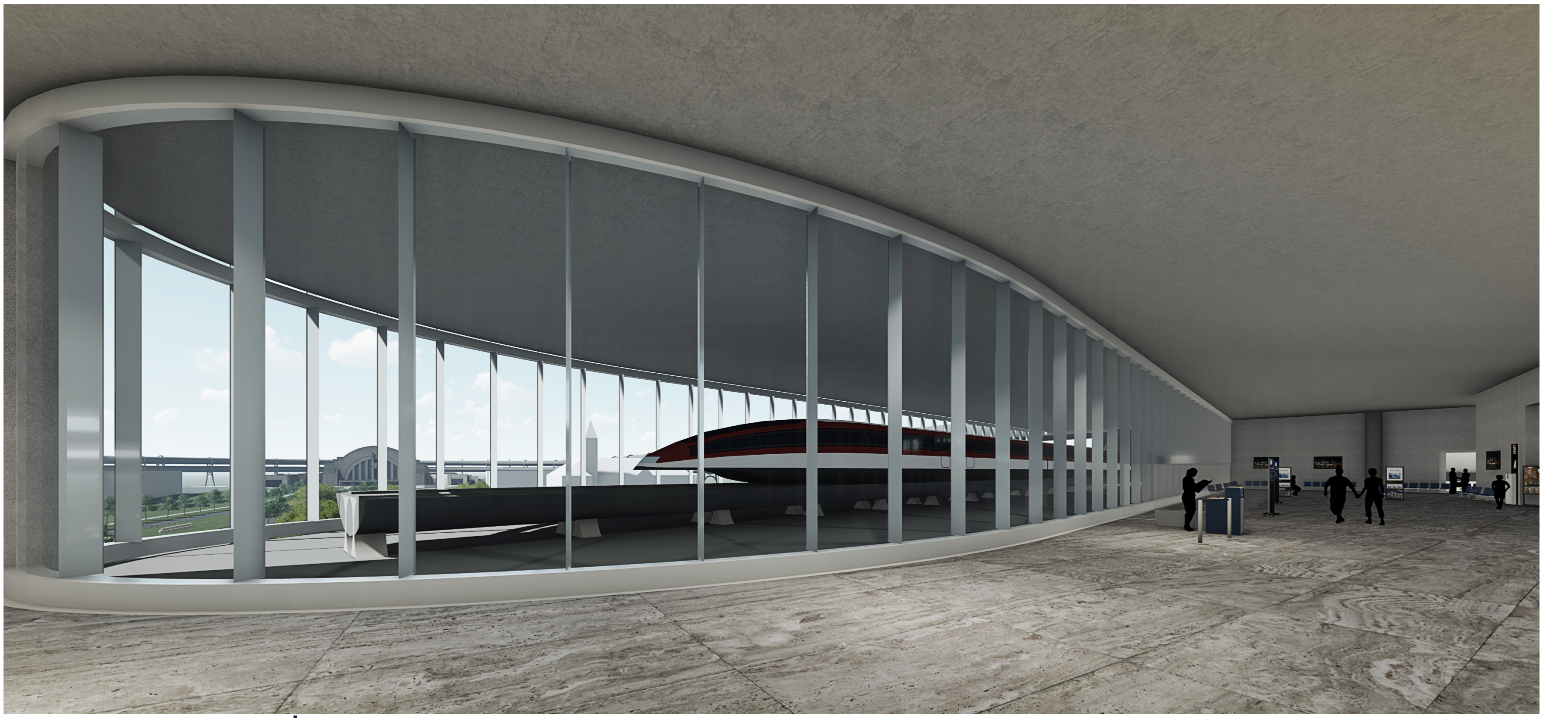


View from Linn St

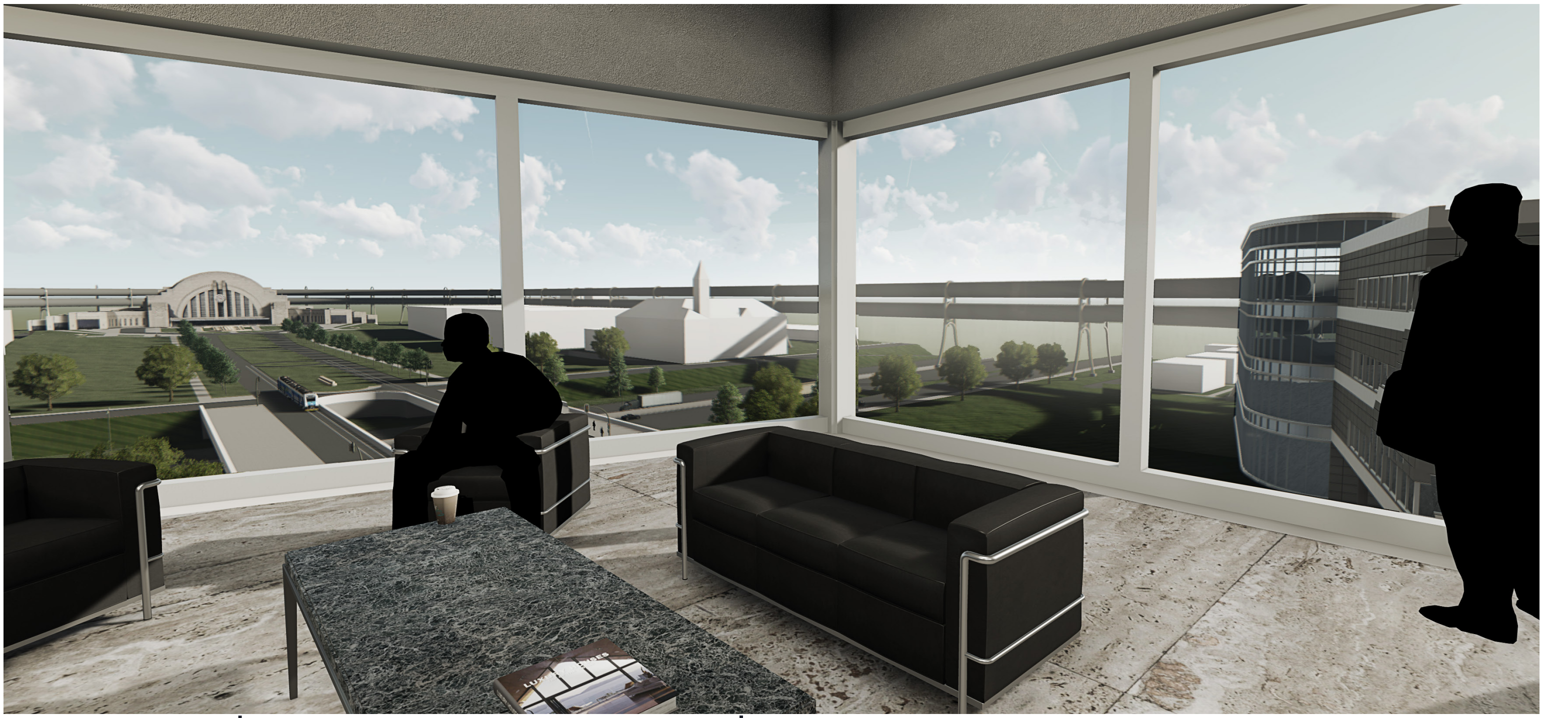


View from Incoming Train

Renderings



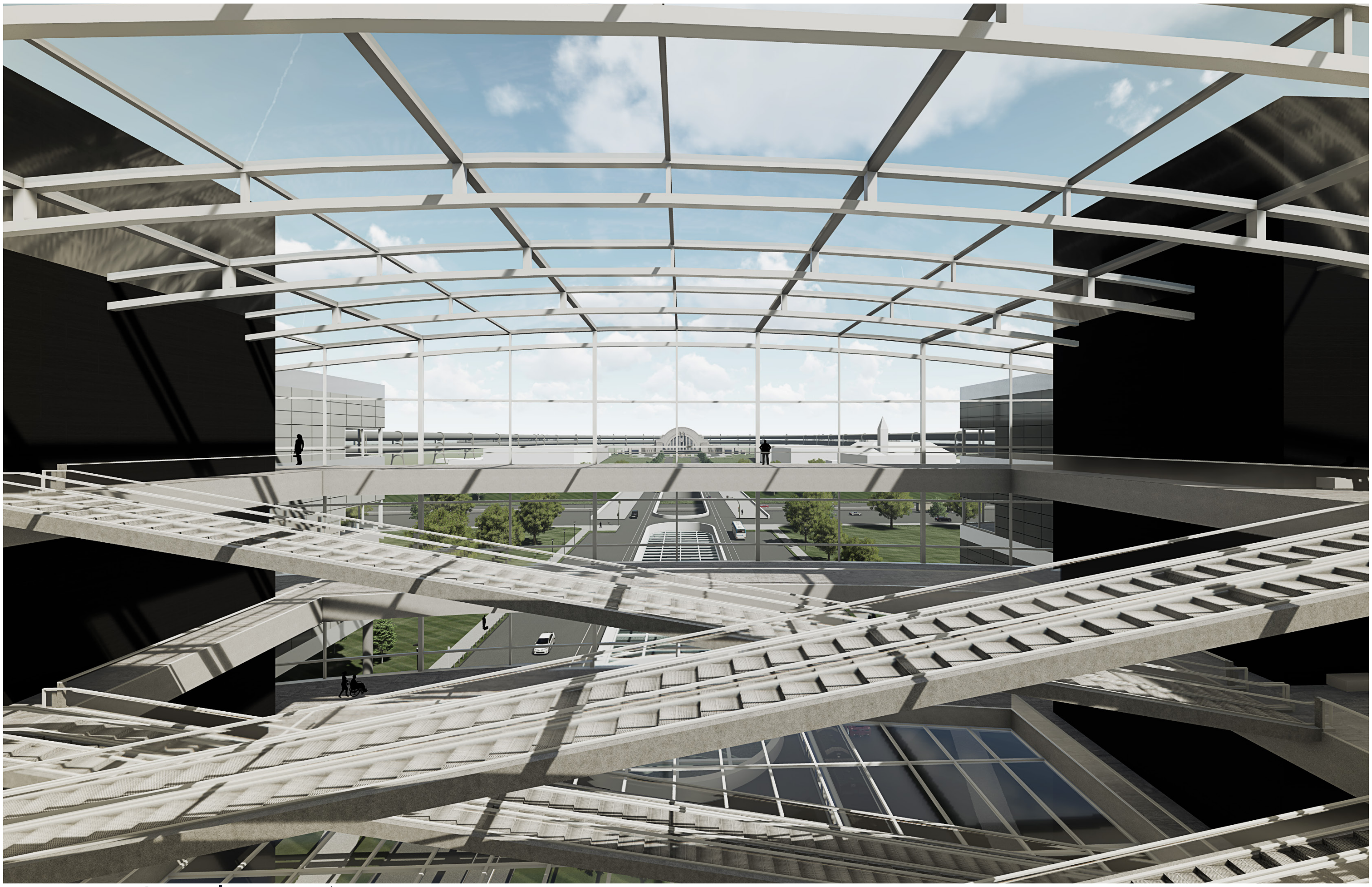
Interior Terminal Gate



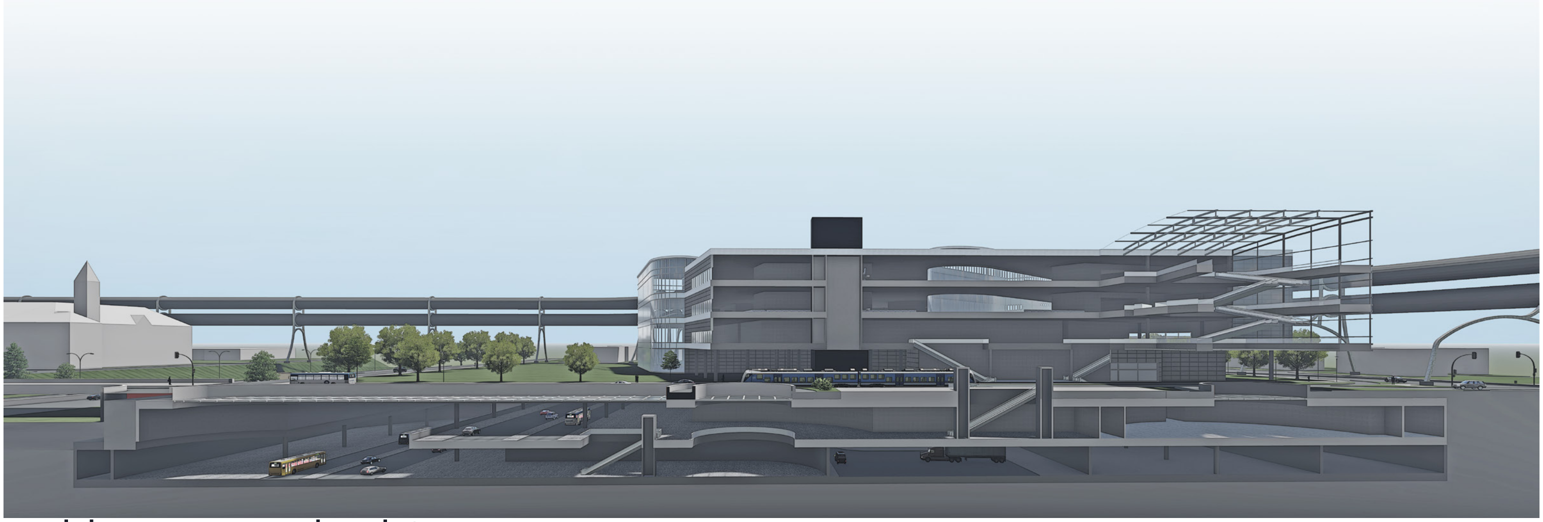
View Towards Cincinnati Union Terminal

Thesis Presentation

Renderings



Interior Circulation Atrium



Building Longitudinal Section

Thank You