SMART PUBLIC TRANSPORTATION AND MOBILITY HUB DESIGN IN EL PASO

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Master's Program in Civil Engineering

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SMART PUBLIC TRANSPORTATION AND MOBILITY HUB DESIGN IN EL PASO

by

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Declaration

This thesis is an output of the International Dual Master's Degree Program in Smart Cities and Engineering, a collaboration between the Czech Technical University in Prague, Czech Republic and The University of Texas at El Paso, USA.

This research is jointly supervised by the following faculty members:

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I declare this master's thesis is my own work and that I list all references in compliance with ethical guidelines on elaboration of master's thesis.

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El Paso, Texas, USA

May 2, 2024

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Abstract

This thesis explores the potential of a Smart Public Transportation concept and mobility hub design as tools to mitigate the growing trend of transportation issues, such as traffic congestion, reliance on privately owned vehicles, or unattractive public transportation. Consequently, residents' lives are negatively affected by excessive noise, air pollution, and travel delays, leading to increased safety risks, lost productivity, and a lower quality of life. Considering these challenges, the study begins by analyzing the current state of public transportation in El Paso. Next, it introduces a toolkit from the Smart City concept, followed by case studies of best practices of public transit and mobility hub implementation from American and European conditions. Lastly, the core of this thesis lies in the design of a mobility hub in Downtown El Paso, accompanied by implementation recommendations. Hopefully, this work will serve as a roadmap and contribute to more sustainable and accessible transportation for the benefit of El Paso.

Keywords: Mobility Hub, El Paso, Sustainable Mobility, Smart City, Public Transportation, Micromobility

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- Identification of the best practices – case studies
- Solution and improvements proposal

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I confirm assumption of master's thesis assignment.

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1. INTRODUCTION

1.1. Location and Population

El Paso is located in the Chihuahuan Desert in the western corner of Texas in the USA. It surrounds the Franklin Mountains to the north, with a downtown elevation of 3,740 feet above sea level. El Paso has a high desert climate characterized by wind, resulting in sand and dust storms mainly in the spring, monsoon season in the late summer, and mild winters. On average, there are 302 sunny days per year. The city's southern border is defined by the international border between the USA and Mexico, formed by the Rio Grande River running in a system of artificial channels. As of July 1, 2022, its residential population was 677,456 citizens, while El Paso County had 868,763 residents (“U.S. Census Bureau QuickFacts” n.d.). That makes El Paso the 22nd biggest city by population in the USA (“Largest cities in the United States by population,” n.d.). Its unique location makes the city rare in various characteristics. Across the border in the Mexican state of Chihuahua lies its most populous city, Ciudad Juárez, with a metropolitan population of 1,582,313 people (“Ciudad Juarez Population 2023,” n.d.). These two cities create one of the largest bi-national metropolitan areas in the world, combining for more than 2.7 million people (“El Paso, Texas” 2023), making El Paso a crucial border crossing point for both people and goods movement, turning it into an important economic hub. Consequently, more than 80% of people in El Paso identify as Hispanic, and families and relatives are often split between Mexico and the US. (“U.S. Census Bureau QuickFacts” n.d.). Despite the misconception that being right on the border would be dangerous, the city was ranked the third safest large city in America (“Quality of Life & Migration,” n.d.). It might be because of the strong military and law enforcement presence since El Paso is home to Fort Bliss military base, the Drug Enforcement Administration (DEA) division, and the local headquarters of Customs and Border Protection (CBP).

1.2. Transportation

Road Transport

The most important road that passes through El Paso is I-10, the fourth-longest interstate in the USA. It runs from Santa Monica, California, west through Phoenix, Arizona, continues to Las Cruces, New Mexico, and enters Texas at El Paso, runs through San Antonio, and continues to Houston, Texas, Baton Rouge, and New Orleans, Louisiana, further east to Mobile, Alabama, finally terminating in Jacksonville, Florida (“Interstate 10” 2023).

Connecting highways in El Paso include the following:

- **U.S. Route 54,** which runs from El Paso to Griggsville, Illinois,
- **U.S. Route 180,** which starts in Valle, Arizona, and runs through El Paso to Hudson Oaks, Texas,
- **U.S. Route 62** connecting the USA and Mexican border in El Paso and the USA and Canadian border in Niagara Falls, New York,
- **U.S. Route 85** is part of the CanAm Highway and represents another connection between Mexico, the USA, and Canada, starting in El Paso and ending in Fortuna, North Dakota.

From the list above, it can be observed that El Paso is not only an international crossroad but also the origin and destination of many trips inside the USA. That leads to high traffic counts and often traffic congestion, while I-10 from U.S. 54 to Hawkins Blvd ranks 87th on the list of Texas’ 100 most congested road sections, with a daily volume of nearly 154,000 vehicles (“Texas’ Most Congested Roadways - Mobility Division” 2021). However, in 2009, three of El Paso’s road sections were on the list (two more than in 2021), which shows the city’s progress in addressing congestion over the last decade (GISGeography 2018).

Four international Ports of Entry (POEs) connecting El Paso with Juarez are equally significant to the city's transport network. Bridge of the Americas (BOTA) and Ysleta-Zaragoza POE, where most of the commercial cross-border traffic is concentrated, are essential. Stanton POE is mainly used by pedestrians and passenger cars crossing only from the USA to Mexico. Paso del Norte is the last POE located within the city, which is used for pedestrian crossing both ways and passenger cars crossing only from Mexico to the USA. Daily averages of 2022 movement at all of the points of entry combined, including further away located Santa Teresa POE, and Tornillo – Guadalupe POE in the northbound direction were 13,733 pedestrians, 31,468 passenger vehicles, and 2,591 commercial vehicles ("PDN | El Paso Juarez Border Crossings" n.d.). An overview of the city's points of entry can be observed in Figure 1.

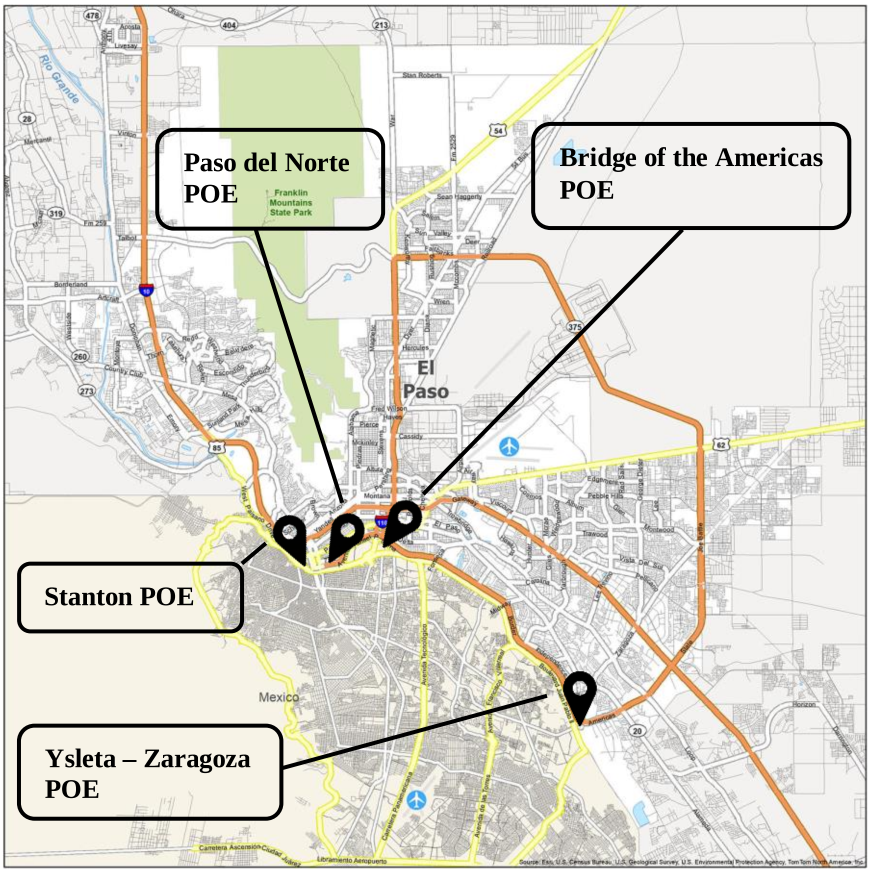

Figure 1: Point of Entries locations in El Paso (GISGeography 2018), edited

In summary, according to walkscore.com (“El Paso Neighborhoods Walk Score” n.d.), El Paso is a car-dependent city, when scoring 40/100 on walkability, 28/100 on transit, and 42/100 on biking. The most walkable neighborhoods were Union Plaza, Chihuahuita, and Virginia, located in the historic downtown area. These neighborhoods combine for about 3,500 inhabitants, making up a negligible portion of the total population (“El Paso Neighborhoods Walk Score,” n.d.). In the United States, car dependency is common since 91.7% of American households had at least one vehicle in 2021. In Texas, that number is 94.8%, while El Paso is between the national and state rate at 93.35% (“How Many Vehicles Are There In The U.S.? – Forbes Advisor” n.d.), This leaves the remaining 6.65% of El Paso residents, about 45,000 people, without a vehicle which provides practical access to essential services such as doctor’s appointments, agency visits or food shopping. These findings create demand and motivation for the topic of this work on public transportation in El Paso even more urgent.

Moreover, the number of registered vehicles in the USA is consistently rising, and the trend is unlikely to change in the near future because such changes require revolutions in travel behavior, an urban fabric with connected infrastructure, reliable and good public transit services, and political will. All these aspects add to the complexity of the problem of car dependency in the everyday lives of Americans.

Railway Transport

El Paso’s rail transit is heavily oriented to freight transportation. It serves as a crossover station for both international rail traffic and east-west traffic within the United States. Currently, the traffic capacity is limited by infrastructure, and only two bridges are on each side of the POE Paso del Norte. Another limit presents safety and congestion concerns on the Mexican side, resulting in trains permitted to operate between 10:00 pm and 7:00 am (Center for Neighborhood Technology

2017). However, freight rail transport presents a significant opportunity for the future, taking into account the Biden administration's focus on railway safety and capacity projects all over the USA in both passenger and freight railway transportation ("Biden administration announces $1.4 billion to improve rail safety and boost capacity in 35 states" 2023). In Downtown El Paso, a passenger railway station is located at Union Depot and is served by Amtrak. There are two lines Amtrak lines running through El Paso:

- **Sunset Limited** runs from Los Angeles, California to New Orleans, Louisiana, three times a week, concretely Wednesday, Friday, and Sunday once a day ("Schedule Results | Amtrak" n.d.),
- **Texas Eagle** runs from Los Angeles, California, to Chicago, Illinois, seven days a week, once a day ("Schedule Results | Amtrak" n.d.).

The two lines mentioned above are of little importance to El Paso residents since their ineffective scheduling and inability to compete with road and air transport time and pricewise makes them undesirable, resulting in their use solely for recreation rather than as a commuting tool. However, it is worth noting that in 2017, a final report was released on a feasibility study of a Las Cruces – El Paso Commuter Rail line (Center for Neighborhood Technology 2017). This project is of regional importance since Las Cruces is about 45 miles from El Paso. With a metropolitan population of over 200,000, it is the second-biggest city in New Mexico ("Las Cruces, New Mexico," 2023). The study estimated median person-trips/day of 5,000 people, resulting in an annual ridership of 1,314,560, which would significantly relieve the traffic network. The study found the project applicable, however, at the cost of considerable capital expenditures, deferring its implementation.

Air transport

El Paso is accessible by plane via El Paso International Airport (ELP). In October 2023, it offers 265 routes, mainly within the USA but also internationally, operated by 60 airlines, of which 14 are non-stop. The airport offers connections to six different countries (“El Paso Airport Facts & Figures,” n.d.). In 2022, ELP handled 3,667,439 passengers, with the highest demand for Dallas/Fort Worth (DFW), Phoenix (PHX), and Denver (DIA). The dominant carrier is Southwest Airlines, with approximately 48% market share, followed by American Airlines with roughly 28%. The airport also handles freight transport, nearly 93,000 tons yearly over the last ten years (“ELP Operating Reports” n.d.). The only other airport in the city is Biggs Army Airfield at Fort Bliss, the United States Army Military Airport.

Public transport

El Paso public transit is served by Sun Metro - El Paso Public Transit Department, which provides four types of services:

- **Fixed-route bus service**,
- **LIFT -** paratransit service for people with individuals with disabilities,
- **Bus Rapid Transit (BRT) -** the BRIO service,
- **Streetcar service**.

It is worth noting that in the past, there was a streetcar line connecting El Paso and Ciudad Juarez that was terminated in 1973 when all other streetcar lines ceased to run as well. The current streetcar two-loop route was recently opened in 2018. A more detailed examination of the current state of public transit in El Paso will follow later in the document. Lastly, long-distance bus connections are provided via three Greyhound bus stations: El Paso Bus Station, El Paso, and El Paso East.

1.3. Role of Mobility Hubs in Enhancing Public Transportation

Mobility hubs represent an efficient way of integrating different modes of transportation in the first place. A multi-modal supportive infrastructure maximizes last-mile connection, bringing together public, shared, and active travel modes ("Mobility Hubs - A Readers Guide," n.d.). This fact becomes even more critical than ever in times of need for a shift towards sustainable and ecological transportation, especially in American car-centered cities, with designs inherited from the past, resulting in congestion, car accidents, time lost by inefficient commutes, etc. Mobility hubs represent one of the ways to change behavior towards biking, walking, and shared modes of transport, the most impactful being public transportation, thus increasing motivation and supply for private car alternatives (Box and Paul n.d.). All the abovementioned factors are the critical inputs of mobility hubs. They often have strategic locations within the urban environment, which poses an opportunity for logistics use in last-mile deliveries and pick-ups/drop-offs. This role is enhanced by serving as a gathering place promoting inter-community engagement via various events and activities. That brings economic opportunities for their ability to attract shops and commercial projects. This flexibility generally leads to revitalizing surrounding areas and creating lively urban spaces (Karen n.d.). However, mobility hubs must function in synergy with a well-designed interconnected transit network that ensures attractive travel times, level of service, short waiting times, and affordable prices, coming with reasonable reliability. In addition, they can be a tool for bringing equity into public transportation service, making up for historically underserved communities' exclusion (Anderson et al. 2017). With a diversity of options, improving the city's transit network's resiliency is another benefit. Lastly, planning, funding, and operation complexity require significant cooperation between the public and private sectors toward the common goal, thus bringing communities and the city together.

2. RESEARCH OBJECTIVE AND METHODOLOGY

The objective of this thesis is to examine existing practices for making public transportation more attractive, motivating people to change their transportation choices, and providing alternative modes of transport to privately owned vehicles. The research materializes as a roadmap to mobility hub implementation, thus contributing to the mitigation of adverse effects of traffic congestion, greenhouse gas emissions, and associated issues. The thesis structure is outlined in the following steps:

Task 1: Conduct literature review – summary of available literature on the topic of mobility hubs and sustainable public transportation

Task 2: Evaluate the current state of public transit in El Paso – analysis of publicly available data and scheme of the public transit network, identification of its significant challenges and their view in the approach of the Smart City concept

Task 3: Describe Smart City Technologies –introduces available technology solutions and their potential use for addressing the issues of public transportation in El Paso, their benefits and limitations

Task 4: Investigate case studies – analysis, transfer, and summary of the best practices from cities with generally considered good public transit, namely Tucson, Arizona, and Portland, Oregon in the USA and Finland capital Helsinki in Europe

Task 5: Data collection – collection of publicly available data for the implementation part of the mobility hub – location, size, type, types of services provided, etc.

Task 6: Analysis – spatial analysis using ArcGIS Pro online tool to find the optimal location for the mobility hub based on the selected criteria

Task 7: Implementation proposal – using mobility hub implementation toolkits to design

a roadmap, using visualizations created using the ArcGIS Pro online tool, and an overview sketch with the site layout drawn using AutoCAD graphic software

Task 8: Directions and Recommendations – applying general guidelines for mobility hub implementation in terms of organizational structure, funding securement, operation, and impact, finished with mobility hub implementation limitations

Task 9: Conclusion – summary of the key findings of the thesis, the outcome accompanied by the study's limitations and future research suggestions

3. LITERATURE REVIEW

This chapter aims to provide a brief overview of the research work done in the field related to this thesis. A relevant paper is a case study evaluation of Abano Terme in northern Italy by Bracco et al. (2018), where the current transportation system needed to be improved to offer better service with a proposed solution of a sustainable concept of electric buses and car sharing services adoption. The work of Anderson et al. (2017) presented a multicriterial analysis framework designed to help municipalities with hub location selection. Equity and resiliency factors were also included in the analysis. The case study was in Oakland, California, and the unavailability of street and travel data limited it. Future research proposes, among other things, funding mechanisms and interagency cooperation. In a recent study (Luo et al. 2021), a theoretical stochastic method for designing intermodal mobility networks was developed, where travelers use micro-mobility for the first/last mile connections to Mobility-on-Demand Transit (MoDT) and implemented in New York City. Besides the network design, their result also reduces excess empty-car miles by conventional Mobility-on-Demand services. More information on this topic is presented in Chapter 5, which delves into Smart City technologies.

Additionally, a study by Arnold et al. (2023) examines the decision-making factors behind mobility hub implementation. It was done through semi-structured interviews with experts in Europe and the USA. Among other things, it showed that the definition of mobility hubs in the discussed cases was driven by contextual priorities such as environmental sustainability and social objectives such as community and equity. Lastly, thorough research on mobility hub design practices is presented in Chapter 6. By putting together these works, this literature review provides context and theoretical background to support the objectives of this thesis and ensure their credibility and relevance.

4. CURRENT STATE OF PUBLIC TRANSPORTATION IN EL PASO

4.1. Local Connectivity

According to the 2022 State of the System Report, public transportation in El Paso ("State of the System Report | City of El Paso & Sun Metro 2022," n.d.) is provided by the Sun Metro Public Transit Department via various bus services and one streetcar loop line connecting downtown and uptown areas. The network consists of eight transit centers and 53 routes covering approximately 75% of the city's area. There are three types of bus routes that are listed as follows:

- **BRIO** – Bus Rapid Transit (BRT) service of El Paso, currently operating in four corridors: Mesa, Alameda, Dyer, and Montana; characterized by high frequency (six buses/hour in peak hours and four buses/hour in non-peak hours), lower number of stops compared to the regular bus routes resulting in higher speeds and provided with signal priority at intersections.
- **Regular Bus Routes** – can be further split into four categories according to their purpose:
    - **Local** – frequent stops, usually on arterial streets, the foundation of the network,
    - **Circulator** – serving one or more districts via looped alignments, somewhat shorter than local routes, providing last-mile connection to the areas in high demand,
    - **Feeder** – connecting more remote areas to transit centers, typically shorter than local routes,
    - **Express** – serving longer distances along major highways and arterial streets with a lower number of stops compared to local routes,
- **LIFT** – paratransit services for Americans with Disabilities Act (ADA) eligible riders, offering on-demand curb-to-curb transport.

The overview of the Sun Metro transit network can be found in Figure 2 on the next page.

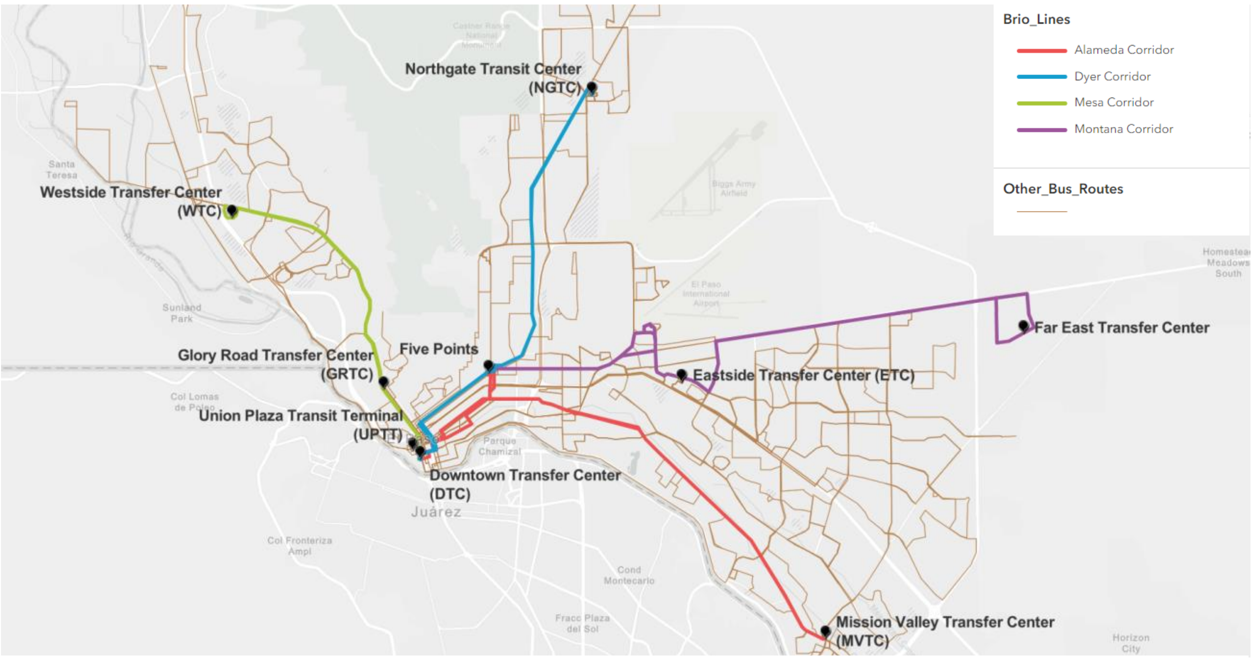

Figure 2: El Paso Public Transportation Network Map. Created using ArcGIS tool and ESRI library. ("Sun Metro BRIO," n.d.)

4.2. Regional Connectivity

Sun Metro operates public transit in El Paso; however, other bus providers operate in El Paso County. Below can be found their overview:

- **New Mexico Department of Transportation (NMDOT) -** the Gold Route runs between El Paso, and Las Cruces, New Mexico,
- **El Paso County Transit** – operates six rural routes during the same times as Sun Metro routes,
- **Route 90** – senior mobility service operated by Amistad connecting Eastside and Westside transit centers South Central Regional Transit District – Nex Mexican Dona Ana County transit operator securing connection with El Paso via three lines, two of which connect Sunland Park, New Mexico with El Paso, and one running from Anthony, New Mexico and Chapparal, New Mexico to El Paso.

In the beginning, it is vital to mention that the Sun Metro transit network operates in a challenging environment characterized by complicated geographical conditions, a largely sprawled urban area with uneven population density and places of interest distribution, and a non-homogenous group of target customers, due to language, cultural, and national differences. Despite that, the recently introduced BRT routes have attracted new riders, although the continuous problem is that the BRT routes mirror the major highways and arterial streets. Since the buses share the road with other vehicles, their average speed is indifferent, and they often get stuck in traffic congestion, just like regular cars, especially in peak hours. This makes public transit uncompetitive compared to private cars. Moreover, the rest of the bus network, with the purpose of "feeding" the major travel routes, seems not to be working efficiently, as seen on the ridership activity map in Figure 3. The reason for that is likely the insufficient frequency of the local route's connections, because with the average 70 minutes interval, while the major route buses go every 10-15 minutes, which makes it a challenging planning task for the rider because missing the connection bus means missing four to seven BRIO buses at one time. The frequency of 60-120 minutes or even longer cannot be considered convenient for any kind of traveler. The only exception is the streetcar, which covers a small area. Unfortunately, the same goes for Saturday's connections, even for the BRIO lines, which are the only routes in use, since all the other types of routes barely generate any ridership, disrupting the connection ties between the backbone routes and its supply lines. This combination results in no car alternative for possible weekend riders, especially in the evening. In the report, it is said that Saturdays average 37% less than boardings on weekdays. It must be taken into account that the travel patterns on weekends are different; however, the schedule does not reflect those statistics, which results in an inefficient and expensive service.

Moreover, this issue is not the only scheduling problem. It is complemented by the service hours, which run from early morning hours but terminate at 6 pm. In addition, Sunday service was terminated in December 2020 due to the COVID-19 pandemic and has not been restored. On the other hand, in October 2021, the transit system averaged 85% on-time performance, which is a good result given the traffic conditions. It is also worth noting that the entire bus fleet is CNG fuel-powered, making it energy efficient, economically beneficial, and environmentally friendly. The six streetcar vehicles are electric and were recently refurbished in 2017. The ridership in April 2022 was about 63% of pre-pandemic levels. Each Brio line is more productive on Saturdays than on weekdays, which can be explained as a trend of using public transit for leisure travel and not for work/school commutes. Most of the local bus routes require one or two buses to operate.

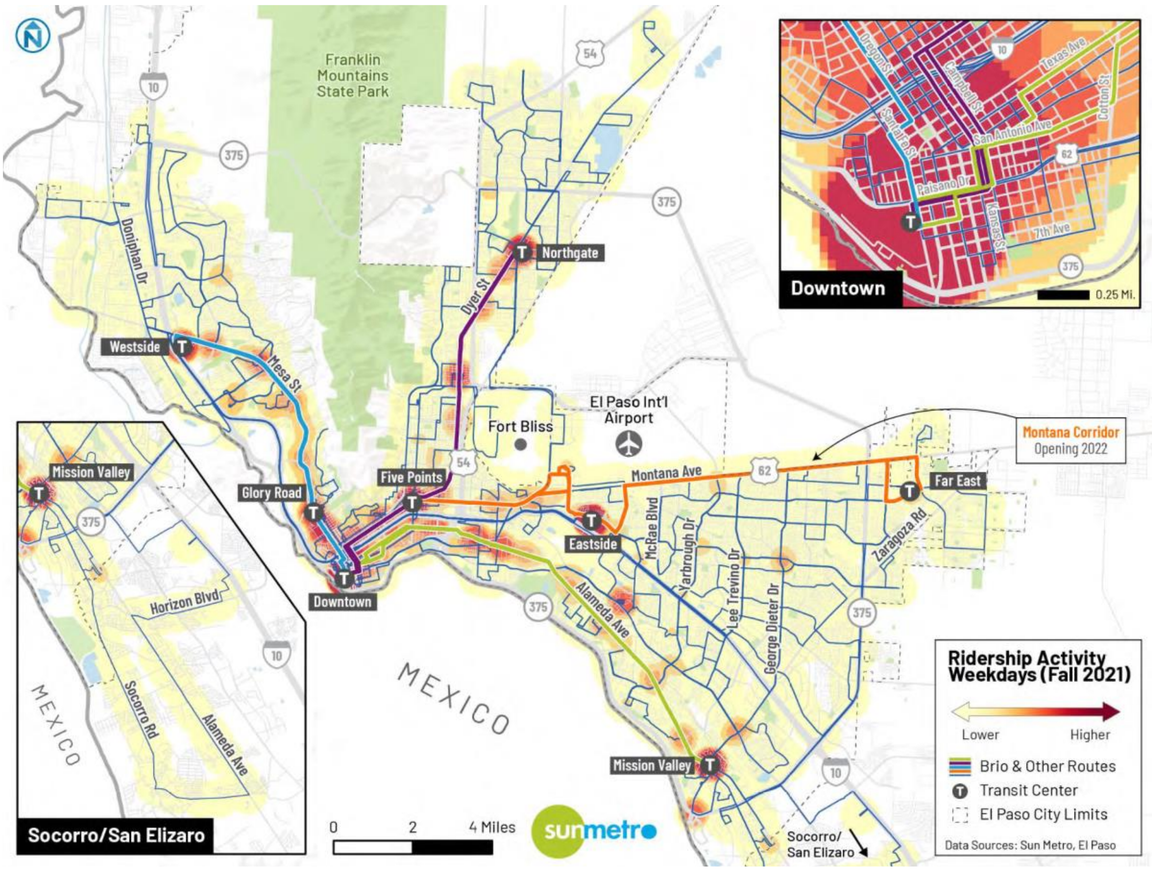

Figure 3: Ridership Activity Weekdays Map. Taken from ("State of the System Report," n.d.)

5. SMART CITY TECHNOLOGIES AND APPROACH

The concept of a Smart City includes approaches that could be applied to this thesis's subject and help tackle the challenges of today's transport, such as congestion, pollution, car dependency, or affordability and accessibility. Below are described the three most relevant ones:

5.1. Smart Mobility

The idea behind the concept of Smart Mobility is to limit the use of or replace entirely privately owned gas-powered vehicles by providing easily accessible alternatives that are affordable and sustainable (Chipilska, 2023). Some policies already being implemented include congestion pricing, demand-based parking fees, low-emissions zones, and highway toll lanes ("Smart Mobility in the Smart Cities of Tomorrow," n.d.).

An essential part of Smart Mobility is the Mobility-as-a-Service (MaaS) concept, which provides a framework for change in transportation as we know it today, being user-centered, personalized, and promoting active transportation and sustainability (Storme et al. 2020). It builds on the idea of combining different transport modes (public transport, biking, walking, e-scooters, carpooling, etc.) to provide a customer with various options for getting from point A to point B conveniently through a single interface. That is achieved by bringing together different actors – transportation service providers, governments, and MaaS coordinators - who then provide a tailored transportation service to the traveler. The scheme depicting the concept can be observed in Figure 4 on the next page. Whereas the concept seems promising, wider adoption is problematic, and only a few implementations can be found in Europe (Liu et al., 2020).

The main challenges of the MaaS' large-scale applications consist of the following:

- **Fragmentation of Transport Services** - different operators, modes or payment systems,
- **Economic Viability** - from which might often stem resistance from traditional transport services providers, holding the adoption back,
- **Accessibility and Equity Issues** – the system is heavily dependent on digital technologies and makes heavy use of those; however, at the same time, it leads to discrimination and unequal access for those who lack the skill, the equipment, or both,
- **User behavior and awareness**,
- **Infrastructure limitations.**

Ultimately, despite these drawbacks, the use of sustainable mobility choices and the MaaS concept offers a direction that might be useful for this thesis's objectives.

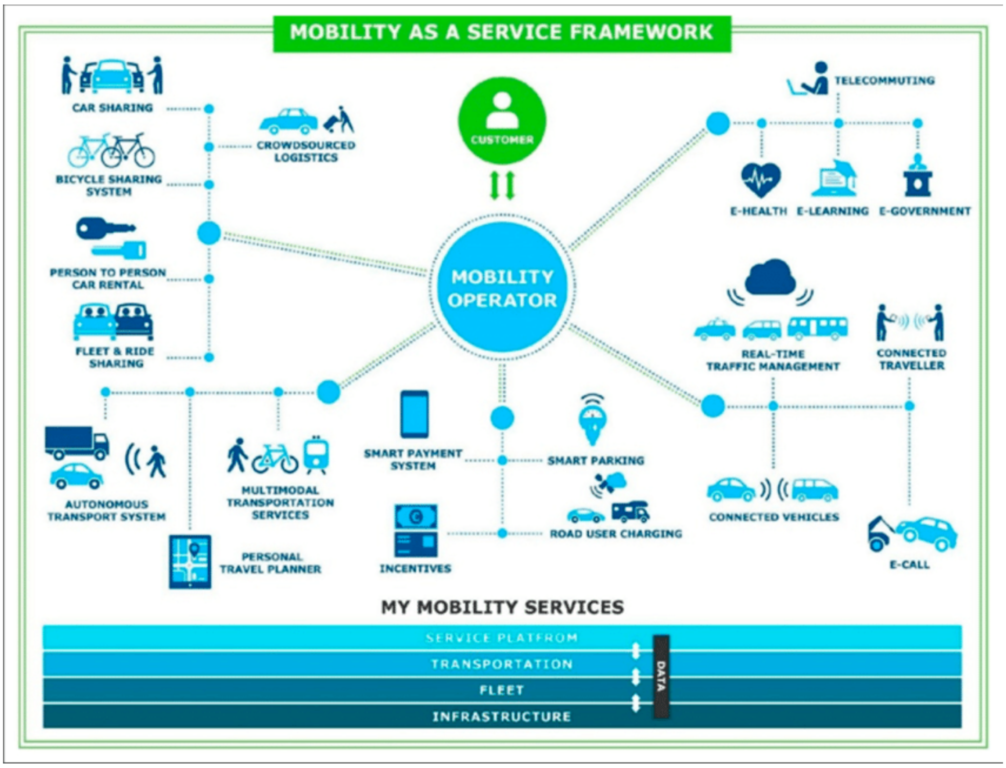

Figure 4: The Mobility as a Service Framework. Taken from (Reyes García et al. 2019)

5.2. Smart Infrastructure and Technology

The critical component of Smart Infrastructure is the Internet of Things (IoT), which consists of wireless sensors, where the wires and associated maintenance and installation costs are replaced with radio connection, leading to substantial cost savings. There are many different types of sensors and network topologies; however, they primarily differ by the sampling time depending on their use (Hoult et al. 2009). For example, a bridge structure monitoring sensor network may collect and update data once a day. In contrast, a pipeline leak sensor must have a higher frequency of data collection because any delay may lead to a substantial leak, and the delay in response means a loss of revenue or longer-lasting service unavailability.

A specific sub-topic relevant to the work is that of Intelligent Transportation Systems (ITS), which builds on the Smart Infrastructure and expands it towards transportation. The idea behind the ITS is to take full advantage of the existing infrastructure and enhance its efficiency using data and technology. Often, it is a viable alternative to further infrastructure development and construction for the authorities since it saves money, time, and space. The system's types range from single machines - Automatic Passenger Counters (APCs) to complex Traffic Management Systems of whole areas. In a study, the following categories of technologies were identified (Elkosantini and Darmoul 2013):

- **Automatic Vehicle Location Systems (AVLS)** – provides information about vehicles, their exact location, speed, direction, etc., enabling real-time operational decisions based on the information, using technologies such as Ground Based Radio (GBR), infrared beams, and currently the most used one Global Navigation Satellite System (GNSS),
- **Traveler Information Systems (TIS)** – provides information about arrivals, departures, delays, and other operational constraints of the network in real-time, closely cooperates,

and receives data from the Automatic Vehicle Location Systems (AVLSs), the information to operators is then conveyed in transportation management centers and for the passengers it is done so via SMS, web and cell phone applications or street displays located at the stops or terminals,

- **Geographic Information Systems (GIS)** – find utilization, especially in planning decisions, including traffic flow analysis, route planning and evaluation, and vehicle service assessment. It uses different GNSSs such as Global Positioning System (GPS) or European Galileo,
- **Decision Support Systems (DSS)** are used in the creation of timetables as well as in the creation of controlling strategies to ensure an acceptable level of quality of service according to the established schedules and emergency situations management.

Figure 5 depicts the USA Department of Transportation National ITS architecture.

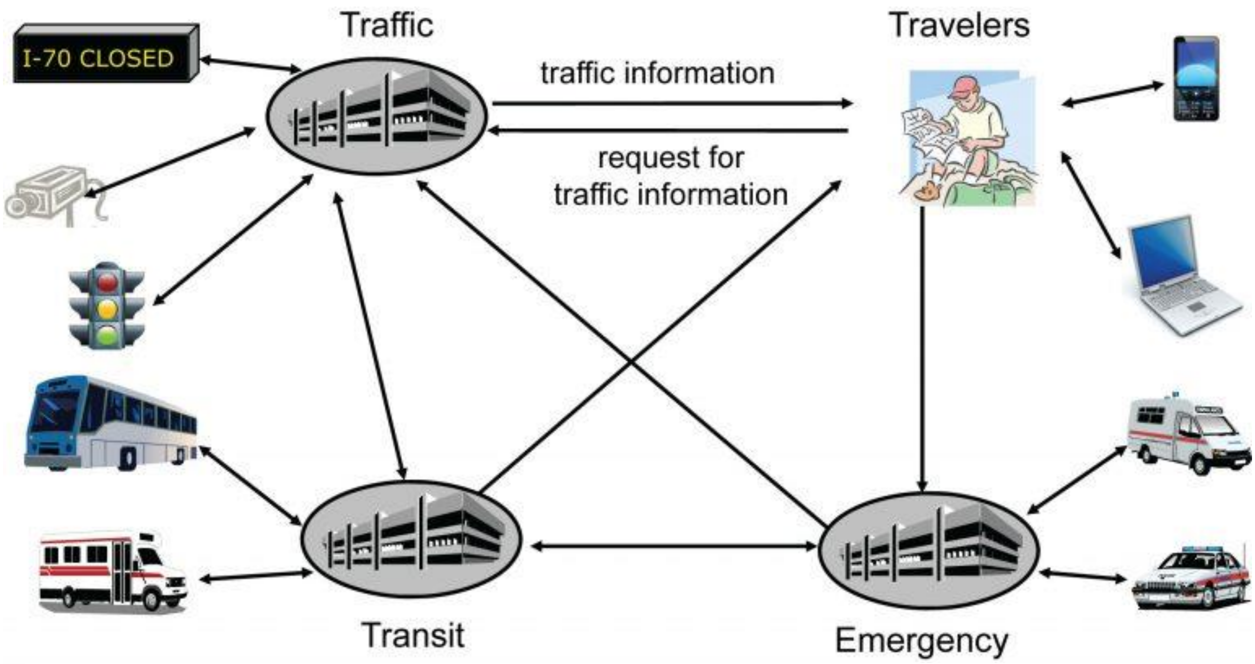

Figure 5: National ITS Architecture. Taken from (“East-West Gateway Council of Governments (EWGCOG)” n.d.)

Smart Infrastructure and Intelligent Transportation Systems are closely tied to a promising future in Connected and Autonomous Vehicles (CAVs), representing a radical shift in transportation. These vehicles rely on different technologies, such as LiDAR, video cameras, various sensors, or positioning estimators. Equally important is the software enhanced by machine learning and artificial intelligence (AI), which enables the processing and evaluation of all the data collected in real-time. These vehicles can communicate not only with each other – Vehicle to Vehicle (V2V), but also with pedestrians or sensors – Vehicle to Everything (V2X), or to the infrastructure – Vehicle to Infrastructure (V2I), sharing information about the vehicle's size, position, speed, and other variables necessary for decision making in the traffic, which leads to network capacity optimization, congestion and pollution reduction, and increased safety (Farsi et al. 2020). An overview of communication schemes can be observed below in Figure 6.

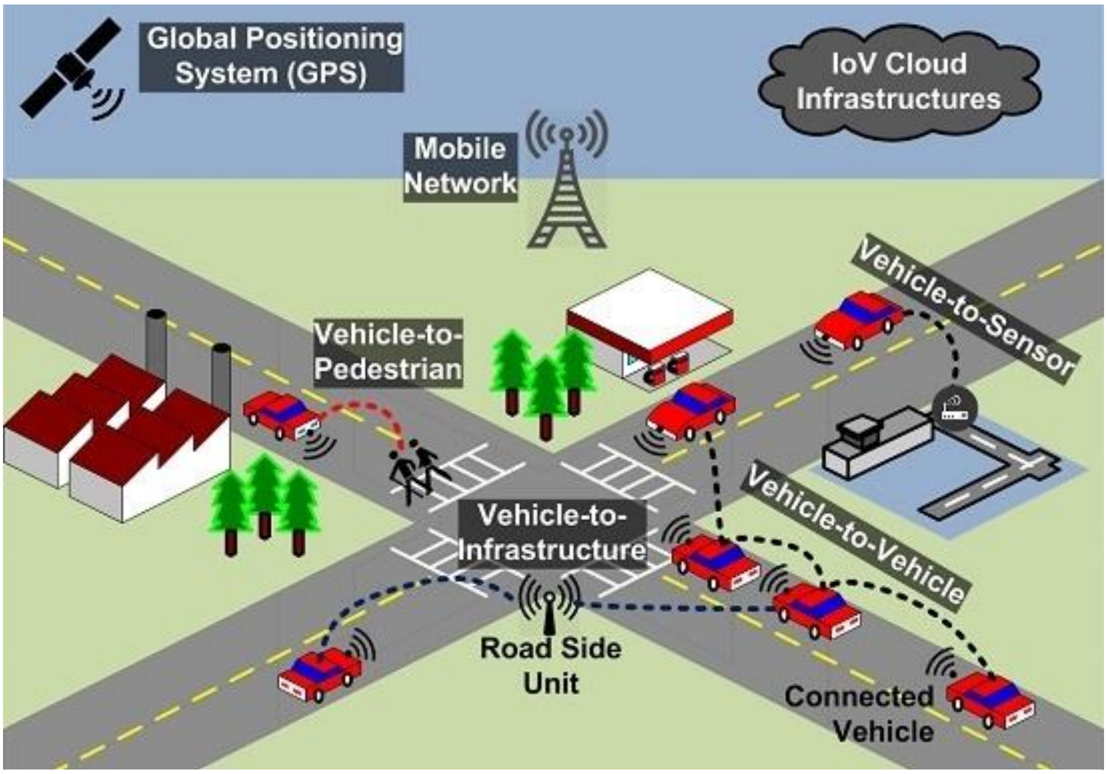

Figure 6: Intelligent Transportation Systems Infrastructure. Taken from (Javed et al. 2016)

5.3. Smart Logistics

As for the supply chain, the topic of transportation is the most relevant to this thesis, concretely road transportation, since last-mile trucks are a critical part of the supply chain just as well as of the traffic flow; therefore, they play a significant role in traffic congestion. Moreover, transportation costs account for 58% of the logistics cost, making it a logical candidate for improvements with the most significant impact ("Global Logistics Costs by Function and Mode, 2018 | The Geography of Transport Systems," 2017). The standard definition of Smart logistics agrees on incorporating Information and Communication Technologies (ICTs) at some level. Specifically, IoT, Big Data, Cloud Computing, and AI are used to make conventional logistics smart. Moreover, these technologies help to tackle the challenges of logistics, such as waste of low-efficiency operations, transportation security, and goods safety (Ding et al. 2021). For last-mile delivery, the newest trends include the placement of micro depots into locations where the last mile can be delivered via electric cargo bicycles and on foot. Another option is a pickup point where the customer collects the delivery himself. However, efficient delivery to the pickup points must be ensured by effective travel route planning (Leyerer et al., 2020). The IoT can be used for real-time monitoring and tracking of the deliveries, informing the operator and the customer about the current location of the order. A case study (Jílková and Žížalová n.d.) focused on last-mile delivery and placement of micro delivery hub in Prague, Czech Republic, was examined. Its aim was to find the optimal location for the hub to serve a given area using data from parcel deliveries, identifying high-intense delivery addresses. The final location was then selected using spatial analysis to cover the highest possible number of high-intense deliveries. The field survey followed to observe the site and its viability. This study underlines the importance of last-mile deliveries in the supply chain and highlights the trends of data analysis to improve it.

6. MOBILITY HUB DESIGN PRINCIPLES

The term Mobility Hub (MH) first appeared around 2000 in Germany in times of need for a place providing sustainable transport options and strategic location (Arnold et al. 2023). The paper also refers to a definition that says, “A mobility hub is a recognizable place with an offer of different and connected transport modes supplemented with enhanced facilities and information features to both attract and benefit the traveler.” It is characterized by the three following components:

- **Mobility Components** – public transport and non-public transport (bikes, cars, e-scooters),
- **Mobility Related Components** – supporting infrastructure (bike or car chargers, bike lockers, information displays, etc.,
- **Non-mobility Components** – amenities, surroundings design encouraging to walk etc.

Furthermore, four Ps are identified to aid the decision-making process as follows:

- **Purpose** – objective(s) of the MH, modes integrated etc.,
- **Process** – public consultation, external organizations involvement, policies in place, individual/network design etc.,
- **Place** - location, transit connections, existing infrastructure, etc.
- **Performance** – life cycle of the project and its effective operation.

According to their placement in the existing development, there are three main types of mobility hubs, namely Central, Regional, and Neighborhood (“Mobility Hubs - A Readers Guide,” n.d.). Then, the MH can be characterized by its transportation function, concretely Entry, Transfer, and Destination. In addition, the Germany-based Bayern Innovativ organization promotes a specific type of mobility hub in cooperation with the EU focused solely on e-mobility; such MH is called the eHub (“How eHUBS can influence the future of mobility,” n.d.).

Based on the Los Angeles Urban Design Studio tool book ("Mobility Hubs - A Readers Guide" n.d.), TransLink agency based in Vancouver, Canada guide ("Identifying Best Practices for Mobility Hubs" n.d.), and mobility hub focused research paper (Karen n.d.), the following elements that are essential to meeting the MH objectives were identified:

6.1. Mobility Components

Bicycle and E-Scooter Transportation

Cycling is an effective way of moving around and can play a significant role in shifting away from car-dependent transportation. To ensure that, it is necessary to provide sufficient infrastructure, especially a bike path network that is safe and well-designed for point-to-point transportation. The same applies to e-scooters, which can share bike paths with cyclists, and their space requirements are comparable. Mobility hubs can enhance such networks by providing secure bike parking, bike-sharing stations, and e-bike and e-scooter charging infrastructure. Depending on the location, the charging infrastructure can be powered by renewable energy. In places with high demand, the MH can be enhanced by a bike rental or a repair shop to provide even broader supportive services to promote cycling, just cargo bikes, and parcel services.

Vehicle Connections

Although it might seem illogical, the car is an integral part of the modal shift. Park and Ride is a great example. The idea of people from remote areas driving with their private car to the city edge, where a mobility hub is located, leaving their vehicle there and continuing to the place with high transport demand via public transport, has gained popularity. However, in highly dense areas, space-efficient solutions such as multi-level parking buildings or underground parking are being favored. The surroundings of the mobility hub can be complemented by flexible curbside management and smart parking – the price varies based on the location, occupation of the parking places, and time of the day or depending on what day of the week it is.

Another aspect is the presence of supporting facilities for various kinds of car sharing – city-based, peer-to-peer, on-demand services, or ride-hailing. For smooth transfers, passenger pick-up/drop-off zones have been put in place. Electric vehicle (EV) charging infrastructure is a standard nowadays.

Bus Connections

Buses are the primary type of public transport in use. Its most significant advantage is it does not require special infrastructure, like rail transit. However, sharing the road is often very limiting in terms of travel speed and time. For a mobility hub, it is crucial to recognize the importance of bus transit and secure bus layover zones, safe loading/unloading zones for passengers, and easy connections when transferring between the lines, such as platforms, passenger queues, or proper waiting space. All of the above are to be designed in compliance with universal design principles.

6.2. Mobility Related Components

Information and Signage

Informing travelers is vital to ensure efficient and safe traveling, and that helps them make informed choices about which mobility service is the most efficient and convenient. Real-time travel information affects user experience, and its good quality helps to improve it. Journey planning information can be conveyed via various channels, such as a website, a mobile app, or a digital kiosk. Wayfinding and signage used for orientation around the facility of a mobility hub and in the surroundings is also helpful; moreover, it presents easier accessibility to various kinds of disadvantaged users such as kids, the elderly, or the disabled population.

Pedestrian Connections

A good quality pedestrian infrastructure that is safe and welcoming to its users can make a significant impact on people's choice to walk. While these features are essential in the proximity of a mobility hub, they should be provided in the context of different urban areas. Examples of this infrastructure include lighting, marking, or safety features, especially against automobiles, such as bump-outs, curb extensions, or interconnected network design. Convenient and safe pedestrian linkages between all transit options within a mobility hub should be put in place as well. They are characterized by clear signage, direct paths, or safe spaces.

6.3. Non-Mobility Components

Services

Nowadays, a high-speed internet connection is a standard request of travelers, and so is a reliable mobile signal and Wi-Fi coverage. Other services that enable comfortable traveling are storage lockers, washrooms, retail services – food courts, kiosks, and shops- along with parcel services or pick-up boxes. A mobility hub should embrace public space since it sparks social interaction and community participation via public art displays, for example, resulting in the effective and elegant placement of benches, outdoor waiting shelters, and lighting. All are universally designed to accommodate people, encouraging them to spend time in public spaces.

Safety and Security

A crucial part of the travel experience is to ensure that the passengers feel safe and comfortable while traveling. The same applies to their belonging in the previously mentioned storages, lockers, or parking facilities, for example. It is vital to make sure that the mobility hub area does not become a crime-prone zone. Measures such as security personnel presence, security camera systems (CCTV) with footage can help ensure traveler safety.

6.4. Other Aspects

Sustainability

Mitigating the negative impacts of climate change and global warming, in the case of mobility hubs, can be done by using sustainable materials during construction and energy-efficient design. For the operational part of the building, renewable energy and energy-efficient equipment are preferred if possible. Stormwater management for effective water treatment and landscaping design to minimize irrigation and prevent heat islands is recommended as well.

Typology

There were six different typologies identified according to the form, function, and amenities to address the specific needs of the location, as follows (Box and Paul n.d.):

- **Regional Downtown Hub** – defined by easy access, located at the center of economic and cultural activity in high-density areas with mixed development,
- **Urban District Hub** – located at the local centers, often serving as commuter hubs,
- **Emerging Urban District Hub** – placed to support future growth in priority areas,
- **Suburban and Rural Hub** – usually car-oriented placed in residential neighborhood areas providing connection to regional transit,
- **Pulse Hub** – based near high trip generators such as airports, arenas, or universities,
- **Opportunity Hub** – placed in disadvantaged districts without many transit options.

Challenges

The biggest challenges of mobility hub implementation can be found as identified below:

- **Parking** – especially suburban areas rely on inexpensive large parking facilities, which creates an environment that discourages active transportation,
- **Policies and Land Ownership** – a common limit is a zoning plan, when areas suitable for mobility hub placement are designated for a single purpose.
- **Equity and Accessibility** – mobility hubs must ensure equity for all users considering the local context; MH features benefiting the most disadvantaged should be prioritized,
- **Data Availability** – for successful implementation as well as for effective operation, it is crucial to acquire accurate data for planning, development, and operation.

7. PUBLIC TRANSIT & MOBILITY HUB DESIGN CASE STUDIES

This chapter delves into public transit praxis in other cities and identifies the best practices that might be applicable to El Paso. It consists of an analysis of public transportation, available modes, mobility plans, and future transportation goals. Lastly, an investigation of a mobility hub follows if it exists. Cities comparable to El Paso in aspects such as location, size, or climate were chosen.

7.1. Tucson, Arizona

The city of Tucson, which lies in the state of Arizona and is south of Phoenix, has a lot in common with El Paso and, therefore, presents a good comparison choice. According to 2020 United States census data, the city population was 546,290 people, compared to 677,456 in El Paso, with land area of 241 sq mi being almost equal to 259 sq mi in El Paso ("Tucson, Arizona," 2024). Both cities are located in a desert with a hot climate surrounded by mountains. As a typical

American city, Tucson is a car-dependent city. However, it brings something more to the table than ordinary municipalities since it was awarded America's Best Transit System in 2005. Public transit is provided via Sun Tran, an equivalent to El Paso's Sun Metro. The concepts are very similar – Tucson's public transit backbone lies in buses, which are concretely two types of bus lines – express routes and circular routes. In addition, there are on-demand shuttles (for ADA citizens, but also a shuttle connecting Tucson with Phoenix International Airport) and regional bus lines connecting Pima County and the metropolitan area. However, since 2014, there has been a streetcar line called Sun Link connecting the University of Arizona (UA) with Tucson Downtown, the 4th Avenue, the Tucson Convention Center, and the Mercado District. Its length is 3.9 miles and includes 18 stops. Unlike El Paso, its location is suitable for daily use by passengers, especially students, thanks to its connection to the UA campus and places of interest in the city center. Also, its competitive service headway up to only 10 minutes in peak hours and convenient service hours until midnight on selected days make it a useful mode of transport. This is enhanced by the online real-time tram location tool on the website and in the app. Furthermore, the fare collection system is swift and easy to use. The previously mentioned features, combined with bus routes and city-wide popular biking and walking, create a set of appealing transit choices. It is also important to note that public transit in Tucson has been free of charge since the COVID-19 pandemic in 2022. The Sun Link Tram Route map can be observed in Figure 7 on the next page. Tucson supports cycling in many ways via a network of marked bike routes, on-street bike lanes, shared-use paths, and car-free trails. The Loop is a 131-mile long, mostly paved bike route free of vehicles around the whole city. The buses serving the routes are equipped with bike racks to allow for the use of both modes. The city of Tucson also supports pedestrians by promoting the installment of parklets and strategies to encourage people to support local businesses within their neighborhoods, introducing new parks and improvements along with new street designs such as bike boulevards, greenways, and shared use paths (“Parks and Connections” n.d.).

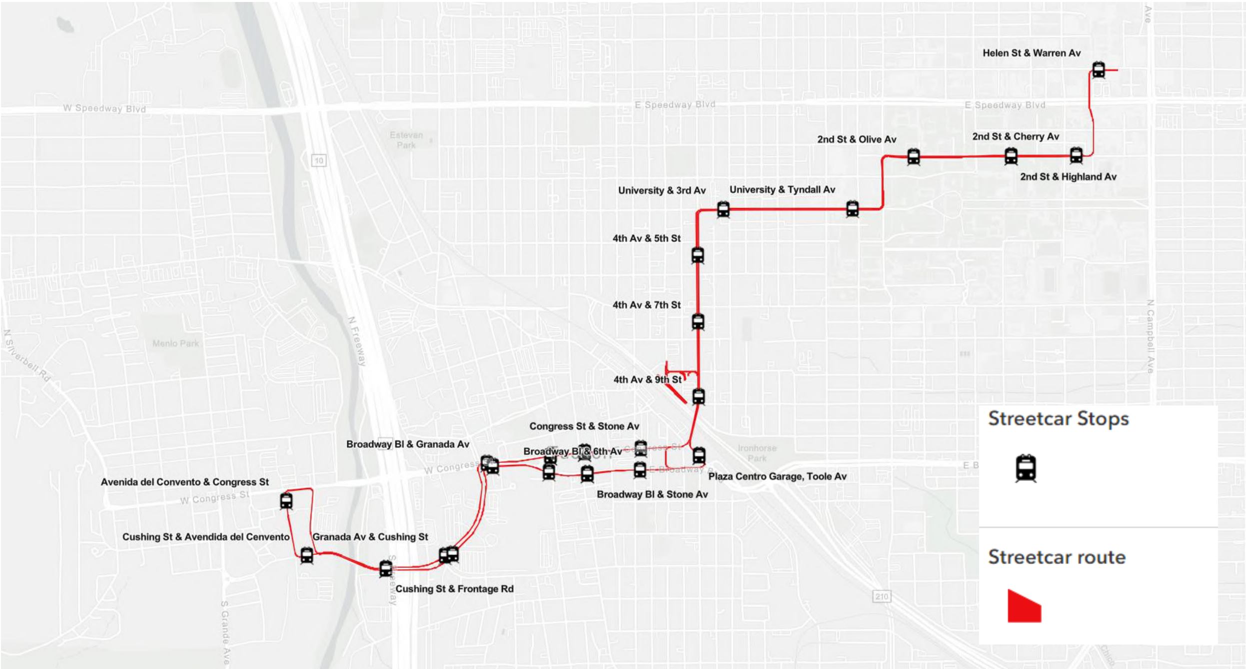

Figure 7: Sun Link Tram Route Map. Created using ArcGIS tool and ESRI library. (“Tucson Streetcar Route,” n.d.)

7.2. Helsinki, Finland

The subject of the next case study is Helsinki, the capital city of Finland, with a population of 673,011 inhabitants. It lies in Scandinavia, the northern part of Europe with a humid continental climate, with daily mean temperature yearly being 43.7 °F (6.5 °C) and 176 average rainy days a year. Helsinki covers an area of 276.25 sq mi, which is of comparative size to both El Paso and Tucson (“Helsinki” 2024). Helsinki presents a great contrast and proves that geographical conditions play a significant role in transportation behavior but are not deterministic. This city was picked for comparison because, according to Bloomberg, in terms of urban mobility, Helsinki is the best in the world (out of 65 cities studied), highlighting its extensive cycling network, public transit network, and electric vehicle infrastructure ("Helsinki, Amsterdam Named Best Cities for Urban Transportation" 2023). Additionally, according to the Deloitte City Mobility Index journey modal split, 39% of trips are made by a privately owned vehicle, whereas walking, cycling, and public transport combine for 59%, while others are 2% ("Deloitte City Mobility Index" n.d.).

The company operating the public transport in Helsinki is Helsingin seudun liikenne -kuntayhtymä - Helsinki Regional Transport Authority (HSL). The most recent public data available from 2019 indicates that HSL has 99% reliability of the services operated on more than 300 different routes ("HSL Helsinki Region Transport," n.d.). The transportation modes available in the city are bus, metro, tram, ferry, and train. There is a distinguished type of bus line called the "trunk" bus line designed in a similar way to BRIO BRT lines in El Paso besides the regular lines. Along with the tram network, there is one light rail transit (LRT) line compatible with the other tram lines. Figure 8 below shows the dominance of the bus mode by number of passengers, which accounted for more than half of the total trips made (Firew n.d.).

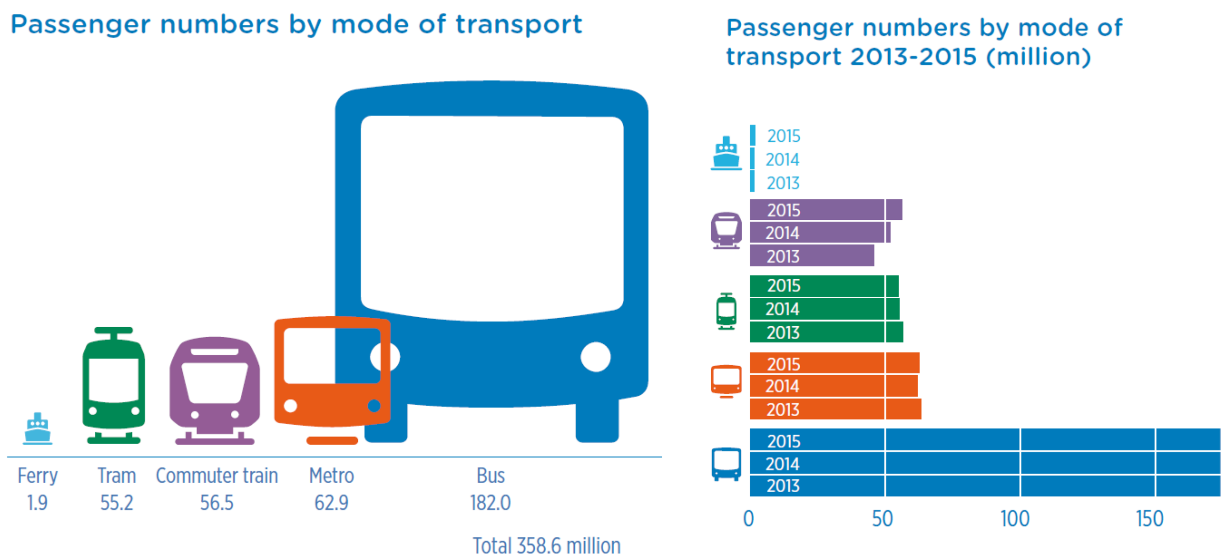

Figure 8: Passenger Number by Mode of Transport. Taken from (Firew, n.d.)

The public transport within the city center is primarily served by eleven tram routes and two lines running the east-west metro system. This backbone is supplemented by more than 300 bus routes serving the majority of neighborhoods. In addition, 14 commuter train lines serve those living further from the city, mostly in its metropolitan area. There is one ticketing and pricing policy in place for the entire transportation network, merging all available transport modes making it easy to use. In relation to this thesis, the biggest potential for El Paso lies in the rail transit mode or some kind of LRT implementation since El Paso's geological conditions are not favorable for underground construction, and the feeder bus routes are already in place. Another possibility lies in promoting walking and cycling and designing the infrastructure to suit these modes. Figure 9 shows a screenshot of the Helsinki City Center public transit map, where regular bus lines are marked with blue color, trunk bus lines with orange, tram lines with green, metro lines with dashed orange, railway lines are purple, and ferry lines marked with dashed blue ("Maps | City of Helsinki" n.d.).

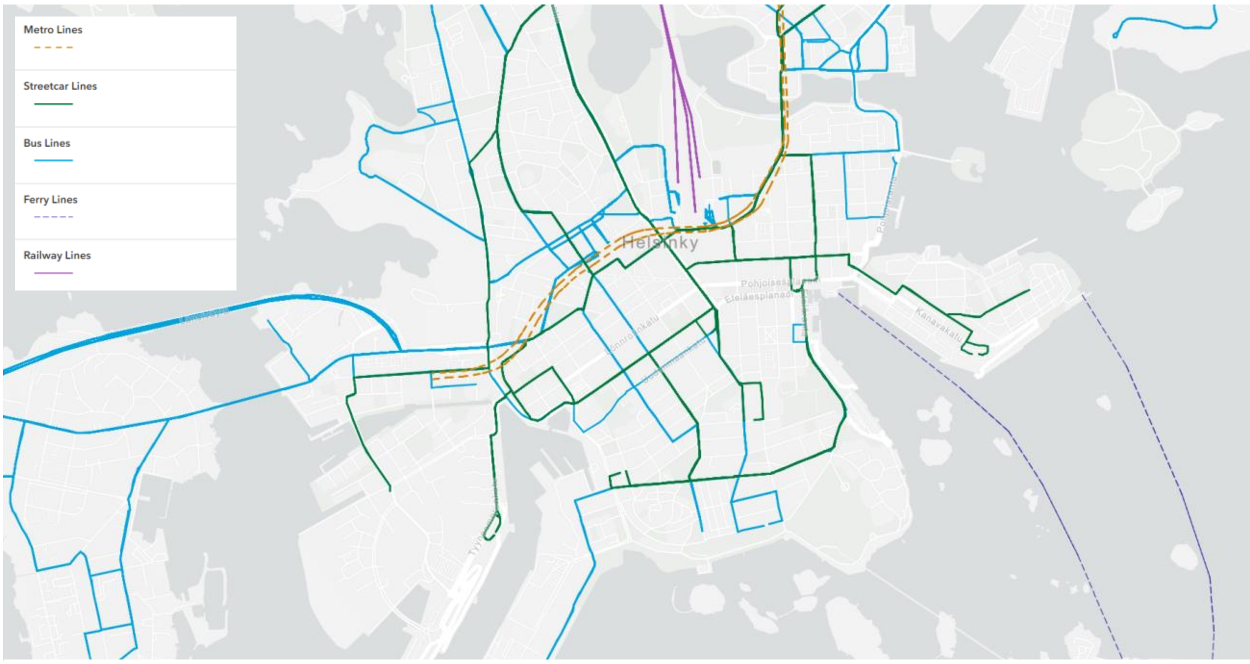

Figure 9: Helsinki City Center Public Transit Network Map. Created using ArcGIS tool and ESRI library. ("HSL linjat," n.d.)

Tram Network

The combined length of the tram and LRT network is 68.7 miles, which serves 344 stations with 137 vehicles. It is formed by double track rail, which is either completely separate from the road traffic or shares space. Their timely scheduled operation is ensured by their priority on traffic lights. LRT line number 15 replaced the busiest trunk bus line 550 in 2021. It is a 16-mile-long orbital running parallel to the Helsinki ring road. The service headway projected was 12 minutes seven days a week, but an increase of up to six minutes during peak hours is planned, for which a total of 17 units will be used (“Trams in Helsinki,” 2024). There is currently another LRT line under construction of length 6.2 mi. The route will include three new bridges. The bridges will accommodate bicycle lanes and pedestrian paths in addition to the tramway, but no lanes for passenger vehicles. The construction is scheduled to end in 2026 (“Crown Bridges” 2023). Additionally, another tram line, number 13, is undergoing construction and is 2.8 mi long and planned to finish in August 2024 (“Planned tram projects in Helsinki” 2023).

Walking and Cycling

A complex city with accessible sidewalks where everything necessary is located within walking distance is a key aspect of promoting walking in Helsinki. Although this structure is difficult to alter, especially in the short term, El Paso can get inspired by other actions that the Finnish capital undertakes. The biking season’s duration is seven months, starting in April and ending in October. All the new bikeways are completely separated from vehicle traffic and clearly distinguish between spaces for cyclists and pedestrians. Another step is the addition of public bicycle parking spaces, including the city bike share system. The goal is an interconnected network of bikeways/pathways throughout the entire city. The key Baana bike regional network is projected to be 92 mi once finished (“Promotion of cycling,” 2021).

Transit Hubs

- **Helsinki Central Station** – serves as the best example of a mobility hub, efficiently connecting all available transport modes in the city at one point: train, bus, tram, bike, and metro + car parking garage. The main bus terminal is about 0.25 mi away. All this is enriched by supporting travel and leisure services provided at the station.
- **Pasila Railway Station**, which is also called **the Tripla development** – a new building opened in 2019 featuring a seamless transition between all kinds of transport in the city. After the Helsinki Central Station, it is the only railway station to serve long-distance trains in addition to the commuting trains and airport connection, multilevel pedestrian connections, trams, buses, P+R facility with 350 charging stations for EVs, bicycle parking facility of capacity of 3,400 bikes. In the future, there is a planned metro line reaching the hub and the station of the future City Rail Loop ("Transport hub" n.d.).

Summary

All in all, the transportation system in Helsinki is on a world-class level with its high efficiency, ridership, and development. Despite its challenging weather and geological conditions, it provides reliable service to the citizens, but at a considerable cost. Even in the context of the Finnish economy, the prices are high. Yearly passes cost $727, while a single ticket, which is valid for 80 minutes, costs $3.20. People with disabilities, students, children, and pensioners can get a 40-50% discount ("HSL tickets and fares," n.d.). Helsinki also serves as a testbed for various research activities for which there was established a Mobility Lab Helsinki, which brings together public and private efforts in smart mobility initiatives such as automated transportation and Mobility-as-a-service (MaaS) – in the past there was a MaaS app Moovit in trial run in Helsinki, a city bike scheme including e-scooters, and many other ("Helsinki Ecosystem" n.d.).

Since 2022, the lab's activity has shifted towards the area of digital twin – concretely to more efficient and better use of traffic and transport data used in city models. Moreover, various publications were published in cooperation with the Helsinki innovation agency, Forum Virium, for example, on the topic of Innovative Districts, Urban Air Mobility, a handbook on green infrastructure in urban areas, or Last Mile Rides Publication. As for the near future, the Helsinki city center transport system plan ("Transport system plan for the city centre" 2023) is currently in the planning process. The plan is based on the following premises, which can be an inspiration:

- **Resident's Jury** – active community engagement,
- **Sustainable Mobility**,
- **Motor Traffic Concentrated on the Main Arteries Only**,
- **Underground Parking Facilities**,
- **Local Streets Turned into Calm Traffic Environment** – walking prioritization.

7.3. Portland, Oregon

The last case study takes place in the USA in the city of Portland, Oregon. In 2020, the city's population totaled 652,503 inhabitants, with a metropolitan population totaling about two million. Similarly to El Paso, it has several limitations to its future growth areas. In spite of that, it takes an area of 133.45 sq miles, which is about 50% of the size of El Paso. El Paso's population density makes up about 40% of Portland's, with 2,627 population per square mile in El Paso compared to 4,890 population per square mile in Portland ("U.S. Census Bureau QuickFacts" n.d.). In 2019, Portland's public transit system was ranked the 10th best in the country (McCann 2020). Despite its limited space for growth, the city is motivated to accommodate more people. To ensure functional transportation, Portland tackles traffic congestion and travel delays by promoting public transit, alternative transportation modes, or tolling. For these purposes, the city has adopted various strategic documents such as the Transportation System Plan ("Transportation System Plan Documents" n.d.), Metro's Strategic Plan or Urban Mobility Strategy, followed by detailed action plans. The city also belongs to one of the biggest promoters of walking, biking, public transit, and other multimodal modes of travel, of which it conducted several studies and publications in several partnerships. In general, the availability of public information and data is very good compared to the previous two case studies. The Tri-County Metropolitan Transportation District of Oregon (TriMet) is a public agency operating public transit in the Portland metropolitan area, and it is equivalent to Sun Metro in El Paso. The entire system had annual ridership of almost 54 million people in 2022. An overview of the system map can be seen in Figure 10. In the legend, MAX stands for Metropolitan Area Express light rail, SC for streetcar, AT for aerial tram, and CR for WES Commuter Rail. Buses are under the abbreviation BUS.

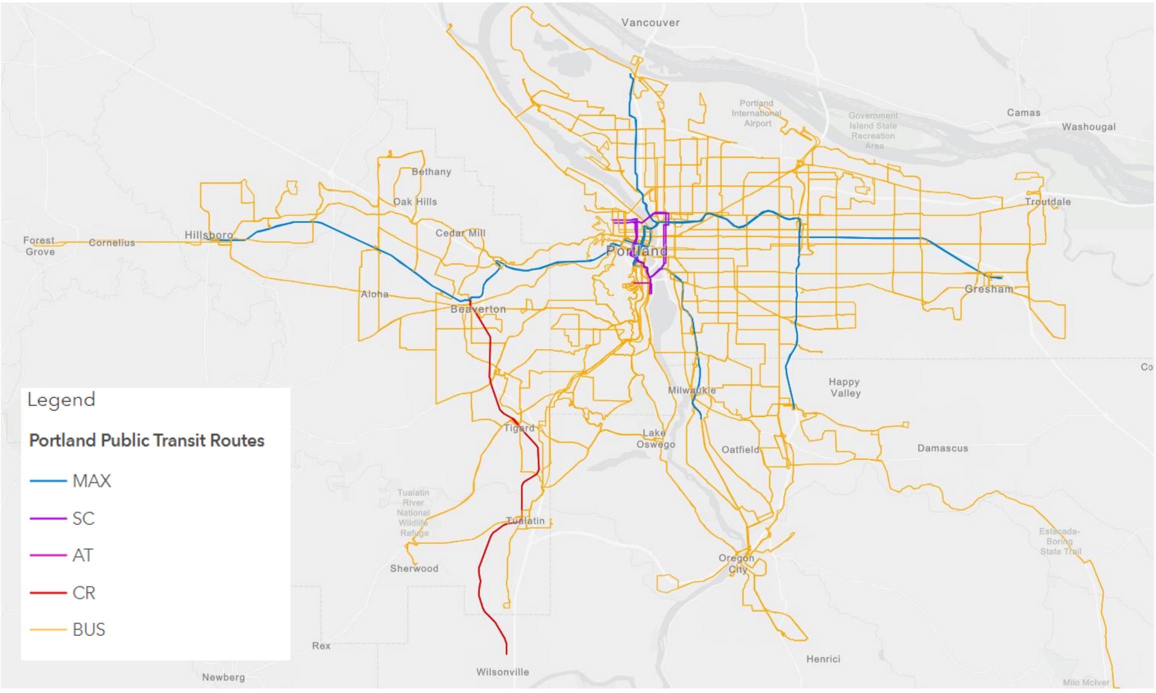

Figure 10: Portland Metro Public Transit Network Map. Created using ArcGIS tool. ("TriMet - Geospatial Data," n.d.)

Bus Network

There are 76 bus routes, out of which 17 are designated as frequent service, meaning their frequency is 15 minutes most of the day. Line FX2 is of a BRT character with service headways of 12 minutes and complying with services such as traffic signal priority, dedicated bus lane, etc. In addition, it operates a paratransit service, LIFT, which provides door-to-door services for disadvantaged citizens (“Bus Service,” n.d.).

Railway Network

The main commuter routes are served by five light rail transit (LRT) lines and Metropolitan Area Express (MAX). The network is about 60 miles long and totals 94 stations operated by 145 vehicles, with service headways ranging from three minutes in peak hour to 30 minutes off-peak. In Portland, the downtown lines operate at grade, and outside, they run alongside freeways and roadways on a dedicated route. They serve as a backbone of the metropolitan transit network, connecting major transfer terminals, the city center, airport or business districts and centers. The stations are enriched with P+R parking lots or garages and other amenities, such as surveillance, bicycle parking, or lockers, promoting multimodal travel. Daily weekday ridership of all the lines combined in the third quarter of 2023 totaled 72,200 (“MAX Light Rail” 2024). On behalf of the city of Portland, TriMet operates a streetcar line containing three lines of combined length of circa seven miles that runs around the downtown area, from the Downtown to the Central Eastside Industrial District, and North South Line. The total number of 76 stops is operated by 17 vehicles in typically 15-minute intervals. Technology-wise, it is compatible with the MAX system, and it shares track in some segments. However, it does not use the same privileges, such as dedicated rail track or right of way (“Portland Streetcar” 2024). The average weekday ridership oscillates around 8,000 riders (“Ridership + Performance - Portland Streetcar,” n.d.).

The Westside Express Service (WES) Commuter Rail connects the cities of Beaverton and Wilsonville in the greater Portland area. The line is nearly 15 miles long, serving five stations. On weekdays, it operates in 45-minute intervals mostly, shortened to 30 minutes in rush hours, and daily weekday ridership as of 2023 totals about 500 riders, compared to 1,500 to 2,000 in the years 2012-2018. There is an ongoing investigation into a possible 29-mile extension to Salem, but due to low ridership, it does not have many proponents. The overall design of the network, however, is well designed in terms of transfers – there are two options to transfer to one of the MAX lines. The WES stations are also served by several bus lines, and some are amended by P+R parking lots. Still, the length of the trip is an issue, while solely the trip form Wilsonville to Beaverton takes 27 minutes ("WES Commuter Rail" 2024). This problem applies to Portland's commute in general, with the average amount of time spent on commute being reported as 90 minutes, and 36% of riders reported spending more than two hours commuting daily ("Transportation in Portland, Oregon," 2024). Lastly, the aerial tram is also a part of the Portland Transit Network - a cableway of a length of 0.75 miles connecting the South Waterfront neighborhood and Oregon Health and Science University on Marquam Hill.

Walking and Cycling

Due to the adaptation of the urban growth policy and its coming reduction to the maximum block size, Portland Downtown is walking friendly. In order to promote walking as a mode of transport, the city has introduced PedPDX – Portland's Citywide Pedestrian Plan ("Portland's Citywide Pedestrian plan" n.d.) that contains concrete steps for prioritizing sidewalks, crossings, and other infrastructure. It identifies sidewalk gaps and prioritizes their filling according to their priority, preferably in cooperation with private development to encourage pedestrian movements. Another part is marked crossings and their implementation guidelines.

This feature is being aided by an efficient wayfinding system. Except for regular sidewalk routes, the city has, as of today, about 100 miles of Neighborhood Greenways – residential streets with low traffic volumes designed for shared use of cyclists and pedestrians ("Walking in Portland," 2022).

Biking in Portland is a highly used mode of transport in the national context. Although belonging on the nation's list of top biking cities in the last 20 years, Portland has recently been experiencing a decline in biking. However, the number of people using bikes for commuting, oscillating around 3%, is still highly above the national average, and so is the total number of commuters - almost 10,000 (O'Toole, 2023). The city has been ranked 2nd most bicycle-friendly city in the USA (Higgins-Dunn 2019), emphasizing its developed biking infrastructure and policies such as the Portland Bike Plan ("Portland Bicycle Plan For 2030" n.d.). The infrastructure consists of 385 miles of bikeways – 85 miles of bike paths, 94 miles of Neighborhood Greenways, and another 171 miles designated as bike lanes on streets (O'Toole 2023). There is also a bike-sharing system called Biketown in place with more than 1,000 bikes at 100 stations.

Transit Hubs

There are different types of transit centers in Portland connecting multiple modes of transport thanks to the various public transit options available. The concrete examples can be found below:

- **Gateway/NE 99th Ave Transit Center -** the most important transit node combining three MAX lines from which one connects the airport with the city, seven bus lines, and the Columbia Area transit shuttle. In addition, it is aided by P+R and car sharing. Other amenities include ticket machines, retail, bike racks, lockers, and a passenger information system. In proximity runs the I-205 multi-use path, and a shopping center is located nearby ("Gateway/Northeast 99th Avenue Transit Center," 2023).

- **Rose Quarter Transit Center** – served by four MAX lines, six bus lines, and a transit service connecting Portland with Vancouver, Washington, and the Swan Island Evening Shuttle line. Just like the Gateway transit center, the Rose Quarter is complemented by various amenities, such as bike racks, lockers, vending machines, and a passenger information system ("Rose Quarter Transit Center," 2023).

Summary

In the context of the USA, the public transit system in Portland can be called advanced and rich in transportation options. The city features buses, a commuter rail, several LRT lines, and an aerial tram. Transit centers located on intersections of several lines and different transit modes provide easy transfer options for multimodal transportation. However, despite that, the city still suffers from congestion and has difficulties attracting riders. Nevertheless, the approach to alternative solutions seems open-minded, given the example of the recently adopted Urban Mobility Plan, which includes a proposal for a toll system on the major highways, with the revenue being re-invested in multimodal transport options, a practice more typical in Europe ("Oregon Urban Mobility Strategy" n.d.). Walking and cycling in the city are being prioritized. The city features a pedestrian plan for filling sidewalks gaps, and a wayfinding system in the city center. Biking in Portland is a popular mode for commuting, which the city reinforces by providing infrastructure such as bikeways or shared use residential streets called Neighborhood Greenways. This innovative approach is also demonstrated in the city's participation in the pilot MaaS app called Moovit, and, more recently, Get There Oregon, helping to shift commute habits and work practices. It offers a trip planning tool, travel option comparison, carpool finding, or saved emissions calculator ("Get There Oregon" n.d.).

Lessons Learned and Their Applicability to El Paso

From the case studies introduced earlier in this thesis, it can be concluded that public transit has many types and different stages of development. There are also several factors contributing to its effectiveness. However, since cities nowadays are not being built from scratch but are already developed to various degrees of complexity, any change is difficult.

In the example of Tucson, it can be observed that the most important thing is to start, and even one streetcar line can be used by riders, making the city center more accessible to people, promoting biking, and making it more livable and alive. It is a foundation that can be built upon in the future. However, it might not seem like that from the start.

The case study of Helsinki showed that even in difficult geographical conditions, with the right policies and incentives in place supported by sufficient infrastructure development and planning, it is possible to build a functional public transport that is eventually going to become a favored transportation choice for the citizens. Overall, Helsinki represents the ideal, generally desired state of the system that other cities can aspire to achieve.

Lastly, the Portland case study serves as an example that even in American conditions it is possible to create a functional urban structure of the city, despite the existing cultural, institutional, and historical limitations. The city's policy of Urban Growth Limits is an example of good practice for El Paso, limiting the area of future development of the city and, at the same time, subsidizing the urban core densifying of old abandoned neighborhoods usually in city centers. Then, the city can move on to planning an effective transit system serving more densely populated areas offering various transit options starting with the infrastructure design, means of transit, and ending with fare policy. This is the trajectory El Paso should strive for to change its urban structure, thus reducing car dependency and becoming a more people-friendly city.

8. PROPOSED MOBILITY HUB DESIGN IN EL PASO

The *Orange County Mobility Hub Strategy* ("Orange County Mobility Hub Strategy" n.d.) and *Mobility Hub Planning and Implementation Guidebook* (Box and Paul n.d.) were used as guidelines for the mobility hub design proposal.

8.1. Problems and Objectives Definition

The first step is to define what kind of problem the mobility hub is trying to solve and, with that, go hand in hand with its objectives. In the case of El Paso, the main problem can be defined as a lack of alternative transportation options to privately owned cars. From the existing public transit network, only the four BRT lines meet the requirements for an effective way of moving around. However, the BRT system can serve as a good starting point, a backbone of the transit network on which improvements can be later built. Therefore, the objectives of the mobility hub can be defined in order of priority as follows:

- **Increase the attractiveness of public transport** – facilitating convenient, high-level, reliable service respecting local context and needs,
- **Improve access to transit and its connectivity** – providing first- and last-mile access, connecting people to places they want to go, addressing localities of mobility needs,
- **Enhance active transportation modes and multimodal travel options** – offering options that complement driving, not eliminate it, creating seamless and intuitive connections,
- **Enhance equity, place-making and serve local needs** – providing travel options to areas underserved by the existing transit system and creating attractive public space,

To create attractive travel options, shared mobility choices must compete with the convenience of the private automobile. This requires a human-centered design aimed at eliminating barriers such as unsuitable location, high cost, level of service, reliability, or payment methods.

8.2. Location Selection

The final location choice is an input of different variables into a complex decision-making process. The result should reflect existing conditions, future plans, and deciding factors. There are various location classifications intended to aid in determining exactly what kind of mobility hub should be implemented based on local characteristics like demand, trip purpose, location, or scale. The mobility hub designed for El Paso used a spatial analysis based on population and transit data, listed on the next page, and these stages (Box and Paul, n.d.):

1) Initially, mobility hubs can be distinguished depending on the layout of mobility amenities. Based on the available space, there are Fully Integrated Hubs and Dispersed Hubs.
2) Local characteristics determine place classification, for example, Downtown Area, University, Multimodal Transportation Center, Entertainment Center, Park and Ride, Residential Neighborhood, and Neighborhood Center.
3) Lastly, the site organization of mobility amenities is organized based on prioritization following the scheme in Figure 11.

Figure 11: Transit Mode Access Hierarchy Scheme. Taken from (Box and Paul, n.d)

The goal of the spatial analysis was to identify places in El Paso where people live and travel, and where people without a car live as a potential target user group, in order to determine the best location for a mobility hub. As an analytical tool the ArcGIS software by ESRI was used. All rights reserved. Lastly, the following data from the data source Esri – Axle Data were used (“Data Axle—Esri Demographics Reference | Documentation”, n.d.):

- **2023 Population Density** (“El Paso Population Density”, n.d.),
- **2023 Daytime Population Density** (“El Paso Daytime Population Density”, n.d.) – working population, while both types of densities are in population per square mile,
- **2021 Owner Households with 0 vehicles (ACS-5Yr)** (“El Paso Owner HHs with 0 Vehicles”, n.d.),
- **2023 Total Sales Standard Industrial Classification (SIC)** (“El Paso Total Business Sales (SIC) - Overview”, n.d.) **-** leisure,
- **Sun Metro BRIO lines** (“Sun Metro Brio Lines”, n.d.) **–** public transit network**,**
- **Sun Metro Terminals** (“El Paso Transit Network and Terminals - Overview”, n.d.)**.**

Three different maps were created, mapping the whole city, each focusing on one variable in relation to the population density and transit network. These maps are shown in Figure 12, Figure 13, and Figure 14. Visual analysis was used to verify the suitable location of the mobility hub. For this purpose, all three maps were overlapped in Figure 15 to examine if any values significantly concentrate in a specific area. To ensure maximum utilization of the mobility hub potential in tackling negative traffic impacts, the main focus was put on the places where people live and where people work as main travel generators. The spatial distribution of households with 0 vehicles was included in order to assess its accessibility by public transit network route rather than by a mobility hub. That is why it didn’t play as significant role as the two previously mentioned variables.

Figure 12 is a map showing the most populated areas of the city, as well as areas with the biggest number of jobs. It can be observed that the highest concentration of jobs is in the Downtown. The second substantial concentration can be found in shopping areas along I-10 south of the Montana Corridor and north of the Alameda Corridor. Along the Mesa Corridor can be found significant concentrations of jobs too.

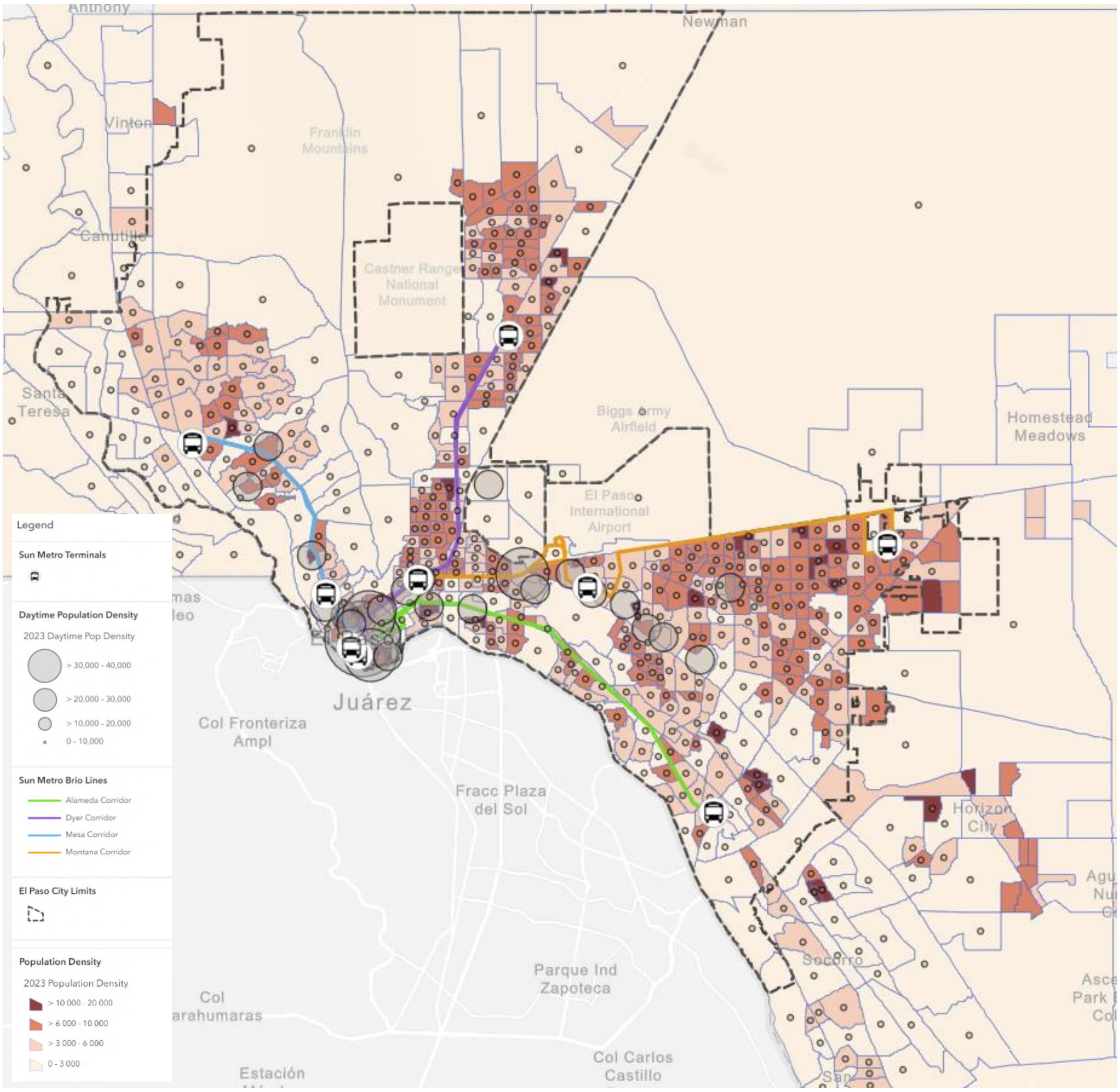

Figure 12: Population Density and Daytime Population Density Map (Screenshot). Created using ArcGIS tool and ESRI library.

Figure 13 depicts the relationship between population density and places of businesses where people spend the most money. That suggests that trips people where would be headed in their free time. The biggest concentration can be found in El Paso Airport and the industrial businesses district south of the transit terminal on Montana Corridor. Lastly, it is useful to mention shopping malls along I-10, just like in the previous case, and in the Downtown.

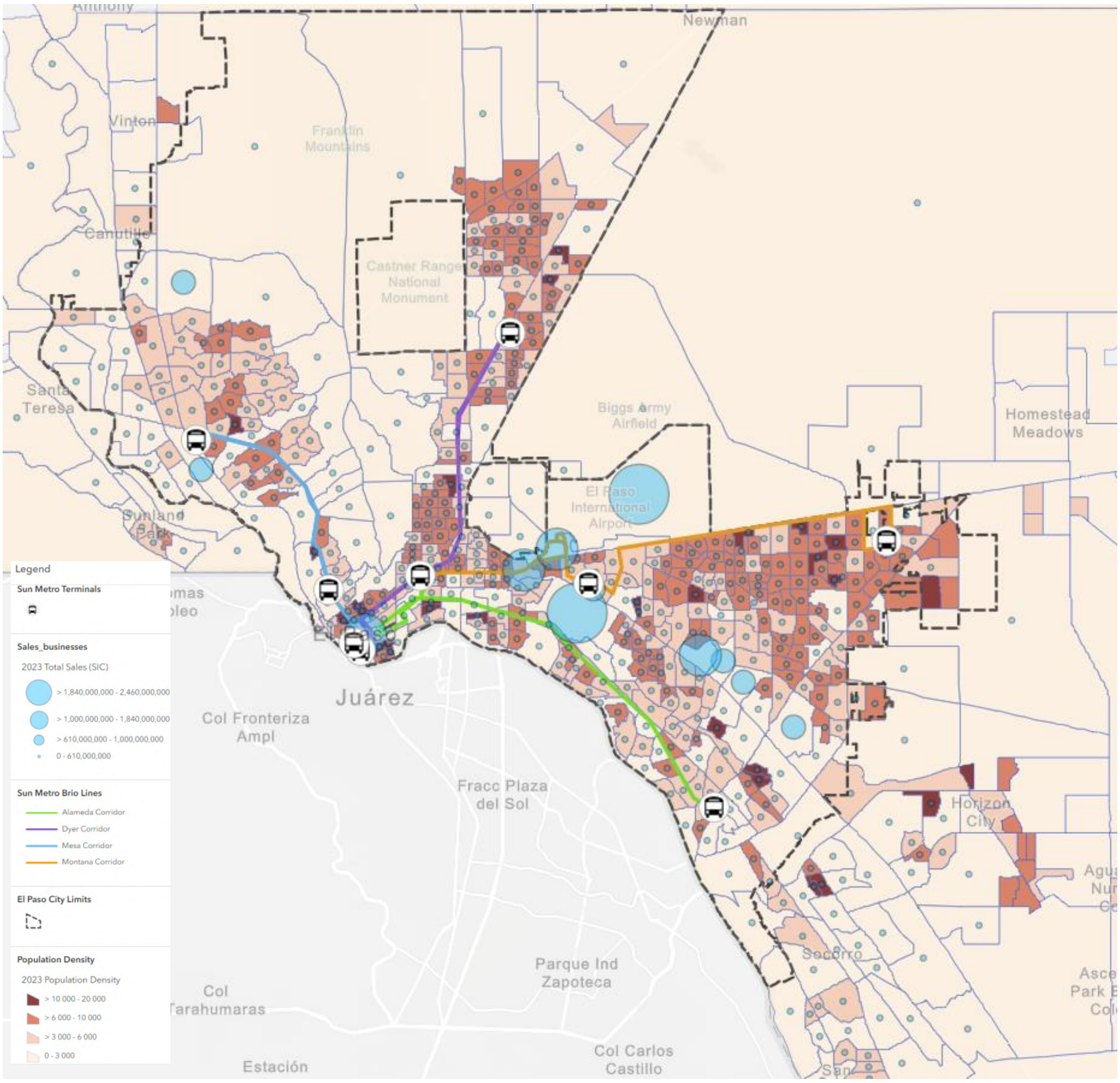

Figure 13: Population Density and Business Sales Map (Screenshot). Created using ArcGIS tool and ESRI library.

In Figure 14, a spatial distribution of households without a vehicle is shown. The biggest concentration is in the southwest, near the city limits beyond reach of the BRIO transit terminal and its Alameda Corridor. Then, on the other side of El Paso, in the northwest beyond Mesa Corridor. Also, high density can be found west of the Dyer Corridor and near the downtown area, and along the Alameda Corridor Brio Line both to the north and to the south.

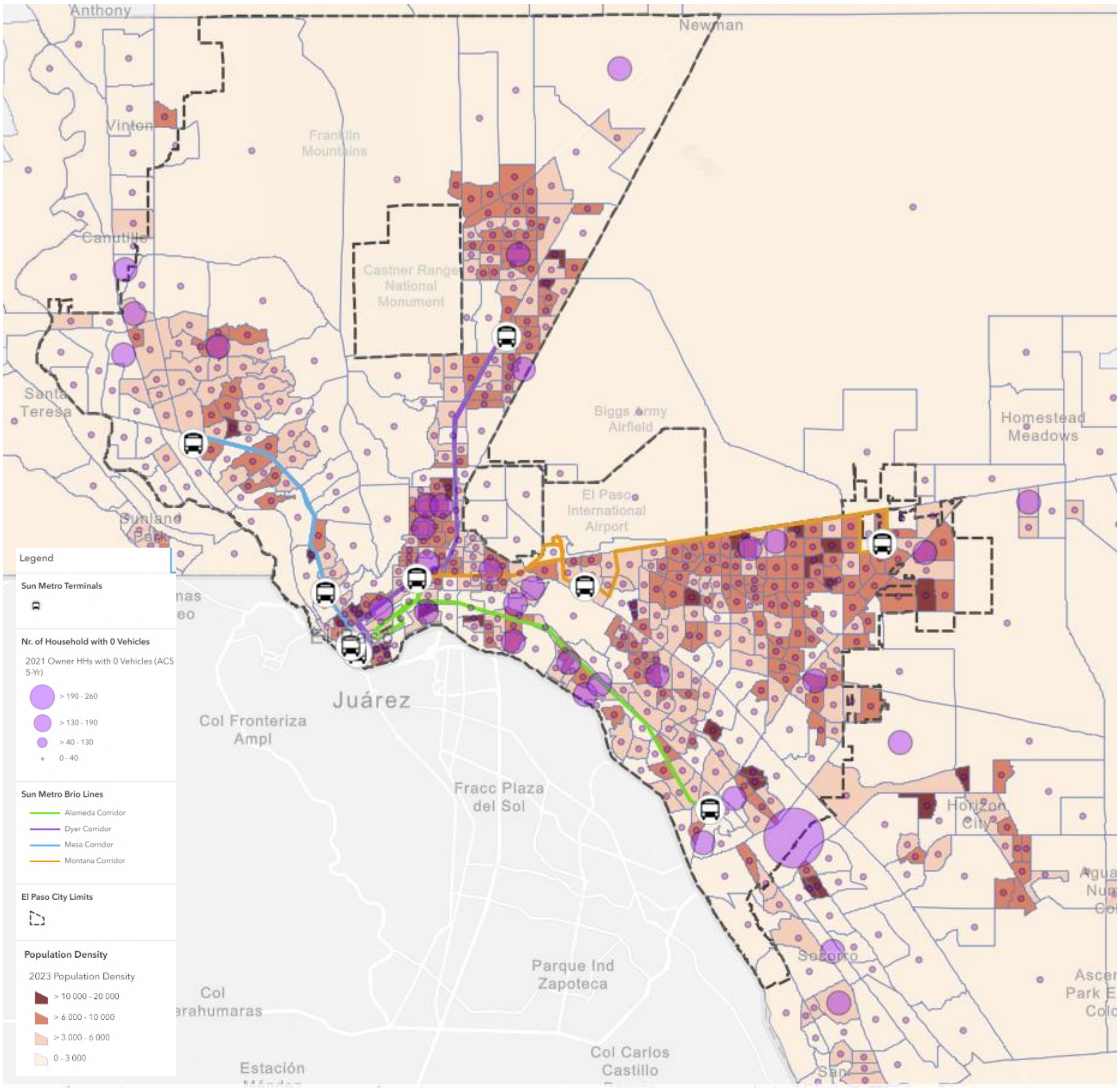

Figure 14: Population Density and Zero Vehicles Households Map (Screenshot). Created using ArcGIS tool and ESRI library.

When the maps overlap, as can be seen below in Figure 15, it is observable that the biggest concentration of potential trip destinations that a location of a mobility hub can benefit from is in the downtown area in alignment. The downtown is the center of the city and a highly populated area, which has the highest potential to use the placement of the hub for further economic and transportation development. The choice is also in alignment with the previously mentioned goals.

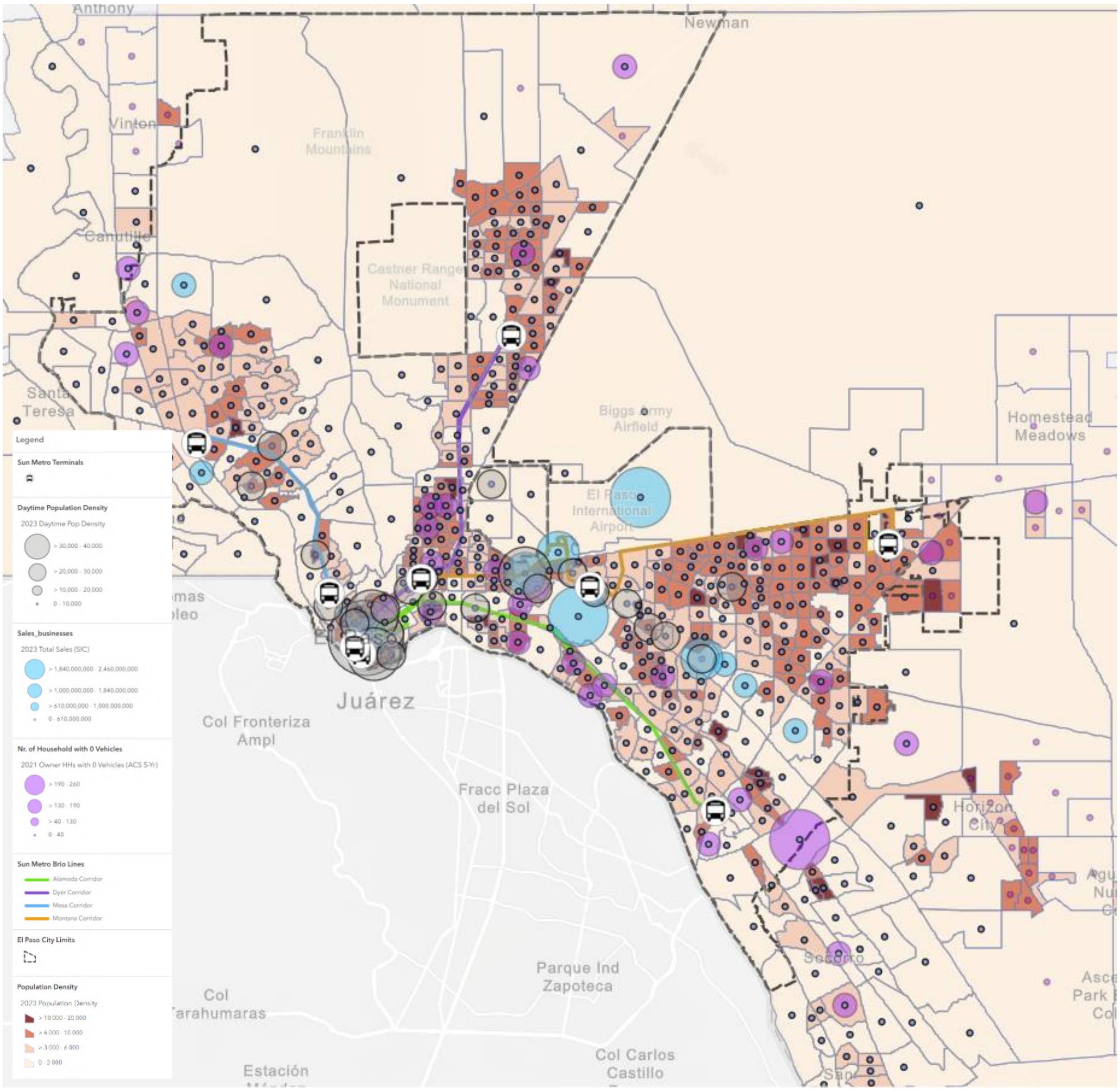

Figure 15: Population Density and All Three Variables Combined Map (Screenshot). Created using ArcGIS tool and ESRI library.

If it were to address every issue separately, it would be very difficult to find one location that suits all needs. But as a further research direction, it seems viable to address the leisure places by placing an entertainment center type of mobility hub close to the concentration of sales places along I-10, either served by a dedicated fifth BRIO line or with a high-capacity connection to one of the already existing terminals. The lowest car ownership consolidation on the southeastern city limits border of El Paso can be addressed by dedicated neighborhood MH type on the prolonged Alameda Corridor served at a reasonable frequency. The same goes for the places beyond the Mesa Corridor in the northwest. It seems viable to put another small-scale type of urban district mobility hub in the area west of El Paso International Airport, where there is a higher concentration of jobs and households without a car. However, the best place in alignment with the thesis objective and the biggest impact is a decision to place a regional gateway mobility hub in El Paso Downtown with the highest concentration of jobs and a suitable location with other places of interest in its proximity within walking/biking distance aided by for El Paso standards extraordinary transit connections. Additionally, as a side effect, it can lead to an increase in tourist attractivity in the city center as well. Lastly, the city adopted a Downtown, Uptown, and Surrounding Neighborhoods Master Plan in July 2023 ("Downtown, Uptown, and Surrounding Neighborhoods Master Plan," n.d.). It is a comprehensive document containing improvement suggestions and concrete steps for the revitalization of the entire urban core of old El Paso. The focus is put on the walkability and livability of the area via complete streets design, economic growth, and housing opportunities. Moreover, it suggests an addition of parks and public space to attract people and provide them with a place to relax. The mobility aspect is accented in multimodal transportation and transit-oriented development. The plan also mentions potential new riders generated by the mentioned development in various stages by leveraging the existing BRT system and transforming the streetcar into “a true transit corridor with service in both directions,” achieved by double-tracking the northern loop.

Finally, by identifying the existing transit terminals in the downtown area, the final choice of MH location has been narrowed down to three places, which can be observed in Figure 16, with a depiction of a five-minute walk area indicating accessibility and helping to determine the final site selection.

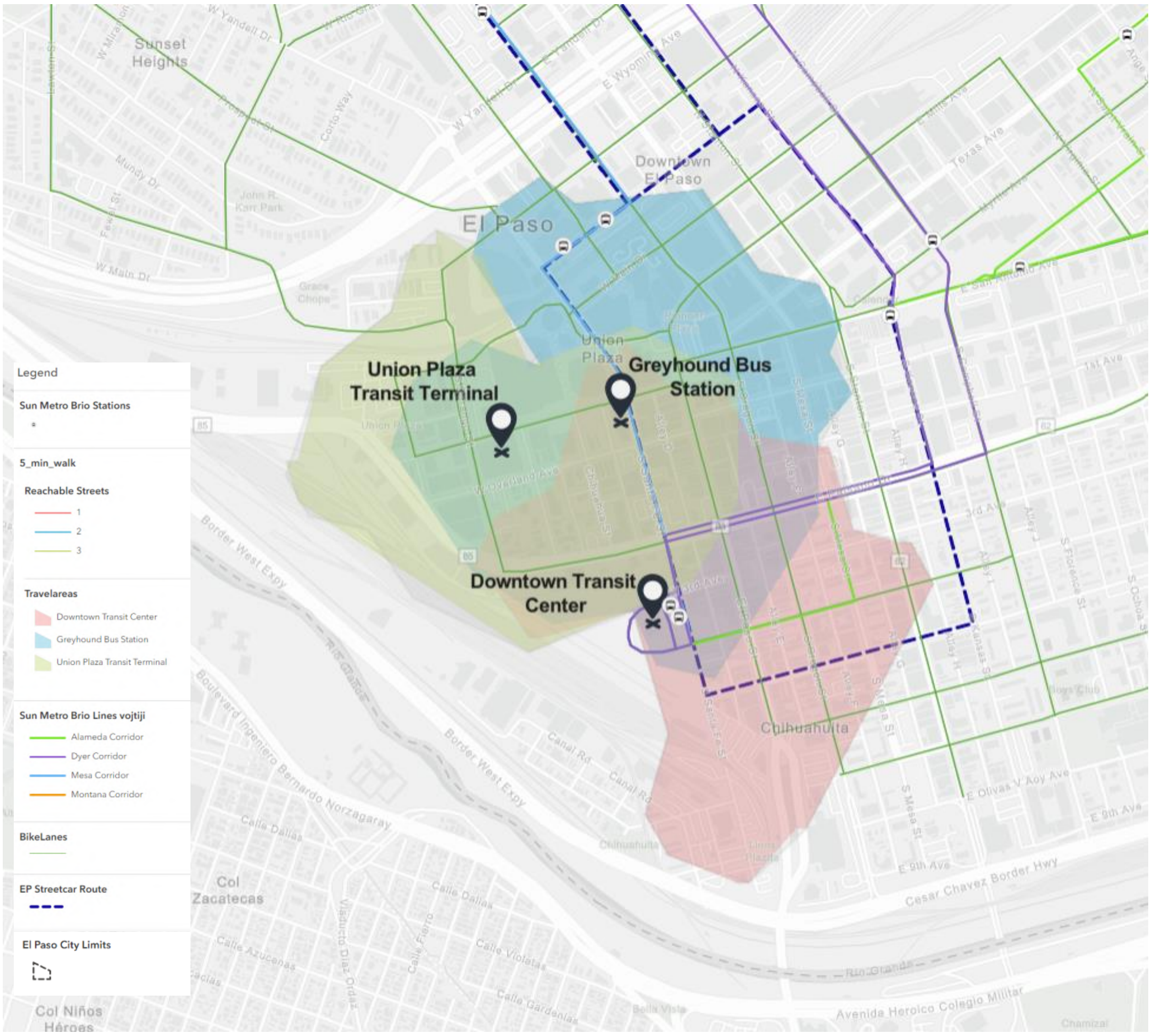

Figure 16: Downtown Area MH Possible Locations Map (Screenshot). Created using ArcGIS tool and ESRI library.

First, transportation accessibility was evaluated. Transportation accessibility of the **Union Plaza Transit Terminal** is poor compared to the other two options, given there is no direct transfer from a BRIO Line or the Streetcar. Cycling accessibility of the site can be considered good; however, that applies to the other sites as well. On the other hand, the **Downtown Transit Center** has existing infrastructure for bus and streetcar transfers and is owned and operated by Sun Metro; however, it lacks connection to other modes of transport. Its location closer to the border adds to the attractivity for cross-border commuters although the 5-minute walk proximity does not reach the downtown area with the biggest number of jobs and points of interest (POIs). There is not enough available data for the number of pedestrians crossing to Mexico from El Paso. However, it can be assumed that their number does not exceed the number of commuters going to El Paso, including the potential generated by the development of the Downtown, which centers around businesses and jobs. Surrounding neighborhoods like Chihuahuita, South Central or El Segundo Barrio are characterized as residential with small businesses. A rough estimate from the monthly number of crossings in the northbound direction averages around 7,500 people. Lastly, the **Greyhound Bus Station** is equipped with sufficient bus infrastructure and is directly accessible by one BRIO line under current conditions and by the streetcar line as well. The downside is it is not owned by El Paso or Sun Metro, which would require either a switch of land or a buyout and negotiations from Sun Metro. Despite this fact, its location might be worth undergoing the negotiations process because even though the Sun Metro Downtown Transit Center is endowed with the infrastructure for buses, it is insufficient to serve as a mobility hub, and it would have to be completely rebuilt. In addition, it can be viewed as an opportunity to engage in Public-Private Partnership (PPP), bringing together both the public and private sectors, collaborating towards the same goal, and participating in both the capital costs and the revenue.

The Greyhound Bus Station is situated directly across the street from the cultural venue Union Plaza, lying within a 0.25-mile radius of the El Paso train station, providing it with potential for future intercity rail transit (Janos et al. 2019). On foot, it is also possible to conveniently reach San Jacinto Plaza or Southwest University Park baseball stadium. Additionally, in the downtown is a high concentration of parking garages, hotels, restaurants and other attractive amenities and places. According to walkscore.com, the Greyhound Bus Station scored 98/100 points in walk score, 64/100 points in transit score, and 69/100 in bike score while identifying the nearby Union Plaza neighborhood as the 2nd most walkable neighborhood in El Paso ("The Walk Score of 200 West San Antonio Avenue, El Paso TX" n.d.). The overall good bike score can be confirmed while looking at Figure 16, where several bike lanes go through the proximity of the location. The summary of the assessment is available for an overview in Table 1, where the observed variables are characterized on a three-point scale in order of importance from left to right.

Table 1: Candidate Locations Summary

Candidate Location	Transportation Accessibility	Downtown Accessibility	POE Proximity
Union Plaza Terminal	Good	Good	Poor
Greyhound Bus Station	Excellent	Excellent	Good
Downtown Transit Center	Excellent	Poor	Excellent

8.3. Greyhound Bus Station Proximity

Based on the arguments presented in the previous chapter, the location for the mobility hub was selected as the site of the current Greyhound Bus Station, as illustrated in Figure 17. According to the Metropolitan Council Document, average trip distances corresponding to the given transit mode were identified.

Figure 17: Aerial Map of Mobility Hub Location Selection (Screenshot). Created using ArcGIS tool and ESRI library.

The average trip distances characterize the typical distance that the selected mode of transit is useful for. Once the distance exceeds a certain threshold, the mode becomes inefficient, and people are more likely to use a car instead. The mobility hub in El Paso is going to focus mainly on walking, biking, and e-scooters because of the placement and El Paso urban structure. For the car-oriented services, carpool and ride-share transportation provided by private companies will be considered and supported by the design. An overview of the modes and their average trip distances can be observed in Table 2.

Table 2: Average Trip Distances According to Mode. Edited. (Box and Paul, n.d.)

Mode	Average Trip Distance
Walk	0.25 Miles
Bike	1 – 1.5 Miles
e-Scooter	1 – 1.5 Miles
Micro transit	5 – 7.5 Miles
Carshare	5 – 10 Miles (one-way)

Reflecting on the numbers on the previous page and the outline of the supported services, the reachable areas by the said modes can be seen in Figure 18. People on bikes and e-scooters starting their trip at the mobility hub can encompass the whole UTEP campus, travel up to Schuster Avenue in the northwest, and reach significant distances along Montana Avenue or Texas Avenues. Several BRIO line stops are accessible too. Assuming the stops will be equipped with bike racks or e-scooter parking places, it would be an attractive way how to reach the stops and transfer to BRIO lines not only in the downtown area but also at stops located more conveniently to the rider. Lastly, the entire downtown area and surrounding neighborhoods and the Paso del Norte POE are conveniently accessible too. Considering the number of border crossings in the northbound direction, it might seem viable to provide the Paso del Norte POE with sharing stations as well, which would serve as a convenient transfer either to the mobility hub or around downtown for the target destination to motivate people to cross on foot.

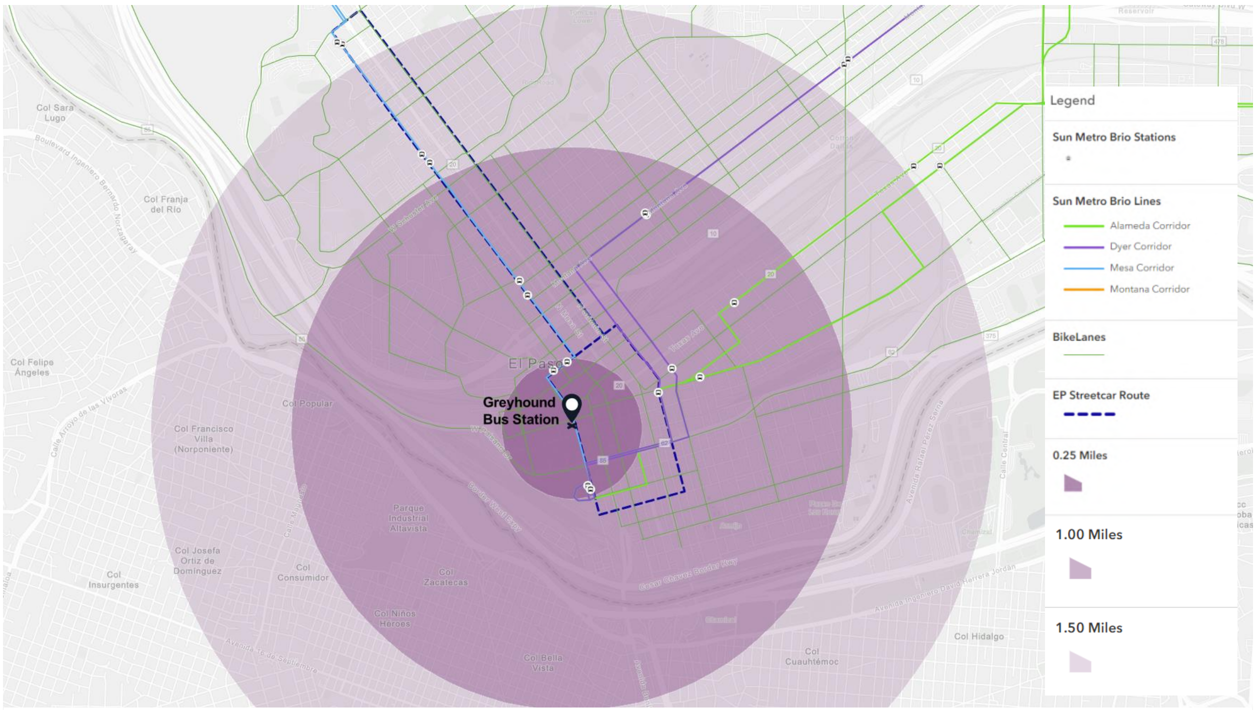

Figure 18: A Map of average travel distances from the mobility hub (Screenshot). Created using ArcGIS tool and ESRI library.

The downtown area, accessible on foot from the mobility hub, provides all different kinds of services. In addition to the offices of big employers, there are also government agencies present. Other than that, the downtown is the cultural center of the city, featuring a convention center, the Plaza Theatre, a library, museums, and a tourist information center. Their location is marked in Figure 20. In addition, it includes locations of proposed unified wayfinding system components. This system is designed to make orientation around downtown easier by showing directions via the safest and the shortest way to the places of interest. The components can be either street signs, sidewalk markings, or information kiosks. The kiosks are to be placed near busy areas with a high share of potential newcomers. The components will be designed in a unified style regarding size, color, font, and shape to avoid confusion and allow straightforward navigation. This system, together with public art displays and complete street design, will shape the city center and make it more accessible to people, making the downtown more livable and local businesses thrive.

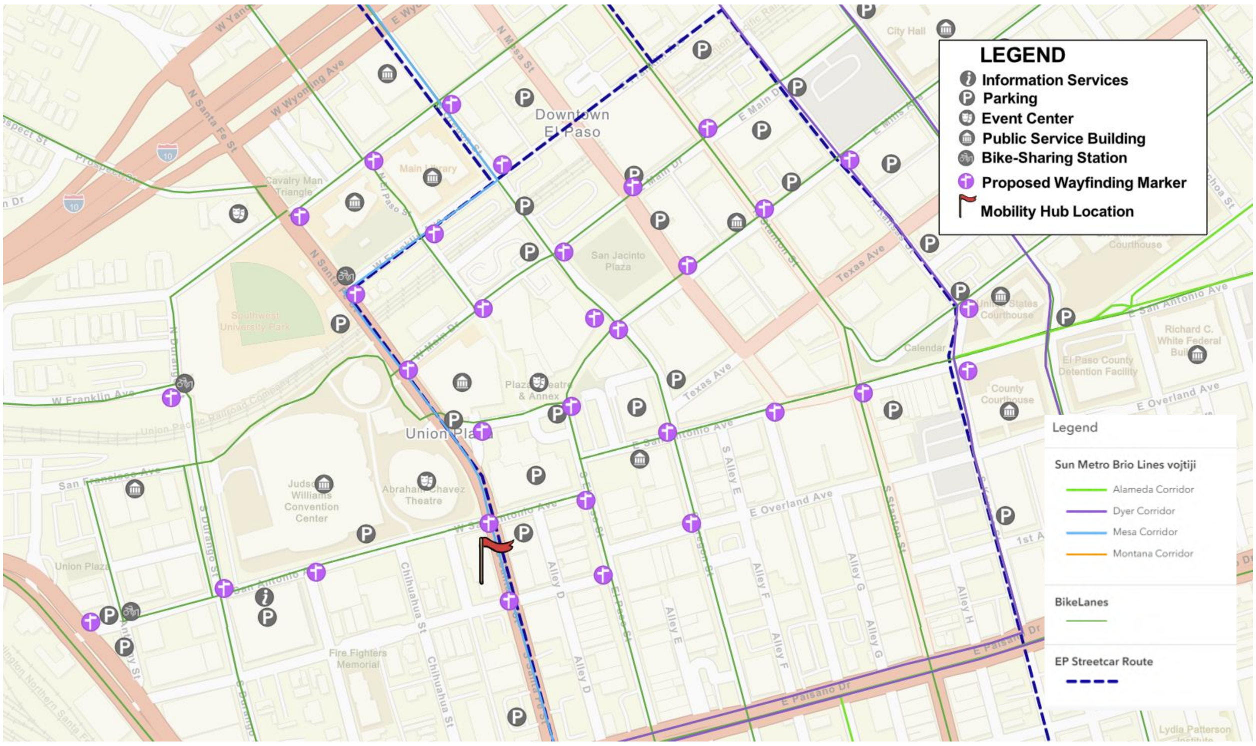

Figure 19: A Map of Points of Interest (POIs) in El Paso Downtown (Screenshot). Created using ArcGIS tool and ESRI library.

8.4. Greyhound Bus Station Site Overview

According to the El Paso Central Appraisal database ("El Paso Central Appraisal District" n.d.), the main land of interest is owned by a company called EPT 200 San Antonio LLC. Its size is about 0.62 land acres. The building situated on the property was built in 1975 and is approximately 13,600 square feet. It is now being used as a bus station for the Greyhound Bus. For the purposes of this thesis the following is just a brief overview of the idea and design, which will be elaborated more in the following chapters. The proposal suggests a contract between the company and Sun Metro allowing Greyhound buses to park in their parking lot in the Downtown Transit Center. The building that is currently in place will be demolished because it does not meet the mobility hub requirements due to its size and design. The building will be replaced by a new one of the latest energy and technology standards, designed to meet the needs of the included transit modes, its users, and associated services. Including the building, which will provide over-the-counter information services, a food store, a bike shop, and an ATM, the site will be designed to comply with the complete street design, following the example of redesigning the W Overland Ave and equipped with bike lanes connecting to the existing infrastructure. In the direction of the Convention Center and San Jacinto Plaza will be bike parking and e-scooter parking. To ease the access to the MH area and congestion, there will be car pick-up/drop off zones on both W San Antonio Ave and W Overland Ave. The streetcar stop on the opposite side of the street will be shared with buses, both Greyhound buses and BRIO lines. Additionally, an outdoor picnic area will provide a getaway for those waiting while spending time outside. For electric vehicles will be provided a small parking lot equipped with electric chargers, and next to it will be a carpooling pick-up/drop-off zone. The outline can be viewed in Figure 21 on the next page.

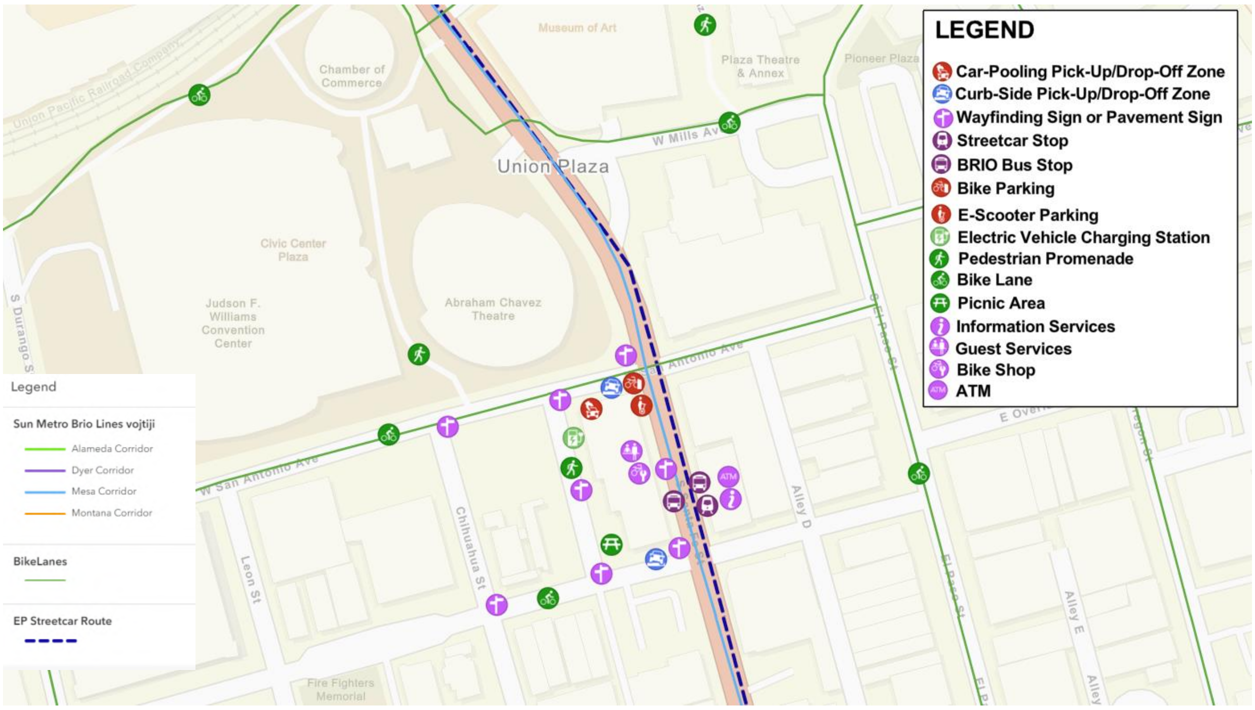

Figure 20: An overview of location of services and amenities on the site of MH (Screenshot). Created using ArcGIS tool and ESRI library.

8.5. Detailed Site Layout

Depending on the hub type, each type is recommended or expected to contain a certain type of anchor services that are going to be served by. For a downtown regional hub, typology is typically a combination of high-capacity and high-frequency transit modes complemented by a mix of other modes of transit. The site is separated into three sections – outdoor and indoor mobility hub area and mobility hub surroundings. The detailed sketch has been created for a better overview of the location of individual items and it can be viewed in Appendix 1. The blueprint is not up to scale and serves as a guideline. In the event of implementation, detailed plans for every aspect would have to be drawn up by the selected architecture firm and the design team. However, the overall design should follow the guidelines and city code, respect the downtown characteristics, and complement the design pattern. All the pedestrian, biking, or car connections should consider the existing built environment and ensure smooth linkage. On the other hand, the place as a whole should stand out and serve as a place to spend time, a new dominant of the downtown, and a stop-by destination for tourists.

The primary function of the hub will be transportation. However, almost equally important is the placemaking function, which means enhancing the space by creating a place for the public to spend time outside, attend events, and enjoy accessible locations and easy transportation.

High-Frequency Transit

The main supply of passengers will be provided by the existing BRT system. A stop will be designated traffic in the southbound direction with a shelter in the design style of the mobility hub on Santa Fe St, so the buses do not need to go into the area of the hub every time to stop. The lines' schedules and routes may have to be adapted so all four lines stop by the mobility hub. The same stop will be used by long-distance Greyhound buses, which will not have a significant impact on the traffic flow because their frequency is low. On the other side of the street, the same stop will be designed, which will also be shared with streetcars. Although currently offering only a limited opportunity to move around the town, namely around downtown and along Mesa Street to Uptown alongside the UTEP campus and back, the sole existence of a streetcar route presents a great opportunity for the future, where it is recommended in the Downtown & Uptown Master Plan previously mentioned, to enable two-directional traffic by making it double track and creating a high-frequency schedule that respects morning and afternoon peak hours, to turn it into a reliable, legitimate mode of travel. The design of the hub should, in this way, reflect the possible improvements and enhancements and satisfy growing needs. A public curbside drop-off zone will be located south in the same block on W. Overland St in the existing parking bay, and a public curbside pick-up zone will be on W. San Antonio in the neighboring block in the existing parking bay, both conveniently in the close proximity and easily accessible on foot. The mobility hub area will be separated from the streets' sidewalks by green belts with local plants or trees to provide a visual and also noise barrier between the spaces.

<u>Sustainable Mobility Modes</u>

The other modes served by the hub will be biking and hybrid mobility – e-scooters, for which will be designated an outside parking zone on the corner of Santa Fe and W San Antonio St. The zone will be both physically designated with pavement marking and a visual totem for easy orientation from a distance, and virtual for mobile applications. It will provide available accommodation for shared e-scooters operated by licensed companies by the city council, as well as the shared bikes of the El Paso bike-sharing company BCycle. The hub design does not include the design of e-scooter sharing stations around the city; however, it reflects the future possibility of such service being offered and thus designates a space to include it. To promote biking mode even more, right by the zone will be a long-term bike and e-scooter parking facility, where it would be possible to rent a spot to park a privately owned bike/e-scooter. The facility will be equipped with an automatic rack for storage, which will reduce the need for staff and allow the facility to operate non-stop. It will be operated by an easy-to-use terminal, where people will just select the number of the spot they picked when parking the bike/e-scooter, and after a phone/email verification and payment, the rack will automatically deliver the right stored bike/e-scooter. On the roof of the facility will be local greenery to reduce the heat island effect and solar panels, which will generate electricity that will be used either to operate the rack, and leftovers will supply the bike/e-scooter chargers outside available to the people. Security cameras will be installed to monitor the inside as well as the surroundings of the facility, including the bike parking zone, to prevent crime.

Car-Related Mobility Modes and Parking

The inner outdoor area of the hub is designed one-way as a roundabout with a decorative rock sculpture in the middle and local greenery to create an aesthetic impression. The roundabout serves as an EV charging spot, where along its perimeter are 12 EV charging spaces, primarily designated for either rideshare/carpool or delivery companies operated EVs. However, the public will be able to reserve a charging spot as well, both online and offline. Additionally, six regular parking spaces and two parking spaces for people with disabilities are reserved for employees or official inspections. On the outer side of the roundabout will be one designated spot for delivery vehicles as a loading zone to serve the logistics and retail services. The rest of the outer side is designated as a pick-up/drop-off lane to be used by carpool/rideshare companies that operate in El Paso. To offer more flexibility, the drop-off lane will accommodate a multitude of cars and vans at once and, if needed, even a bus. The lane will be separated into flexible sectors based on the companies currently operating in the city and the types of services. Along the zone are designed wooden pergolas covering the 'platforms' from the sun, rain, or hail. The emphasis on the use of local and renewable materials ensures the reduction of the carbon footprint of the construction and increases the sustainability of the whole project. Airy, heavy-duty textile shade connects the pergolas, providing shade and an aesthetic enhancement of the platforms. Under the pergolas will be outdoor furniture, including benches and tables, and free public Wi-Fi signals to offer a quality experience to people waiting for their ride. Real-time information boards displaying information about incoming rides/routes will be located under the pergola roofs to protect them from the weather while also being conveniently located for easy access. For easy navigation between the individual stops or even areas of the mobility hub, a wayfinding system will be installed consisting of navigation totems, sidewalk signs, arrows, or simple maps on poles and pillars. Additionally, CCTV cameras will be in place to monitor the 'platforms' to ensure people's safety and prevent vandalism. Near the pergola will be placed a marked digital kiosk operating non-stop providing information services to the travelers, supplementing services of the main building's info center after its hours such as ticket vending, bus schedules, carpool/rideshare companies' information, reservation of the EV charging spot, map of the city and downtown area, city events calendar, and all different kinds of useful information for the riders.

Placemaking

The space between the transportation area and the mobility hub main building is designed as a plaza. Its purpose is to serve as a gathering place, and it offers multiple ways of use. In the design phase, it would be vital to incorporate the local community and artists into the design and find use cases. It can serve as a gathering place, for which there will be permanently placed tables with chairs to encourage people to spend time. Events such as talks or presentations could be held on the plaza on a one-time basis, bringing foldable chairs and covering the plaza with a retractable sunshade located on the main building. Local artists can come up with ideas on how to decorate only the plaza with various elements such as pavement patterns, sculptures, or the main building's facade decoration to reflect and promote local specifics and unique features characterizing El Paso. A food truck or a local shop can be parked on the plaza to make the place come alive and also support local businesses. A small park will stretch alongside the L-shaped main building, where local plants and trees will be planted alongside a designated stone paved path leading to the main building's entrances equipped with benches, make either waiting or spending free time such as reading a book comfortably. Diagonally across the park, a stream will flow to refresh the people during hot weather. It is crossed by two wooden bridges made from wood. Rainwater storage will be placed underground where the leftover rainwater not soaked up by the plants from the entire site will be collected. The stream will use the collected stormwater, and it will be designed as a sustainable circulation, minimizing water waste and ensuring continuous water recycling. Part of the storage tank will be a water treatment system processing the water to the level when it is safe to use for the main building's facilities like faucets, toilets, urinals, or showers. The collected water will not have to be used for irrigation since the use of local plants, which, due to the native climate, do not require irrigation. Additionally, suitable intelligent lighting will be proposed to serve both as a design component and a source of light to make the place lively and also to make people feel safe during night hours. The streetlamps will be equipped with motion sensors, which will turn on the light during night hours when someone is walking by. Otherwise, the light will be turned off at night to save energy.

Amenities and Supportive Services

The main building is the core of the supporting services provided in the mobility hub. Its design will reflect the latest sustainability trends previously mentioned, such as intelligent lighting, economical water and piping facilities, use of sustainable materials for construction, insulation, and facilities and equipment. Solar panels on the green roof will supply energy to power the building, complemented by a battery storage system, which will further decrease operational costs by storing the leftover electricity and selling it to the grid during peak periods while accumulating it during off-peak periods. The part of the building facing the plaza will serve as a delivery hub for the storage, sorting, and distribution of parcels available for sharing with multiple delivery companies. For the users, it will be accessible from the plaza in the form of an automated parcel locker that operates non-stop. Other parts of the building will be distributed between a bike shop for rent and a private company, which will provide repair services, equipment, and support for bike riders. Public restrooms will be enhanced with automatic but paid showers. Then, to make the travel experience comfortable, an air-conditioned waiting room will be in place, along with retail space for rent, preferably for a food business. An information center providing various tourist services, ticket vending, EV charging space reservations, travel plans and schedules, and maintenance information will be operated in the building. The overall look of the building should be spacious and comfortable, furnishing a pleasant environment during both winter and summer, easy to navigate, and make people feel welcome and relaxed while also fulfilling their travel-related needs. The building will have separate from the business operators its own keeper, security on-siteon site during operating hours and cleaning personnel.

8.6. Implementation

The mobility hub project will include a team of a public agency, private sector, community, and mobility providers. The multi-disciplinary teams will cooperate in order to ensure the project meets its goals. Community engagement is crucial for the successful implementation and acceptance of the community; thus, the final design will represent the dynamic of the neighborhood and the people it is going to serve. The iterative approach is to be applied by separating the implementation into stages, while each stage will pilot a different item. The project will scale up over time starting with small, low-cost solutions to introduce the idea and design to the public, collect feedback and assess its functionality after every stage, and incorporate it in the next design phase. A public participation plan will be created for this purpose. The iterative process will also be applied during the main construction process, after the pilots, which will help to distribute costs and timeline pressure, therefore ensuring continuous implementation and mitigating the negative impact of delays. The stakeholders' engagement document will describe the strategy and roles of each stakeholder in delivering the objectives of the hub. The main stakeholders will be the city of

El Paso, Sun Metro, El Paso County, private mobility providers, downtown community leaders, and an award of the contract for the construction. However, participation from other stakeholders might be required during the planning process. To secure funding, a mobility hub implementation public-private partnership (PPP) will be formed mainly from the selected stakeholders – mainly El Paso town hall and Sun Metro, through financial agreements, joint development contracts, etc. Additional contracts might specify the distribution of selected investment costs between external subjects, such as private mobility providers. Eligibility requirements for state and federal grant funding will be reflected during the technical design and planning process of the project to raise additional funding. Lastly, Figure 22 presents a framework summarizing valuable considerations that should be kept in mind during the process of creating the implementation plan. Acknowledging these practices promises success stories that can be reproduced elsewhere.

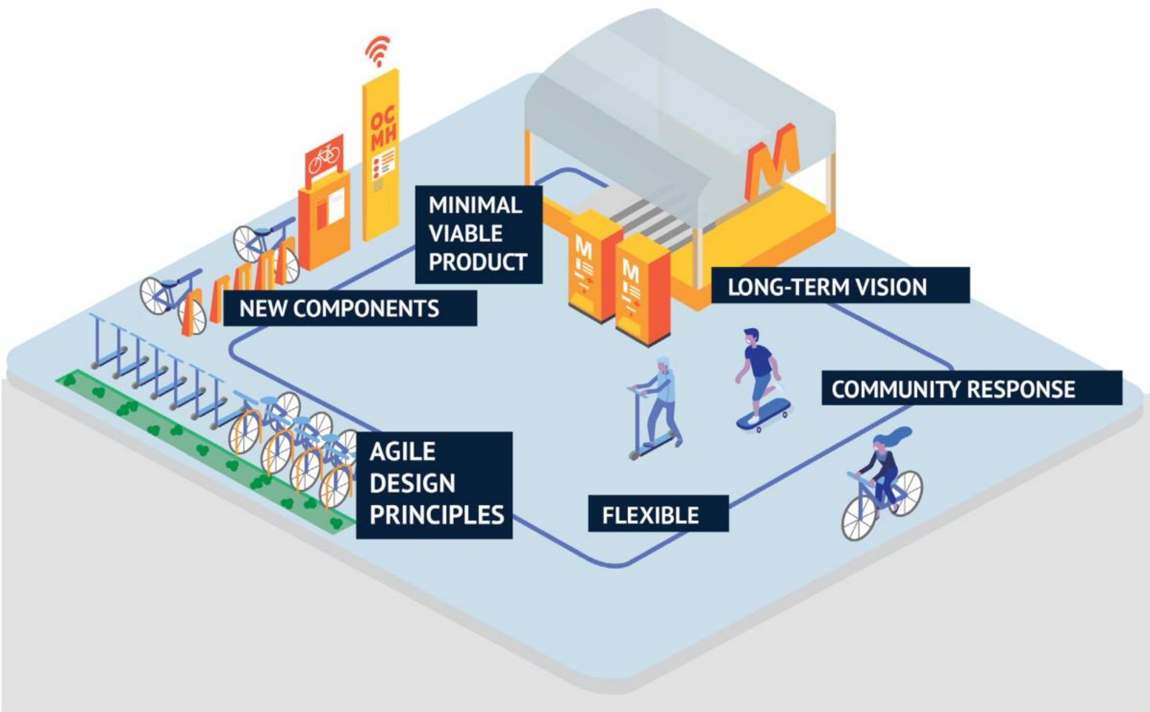

Figure 21: Implementation Plan Considerations. Taken from ("Orange County Mobility Hub Strategy" n.d.)

8.7. Organization and Operation

The operation of the hub will fall under Sun Metro, where a single entity of a Mobility Hub Manager will be put in charge. The transit agency will manage and operate most of the hub operations, contracts with private mobility providers, and also maintain any feature in the public right-of-way, since it is a single piece of property in an isolated location. However, the responsibilities can be enlarged in the future in the event of building other mobility hubs in other parts of the city creating an interconnected mobility hub network. Specific management duties related to public space, like cleaning, local art public display, street furniture placement and upkeep, brand management and marketing, and many others, will be outsourced in the form of partnerships such as with El Paso Downtown Management District (DMD). Additionally, concession grants to external companies will be used to generate revenue from a controlled advertisement program. The last entity included in the operation is the local community in the form of volunteering, local hire, and coordination. A service integration plan will be created to determine the service hierarchy and specify service quality requirements. Preferred services might be incentivized by the mobility hub by providing subsidies, priority access to facilities and locations, reduced permit fees, etc. The main sources of funding for the operation of the hub will come from local fees and tax revenue and state and federal grants, complemented by other local sources of income such as fare revenue, sponsorships, and external contracts like space rent, advertising concession, or fees from private mobility providers or parking. If the requirements to operate and manage the hub exceed the city’s agency’s capacities, it is possible to employ PPPs to outsource operations and maintenance to external companies, and the arrangement can be adapted to include, for example, the concession of the mobility providers, marketing services or retail space users.

8.8. Evaluation and Impact

Starting with the feasibility study, in the early stages of the design process, the impact of the following core areas should be assessed:

- **Equity impact** – assesses the benefits the mobility hub brings to the disadvantaged and low-income groups of residents, focused specifically on accessibility and affordability,
- **Traffic impact** – determines the hub's impact on the local traffic situation, congestion, and traffic flow; additionally, it considers modal shift and OD relations,
- **Greenhouse Gases (GHG) impact** – estimates the impact emissions release in the area, not only from the generated traffic but also through the hub's facilities and services,
- **Ridership impact** – evaluates the impact on ridership of individual services of the mobility hub as well as public transport in El Paso and its attractivity for new riders.

However, since the mobility hub must constantly adapt to frequent changes, regular monitoring and transparent reporting on the above-mentioned areas, as well as others, is required to ensure resiliency and advancement in meeting its objectives. For this purpose, specific KPIs and metrics will be defined and measured to determine whether the goals are being met and to help identify potential improvements to better meet them. The data sources for evaluation will be both quantitative and qualitative, using active and passive methods. The maximum level of automation is desired in this case to boost effectiveness, not only for data collection but also for processing and evaluation. With the increasing adoption of AI tools, the cost of such software applications can be expected to decrease in the near future. During the entire data management process, it is crucial to follow the public data ethical standards to ensure privacy and protection.

8.9. Limitations of the Mobility Hub

Although mobility hub offers numerous traffic and non-traffic benefits, their role in tackling the major transportation challenges like congestion, car dependency, noise pollution, and air pollution must be put into context with other measures because only in synergy can a significant change be achieved. The implementation of a mobility hub alone without carrying out other supportive measures is not going to make a significant difference. For the desired reduction of car use for first/last mile trips and commutes, in addition to the mobility hub, a functional rapid transit network offering an attractive transit connection must be in place to supply the hub with riders efficiently. The dissertation by David Galicia (Galicia 2010) addresses BRT characteristics and challenges and offers a toolkit on BRT improvements specific to El Paso. Even though a mobility hub gives people access to sustainable mobility options, they first must be in place and represent a viable, competitive alternative to a privately owned vehicle. Good customer experience must go for every aspect of the customer's journey, not only some of them because together they function as one travel experience consisting of individual parts. High-level cooperation between particular subjects involved is required and poses one of the biggest challenges. The same level of cooperation is required on the policy-making level, starting with city planning and aligned policy design. Coordination of Metropolitan Planning Organizations (MPOs), transit agencies, and cities is oftentimes problematic due to different interests and priorities. However, compromises are in place here because all of the public agencies work for the good of the people in the first place. Concretely, Transit-Oriented Development (TOD) represents a functional, proven concept of metropolitan planning that has various side benefits in addition to improving traffic and reducing urban sprawl ("Transit-oriented development," 2024).

Moreover, the local conditions should be reflected in the design and, most importantly, in the set of objectives the hub seeks to achieve. Accurate community input and regional values are important parts of the project, and they should reflect the current state while also looking into the future. The hub is a "living organism" that is supposed to be able to adapt to changing consumer preferences and needs and even lead the way by allowing testing of new technologies in real-world environments. Public services, in general, struggle with funding, and transportation is no exception. Public transportation as a business opportunity is not appealing to private companies, and when it is, it does not serve its function of providing affordable, accessible, and convenient transportation services. Therefore, securing funding and a sustainable operation financing model is one of the biggest obstacles to improving public transportation and implementing mobility hubs. Lastly, due to American specifics of car-centered lifestyle, culture, and its vitality for the lives of Americans, the ability of mobility hubs to achieve the desired change appears to be even more difficult than in other parts of the world, such as Europe or Asia. Therefore, the target group of the mobility hub in El Paso is not as large as in other cases, where regular public transit riders make up for dozens of percent of the modal split. The public transit riders in the USA are limited to the group of low-income people without a car. For these people the mobility hub could bring significant benefits and improved travel experience. On the other hand, it cannot be expected that without further measures improving public transit, sustainable mobility infrastructure, planning policies, car-alternative incentives, and related efforts to encourage people to transfer from cars to other modes of transport, the mobility hub implementation will lead to significant changes in travel behavior. The hub represents only one piece of a complex puzzle of tools influencing transportation choices and mobility behavior.

9. CONCLUSION

This thesis investigated options for influencing transportation choices and improving public transit in El Paso toward a more sustainable and accessible future. It was done so by identifying challenges of the current state of the public transit system, researching case studies in the USA and Europe, and using them as best practice examples in the core of this work – the mobility hub implementation proposal. Publicly available data were collected and analyzed to determine the strategic location of the hub in the downtown area. The implementation part recognizes the overall goal of enabling the use of multiple transportation modes, enhanced by supporting facilities such as EV charging, secure bike and e-scooter parking facilities, and real-time travel information in synergy with an attractive public realm, which aims to augment the travel experience and encourage the use of sustainable modes of transport, especially for first/last mile trips as an alternative to a car. The final section outlines general recommendations for the implementation of the individual phases of the hub's planning, implementation, and operation, including funding, organization, and operation, followed by monitoring, evaluation, and impact.

9.1. Limitations

This study was elaborated despite certain limitations, such as limited availability or a complete lack of data. Additionally, it builds on the ability to assume human traffic behavior, which is limited, and the long-term impact of the implementation on traffic in El Paso may require further investigation.

9.2. Future Research

Future research opportunities exist to complement this work, such as assessment of the impact on public transit ridership, project economic feasibility analysis, impact on mobility choices and patterns, or place utility and customer's travel experience evaluation.

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Glossary

Abbreviation	Description
ADA	Americans with Disabilities Act
AI	Artificial Intelligence
APC	Automatic Passenger Counter
AT	Aerial Tram
ATM	Automated Teller Machine
AVLS	Automatic Vehicle Location System
BOTA	Bridge of the Americas
BRT	Bus Rapid Transit
BUS	Omnibus
CAV	Connected and Autonomous Vehicle
CBP	Customs and Border Protection
CCTV	Closed-Circuit Television
CNG	Compressed Natural Gas
CR	Commuter Rail
DEA	Drug Enforcement Administration
DFW	Dallas/Fort Worth
DIA	Denver
DMD	Downtown Management District
DSS	Decision Support System
ELP	El Paso Airport
EU	European Union

EV	Electric Vehicle
EWGCOG	East-West Gateway Council of Governments
GBR	Ground Based Radio
GHG	Greenhouse Gases
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HSL	Helsinki Regional Transport Authority
I-10	Interstate 10
I-205	Interstate 205
ICT	Information and Communication Technology
IoT	Internet of Things
ITS	Intelligent Transportation Systems
KPI	Key Performance Indicator
LRT	Ligh Rail Transit
MaaS	Mobility-as-a-Service
MAX	Metropolitan Area Express
MH	Mobility Hub
MoDT	Mobility-on-Demand Transit
MPO	Metropolitan Planning Organization
NMDOT	New Mexico Department of Transportation
OD	Origin-Destination
P+R	Park and Ride

PedPDX	Portland's Citywide Pedestrian Plan
PHX	Phoenix
POE	Point of Entry
POI	Point of Interest
PPP	Public-Private Partnership
PT	Public Transit
SC	Streetcar
SIC	Standard Industrial Classification
SMS	Short Message Service
TIS	Traveler Information System
TOD	Transit-Oriented Development
Tri-Met	Tri-County Metropolitan Transportation District of Oregon
UA	University of Arizona
UTEP	University of Texas at El Paso
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything
WES	Westside Express Service

Vita

Take The Road Less Traveled: A Master's Journey

My academic path began at the Czech Technical University in Prague, Czech Republic, where I earned a Bachelor of Science in Intelligent Transportation Systems. This experience sparked my interest in transportation, urban planning, and disruptive disciplines such as Smart City. I have always dreamed about exploring new cultures and meeting new people, and a great opportunity to do so presented itself in the form of the Dual Master's Degree Program in Smart Cities in cooperation with the University of Texas at El Paso. I thus embarked on a unique journey combining two of my biggest passions – learning and travel. Life in a different country and culture meant overcoming many obstacles, such as language barriers, a different lifestyle, and a peculiar work ethic, to which I sincerely believe that I successfully adapted. In the end, it turned out to be an invaluable life lesson introducing me to new knowledge, values, and skills, including, but not limited to, the academic setting. I believe that this experience contributed to my growth as a student as well as a person, and it is something I will cherish for the rest of my life. I am confident I will find use for the insights I have gained and discovered upon my return to the Czech Republic, where I am starting an exciting new chapter of my life.

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