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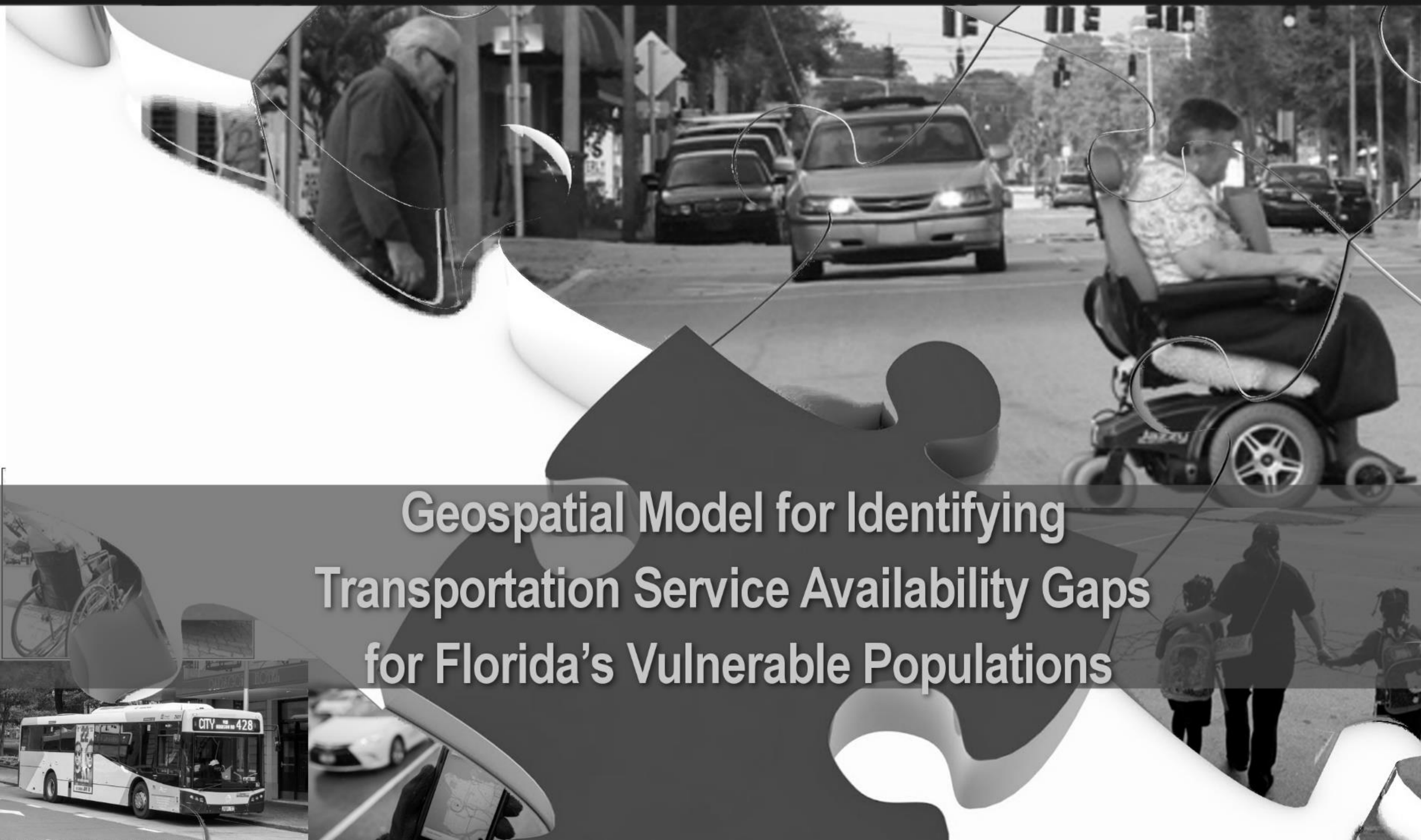
Final Report

Geospatial Model for Identifying Transportation Service Availability Gaps for Florida's Vulnerable Populations



August 2018

Prepared by:

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Florida Department of Transportation
FDOT Contract BDV31-977-67

Geospatial Model for Identifying Transportation Service Availability Gaps for Florida's Vulnerable Populations

FINAL REPORT

Prepared by:
University of Florida

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METRIC CONVERSION CHART

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	Km
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
NOTE: volumes greater than 1000 L shall be shown in m^3				

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16. Abstract

Currently, there are limited transportation options for Florida’s vulnerable populations, such as older adults, individuals with disabilities, and low-income populations. To determine and communicate comprehensive transportation service gaps to policy makers, the evaluation of transportation accessibility including all possible transportation options for those populations is crucial. Thus, this research aims to develop a geospatial model for identifying transportation service gaps by using a comprehensive approach. Based on the results of reviewing existing methods to identify transportation gaps and categorization of transportation service providers, the team developed a GIS model which takes a supply-demand approach using Alachua County data. Transportation supply for vulnerable populations is measured by quantifying the transportation accessibility based on the gravity model and three route types, including fixed route, flexible route, and door-to-door. Transportation demand is computed by calculating the volume of the vulnerable population. The spatial gaps are found by identifying spatial differences between transportation supply and demand using a supply-demand matrix. The GIS model has benefits because the model could be used to identify areas that are not adequately serviced with alternative transportation options for Florida’s vulnerable population, and it can guide policy makers to make decisions that foster equitable provision of transportation. The model is also capable of customizing variables such as users, transportation service providers, and geographic extent. To ensure the long-term sustainability and to serve the vision of the Safe Mobility for Life Program, the research team makes the following recommendations: first, an annual update of model data such as service provider information, street network, destination, and census data; second, adding a new webpage to current Find-a-Ride Florida website to disseminate the gaps maps to stakeholders to support planning and policy actions to improve transportation options in a local context.

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EXECUTIVE SUMMARY

The State of Florida, through the Florida Department of Transportation's Safe Mobility for Life Program and Coalition, strives to provide Florida's growing aging population with suitable mobility options and resources to ensure their safety and mobility beyond the private automobile. Specifically, one of the objectives of the Florida's Aging Road User Strategic Safety Plan[1], aims to increase the number of options and resources available to aging road users to ensure they stay safe and mobile as they transition from driving. To fulfill the needs of Florida's vulnerable population, such as older adults, individuals with disabilities, and low-income individuals, with viable transportation options, it is imperative to determine transportation service gaps to help resolve their mobility issues in both rural and urban areas throughout the state.

The primary objective of this research was to develop a geospatial model for identifying transportation service gaps by using a comprehensive approach that considers available transportation options, including public transportation, on-demand services, and specialized services, at a fine geographic unit.

As a start, a review of literature of existing methods to determine spatial accessibility of transportation services revealed gravity models as one of the most widely used approaches by many researchers. Advantages of the gravity models include the ability to consider both impedance to, and attractiveness of, the destinations and the capability to support spatial interaction and choice theories.

The next step focused on a close review of transportation service provider attributes, such as service type, route type, schedule type, rider eligibility, and supported destinations. As a result, transportation service types selected to support the needs of the vulnerable populations include public transportation, paratransit, specialized transportation, and vehicles for hire. The route types include fixed route, flexible route, and door-to-door service. The schedule types include fixed schedule, call-in-advance, and immediate on-demand. The destination categories included medical, non-medical, education, and work.

Building on the findings from the literature and the requirements to support the needs of Florida's vulnerable populations based on the available transportation service providers as listed in FindaRideFlorida.org, the research team developed a geospatial model that takes a supply-demand approach. The model was developed in the ArcGIS desktop environment and used Alachua County data during the development phase.

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[1] Safe Mobility for Life Coalition. (2017). *Aging Road User Strategic Safety Plan*. Retrieved from http://www.flsams.org/pdfs/FDOT_Aging_SafetyPlan_FINAL.pdf

Transportation supply for the vulnerable populations is calculated by quantifying the transportation accessibility of each census block group based on a gravity model. The model computes the accessibility scores by considering the number of destinations and the travel impedance to them within each service area, by route type. For a fixed route service, the accessibility score considers the number of destinations and travel impedance to them while traveling using transit routes and walking to and from transit stops along transit routes. For flexible route and door-to-door services, the accessibility score considers the number of destinations within the service area, and the travel impedance is calculated by applying the origin-destination (OD) network analysis technique within the service areas of each service provider. Transportation demand is computed by calculating the volume of the vulnerable population—older adults, individuals with disabilities, and people who do not own an automobile. Using the calculated supply and demand scores, each block group is characterized by the level of supply and demand. Finally, spatial gaps, defined as areas of low supply and high demand, are determined by identifying spatial differences between transportation supply and demand using a supply-demand overlay comparison matrix.

The research team tested the model using three different scenarios that combined specific users with selected service types, using Orange County as test bed. The first scenario tested fixed route service for housing units without a vehicle. Services gaps resulted in five census block groups containing 1,276 (4.7%) housing units in the county. The second scenario tested flexible route service for individuals with disabilities. It found gaps in ten census block groups containing 6,992 (11.4%) individuals with disabilities. The third scenario tested door-to-door service for older adults and gaps resulted in eighteen census block groups containing 19,923 (16.3%) older adults.

The model is highly automated, and it is designed to provide flexible selection of riders, transportation service providers and geographic areas. This will allow stakeholders to determine transportation gaps for a variety of study areas, such as county, metropolitan planning organization (MPO), metropolitan statistical area (MSA), or FDOT district.

The research team acknowledges that successful long-term use of the model depends on timely availability data of transportation service providers, destinations, street network, and population demographics. After considering factors that affect relevant data availability, the research team recommends annual data updates to allow stakeholders to adjust the service gaps on annual basis to support planning and implementation of transportation service improvements.

Special considerations should be given to the improvement of spatial depiction of service provider's service areas. At present, most provider's service areas are defined too broadly, usually covering entire counties. It is strongly recommended that transportation service providers start providing maps of their coverage areas in a spatial format that more accurately depicts the areas where they truly serve. With more accurate spatial service boundaries, the geospatial model can more accurately pinpoint areas where interventions are needed. Transportation service providers should also provide consistent information of eligible riders, service type, route type and the destinations they support.

In addition to updates, some data processing will be necessary before the model can be executed. This includes processing of the updated General Transit Feed Specification (GTFS) data and the categorization of destinations to medical, education, work, and other, based on the updated property parcels information.

Important consideration in the future should be given to the dissemination of the transportation service gap maps to the Safe Mobility for Life Coalition members, FDOT, MPOs, and the broader community of stakeholders. We propose development of a webpage that would allow stakeholders to view and print the gap maps and can serve more broadly as a resource for planning and policy actions to examine specific users and transportation options for vulnerable populations in a local context.

Currently, the Find-a-Ride Florida website (FindaRideFlorida.org) provides transportation options to vulnerable populations in Florida and the Find-a-Ride Florida database supports the website information. We envision the transportation gaps model as part of a broader framework aimed at addressing the transportation needs of Florida's vulnerable populations. Supported by the transportation service providers listed in FindaRideFlorida.org at the core of it, this framework would include the transportation gap model, the transportation gap maps, and the FindaRideFlorida.org, which would bring together the stakeholders and the end-users to provide reliable mobility for the 21st century for the most vulnerable among us.

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1. INTRODUCTION

1.1 **Background Statement**

The overall goal of Florida's Safe Mobility for Life Coalition's Aging Road User Strategic Safety Plan (ARUSSP) is to reduce the number of serious injuries and fatalities involving aging road users by improving their safety, access, and mobility (Safe Mobility for Life Coalition, 2017). In order to reach this goal, it is essential to empower individuals considering transitioning away from driving through the identification of viable transportation options and their availability. However, at present, there is limited transportation service availability for Florida's vulnerable populations, including older adults. According to the U.S. Census Bureau, by the year 2040, over 25 percent of Florida's population will be over 65. Considering this increase, it is imperative to determine transportation service gaps in order to develop solutions to address this mobility issue.

This research will aid in developing solutions to address individual mobility needs of Florida's most vulnerable populations by presenting a model for identifying transportation service gaps at the state and local level while addressing the proper services to support the individual mobility needs of Florida's most vulnerable populations. The research thus will help communicate such transportation gaps to state and local partners and stakeholders in order to address the issue at various geographic levels, from individual communities to the entire state.

1.2 **Project Objectives**

The overall objective of this research is to develop a model to help identify transportation gaps by using a comprehensive geospatial approach that considers all available transportation options at a fine geographic unit.

More specifically, this research focused on the following objectives: first, conduct a review of literature and practices to assess existing research, to better understand the available relevant transportation options, and to improve their categorization; second, develop a Geographic Information System (GIS) model for identifying transportation service availability gaps for Florida's vulnerable populations, including older adults, individuals with disabilities, and low income populations; third, explore options for customization of the model to allow the necessary flexibility to find spatial gaps by using a combination of the vulnerable population type, transportation service providers, and different geographic extent, such as a county, Florida Department of Transportation (FDOT) districts, Metropolitan Planning Organizations

(MPOs), Commission for the Transportation Disadvantaged's local coordinating boards, Regional Planning Councils, and district voting maps; fourth, provide recommendations for automation and maintenance of the model as the availability of transportation service options change over time and options for dissemination of the results (gap maps) to stakeholders to support planning and policy.

1.3 Report Organization

The next chapter presents a review of existing literature to understand the efforts conducted by other states, organization, or other counties. Additionally, the review includes existing methodological approaches for determining transportation accessibility and service gaps. The chapter 3 presents an in depth review of providers and their characteristics, including the attributes that are necessary to conduct a geospatial gap analysis. The chapter 4 and chapter 5 describe the development of the geospatial model for gap identification and explore options for its customization. The chapter 6 presents a future framework and options for model automation. The last chapter provides conclusions, recommendations for long term operation of model, dissemination of the results, and directions for future research.

2. LITERATURE REVIEW

The State of Florida strives to help its citizens be safe and mobile for a lifetime. However, the growth of the aging population have a significant impact on transportation safety in Florida. Currently, 17.3 percent of Florida's population is 65 years and older, the highest in the nation (Werner, 2011). Moreover, it is projected that the number of residents 65 years and older will continue to grow. By the year 2040, over 25 percent of Florida's population will be over the age of 65, compared to 14.5 percent for the rest of the nation. To assist the aging road users across the state in both urban and rural communities, the Florida Department of Transportation State Traffic Engineering and Operations Office started the Safe Mobility for Life program with a focus on their safe mobility and connection to the community, which is the main purpose of the Florida's Aging Road User Strategic Safety Plan (Safe Mobility for Life Coalition, 2017).

According to the study, older adults prefer to use a personal vehicle to meet their community mobility needs (Classen, Winter, & Lopez, 2009). However, most older adults will face a period of mobility dependence later in life, estimated to be 10 years for women and 7 years for men (Foley, Heimovitz, Guralnik, & Brock, 2002). Secondary to being a driver, being a passenger with a family member or acquaintance who drives is preferred (Chang, 2013). Transportation from family and friends may have limitations in availability and create unwelcome feelings of dependence (Classen, Winter, & Lopez, 2009). To ensure transportation that meets a variety of individual needs and circumstances, a continuum of transportation has been suggested (Mercado, Páez, & Newbold, 2010).

In addition to older adults, other population groups such as people with a disability or low-income households also require viable transportation options to meet their needs because of their dependence on others to obtain the accessibility to health care, employment, education, shopping, or social activities (Currie, 2010). Particularly, the State of Florida defines these vulnerable populations as transportation disadvantaged (TD) (Florida Statutes, Title XXX § 411-202). These aforementioned demographic changes create an even greater impetus for the development of a widely available network of alternative transportation options, policies, and advocacy efforts to improve the mobility of Florida's vulnerable populations.

Toward the aims of informing policy and provision of alternative transportation to meet the changing needs of Florida's vulnerable populations, this chapter summarizes both alternative transportation provision efforts and theoretical methods to identify the gaps between transportation needs and provision. Section 2.1 covers a broad literature review of the efforts conducted by other states and organizations, at the national level, and in other countries, to learn about their successes and challenges in the provision of alternative transportation to reduce gaps in service to support the transportation needs of vulnerable populations. The focus of section 2.2 is to find previous efforts for measuring transportation accessibility a part of identifying the transportation service gaps. Though concepts of transportation accessibility vary according to research context, various accessibility measures have been applied to a wide range of urban planning issues as well as transportation planning including routing and scheduling of vehicles, travel demand forecasting modeling, and transportation system planning.

This review broadens the understanding of the research team on the wide range of the transportation services including their capabilities and limitations. The findings will be used to establish a methodology to measure geospatial gaps of transportation services in Florida.

2.1 Transportation Provision to Reduce Service Gaps

2.1.1 Alternative Transportation Service

- **United States**

In October 2011, the United States Department of Transportation (U.S. DOT) announced the Alternative Analysis Program to assist in financing the evaluation of all reasonable modal and multimodal alternatives and general alignment options for identified transportation needs in a particular, broadly defined travel corridor. The U.S. DOT specified the transportation planning process of Alternative Analysis and included that public agencies, including states, municipalities and other subdivisions of states, public agencies and instrumentalities of one or more states, and public corporations, boards, and commissions established under state law are eligible for application.

In the past half-decade, the United States has funded large alternative transportation service projects ranging from state and local level. The State of Tennessee unveiled their alternative transportation plan to all Tennesseans (Lowary, 2017). In the State of Kansas, Wichita Mountains Wildlife Refuge (WMWR) received funding for the construction of a nonmotorized trail to resolve many transportation and recreation challenges associated with its current visitation patterns, including parking lot congestion, heavy visitation to sensitive natural areas, bicyclist roadway safety issues, and limited access opportunities (Daddio, Rasmussen, Frazier, Simmons, & Mejias, 2014). The refuge gained a great success in preserving the habitat and environment quality, providing world-class visitor experience, administering public use facilities, and promoting transportation access to all visitors. The Mississippi National River and Recreation Area (MISS) in Minnesota has received over $1.8 million dollars from the Federal Transit Administration (FTA) and National Park Service (NPS) Category III funds to implement a partnership, multi-modal, alternative transportation system (ATS) that builds on existing public transit, Nice Ride MN's bike share program, and existing river access (NPS, 2011) . It will enable park visitors and area residents to travel throughout the park without a car. In Indiana, the City of Bloomington is undertaking an important step toward mitigating traffic congestion and improving the health, fitness, and quality of life of its residents (Winstead et al., 2016). The Alternative Transportation and Greenways System Plan represents a commitment by the City to design, construct, and maintain a network of safe, convenient, and attractive bicycle and pedestrian facilities for commuting and recreational use throughout the City (Fernandez et al., 2000).

At a local level, more and more cities launched various alternative transportation plans under the support of states. In 2012, The City of La Mesa, California aimed to promote a safe, convenient and efficient environment for bicycle and pedestrian travel that encourages the use of public streets, off-street facilities and public transit. During the development of its Bicycle Facilities Plan and Alternative Transportation Element, a comprehensive approach was used to identify bicycle and pedestrian needs throughout the City, review current conditions, examine optional improvements and prioritize implementation strategies with viable funding sources. The plan addresses opportunities to connect and integrate existing and proposed facilities. This plan is conceptual since precise alignments and details will be determined through the implementation process of specific bicycle and pedestrian projects (Singleton et al., 2012). Starting from 2014, the City of Bloomington, Minnesota began work on updating the City's 2008 Alternative Transportation Plan (ATP) (SRF Consulting Group, Hoisington Koegler Group, & Signia Design, 2016). The ATP Update provides a framework for prioritization of implementation of the City's goals to meet the needs of individuals and families living, working and recreating in Bloomington through strategic investments in multi-modal transportation features. Throughout the update process, the residents have had opportunities to provide input into the plan through an online survey, stakeholder meetings and resident open houses.

- **Other Countries**

In 2012, the Department of Planning on behalf of the Western Australian Planning Commission produced Guidelines for Preparation of Integrated Transport Plans for local governments. These Guidelines were designed to help local governments plan a sustainable transport future for their communities and emphasizes to people and businesses the importance of the awareness of alternative options for transport like walking, cycling, and public transport. Meanwhile, the plan specified the alternative transportation strategies and practices to achieve the goals of sustainable transportation planning (Western Australian Planning Commission, 2012).

Local transport in Southeast Asia varies widely from country to country. However, there is no official alternative transportation plan or program launched in Asia so far. Nevertheless, Southeast Asian countries are working on making varies transport methods more systematic, sustainable, accessible and friendly including fasting the boat, expediting the buses, and utilizing water transport. Those alternatives are ensuring the user experiences a real feel for the local way of life and the country at ground level (Chin, 2013).

2.1.2 Transportation Service Gaps

Although multiple alternative transportation services are provided, some deficiencies still exist between travel needs and transportation service supply. Various studies have been completed on transportation service gaps in many countries and states (Table 2-1). Collectively these studies vary in the modes and populations included in the plan. However, many communities identify transportation gaps for all populations, other communities identify the gaps for what might be called special needs populations – students, unemployed, low-income, disabled, and older adults.

Table 2-1. Studies on Transportation Gaps in Different Countries and U.S.

Study	Study area	Mode	Population
Al Mamun and Lownes (2011)	City of Meriden, Connecticut	Public transit	All
Benenson et al. (2010)	Afeka, Israel	Bus and car	All
Bocarejo S and Oviedo H (2012)	Bogota, Colombia	Public transit	All
Casas et al. (2009)	Erie and Niagara Counties, New York, U.S.	All modes	Children 5 - 18 years
Currie (2004)	Hobart, Tasmania, Australia	Public transit	Student, unemployed, low income, disabled, and aged 60+
Currie (2010)	Hobart, Tasmania, Australia	Public transit	Student, unemployed, low income, disabled, and aged 60+ , person 5-9 years
Currie and Senbergs (2007)	Melbourne, Australia	Public transit	Student, unemployed, low income, disabled, and aged 60+ , person 5-9 years
El-Geneidy et al. (2016)	Montreal, Canada	Public transit	All
Fayyaz et al. (2017)	State of Utah, U.S.	Public transit	Working population
Fransen et al. (2015a)	Flanders, Belgium	Public transit	Older adults, unemployed, no car ownership population
Fransen et al. (2015b)	Flanders, Belgium	All modes	Working population

Table 2-1. Continued

Study	Study area	Mode	Population
Jaramillo et al. (2012)	Santiago de Cali, Colombia	Public transit	Persons with transport disadvantage
Karner (2015)	Phoenix, Arizona	Public transit	Working population
Langford et al. (2012)	Cardiff, Wales	Public transit	All
Liu and Engels (2012)	Melbourne, Australia	Public transit	Older adults
Al Mamun et al. (2013)	City of New Haven, Connecticut	Public transit	All
Manaugh and El-Geneidy (2010)	Montreal, Canada	Public transit	Socially Disadvantaged Population (low income, transit dependent, household with low education)
Pyrialakou et al. (2016)	Indiana, U.S.	All modes	All
Ricciardi et al. (2015)	Perth, Australia	Public transit	Older adults residents, low-income households and no-car households
Saghapour et al. (2016)	Melbourne, Australia	Public transit	All

Previous works focused on analyzing transportation service gaps on public transit mode for the TD population. Due to the nature of the TD population's limitations, they heavily relied on public transit to reach their destination. Public transit systems are the major alternative transportation mode for them in various areas.

The report from Transportation for America shows that many older adults experienced problems traveling around due to safety issues, a lack of affordable travel options, and low transit accessibility (DeGood, 2011). They found that a group of older adults' incomes is unable to cover the payment of transportation service. Except for the expense of housing, food, and clothing, there is no extra money for them to spend on transportation service. Aside from an absence of affordable transportation service, transit accessibility is also an impendence for an aging population's ability to travel around their surroundings (Foreman et al., 2003). According to Frey (2007), about 79% of older adults live in the suburban or rural area, where they may have a poor transit service. Regarding these issues, this report proposed some policy recommendations, such as encouraging the state or local government to invest more money on the transit operation system, extending transit service area and time, and including a "complete streets" policy to ensure aging people's accessibility and safety.

Local agencies analyze the transportation service gaps by integrating their localized transportation characteristics. The following local reports analyze their transportation service gaps in terms of TD-population. The City of Brookings evaluates transportation service gaps for university students and TD population (Ripplinger et al., 2007). They found some transportation issues, such as transit service frequency, large-event service, and emergency service. Based on the issues, two potential suggestions were provided, which are extending fixed-route services and sharing vanpool. To analyze the transportation service gap comprehensively, the City of Stockton evaluated public transit service gaps from four perspectives: geographic gaps, transit service quality gaps, policy gaps, and funding gaps (City of Stockton, San Joaquin RTD, & Transportation Management Design, 2010). Based on their transportation gap analysis, they found that the transit system works frequently and reliably in high density and mixed land use areas. Therefore, they suggested building a sustainable transit system to provide productive service. The imbalance between people's demand and transportation service provision causes transportation service gaps, so the people's demand is also an important component of transportation service gaps analysis. Oklahoma did a transportation service gap analysis report to show current passenger transportation services available and the passengers' demand on transportation service in Oklahoma (Brinckerhoff, 2012). To improve the transportation connection, they recommended increasing intermodal choice between railway stations such as intercity bus services, public transportation, and bicycle/pedestrian facilities. Fresno County identified existing mobility gaps for TD population between public transportation service and human service agency transportation (AMMA Transit Planning, & The Rios Company and Transit Marketing LLC, 2015). They surveyed the demographic and social-economic information about TD population and their travel needs. Based on the provision of public transit service, they suggested using cost-effective services and self-help tools to fill the gaps.

2.2 **Methodological Approach to Identify Transportation Service Gaps**

As is described in previous section 2.1, though the transportation policies for vulnerable populations aim to offer a wide range of transportation services, gaps exist between transportation provisions and the needs. Along with those chasms between policy and reality, some professionals, such as urban planners and transportation engineers, have studied how to measure those gaps between transportation supply and demand. Although there is ample literature, we categorized the studies regarding gap measurement into two sections: measure by service types and transportation accessibility measure.

2.2.1 Measure by Service Types

- **Public Transportation**

Although public transportation service has fixed routes and schedules, case studies from Sydney, Australia, and London, UK, demonstrate that public transportation plays a significant role in helping older adults meet their daily needs (Golob & Hensher, 2007; Schmöcker, Quddus, Noland, & Bell, 2008). Public transportation is also helpful for increasing physical activity and reducing ecological footprints (Zheng, 2008). Thus, efforts have been made to understand the public transportation supply, which is based on spatial coverage of the service. These studies have tried to identify the service areas by using public transportation stations or routes and walking catchment areas (Al Mamun & Lownes, 2011; Al Mamun, Lownes, Osleeb, & Bertolaccini, 2013; Cheung & Agrawal, 2010; Currie, 2010; Delmelle & Casas, 2012; Polzin, Pendyala, & Navari, 2002). This kind of research mainly utilized GIS as an assessment tool because it can easily visualize and quantify both served areas and un-served areas.

Although this spatial measurement is useful for determining where it is possible to walk to public transportation, several scholars have pointed out that identical service coverage does not mean identical service availability for all users. They have therefore argued that measurements should consider not only the spatial dimension but the temporal dimension such as frequency of service, hour of service, walking time to service station, waiting time, and transfer time (Currie, 2004; Fu & Xin, 2007; Neutens, Delafontaine, Scott & De Maeyer, 2012; Schoon, 1999).

- **Specialized On-Demand Service**

Although public transportation has many benefits, it can also present challenges to users. First, users' physical mobility limitations affect their use of public transit (Broome, Worrall, Fleming, & Boldy, 2012; Mercado, Páez, & Newbold, 2010). Second, matters of service quality tend to affect the use of public transportation. These include hardware design, as in low-floor buses and seating arrangement (de Boer, 2004), and the generosity of other passengers to the older adults (Rye & Scotney, 2004). In response to these pros and cons of public transit, on-demand services have emerged as an alternative option. On-demand services that provide flexible routes include "route deviation type services, demand responsive bus transport, dial-a-ride buses and flex-route buses" (Broome et al. 2012). Cervero (1997) asserted that these kinds of services provide several benefits, such as increased mobility options for the transportation disadvantaged, improved environmental conditions, and stimulating advanced-transit technologies.

While these options have certain benefits, because of the characteristics of on-demand service, they typically require higher fares than fixed-route public transportation (Chang & Yu, 1996). Thus, several studies have focused on optimal fares and numbers of users (Bearse, Gurmu, Rapaport, & Stern, 2004; Ben-Akiva, Benjamin, Lauprete, & Polydoropoulou, 1996; Franklin & Niemeier, 1998).

In addition to measurement of operational attributes, we can approach these services as public facilities such as social service or medical service. Because on-demand service literally can cover entire municipalities such as city or county, it is hard to find spatial gaps by calculating spatial coverage. Thus, the ratio of the population to the number of services, which quantify the service availability, is one of the indicators to present the on-demand service provision (Case & Hawthorne, 2013; Luo & Wang, 2003; Thouez, Bodson, & Joseph, 1988; Tong, Lin, Mack, & Mueller, 2010). Under this method, a higher number indicates less service availability within the study area.

- **Immediate Request Service**

Like on-demand services, specialized services provide flexible routes, but they also support immediate requests. The location of facilities and the travel time from them are thus critical variables (Benenson, Martens, & Rofé, 2010; Kuo, Shen, & Quadrifoglio, 2013). This method is widely used to verify the accessibility of emergency vehicles (Carr, Branas, Metlay, Sullivan, & Camargo, 2009; Pedigo & Odoi, 2010). To evaluate service provision, most of the studies used GIS to compute service areas by driving time. The closer distance, which is shorter driving time, to service provider shows better service than other areas.

However, the use of response-based services presents some limitations because traffic can vary on a daily or weekly basis. Last, the cost of these services is also an important variable to consider, especially for segments of the population that might not be able to afford them.

2.2.2 Transportation Accessibility

The previous section looks at the efforts to find transportation service gaps using the service types. While those studies have contributed to finding service gaps of a transportation option, they have mainly focused on the service provision aspects. However, to identify the gaps, we need to look at both provision and demand. Based on the initial literature review, we recognized transportation accessibility is beneficial to take into account the users' demand. As Kwan, Murray, O'Kelly, and Tiefelsdorf (2003) argued, "accessibility studies are about the understanding of the behavioral responses to the spatial separation of locations of supply to the locations of demand" (p. 130), transportation accessibility studies examine both the provision and the needs of transportation. Thus, this section also provides a theoretical framework to develop a methodology of this research project.

- **The Concept of Transportation Accessibility**

Transportation accessibility is understood differently in various research contexts. It has been applied to a wide range of urban planning: first, transportation planning, such as routing and scheduling of vehicles, travel demand forecasting, and transportation system planning (Lei, Chen, & Goulias, 2012; Litman, 2003; Miller & Wu, 2000; Morris, Dumble, & Wigan, 1979); second, land-use planning, for example in population allocation and the location of facilities (Allen, Liu, & Singer, 1993; Hansen, 1959; Wang, Zhong, Teo, & Liu, 2015; Yoshida &

Deichmann, 2009). The common understanding of transportation accessibility lies in considering both built environment attributes (e.g. street network) and users' behavioral characteristics.

Table 2-2 shows the variety of transportation accessibility studies published before 2000 and organized in chronological order. Most accessibility studies cite the paper of Hansen (1959), but some scholars argued that Harris (1954) initially made the connection between transportation accessibility and urban form (Mulley, 2012). Early studies in transportation accessibility mainly focused on how to define and measure the transportation accessibility (Hansen, 1959; Ingram, 1979; Dalvi & Martin; 1976). After those efforts, researchers added more variables and refined methods to previous studies (Allen, Liu, & Singer, 1993; Pooler, 1995). The major trend these days, since Dalvi and Martin (1976) added travelers' behavioral pattern on accessibility studies, is to consider both urban form factors (e.g., distance between origin and destination, street network) and characteristics that may affect travel pattern of users (e.g., opportunities, cost).

Table 2-2. Transportation Accessibility Studies (Chronological Order)

Study	Key findings
Harris (1954)	Based on location theory of manufacturing, added transportation cost (distance to market) as a variable.
Hansen (1959)	The potential of opportunities for interaction using distance and attractiveness.
Clark, Wilson, & Bradley (1969)	Economic potential method to assess the attraction for manufacturing industry: Regional income, minimum cost, transport cost, and tariff are considered as four impact components to calculate economic potential.
Ingram (1971)	Relative accessibility index: the inherent characteristic (or advantage) of a place on overcoming some form of a spatially operating source of friction.
Wilson (1971)	Using gravity model, outlined some other theoretical developments, and is particularly concerned with the disaggregation of such models, with the incorporation of time variables, and with the relation of spatial interaction, to more general, model.
Vickerman (1974)	Used accessibility, attraction and spatial interaction variables to determine trip generation.
Dalvi & Martin (1976)	Added other factors of accessibility: travel behavior, travel opportunities, and travel cost.
Morris, Dumble, & Wigan (1979)	Travel behavior to accessibility indicator and consider travel demand and supply as factors to evaluate accessibility level.
Weibull (1980)	Framework to measure transportation accessibility: macro-oriented and micro-oriented.
Allen, Liu, & Singer (1993)	Reviewed existing accessibility measurement & extension of Ingram (1971) method to evaluate accessibility level.
Arentze, Borgers, & Timmermans (1994)	Computed the travel costs that at least have to be made to purchase the complete set of consumer goods.

Table 2-2. Continued

Study	Key findings
Pooler (1995)	Reviewed Allen (1993) method and pointed out the use of spatial separation in measuring transportation accessibility.

Along with those theoretical approaches, some studies aim to specify the accessibility by particular populations. Love and Lindquist (1995) compared the accessibility to hospitals between the general public and the aged population and found no significant difference between two groups. Church and Marston (2003) introduced transportation accessibility measure for individuals with disabilities: measures of absolute access, gross access, closest assignment access, single and multiple activity access, probabilistic choice access, and relative access. These studies specifying the target population of transportation provisions are crucial since the physical differences might affect the accessibility measure of transportation option.

- **Transportation Accessibility Measure**

Traditional methods for accessibility measurement examine the spatial relationships between key locations such as home, work, and health facilities. However, while these space-based methods have contributed to enhancing the understanding of transportation accessibility and its applications, these approaches are increasingly incomplete (Miller, 2005c).

A place-based method is still viable and useful, as Kwan and Weber (2003) argued, the simple distance-based measure can partially explain this complex geography of accessibility. At an early stage, it is hard to trace and record the complex travel activities, but advanced information and communication technologies enable to catch the movement with both space and time information. The technological development allows the personal level of travel activity and interaction that can be explained by people rather than a place.

Thus, in this section, we reviewed both place-based accessibility measure and people-based accessibility measure. Although people-based approach becomes a trend of accessibility studies, the people-based approach does not negate traditional place-based approach but the complete traditional method by focusing on the individual level (Miller, 2005c).

\- **Place-Based Accessibility**

Place-based measurement particularly deals with spatial separation between key locations. The most common types of measures include distance, topological, attraction, and benefit accessibility.

Distance-based measures

These are the simplest indicator. Since this method uses exclusively the distance between two places, greater separation implies lower accessibility. To determine the distance between two points, the simple Euclidean distance and Manhattan distance are used. However, these days, network distance is widely used when measuring along the street network.

As an extension of the distance measure, several studies (Table 2-3) conceptualize cumulative opportunity measures, which count the number of opportunities (destinations) within a fixed distance from the origin.

Table 2-3. Cumulative Opportunity Measure

Core Concept	The number of opportunities reached within a given travel time (or distance)
Studies	Morris, Love, & Wesolowsky, 1988; McKenzie, 1984; Sherman et al., 1974; Wachs & Kumagai, 1973; Wickstrom, 1971
Model	$$A_i = \sum_{j=1}^{j} B_j \, O_j$$ Ai is accessibility measured at point i to potential activities in zone j, Oj is the opportunities in zone j, and Bj is a binary value equal to 1 if zone j is within the predetermined threshold and 0 otherwise.

(Source: Handy & Niemeier, 1997; Miller, 2005c)

While this method is easily applied because the model assumes all opportunities are the same, it is difficult to take into account impedance.

Topological measures

These methods inspect the degree and pattern of nodes' connectivity within a distance (Miller, 2005c). The critical component of this measure is the connectivity matrix. Based on the connectivity matrix, the Shimbel Index is used as a summation of all the shortest path distances among all nodes (Lee & Chi, 2004). While this method is useful in evaluating concentrated levels of networks, same as cumulative opportunity measure, its model assumes all destinations have the same importance (Lee & Chi, 2004; Miller, 2005c).

Attraction-based measures (Gravity-based measures)

The issue shared by both distance and topological measures is that both give the same significance for destinations. However, in reality, each opportunity of destination is distinguished by their characteristics. To compute the accessibility by a destination's attractiveness, the gravity model weights opportunities by impedance (e.g. travel time or travel cost). Since Hansen (1959) conceptualized the attraction-based method, it has been widely used by researchers.

Table 2-4. Gravity Measure

Core Concept	The quantity of an activity as measured by employment, by impedance, generally a function of travel time or travel cost
Studies	Hansen, 1959; Ingram, 1971; Patton, 1976; Vickerman, 1974; Weibull, 1980; Wilson, 1971
Model	$$A_{im} = \sum_j O_j f\left(C_{ijm}\right) \ or$$ $$A_{im} = \sum_j O_j exp(\theta C_{ijm})$$ The aim is the accessibility at point i to potential activity at point j using mode m, Oj is the opportunities at point j, f(C_ijm) is the impedance or cost function to travel between i and j using mode m, and exp(ΘC_ijm) is a negative exponential function to travel between i and j using mode m.

(Source: Handy & Niemeier, 1997; Miller, 2005c)

The popularity of gravity models is due to: first, the method's reflection of both impedance and attractiveness of destinations; second, through this method it is possible to explain spatial interaction and choice theories. However, Miller (2005c) pointed each may have a different hierarchical process to decide the destination (i.e. making a choice between large mall at suburbia and small store at downtown).

Benefit measures (Random utility theory)

These measures calculate spatial accessibility with the benefits provided to an individual from a choice (Miller, 2005c). This method is based on random utility theory, which can summarize with one index indicating the desirability of all possible choice of the set (Handy & Niemeier, 1997).

Table 2-5. Benefit Measure

Core Concept	The probability of an individual making a particular choice depends on the utility of that choice about the utility of all choices.
Studies	Ben-Akiva and Lerman, 1979, 1985; McFadden, 1981; Small 1992
Model	$A_n = \ln\left[\sum_{\forall \in C_n} \exp(V_{n(c)})\right]$ where Vn{c} is the observable temporal and spatial transportation components of the indirect utility of choice c for person n, and Cn is the choice set for person n.

(Source: Handy & Niemeier, 1997; Miller, 2005c)

While this method quantifies the benefit of users, since the benefit measure is also tied with consumer surplus theory in microeconomics, the interpreting of results requires that cross-elasticities be constant. However, as Jara-Diaz and Friesz (1982) argued, assuming all transportation modes have same degrees of substitutability is not realistic in transportation studies.

Implementation issues

Although measures mentioned above differ in the articulation of travel behavior, these methods have several implementation issues. Handy and Niemeier (1997) summarized following issues. First, since these measures perform zone-based analysis (e.g. census unit, TAZ), the accessibility results might differ by analysis units. Since most methods are using origins and destinations as a basic frame, defining origin and destination (e.g. parcel level, census block level) may affect the results of accessibility measures. Second, the way to define attractiveness of destination differs by various factors (e.g. size of destination, distance to destination, the number of staff, and so on). In addition, since those characteristics are very subjective, it is difficult to specify and calibrate.

- **People-based accessibility**

Place-based measurement mainly deals with spatial relationships between origin and destinations, however, the actual spaces covered by transportation service vary by persons and their activities. Thus, to measure accessibility tied to the individual in both time and space, people-based accessibility has emerged. Since these measures depend mainly on individual activity or travel behavior, they have the advantage over zone-based analysis of not being susceptible to the modifiable areal unit problem (Neutens, 2010, p. 563). The theoretical framework of people-based accessibility is based on the time geography concept, which explains both the activity of people with time and the spatial coverage of the activities (Hägerstraand, 1970). Since people-based accessibility is directly tied to the individual in space and time, these measures partially compensate for the issues of place-based measures.

The foundation of time geography is space-time path and space-time station (Figure 2-1). Since each has a different range of activity by trip purposes and distances, the spatial coverage can be defined the possible locations by space-time path of each.

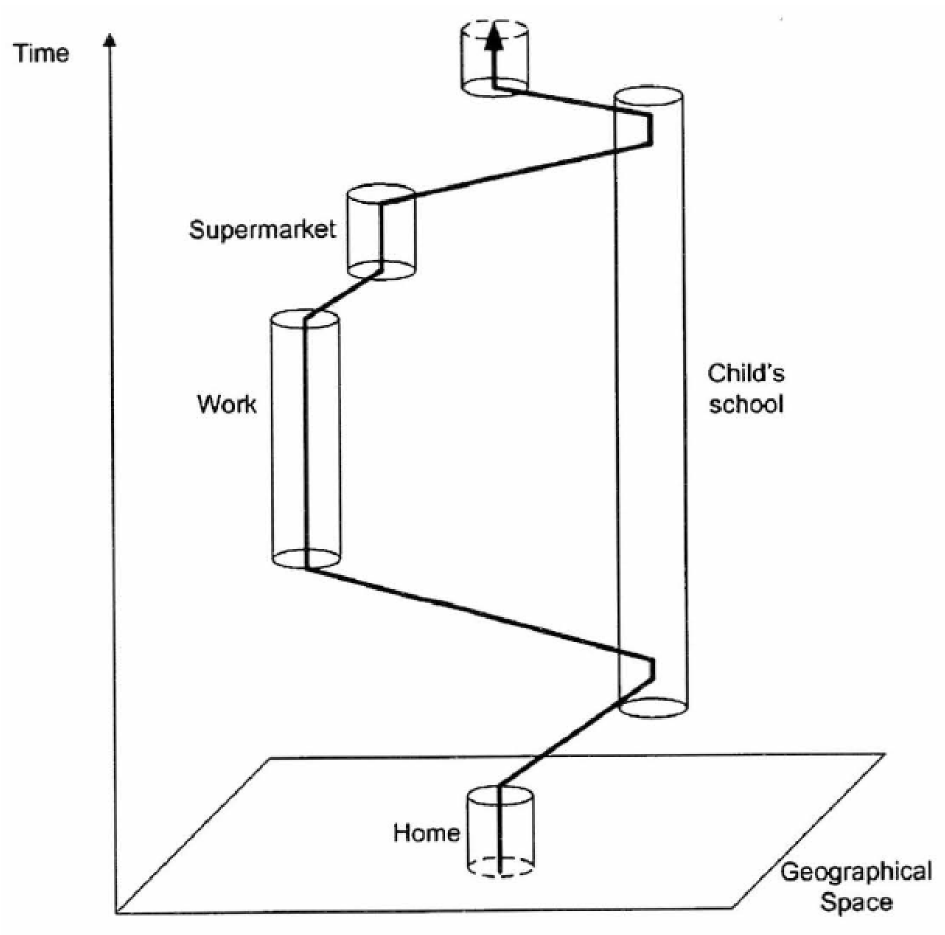


Figure 2-1. A space-time Path and Stations (Miller, 2005c, p. 75)

Miller (2005c) introduced emerging approaches to measuring people-based accessibility within the network and multidimensional spaces.

Network Spaces

Network spaces represent a potential path tree or network area using a space-time prism defined by the topology (e.g. travel distances and velocities). The group of all possible space-time paths that an individual can draw is known as a potential network space and is defined by a space-time prism (Lenntorp, 1976). Because of the difference of time budget, velocity and trip purpose, each space-time prism forms different shapes (Farber, Neutens, Miller, & Li, 2013; Miller, 2005a; Neutens, Van de Weghe, Witlox, & De Maeyer, 2008). Thus, a prism can be interpreted as an indicator of an individual's trip in flexible activities and provides information about a traveler's accessibility (Neutens, Versichele, & Schwanen, 2010). Using space-time prisms, recent studies have tried to understand a potential interaction of different individuals by attempting to determine overlapping spaces among multiple space-time prisms. (Farber et al., 2013; Neutens, Farber, Delafontaine, & Kobe Boussauw, 2013).

Multidimensional Spaces

The multidimensional approach, which can explain geographical spaces by a different time period, expanded from the space-time prism concept. Because of different travel patterns, an individual's space prism may differ by time (Miller 2005b). The multidimensional framework can support high-resolution measurements through the development of technology since the collected information includes very detailed trip data of each individual (Couclelis, 2009).

Although some of these measures require advanced location awareness technologies, since the information and communication technology keeps developing, it is possible to examine accessibility by providing the information about space and time (Ahmed & Miller, 2007). However, Miller (2005c) also pointed out that researchers and practitioners need to have a balance between understanding individual activities and their privacy.

2.3 **Summary of Findings**

This chapter presents the findings from an extensive literature review aiming to understand alternative transportation options for vulnerable populations such as older adults, individuals with disabilities, people with no available vehicle, as well as the methods to identify the gaps between the needs and transportation provision. The research team reviewed a wide range of articles, papers, and reports that are most relevant to the questions raised by the Florida Department of Transportation officials and research team.

The alternative transportation service studies remain the cutting-edge research topic all over the world. In summary, developed countries such as U.S., U.K., Australia, and Canada have had systematic and comprehensive progress in integrating alternative transportation into plans and putting into practice, ranging from the state to local level. However, some developing countries have the tendency toward integrating alternative transportation through more official and powerful practices in the context of urban studies and transportation planning.

In the field of transportation service analysis in the US, common variations exist regarding geographical accessibility, transportation service availability, and government investment. Specifically, geographical accessibility varies in different locations, which indicates that the population distribution and service concentrations within a certain geographic area are often not consistent. Due to the deficiency of transportation accessibility and distinction in transportation service schedule, many service areas are faced with low transportation service availability. Moreover, funding is the crucial part of implementing transportation management and operation in achieving a fair and widespread service. That is to say, funding gaps happen when government investments are not sufficient or available in supporting TD populations.

Although the transportation policies for vulnerable populations aim to provide better transportation services, gaps exist between transportation provision and demand. To specify the methods for identifying gaps, we reviewed that gap measure by service types and transportation accessibility measure.

Because of the variety of transportation services, we categorized three types of services: public transportation, which has fixed routes and schedules; on-demand services that have flexible routes and schedules but requires advance request; and taxi services that have flexible routes and schedule and are available by immediate request. While some researchers developed spatial coverage of those services, previous studies recognized several limitations. First, several points from studies regarding transportation gap measures by service types. Most of the previous studies used census geography boundaries (e.g., census block group or census tract in the U.S.) as the unit of analysis to measure the gaps including transportation accessibility. Census boundaries are useful because they are accompanied by demographic profiles of the older adults or populations with disabilities, but they have some limitations. In particular, the spatial coverage method is effective for showing relative public transport supply and its spatial distribution, but the distribution of each population may not be the same across analysis units (Curie, 2010). Also, most studies have used walking (or bicycling) distance from bus stops and stations to measure accessibility, given that users need to get to stops or stations to use buses, but this may overlook challenges faced by older adults or those with disabilities because of their physical restrictions (Broome et al., 2012). Regarding on-demand services, studies related to system management dominate the literature. These include discussions of reasonable prices, optimal routes, and service frequency. However, on-demand service should not be assessed only by quantitative criteria; because of its spatial and sociodemographic characteristics, its assessment should be expanded to include qualitative studies (Cervero, 1997).

While service provision focused-studies, which have contributed to finding spatial coverage of a transportation service, several researchers suggested that the users should be addressed in transportation gap studies. Thus, we also extended our literature review into transportation accessibility since transportation accessibility is based on travel behavior, especially derived from travel demand (Handy & Niemeier, 1997). Although a substantial literature on transportation accessibility studies has accumulated over the past decades, an accessibility measure should be sensitive to changes in the amount and distribution of the supply of and demand and temporal component (Geurs & Van Wee, 2004). These accessibility studies are mainly classified in two somewhat interconnected ways: place-based and people-based accessibility. Place-based measure put the emphasis on spatial coverages, defining origins and destinations, and street network. This method has the ability to quantify and visualize easily using GIS technology but uses only basic assumptions about the activities of the people. Thus, in addition to spatial information of accessibility, people-based measures incorporate the activities of different groups of users. Thus, for example, households with children would need to include accessibility to school as a part of their considerations. Workers may choose to include residential location and accessibility in their considerations of where they live while retirees may value accessibility to health care and pharmacies. This research has added more variables to allow for more complex accessibility studies but collecting relevant and meaningful data has become another issue. However, it should be noted that the accessibility studies should consider research and conducted regional context since the use of an inappropriate measure may lead to incomplete conclusions and ineffective policy.

In conclusion, the available literature on transportation gaps and transportation accessibilities is shown in a variety of perspectives by each research’s purpose. However, it is hard to draw a general conclusion about complex factors to impact the transportation gap studies. This concluding section summarizes the above review into methodological points of view. This literature is not a closed-list but providing a guideline for rest of this project, which is developing geospatial modeling to identify transportation service gaps between the provision and the needs.

3. REVIEW OF TRANSPORTATION SERVICE PROVIDER CATEGORIES

Transportation services include a variety of options such as public transportation, paratransit, specialized transportations such as on-demand services of various types, taxi, and the transportation network companies, such as Uber or Lyft. While several services serve the general public, others services specifically work for vulnerable populations such as older adults, individuals with disabilities, or patients.

To fulfill the mobility needs of vulnerable populations in Florida, the Safe Mobility for Life Coalition provides a variety of safety and mobility resources to help plan for a safe transition from driving (Florida's Aging Road User Strategic Safety Plan, 2017). To help individuals identify their available transportation options, the Florida Department of Transportation Safe Mobility for Life Program and University of Florida Institute for Mobility, Activity, and Participation partnered to develop findarideflorida.org, which provides listings of transportation options in each of Florida’s 67 counties (FDOT Safe Mobility for Life, 2018). The Find-a-Ride Florida database, which supports FindaRideFlorida.org, maintains three attributes for each service provider including their service area, schedule types, and service type. The service area also captured specific route types. Schedule types could be used by users to plan a trip. Based on user eligibility, reachable destinations, and accommodation, the service types were categorized.

Although the database contains useful information to access transportation options, the team has recognized two issues. First, the terms used in the database might not be consumer friendly. For example, the Find-a-Ride Florida database lists five route types such as, fixed route, route deviation, point deviation, many to few, and many to many. Although the database provides definitions for these route types, the terminology is too technical, confusing and unclear for a lay person. Second, the categorization and the attributes used in the classification process may not be suitable for the spatial analysis of transportation supply and the demand for vulnerable populations.

Thus, this chapter builds upon the Find-a-Ride Florida database and seeks to review further and refine the categorization of transportation service providers using their attributes. The categorization process and results include to create consumer-friendly categories and connect GIS modeling that identifies gaps in transportation services for the vulnerable populations in next chapter.

3.1 Find-a-Ride Florida Database

3.1.1 Data Collection Methods

Two primary methods were used to collect data about the transportation service providers: direct contact and through FindaRideFlorida.org. Data aggregated by direct contact was primarily obtained through phone calls to the transportation service providers. We learned about and discovered transportation service providers through Internet searches, Florida's Safe Mobility for Life Coalition, contacting MPOs, and requested directly from the transportation service providers themselves. Each service provider was listed on FindaRideFlorida.org and were given access to their profile. This allowed each service provider the ability to update their own data at any time through our website. Quality assurance checks were performed by auditing one or more service areas each year for listing accuracy, with selection based on Coalition input. Email reminders are sent twice per year to the transportation service providers reminding them to log into the FindaRideFlorida.org to update their profile.

3.1.2 Data Organization

The data was stored in a relational database, making it easy to access the desired data for end users and GIS analysts alike. The website was run using the Drupal content management system, which provided a safe, secure, and easily maintained system. Under this framework, each transportation service provider became a node with the data as attributes of that node. These nodes were linked with other data in the database for categorization, revision history, and user permissions. The general public could access the data through a search page on the website where they select a county, city (optional), and the categories (optional). A search results page was then returned listing all the transportation services that match the selected search criteria. Detailed information about a service could then be obtained by clicking on the service provider's name. Transportation service providers could additionally access and update their data by logging into the website with their unique account. Specialized queries and scripts were used to provide the GIS analysts with access to the specific data needed.

3.1.3 Data Attributes

First of all, the Find-a-Ride Florida database assigned a unique ID for each service provider. Using the unique ID, each service provider's data was established. Figure 3-1 illustrates the database structure and attributes. The core data frame consisted mainly of the service area, service type, and schedule types. The service area also captured specific route types. Schedule types were categorized as a means to allow users to plan a trip. Based on user eligibility, reachable destinations, and accommodation, the service types were classified.

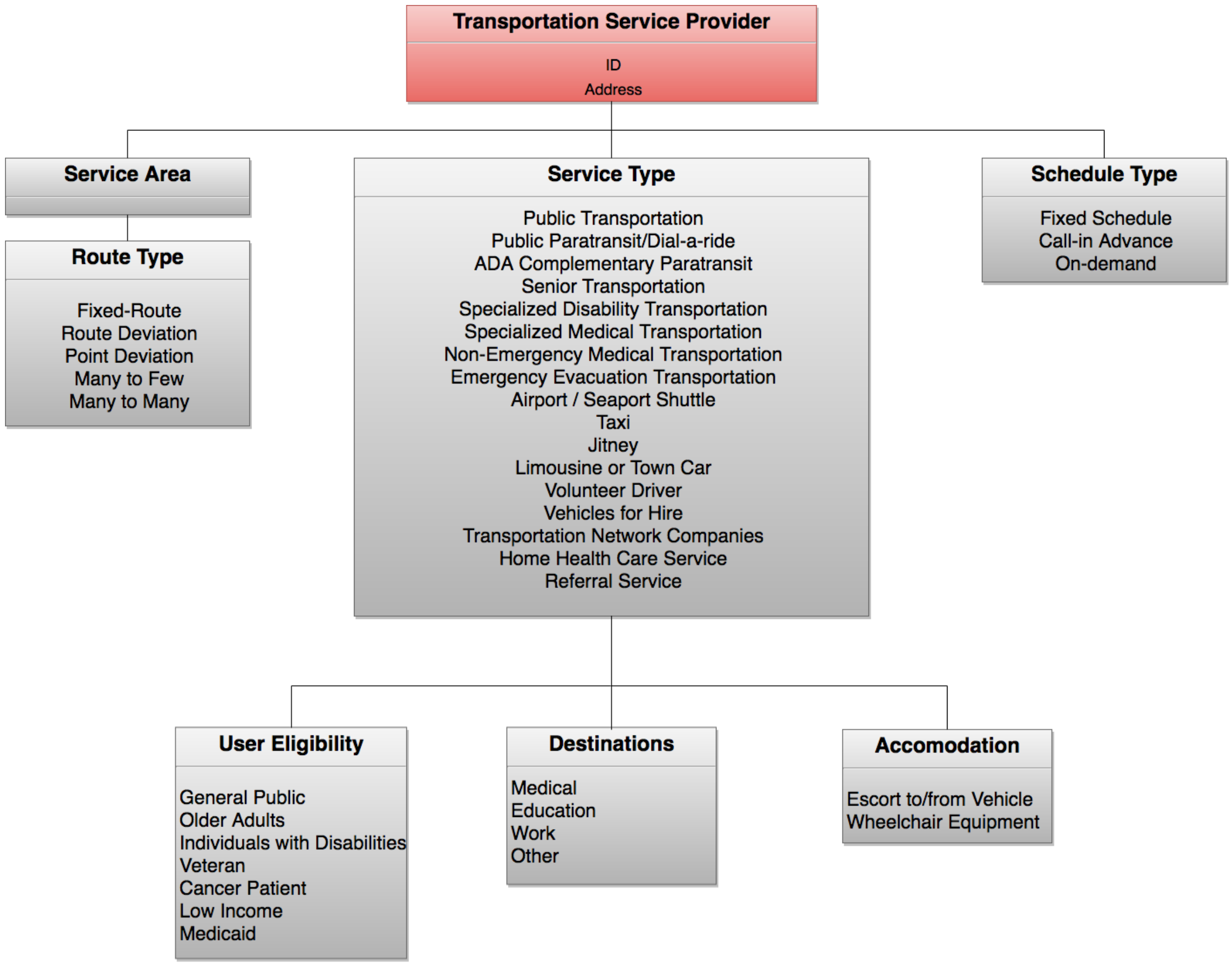


Figure 3-1. Find-a-Ride Florida Database Structure and Attributes

- **Service Type**

The Find-a-Ride Florida database captures a variety of service types such as public transportation, paratransit, various types of senior transportation, taxi, transportation network companies to name a few. Figure 3-1 shows a complete list of all 17 service types. The transportation service providers are categorized in the next section (3.2 Categorization of transportation service providers). Some service types are only available to certain users, destinations and type of accommodations as follows:

Eligible Users

While several services provide mobility options for the general public, some services serve the vulnerable population, including older adults, individuals with a disability, and low-income households. Particularly, the state of Florida defines these vulnerable populations as TD (Florida Statutes, Title XXX § 411-202). Also, there are providers that serve cancer patients, Medicaid recipients, and veterans. Identifying the eligibility of users is crucial since it helps to understand potential users and their characteristics and to identify the geospatial gaps of transportation accessibility for specific population groups. The definitions and descriptions for each user group are as follows:

- Older adults: The U.S. Census Bureau defines the term older population as the population 65 years and over (Werner, 2011). However, the Florida Department of Elder Affairs categorizes individuals with age 60 and older as older adults (Florida Department of Elder Affairs, 2016). For this project, we expect to further detail older adults in sub categories (e.g., 60 to 64, 65 to 74, 75 to 84, and above 85) with the input from the project manager and the transition from driving team.
- Individuals with disability
  - Physically disabled: The Americans with Disabilities Acts (ADA) defines a person who has a physical or mental impairment that substantially limits one or more major life activities, a person who has a history or record of such an impairment, or a person who is perceived by others as having such an impairment (U.S. Department of Justice, 2009). The Social Security Administration (SSA) considers someone disabled if the person cannot do work that they did before. However, SSA decides that the individual cannot adjust to other work because of a medical condition(s). Additionally, the disability has lasted or is expected to last for at least one year or to result in death (SSA, 2017a).
  - Mentally disabled: SSA lists 11 categories as mental disorder including neurocognitive disorders; schizophrenia spectrum and other psychotic disorders; depressive, bipolar and related disorders; intellectual disorder; anxiety and obsessive-compulsive disorders; somatic symptom and related disorders; personality and impulse-control disorders; autism spectrum disorder; neurodevelopmental disorders; eating disorders; and trauma- and stressor-related disorders (SSA, 2017b).

  However, regarding disability and using the specific transportation option, each service provider that provides transportation service to individuals with a disability might have different criteria.

  Although each service provider uses different standards for deciding the eligibility of disabled, the Department of Transportation (DOT) defines the eligibility to use ADA paratransit service. Federal Transit Administration (2017) explains in Appendix D to 49 C.F.R. Section 37.125: "The substantive eligibility process is not aimed at making a medical or diagnostic determination. While evaluation by a physician (or professionals in rehabilitation or other relevant fields) may be used as part of the process, a diagnosis of a disability is not dispositive. What is needed is a determination of whether, as a practical matter, the individual can use fixed route transit in his or her own circumstances." However, each transit agency, with input from the communities, defines the specifics of their individual eligibility processes.

- Low income: Low-income individuals may be defined in various ways. The U.S. Census Bureau determines poverty status by comparing pre-tax cash income such as wages and salaries, Social Security benefits, interest, dividends, pension, or other retirement income against a threshold that is set at three times the cost of a minimum food diet in 1963 in today's price and adjusted for family size, composition, and age of householder (U.S. Census Bureau, 2013). However, like the determination of eligibility for disabled persons, each agency establishes its own criteria to determine eligibility for specific transportation services.
- Medicaid recipient: Medicaid is a joint federal and state program that provides health coverage to certain people including children, pregnant women, parents, older adults and individuals with disabilities. The eligibility is decided by income level (which is based on Modified Adjusted Gross Income), age, pregnancy, or parenting status (Center for Medicaid and Children's Health Insurance Program [CHIP] Services, 2017). Following the Florida Agency for Health Care Administration (AHCA), eligibility for Florida Medicaid is determined by income and asset requirements categorical groups. Particularly, while the Department of Children and Families determines eligibility for low-income children and family programs and the institutional care program, the Social Security Administration determines eligibility for the Supplemental Security Income (SSI) program (AHCA, 2017).
- Veteran: The Department of Veterans Affairs [VA] (2017) defines, for VA health benefits and services, that a person who served in the active military service and who was discharged or released under conditions other than dishonorable is a veteran.
- Cancer patient: Several services, including those operated by the American Cancer Society, provide their transportation options (usually by volunteer drivers) to a cancer patient for the purposes of accessing treatment and related programs.

Destinations

While some transportation services provide service to a broad range of destinations, others specify or limit the destinations. Thus, based on trip purpose, we grouped four destinations: medical, educational, work, and non-medical destinations. Using both 2009 National Household Travel Survey (NHTS) definitions and input from project managers and transition from driving teams, we reorganize and redefine each destination group as follows:

- Medical: This destination category includes medical, dental, or mental health treatment or other similar professional services. Hospital, primary care providers, and outpatient clinics, and dialysis treatment centers are included in this category. Also, this destination category includes places that are medically related other than the primary medical destination, such as pharmacies, labs, and physical therapy locations.
- Education: This destination category includes school, libraries, daycares, and before or after-school care.
- Work: This destination category includes a place to work or volunteer.
- Non-medical: This category could include recreation / social, meal, and shopping destinations. Regarding recreational and social, this sub category covers a place to engage in exercise, a place for a social event, a place to take a vacation, and a place for entertainment (e.g. theater, sports event place, and bar), historical site, museum, park, and places to attend religious activities. Concerning meal-related destinations, this sub category includes a place to get and eat a meal, snack or drink. Regarding shopping destinations, this sub category includes places to buy goods (e.g. groceries, clothing, hardware store), places to buy services (e.g. dry cleaning, post office, car service, bank, and pet care), gas stations, and shopping malls.

Accommodation

Several transportation services provide additional accommodations such as an escort to or from a vehicle and wheelchair services.

- **Service Area**

The database contains service area information at County or City level.

Route

In addition to the service area, each service falls into five route types: fixed route, route deviation, point deviation, many to few, and many to many. The next section (3.2 Categorization of transportation service providers) describes how to define and categorize those route types.

- **Schedule**

To use a transportation service, the user has three options: follow a predefined schedule, call-in-advance, or on-demand request.

3.2 **Categorization of Transportation Service Providers**

The purpose of categorization is creating consumer-friendly categories for Find-A-Ride users and connecting to gap analysis modeling for a vulnerable population. Thus, this part covers how to define the type of service, type of route, and type of schedule. Using the definition the team classifies simplified categories, and the reorganized categories are used for further geospatial gap analysis for vulnerable populations and FindaRideFlorida.org.

3.2.1 Type of Service

The Find-a-Ride Florida database maintains 17 different service types: Public Transportation, Public Paratransit/Dial-a-ride, ADA Complementary Paratransit, Senior Transportation, Specialized Disability Transportation, Specialized Medical Transportation, Non-Emergency Medical Transportation, Emergency Evacuation Transportation, Airport / Seaport Shuttle, Taxi, Jitney, Limousine or Town Car, Volunteer Driver, Vehicles for Hire, Transportation Network Companies, Home Health Care Service, and Referral Service. It is important to note that this categorization process does not include home health care service[2] and referral service[3] since those services do not solely provide - transportation options to users. This section consists of two parts: the team looks at the current categorization of services and proposes simplified categories of service types.

- **Current Categories**

Public Transportation

Transportation by bus, rail, or any other conveyance (other than by aircraft) that provides the general public with general or special service (including charter service) on a regular and continuing basis. National Transit Database (NTD) defines public transportation: “Transportation by a conveyance that provides regular and continuing general or special transportation to the public, but does not include school bus, charter, or intercity bus transportation or intercity passenger rail transportation such as Amtrak (NTD, 2017).”

- Find-a-Ride definition: Transportation on a bus or other vehicle available to the general public.
- Eligible users: General public

[2] Transportation is an additional service provided by caregiver hired to assist with daily activities and self-care.
[3] These services include phone hotlines that refer people to transportation providers or persons interested in carpooling or other similar services.

Public Paratransit Service/Dial-a-ride

Paratransit describes any means of shared ride transportation other than fixed route mass public transit services. The term usually indicates that providers are using smaller vehicles (less than 25 passengers). These services usually serve the needs of persons that standard mass transit services would serve with difficulty. A paratransit service is typically a advanced reservation, demand-responsive service provided curb-to-curb or Door-to-door. NTD also defines paratransit as types of passenger transportation which are more flexible than conventional fixed-route transit but more structured than the use of private automobiles (NTD, 2017).

- Find-a-Ride definition: Public transportation with a flexible schedule and route for people who cannot use regularly scheduled public transportation services.
- Eligible users: Older adults, Disabled, Low-Income, Transportation disadvantaged, Veteran

ADA Complementary Paratransit Service

Demand-responsive service that is operated by public transit providers in addition to fixed route service to accommodate persons who cannot ride the fixed route service because their disability prevents it. NTD defines complementary paratransit service as transportation service required by the Americans with Disabilities Act for individuals with disabilities who are unable to use fixed route transportation systems (NTD, 2017).

- Find-a-Ride definition: Public transportation with a flexible schedule and route for people who cannot use regularly scheduled public transportation services because of a disability
- Eligible users: ADA eligible

Senior Transportation

Senior transportation provided by local government, communities, organizations or businesses including hospitals, assisted living facilities, home health agencies, and other similar providers.

- Find-a-Ride definition: Senior transportation provided by organizations or businesses including hospitals, assisted living facilities, and home health agencies.
- Eligible users: Older adults, Disabled

Specialized Disability Transportation

- Find-a-Ride definition: Service is provided for persons with disabilities to attend special programs like Goodwill and Easter Seals—some of these programs include older adults with disabilities.

- Eligible users: Disabled, Cancer patient

Specialized Medical Transportation

- Find-a-Ride definition: Medical transportation for persons with specific medical conditions such as cancer, that may be provided by car, van, ambulance or airplane.
- Eligible users: Cancer patient, Veteran

Non-Emergency Medical Transportation

Services that are designed to transport riders for medical purposes. The costs of these services are typically paid for by government agencies.

- Find-a-Ride definition: Transportation for persons who need medical services
- Eligible users: Older adults, Disabled, Veteran

Emergency Evacuation Transportation

- Find-a-Ride definition: Services that coordinate and/or provide transportation during a disaster or emergency evacuation.
- Eligible users: Older adults, Disabled, Low-Income

Airport / Seaport Shuttle

A vehicle stops at specified checkpoints (shopping centers, industrial parks) at specified times, but travels a flexible route between these points to serve specific customer requests for doorstep pickup or delivery.

- Find-a-Ride definition: Primary service is to/from area airports or seaports
- Eligible users: General public

Taxi

The vehicle that carries passengers for a fare usually based on the distance traveled.

- Find-a-Ride definition: Vehicles (typically cars) for hire. Fees are often (but not always) based on miles traveled.
- Eligible users: General public

Jitney

Jitney vehicles including trolley service travel along a fixed route with no schedule; passengers are picked up anywhere along the route (flag stops). Because there are no schedules, headways are usually five to 10 minutes, so passengers have only brief waiting periods. NTD defines jitney as a transit mode comprised of passenger cars or vans operating on fixed routes (sometimes with minor deviations) as demand warrants without fixed schedules or fixed stops (NTD, 2017).

- Find-a-Ride definition: Small passenger vehicles that typically travel fixed routes at short intervals and can stop for riders along the way
- Eligible users: General public

Limousine or Town Car

- Find-a-Ride definition: Luxury car for hire. Fees are often based on hours of service and mileage.
- Eligible users: General public

Volunteer Driver (May Charge Fee)

- Find-a-Ride definition: Transportation provided by volunteer drivers for a varying fee.
- Eligible users: Cancer patient

Vehicles for Hire

- Find-a-Ride definition: Vehicles you can use by the hour; some services provide a driver while others are vehicle rental only.
- Eligible users: General public

Transportation Network Companies

Transportation Network Companies (TNC) connects, via websites and mobile apps, pairing passengers with drivers who provide such passengers with transportation on the driver's non-commercial vehicle.

- Eligible users: General public

o **Proposed Simplified Categories**

Based on the characteristics of each transportation service, the team classifies 17 services into four groups. Table 3-1 shows proposed simplified categories and their eligible users.

Public Transportation

Transportation on a bus or other vehicle available to the general public with fixed schedule and route. From previous category, this public transportation category includes only public transportation mode.

Paratransit

The paratransit category includes both public paratransit service and ADA complementary paratransit service.

Specialized Transportation

This category represents transportation options with specific users and purpose including senior transportation, specialized disability transportation, specialized medical transportation, non-emergency medical transportation, emergency evacuation transportation, and airport / seaport shuttle.

Vehicles for Hire

Typically, users pay for the service and providers charge by travel distance.

Table 3-1. Simplified Categories of Service Types

Proposed Simplified Category	Current Category	Eligible Users
Public Transportation	Public Transportation	General public
Paratransit	Public Paratransit Service/Dial-a-ride	Older adults, Disabled, Low income, Transportation disadvantaged, Veteran
	ADA Complementary Paratransit Service	ADA eligible
Specialized Transportation	Senior Transportation	Older adults, Disabled
	Specialized Disability Transportation	Disabled, Cancer patient
	Specialized Medical Transportation	Cancer patient, Veteran
	Non-Emergency Medical Transportation	Older adults, Disabled, Veteran
	Emergency Evacuation Transportation	Older adults, Disabled, Low income
	Airport / Seaport Shuttle	General public
Vehicles for Hire	Taxi	General public
	Jitney	General public
	Limousine or Town Car	General public
	Volunteer Driver (May Charge Fee)	Cancer patient
	Vehicles for Hire	General public
	Transportation Network Companies	General public

3.2.2 Type of Route

Route type is crucial to identify served area for users. The Find-a-Ride Florida database uses five different route types in the database: fixed route, route deviation, point deviation, many to few, and many to many. To classify routes types and link to GIS modeling, the team looked at the current categorization of route types and proposes simplified route types.

- **Current Category**

Fixed Route

The transit vehicle travels a pre-established route. Passengers are picked up or dropped off at pre-designated locations along the route.

- Find-a-Ride definition: Follows a set route, such as those traveled by city buses

Route Deviation

A vehicle travels a basic route, picking up or dropping off passengers anywhere along the route. On request and, perhaps, with additional charge, the vehicle will deviate a short distance from the fixed-route to pick up or deliver a passenger.

- Find-a-Ride definition: Follows a basic route but can deviate from this route based on passenger requests.

Point Deviation

A vehicle stops at specified checkpoints (e.g., shopping centers, industrial parks) at specified times but travels a flexible route between these points to serve specific customer requests for doorstep pickup or delivery.

- Find-a-Ride definition: Travels a flexible route from Point A to Point B based on passenger requests but also stops at specific locations at specific times

Many to Few

Origin points may be anywhere in a defined service area, but destinations are limited to a few activity centers. Conversely, for a return trip, origins are limited whereas destinations are area-wide. The vehicle travels a flexible route between origin and destination points to serve specific customer requests.

- Find-a-Ride definition: Picks up passengers from many locations for travel to a small number of locations

Many to Many

Service is provided to all origins and destinations within a defined service area. Service is not provided outside the service area. The vehicle travels a flexible route between the origin and destination points to serve specific customer requests for pickup and delivery (could be a curb to curb).

- Find-a-Ride definition: Picks up from multiple locations and drops off at multiple locations per customer request

- **Proposed Simplified Category**

Fixed Route

This type of service has predefined routes and stops. To use the service, users need to be at designated stop.

Flexible Route

This service has basic routes but flexibility by request of users.

Door-to-door

Upon request, the service picks users up at the front door and drop off at the destination.

3.2.3 Type of Schedule

To categorize schedule types, the team looks at the current categorization of schedule types and proposes simplified schedule types.

- **Current Category**

Fixed Schedule

Customers board a vehicle at specified times. The schedule is established and published by the transportation agency.

- Find-a-Ride definition: The provider sets the times when customers can board or alight from the vehicles.

Call-in-advance

Service is requested in advance for a single trip to occur at a specific time e.g. 24 to 48 hours in advance of the time of the trip. The customer has control of the pickup time within a specified arrival window with the advance request option but must know complete trip details in advance. (As this is not always possible, this requirement constrains the responsiveness of the service).

- Find-a-Ride definition: Times for getting on and off the vehicle are set in advance by the rider.

On-demand

Service is requested through a central control or dispatcher for a single trip to be made as soon as possible. Requests are made by telephone. The responsiveness of this option is affected by the availability of a telephone or other means of communication, the availability of a vehicle to make the trip and the availability of space in the vehicle. This is the most responsive service possible except for the personal automobile.

- Find-a-Ride definition: Service is arranged for a single trip to be made as soon as possible.

○ **Proposed Simplified Category**

Since all services fall into three schedule types, we use the same categories: fixed schedule, call-in-advance, and on-demand.

3.2.4 Link to the Geospatial Model for Gap Identification

Building upon this categorization, the research team built a GIS model that identifies gaps in transportation services for the vulnerable populations at the census block group level by considering the population’s needs and by calculating the available transportation services supply. However, the relationships among route type, service type, and schedule type are not simple (Figure 3-2). For example, paratransit service may have a flexible route or door-to-door route type as well as require call-in-advance or on-demand.

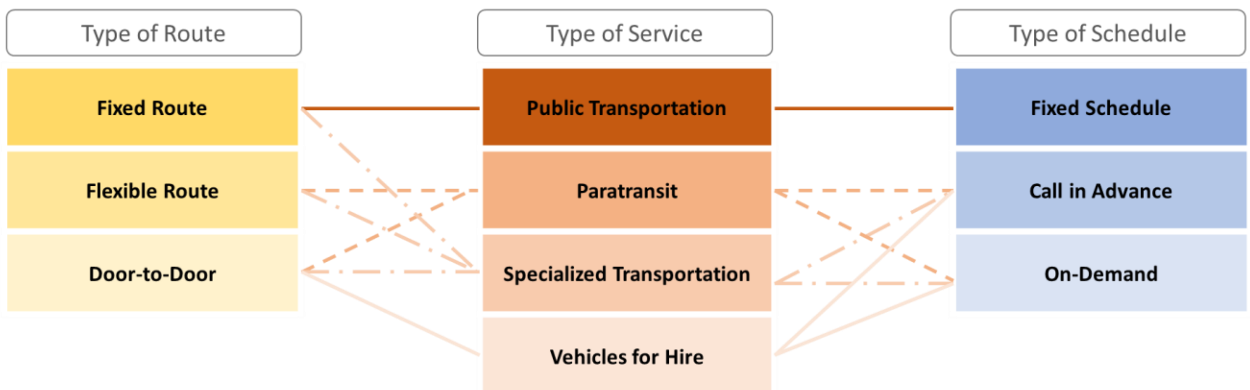


Figure 3-2. Type of Route, Service, and Schedule

Since the purpose of this research is to identify the spatial gaps in transportation availability, the team structures three possible methods to create a transportation supply GIS layer using the categorized database.

Figure 3-3 describes the conceptual process and required data to generate the fixed route service GIS layer. Public transportation and some of the specialized transportation with fixed routes require routes and stops, street network, and destinations data to create a supply GIS layer.

Figure 3-3. Conceptual Framework for Fixed Route Service GIS Layer

Figure 3-4 illustrates the conceptual process and required data to generate flexible route service GIS layer. Some of the Paratransit and specialized transportation with flexible routes require routes, pick up/drop off, street network, and destinations data to create a supply GIS layer.

Figure 3-4. Conceptual Framework for Flexible Route Service GIS Layer

Figure 3-5 represents the conceptual process and required data to generate door-to-door service GIS layer. Vehicles for hire, some of the Paratransit and specialized transportation with door-to-door service require service area, street network, and destinations data to create a supply GIS layer.

Figure 3-5. Conceptual Framework for Door-to-door Service GIS Layer

4. DEVELOPMENT OF THE GEOSPATIAL MODEL FOR GAP IDENTIFICATION

This chapter presents a geospatial methodology for identifying geographic areas and respective vulnerable populations that are not adequately provided with alternative transportation options. The spatial analysis unit is at the census block group level because the census block group data provides demographic profiles of the TD populations. The method is developed using Alachua County data and it is applied to Orange County for testing.

The methodology takes a supply-demand approach. Transportation supply for TD is measured by quantifying the transportation accessibility based on three transportation service route types. First, fixed route accessibility is measured by considering transit stops, transit routes, network walking distance from transit stop, and the number of destinations in close proximity to the transit stop. Second, flexible route accessibility is calculated by applying origin-destination (OD) network analysis within the boundaries of the served areas of each service provider. Third, door-to-door accessibility is also measured by applying OD network analysis. Transportation demand is computed by calculating the volume of TD users—older adults, individuals with disabilities, and people who do not own an automobile. Finally, spatial gaps are found by identifying spatial differences between transportation supply and demand.

4.1 Conceptual Framework

As discussed in the previous chapter, while some transportation services are available to the general public, other services are only available to eligible users. Thus, to find transportation gaps for the vulnerable population, recognizing the *users* is an essential step to develop the geospatial model.

Figure 4-1 describes the conceptual process to identify spatial gaps. As a first step, the model selects the users. This step determines the proper demographic profile of users as well as the relevant transportation service providers.

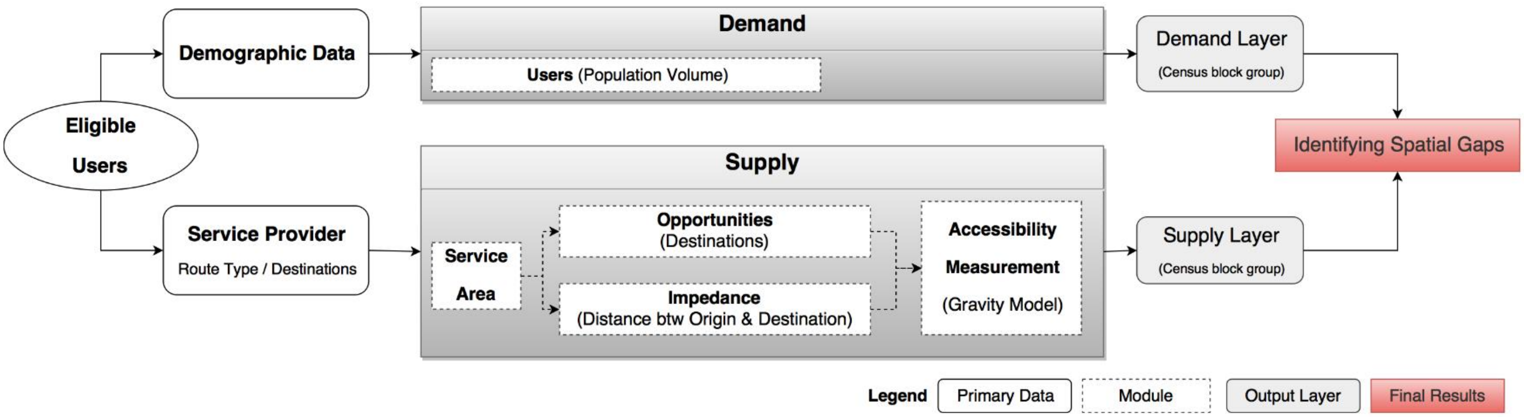


Figure 4-1. Conceptual Model to Detect Service Gaps

The supply model consists of several modules including service areas, opportunities, impedance, and accessibility measurement. Organization of the supply model by modules provides many benefits due to its flexibility. For example, the service areas module, operates differently for different route type. The fixed route service is determined by stops, street network, and walking catchment area. The door-to-door service depends on the street network, destinations and service area boundaries of the transportation service providers. For flexible route, the service areas are calculated by considering service routes, deviations, or pick up/drop off areas. The next two modules calculate opportunities based on destinations and the impedance within service areas. The results from opportunities and impedance modules are used by the accessibility measurement module. As discussed in chapter 2, there are several methods to measure accessibility such as based on cumulative opportunity, gravity, or benefits. We chose the gravity method as it is more relevant for our goals. The gravity model has been been widely used by several researchers (Handy & Niemeier, 1997; Hansen, 1959; Ingram, 1971; Miller, 2005c; Patton, 1976; Vickerman, 1974; Weibull, 1980; Wilson, 1971). Gravity models consider both impedance to and attractiveness of destinations, and they are able to describe spatial interaction and choice theories (Miller, 2005c). The supply model outputs a single measure to represent transportation supply of the selected service provider. The demand model computes the needs of the users by calculating population volume of users. The final part of the model detects services gaps based on the supply and demand layers.

4.2 Developing GIS Model to Identify the Gaps

This section describes the methodology aimed at identifying significant gaps in alternative transportation services for vulnerable populations. Using GIS datasets and calculation modules, the team develops a geospatial model for calculating transportation supply through a transportation accessibility measure. Gaps in service are identified by overlaying the vulnerable population demand volume with transportation accessibility. The resulting supply-demand matrix reveals transportation deficient areas and populations, based on the overlay of higher demand and lower supply.

4.2.1 Data

The necessary data to develop this methodology include locations and attributes of transportation service providers, travel origins, destinations, street network, and TD populations' demographic profile.

- **Service Provider and Service Areas**

First of all, the service areas of fixed route transportation service providers are defined by the location of stops, routes, and walking catchment areas. Stops and routes information for the public transportation category were obtained from the General Transit Feed Specification (GTFS). Since the GTFS dataset is available to the public by Google and is frequently updated, we could use the most up to date information. However, the data is in text format. Using GTFS's conversion tool (ESRI, 2017), the team converted the text data into GIS format.

Flexible route and door-to-door service might have predefined service areas, i.e. these types pick up and drop off users within predefined geographic extents. The service area information for these providers was obtained from the Find-a-Ride Florida database.

- **Street Network**

The GIS street network is used to determine the transportation service areas and to calculate the accessibility. The OpenStreetMap was chosen as the network layer because OpenStreetMap is compatible with GTFS data and has a detailed street network.

- **Origins and Destinations**

Transit stops represent both origins and destinations for the fixed route service. For flexible route and door-to-door service, travel origins are established at the centroid point of each census block group boundary. The block group information is obtained from the Florida Geographic Data Library (FGDL).

Possible destination categories determined in chapter 3 include medical, educational, work, and other destinations. We created a destination layer for each destination category using property parcel data and other available data in FGDL. However, it was difficult to define and acquire work destination at the parcel level, therefore work destinations were not included.

- **Users**

Eligible users determined in chapter 3 include older adults, individuals with disabilities, low income, Medicaid recipients, veterans, and cancer patients. However, at the census block group level, the demographic information based on the 2010 US Census and the 2010 –2014 American Community Survey (2014 ACS) only includes older adults, individuals with disabilities and housing units without a vehicle. Demographic information for older adults is available only for people over 65, not over 60.

4.2.2 Geospatial Model for Gap Identification

Based on the conceptual framework, we developed modules and incorporated the modules into a single model (Figure 4-2). The demand model uses a single module. The supply model consists of multiple modules. The method is developed using Alachua County data.

Module 1: Users

Input	Output
Demographic Data (Eligible Users)	Population Volume (Census block group)

Module 2: Service Areas

Route Type	Input	Method	Output
Fixed	Stops, Street Network	Creating walking shed from stops	Service Areas
Flexible	Routes or Pick-up/Drop-off Areas	Creating polygon(s) using buffer from routes or pre-defined service areas	
Door-to-Door	Service Areas		

Module 3: Opportunities

Route Type	Input	Output: O_j
Fixed	Destinations within Service Areas	Opportunity at destination j
Flexible		
Door-to-Door		

Module 4: Impedance

Route Type	Input	Output: $f(C_{ij})$
Fixed	Stops, Routes	Network distance between Origin and Destination
Flexible	Origins and Destinations within Service Areas, Street Network	
Door-to-Door		

Module 5: Accessibility Measurement

Route Type	Input	Method (Gravity Model)	Output: A_i
Fixed	Opportunities: O_j Impedance: $f(C_{ij})$	$A_i = \sum_j O_j f(C_{ij})$	Accessibility at point i
Flexible			
Door-to-Door			

Figure 4-2. The Modules

As explained previously, the model starts with the selection of the users, which decide both the demographic profile and the available transportation service providers.

- **Transportation Demand Model**

This section covers the demand model and examples of outputs produced by the model. Once the users are selected, the demographic information of users available from the census data is processed (Table 4-1) including older adults, individuals with disabilities, and housing units without a vehicle.

Table 4-1. Users' Module

Input	Output
Demographic Data (Eligible Users)	Population Volume (Census block group)

Since each dataset has different units and distributions, it is necessary to normalize these datasets so that they are placed on the same scale. The normalized or standardized score is also useful to compare or combine different layers. We standardized the values in a scale of 0 to 1 based on the relationship of the score to the highest value in its series using the formula below:

$$SS = \frac{D_i - \min(D_i)}{\max(D_i) - \min(D_i)} \qquad (1)$$

where SS = standardized score; Di = original value of dataset i; min (Di) = minimum value of dataset i; and max (Di) = maximum value of dataset i.

Outputs: Demand layers examples

- Older adults

  The demand for older adults is standardized in a scale of 0 to 1 with zero indicating no transportation needs and 1 representing highest transportation needs. Figure 4-3 shows an example of the standardized demand layer for older adults in Alachua County.

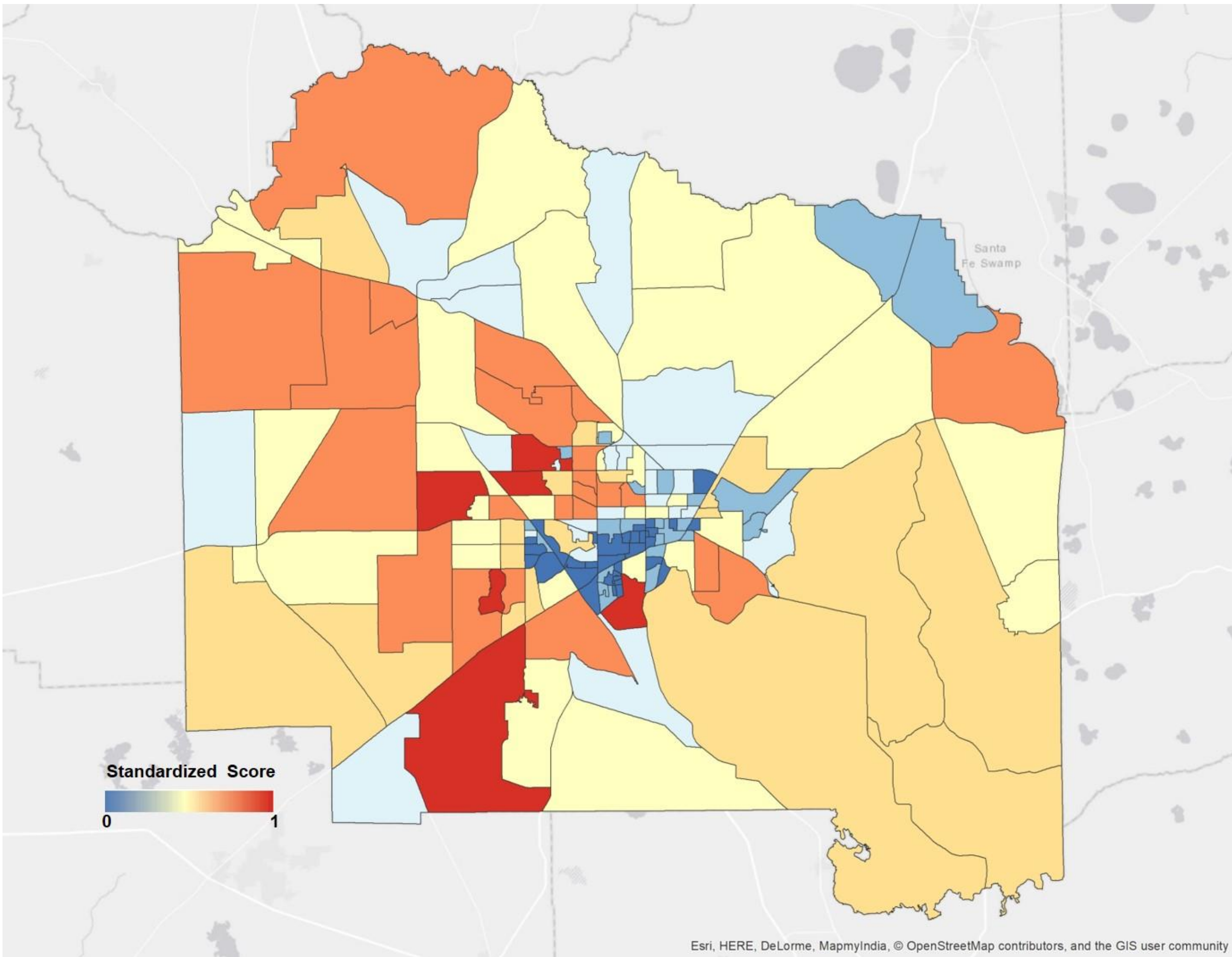


Figure 4-3. Demand Layer Example (Older Adults)

- Individuals with disabilities

  The number of individuals with disabilities, provided by 2014 ACS, applies to people between the age of 20 and 64 years old. After standardizing the data using equation (1), the transportation demand values for individuals with disabilities range from 0 to 1, with zero indicating no transportation needs and 1 representing highest transportation needs. Figure 4-4 shows an example the demand layer for individuals with disabilities.

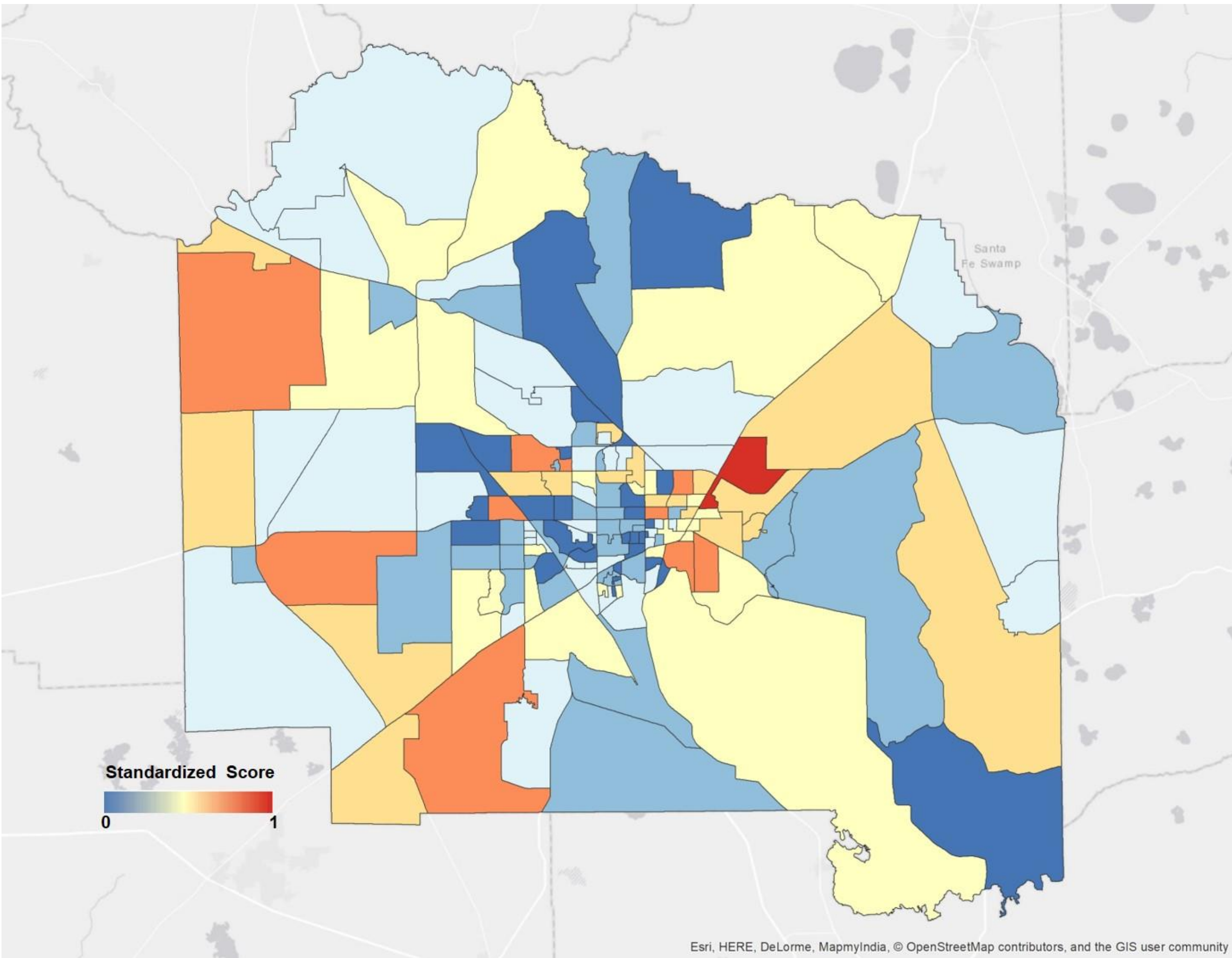


Figure 4-4. Demand Layer Example (Individuals with Disabilities)

- <u>Housing units without a vehicle</u>

  The number of housing units without a vehicle is provided by 2014 ACS. After standardizing by equation (1), the transportation demand values for housing units without a vehicle range from 0 to 1, with zero indicating no transportation needs and 1 representing highest transportation needs. Figure 4-5 shows the demand layer for housing units without a vehicle.

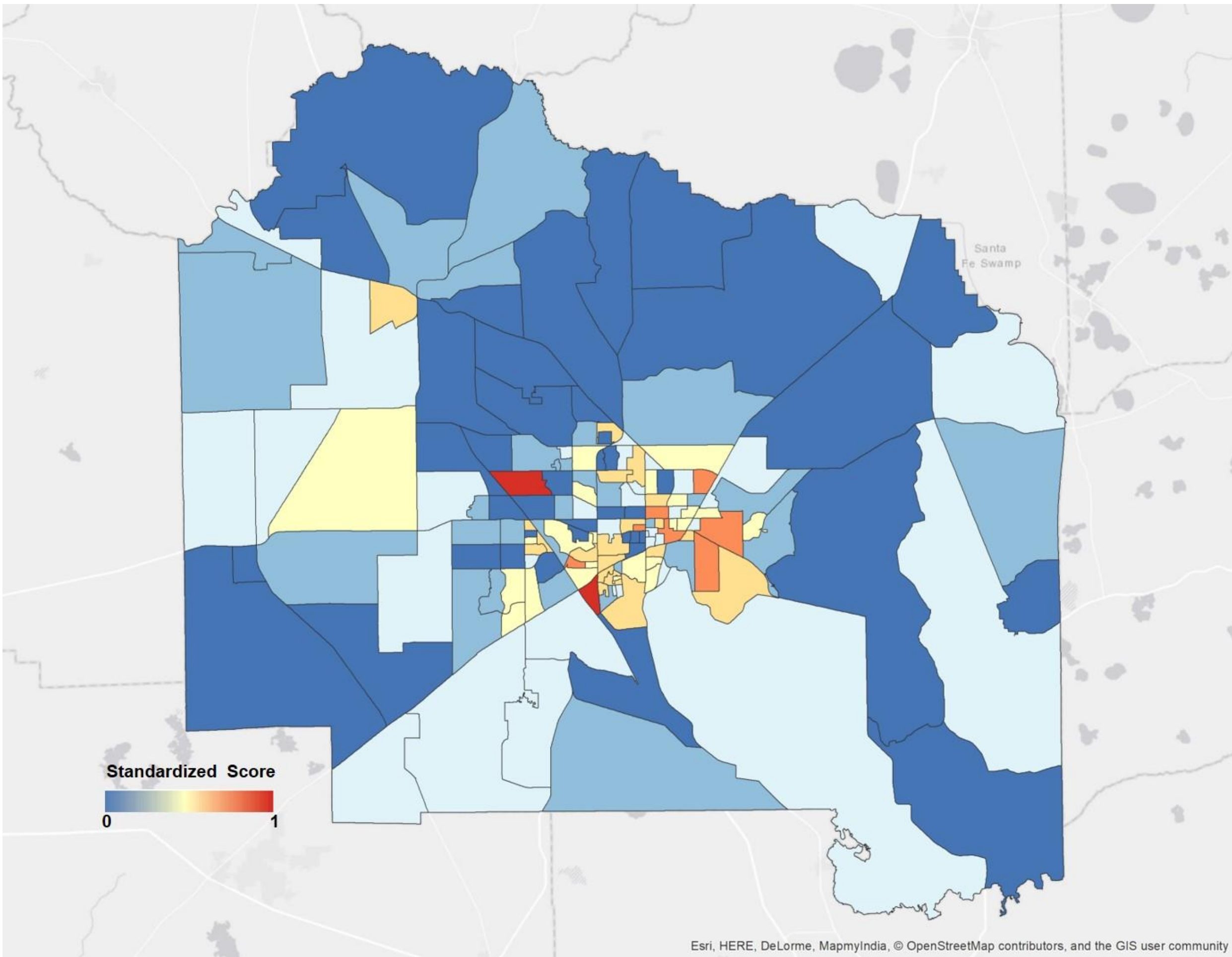


Figure 4-5. Demand Layer Example (Housing Units without a Vehicle)

- **Transportation Supply Model**

This section describes the supply model built as a sequence of individual modules and provides examples of the model outputs. The supply model generates the accessibility scores by calculating opportunities at the destination and the impedance between origin and destination within the service areas. Given the differences of inputs, outputs, and calculation method, there are three modules, one for each route type.

Service area module

Table 4-2 shows the input, the method, and the output of the service areas module, by route type.

Table 4-2. Service Areas Module

Route Type	Input	Method	Output
Fixed	Stops, Street Network	Creating walking shed from stops	Service Areas
Flexible	Routes or Pick-up/Drop-off Areas	pre-defined service areas (or creating polygon(s) using buffer from routes)	
door-to-door	Service Areas		

- **Fixed route**

  Using the stops and the street network, the module generates a walking catchment area. Typically, ¼ mile (about 400 meters) is recognized as an acceptable walking distance, but this distance could be changed by users' physical condition, e.g., 300 meters for older adults. Thus, the walking distance is set as a modifiable variable.

- **Flexible route**

  For this service, the service area boundaries are expected to be provided by the transportation service providers.

- **Door-to-door**

  Similar to flexible route service, the service area boundaries for door-to-door service are expected to be provided by the transportation service providers.

Opportunity module

Table 4-3 shows the parameters of the opportunities module. This module computes the opportunities at each destination for each route type.

Table 4-3. Opportunities Module

Route Type	Input	Output: O_j
Fixed	Destinations within Service Areas	Opportunity at destination j
Flexible		
door-to-door		

- **Fixed route**

  This module calculates the total number of opportunities at each stop.

- **Flexible route**

  This module computes the total number of opportunities at each census block group within the service area.

- **Door-to-door**

  Similarly, this module computes the total number of opportunities at each census block group within the service area.

Impedance module

Table 4-4 shows the parameters of the impedance module by route type.

Table 4-4. Impedance Module

Route Type	Input	Output: $f(C_{ij})$
Fixed	Stops, Routes	Impedance between Origin and Destination (= 1/distance)
Flexible	Origins and Destinations within Service Areas, Street Network	
Door-to-door		

- **Fixed route**

  This module measures the distance between stops and calculates the impedance as a function of inverse distance.

- **Flexible route and Door-to-door**

  Using network distance, it computes the impedance between origin and destination as a function of inverse distance.

Accessibility module

Based on the results from opportunities and impedance module, this module computes accessibility using a gravity model (Table 4-5).

Table 4-5. Accessibility Module

Route Type	Input	Method (Gravity Model)	Output: A_i
Fixed	Opportunities: O_j Impedance: $f(C_{ij})$	$A_i = \sum_j O_j f(C_{ij})$	Accessibility at point i
Flexible			
Door-to-door			

As explained earlier, the transportation supply model consists of four modules: service area, opportunities, impedance, and accessibility module. However, the actual model varies by route type. The supply model for fixed route service uses stops, street network, walking distance, routes, destinations, and census block group as parameters (Appendix A). The walking distance is set as a parameter that can be changed by the user. The output of this model is a standardized accessibility score ranging from 0 to 1, with zero indicating no accessibility and 1 representing maximum accessibility. The model for flexible route service uses service areas, street network, destinations, and census block group as parameters (Appendix B). The output of this model is a standardized accessibility score ranging from 0 to 1, with zero indicating no accessibility and 1 representing maximum accessibility. Similarly, the supply model for flexible route service also uses service areas, street network, destinations, and census block group as parameters (Appendix C). The output of this model is a standardized accessibility score ranging from 0 to 1, with zero indicating no accessibility and 1 representing maximum accessibility.

Outputs (Supply layers)

The values of the supply layer range from 0 to 1, with zero indicating no accessibility and 1 representing maximum accessibility. Figures 4-6, 4-7, and 4-8 show examples of the results produced by the transportation supply model.

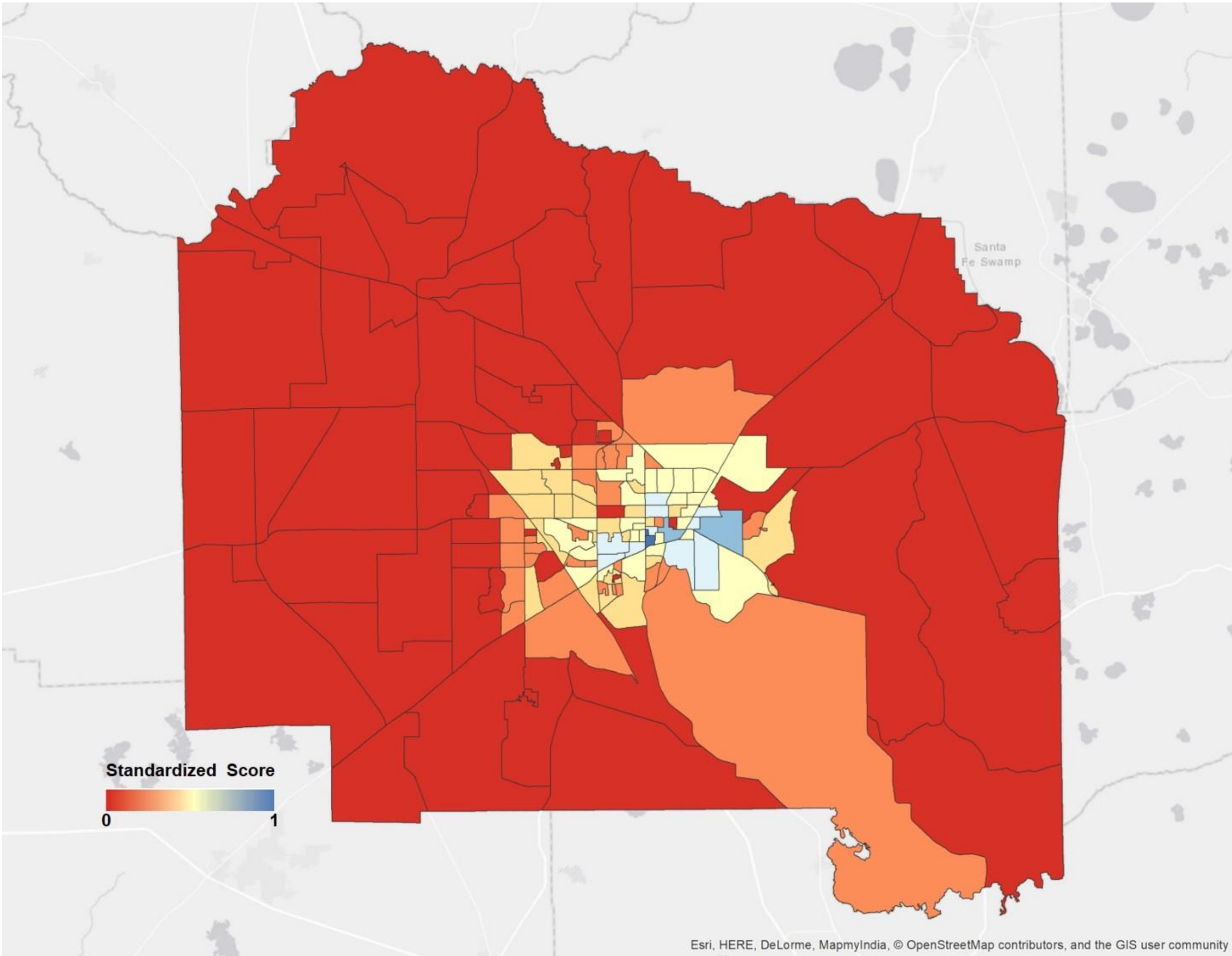


Figure 4-6. Supply Layer Example (Fixed Route)

Figure 4-6 shows an example of the supply layer produced by the fixed route module using RTS stops, routes, street network, destinations, and census block group as parameters.

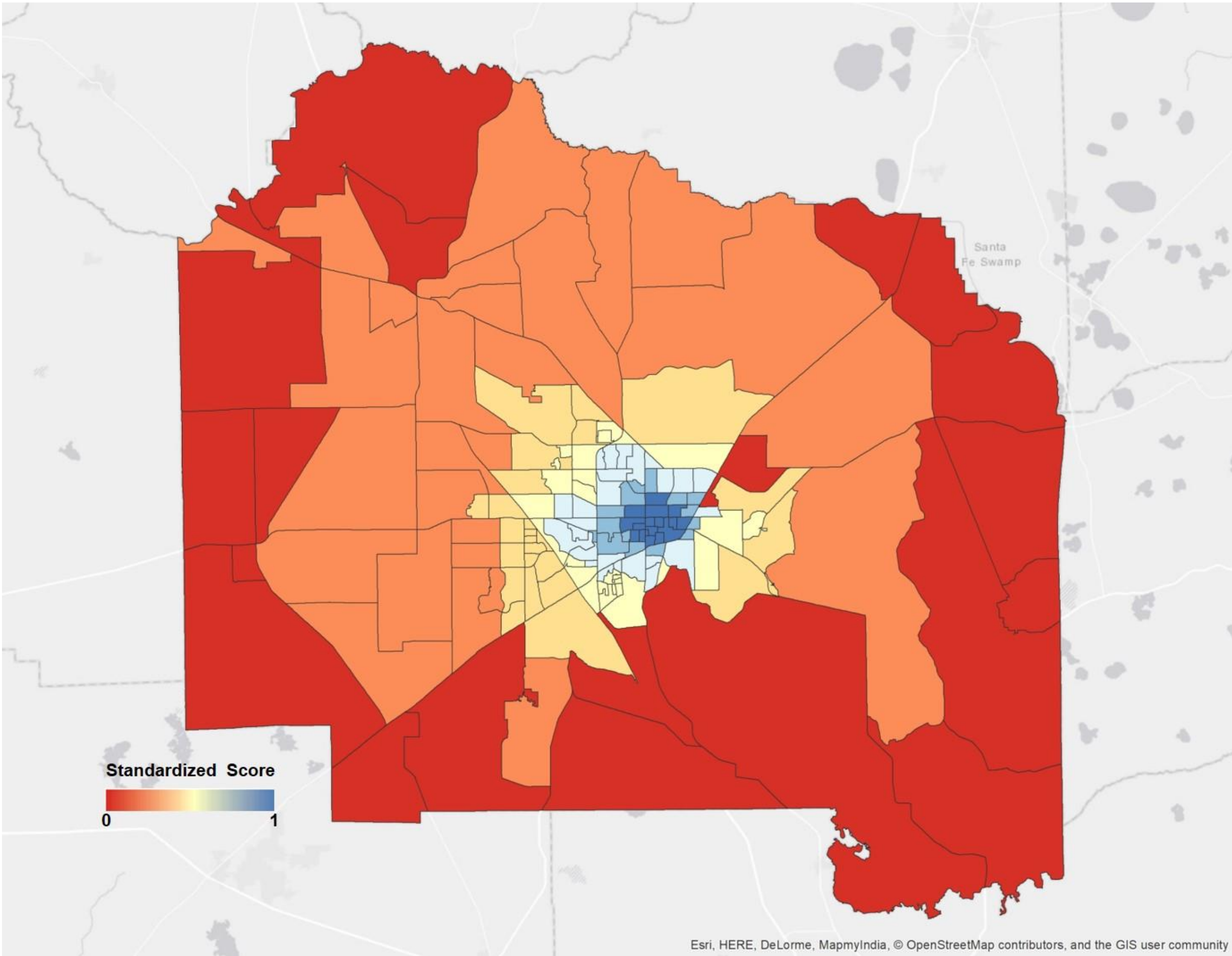


Figure 4-7. Supply Layer Example (Flexible Route)

Figure 4-7 shows an example of the supply layer produced by the flexible route module using service areas, street network, destinations, and census block group as parameters.

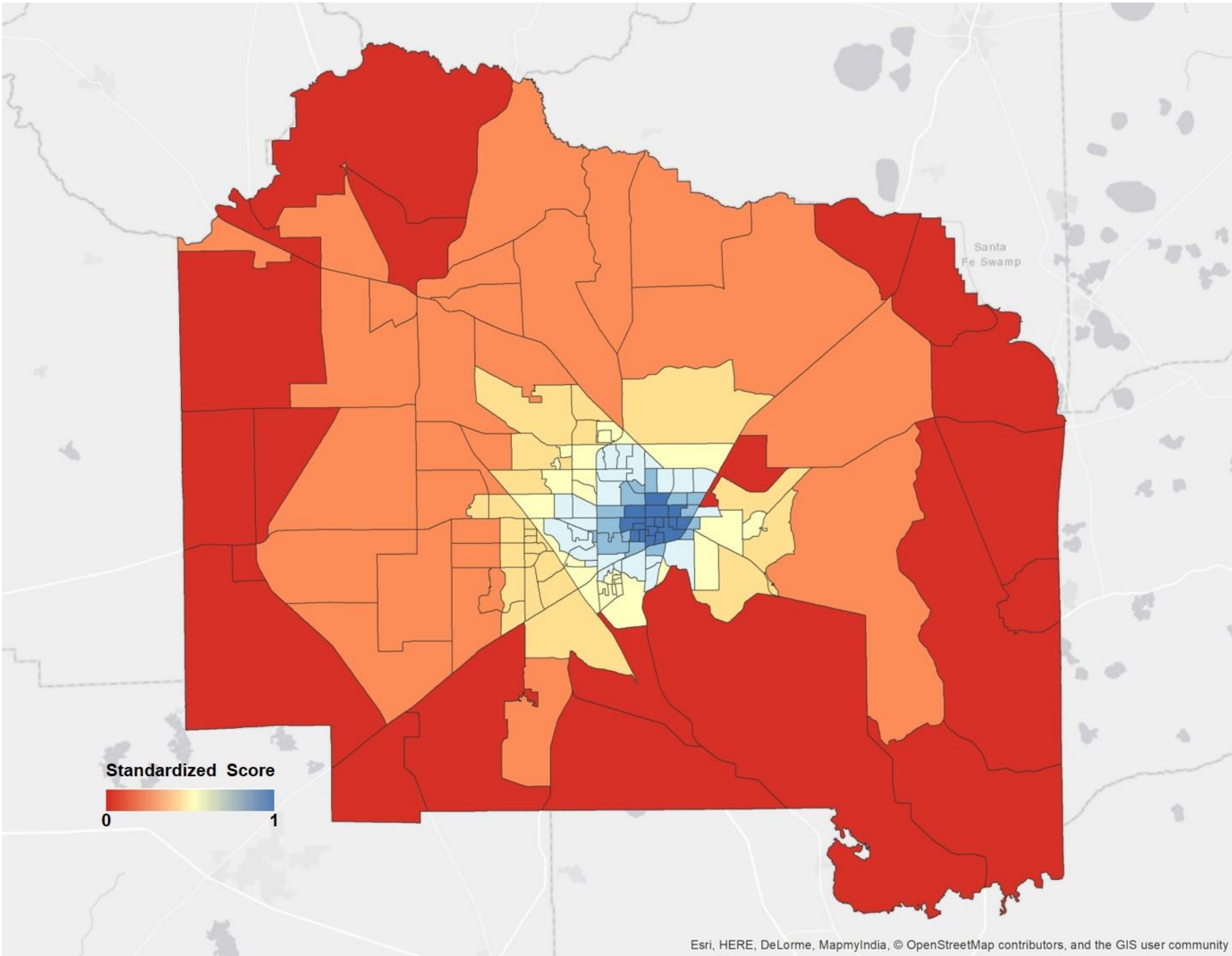


Figure 4-8. Supply Layer Example (Door-to-door)

Figure 4-8 shows an example of the supply layer produced by the door-to-door module using service areas, street network, destinations, and census block group as parameters.

- **Gap Analysis**

Categorize results

The gap analysis aims to determine spatial gaps between transportation supply and demand. For this analysis, we classified the demand and supply scores into seven categories: very low, low, medium low, medium, medium high, high, and very high (Curie, 2004; Curie, 2010; Bejleri, Noh, Gu, Steiner, & Winter, 2018). This categorization is performed by using the *natural breaks* classification method which groups the data in categories with similar values by exploiting the natural gaps in the data. That is, this method reduces the variance within classes and maximizes the variance between classes (Baz & Er, 2009; Jaramillo, Lizárraga, & Grindlay, 2012).

The additional categorization of layers could be beneficial because of following reasons: first, the categorization results could reflect the relativity of the selected study area. Although the numbers (i.e., standardized score of supply or demand) fall between 0 and 1, the numbers could represent different conditions. For example, assuming we select one census block group having the same supply score (0.5) from both Alachua County and Orange County, though the standardized score of supply is the same, it is difficult to say the accessibility of this census block group is the same. In other words, without considering other values, it is challenging to decide if the supply score shows lower accessibility or higher accessibility. This is because the value might represent lower accessibility for Orange County while Alachua County, it could represent relatively moderate accessibility. However, if we classify the values using natural breaks, it could help to group the scores with similar values. Thus, additional categorization could reflect the relativity of the selected study area; second, it is helpful to generate a supply-demand matrix to find the gap areas. Without simplified categories, it is difficult to generate the supply-demand matrix.

Figure 4-9 shows the classification results using a demand layer of older adults (Figure 4-3) as an example. The demand for each census block group is categorized as very low, low, medium low, medium, medium high, high, and very high.

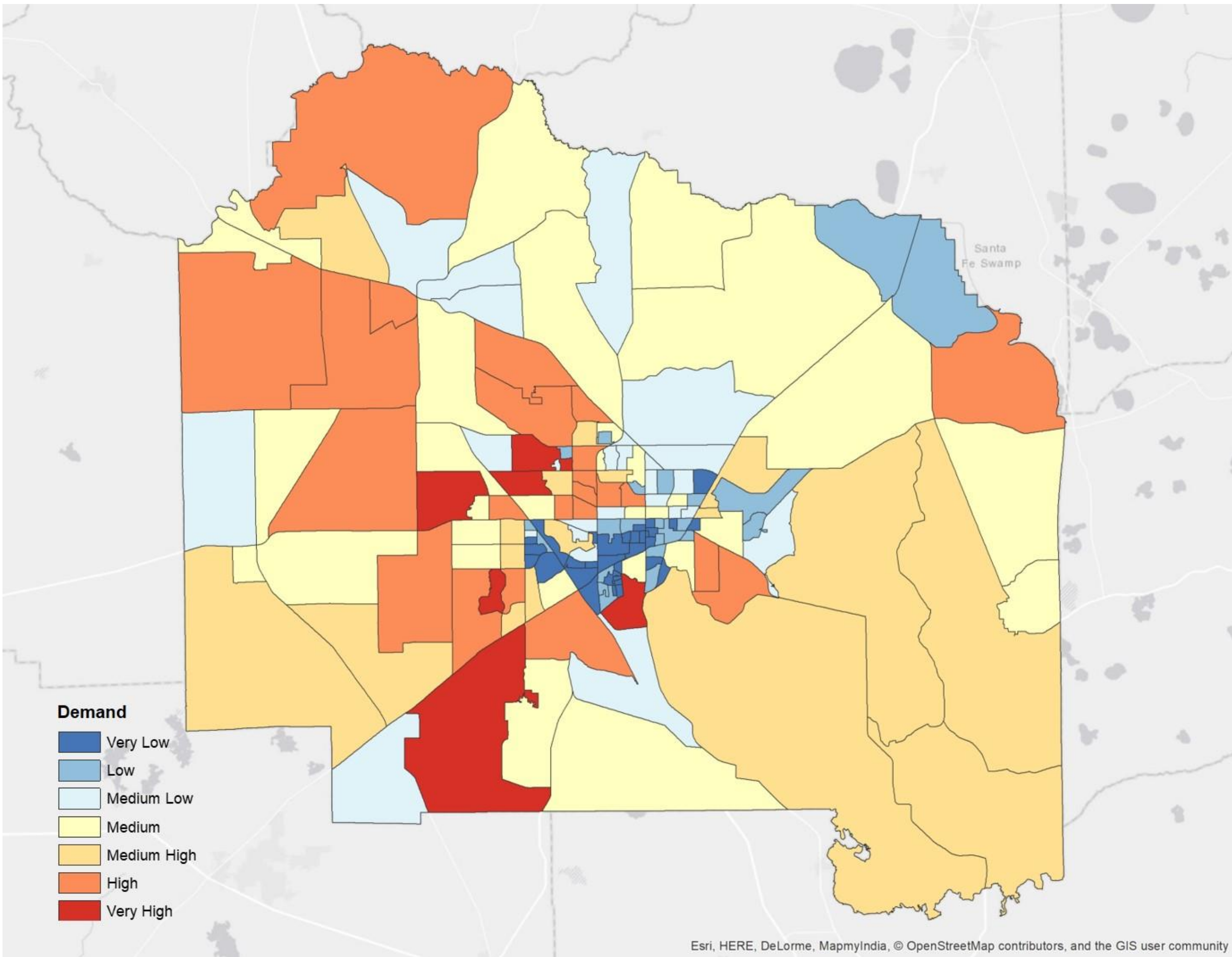


Figure 4-9. Categorized Demand Layer Example (Older Adults)

Figure 4-10 shows classification results using a supply layer for the door-to-door service (Figure 4-8) as an example. The demand for each census block group is categorized as very low, low, medium low, medium, medium high, high, and very high.

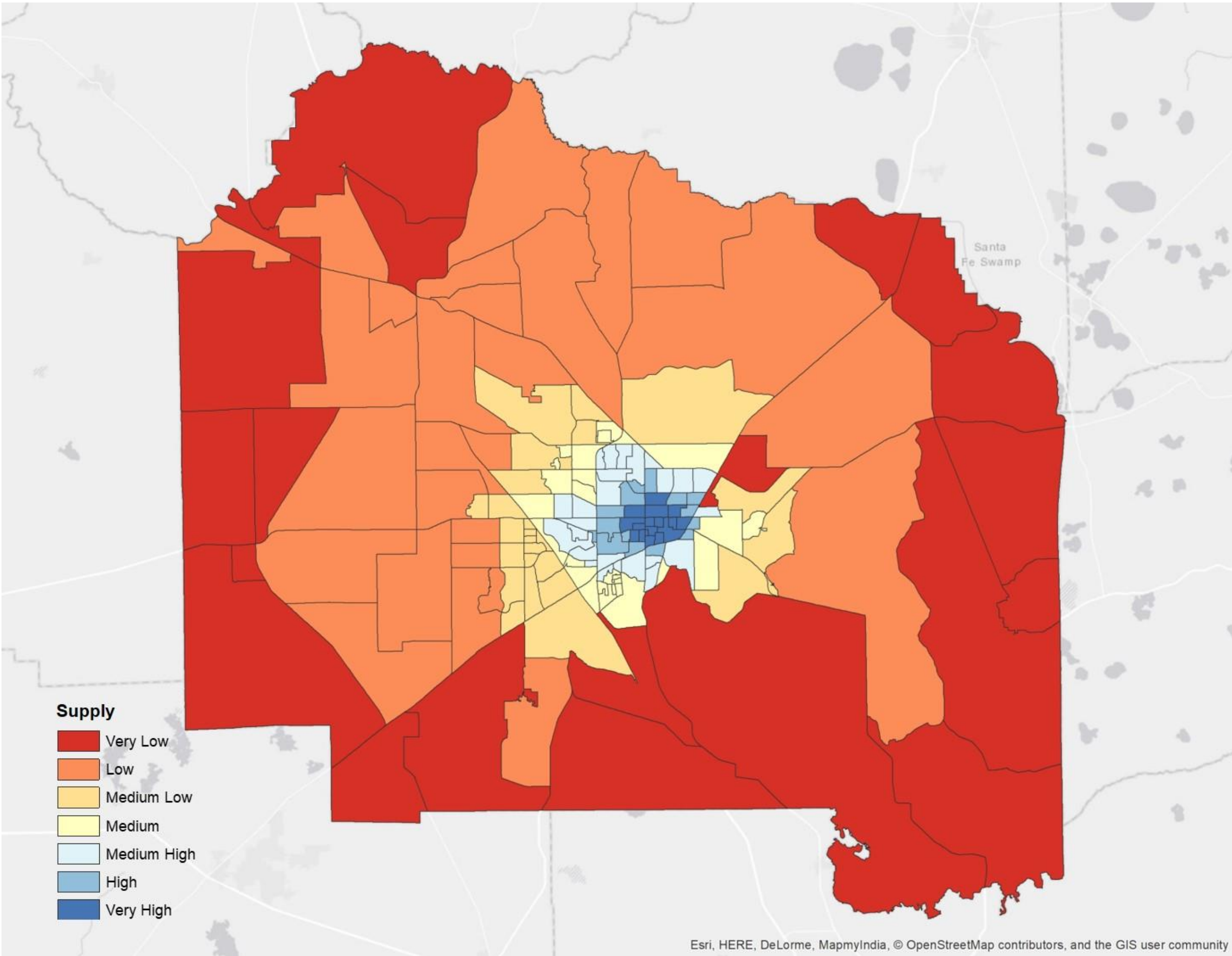


Figure 4-10. Categorized Supply Layer Example (Door-to-door)

Prioritize areas

To understand the association between the demand and supply, we created a demand-supply matrix, which shows a population impacted by each combination of the supply and demand categories. Table 4-6 illustrates the supply provided by the door-to-door service and the demand for it from the older adults. The matrix is useful to review both supply and demand as well as the target population volume. The most deficient areas, are those with 'very high or high' demand and 'very low or low' supply scores. Additional deficiencies or gaps can be identified by adding other combinations e.g. only very high demand and very low supply, or others.

Table 4-6. Supply-Demand Matrix Example (Door-to-door Service for Older Adults)

Demand \ Supply		Very Low	Low	Medium Low	Medium	Medium High	High	Very High	Grand Total
Very High	Older Adults	**632**	**1,578**	1,605	753				4,568
	block group(s)	**1**	**2**	2	1				6
High	Older Adults	**1,200**	**2,516**	2,257	1,622	1,360	500		9,455
	block group(s)	**3**	**6**	6	4	3	1		23
Medium High	Older Adults	1,363	731	1,300	246	742			4,382
	block group(s)	5	3	5	1	3			17
Medium	Older Adults	1,141	2,262	365	593	837	198	366	5,762
	block group(s)	6	12	2	3	4	1	2	30
Medium Low	Older Adults	497	481	328	380	877	337	199	3,099
	block group(s)	4	4	3	3	7	3	2	26
Low	Older Adults	150		115	352	147	313	342	1,419
	block group(s)	2		2	5	3	5	5	22
Very Low	Older Adults			64	97	109	58	61	389
	block group(s)			4	9	5	5	8	31
Grand Total	Older Adults	4,983	7,568	6,034	4,043	4,072	1,406	968	29,074
	block group(s)	21	27	24	26	25	15	17	155

Based on Table 4-6, we can see one census block group located in areas with ‘very low’ supply and ‘very high’ demand. This census block group has 632 older adults. In the second highest deficient category, there are three census block groups ranked as ‘very low’ in supply and ‘high’ in demand. They have 1,200 older adults. The bottom two deficient areas contain eight census block groups with ‘low’ supply but ‘very high’ and ‘high’ demand. They contain 4,103 older adults.

Identify gaps

Finally, by using the supply-demand matrix and by spatially comparing the demand and supply layers, we can identify the transportation service areas with higher demand and lower supply. Figure 4-11 illustrates door-to-door service gaps for older adults in Alachua County. Along with the supply-demand matrix, the map can pinpoint the gap areas that need the attention to improve the supply.

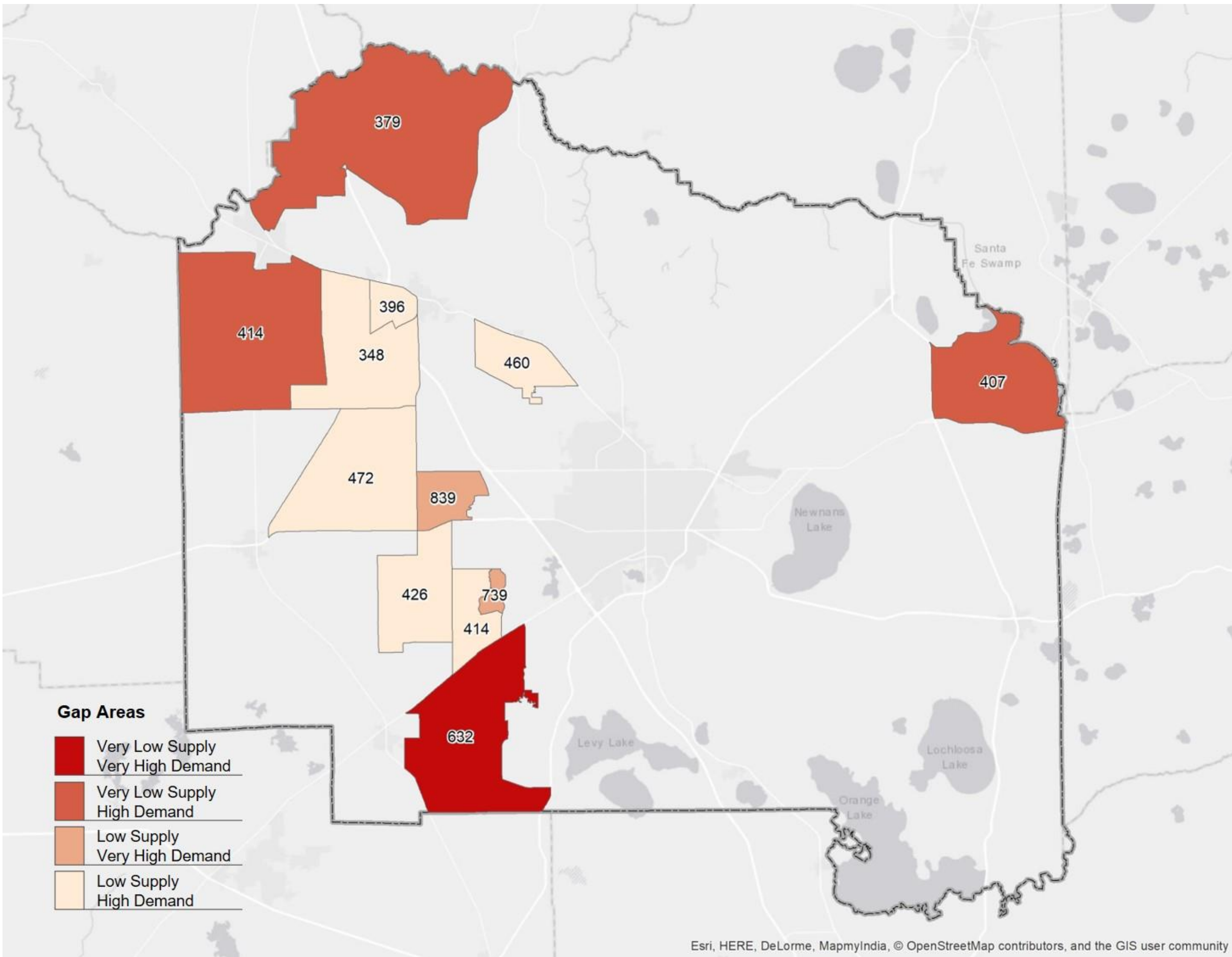


Figure 4-11. Door-to-door Service Gaps for Older Adults (Alachua Example)

4.3 **Method Application: Orange County**

Using the method described in the previous section, the team applied the models to Orange County. To test the model, the team established three different scenarios in which we combined certain users with selected service types: first, the service gaps of fixed route service for housing units without a vehicle; second, the service gaps of flexible route service for individuals with disabilities; and third, the gaps of the door-to-door service for older adults. In this test, the most deficient areas identified from the demand-supply matrix are those with 'very high or high' demand and 'very low or low' supply scores.

4.3.1 Gaps of Fixed Route Service for Housing Units without a Vehicle

- **Supply**

To create the fixed route supply layer, the model uses Lynx data (stops and routes), Orange County street network, destinations, and census block groups as input data. Figure 4-12 and Table 4-7 show the spatial distribution of transportation supply based on the fixed route service and populations impacted in the study area. 22.76% (6,216 housing units) of housing units without a vehicle in Orange County have poor accessibility (categories 'very low' and 'low').

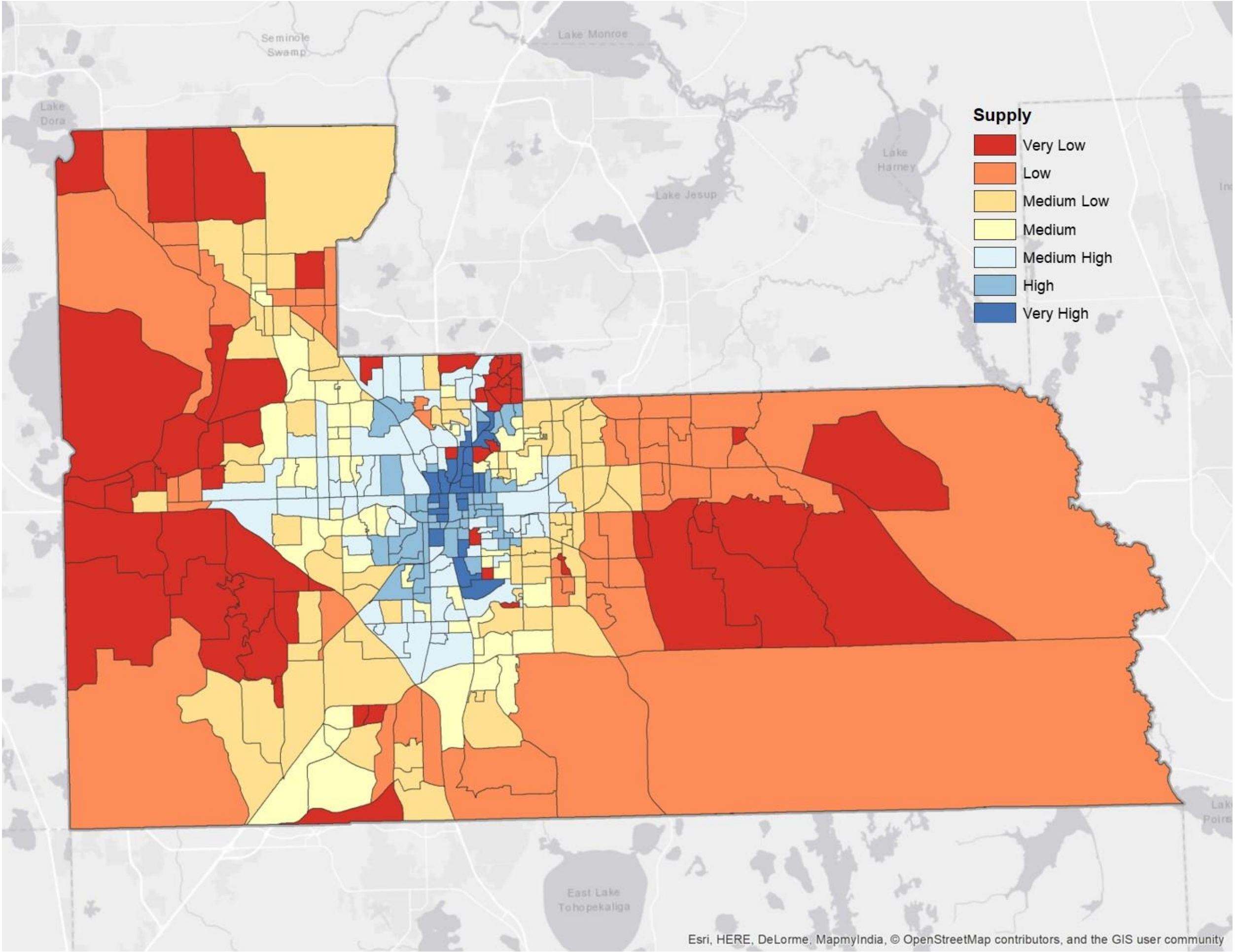


Figure 4-12. Supply Layer (Fixed Route: Lynx)

- **Demand**

Figure 4-13 and Table 4-7 show the spatial distribution of the transportation demand and the populations impacted. 28.10% (7,675 housing units) of housing units without a vehicle in Orange County have high transportation need (categories 'very high' and 'high').

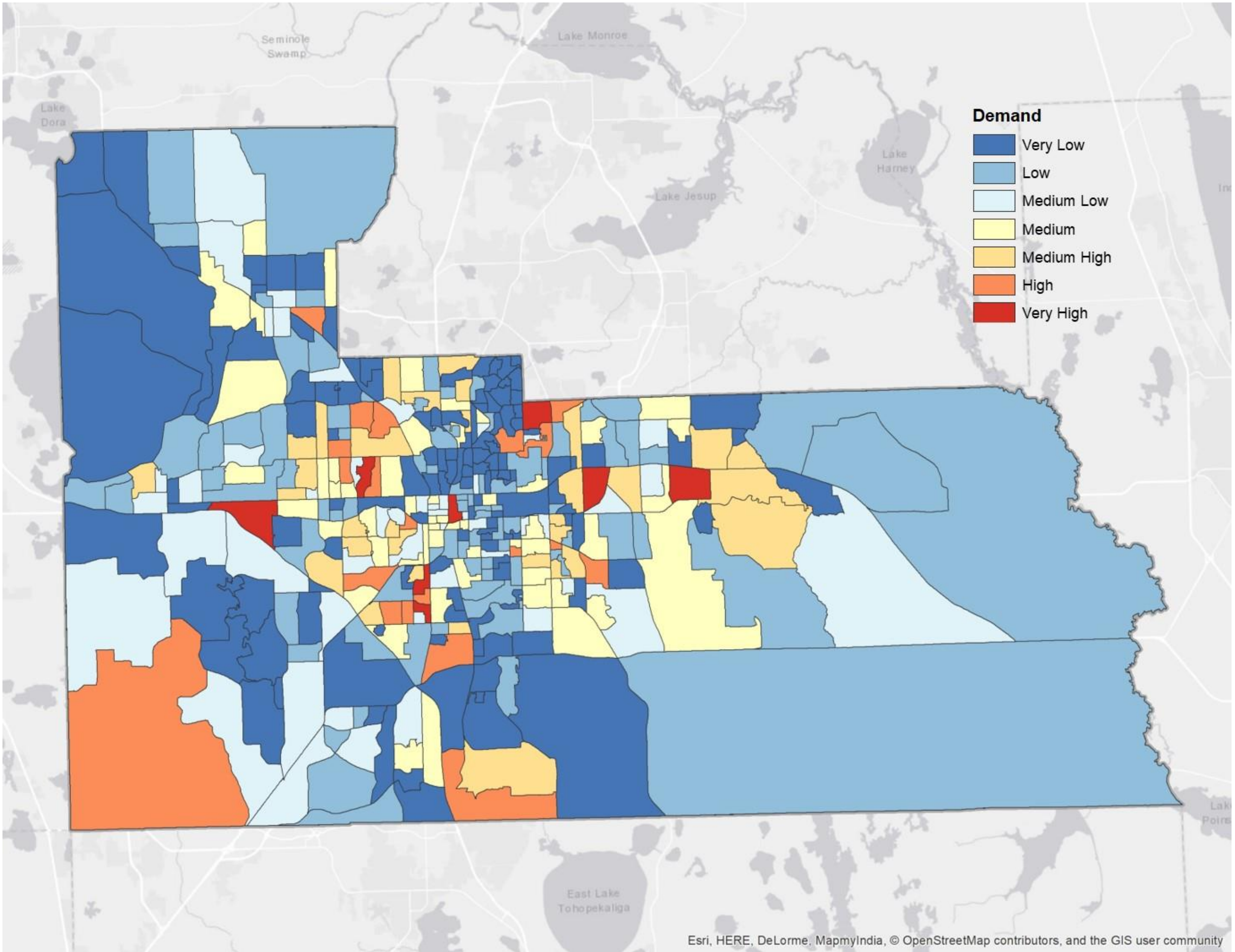


Figure 4-13. Demand Layer (Housing Units without a Vehicle)

- **Gaps**

Based on the matrix (Table 4-7), we can see one census block group located in areas with ‘low’ supply and ‘very high’ demand. This census block group has 301 housing units. Other deficient areas contain four census block groups with ‘low’ supply but ‘high’ demand. They include 975 housing units. Figure 4-14 illustrates the spatial distribution of the fixed route service gaps for housing units without a vehicle.

Table 4-7. Supply-Demand Matrix: Fixed Route for Housing Units without a Vehicle

Demand \ Supply		Very Low	Low	Medium Low	Medium	Medium High	High	Very High	Grand Total
Very High	Housing units		**301**	858	322	621	631		2,733
	block group(s)		**1**	2	1	2	2		8
High	Housing units		**975**	1,485	958	978	546		4,942
	block group(s)		**4**	6	4	4	2		20
Medium High	Housing units	502	853	1,413	584	1,853	337		5,542
	block group(s)	3	5	8	3	11	2		32
Medium	Housing units	237	1,090	1,221	375	1,516	1,421	513	6,373
	block group(s)	2	9	10	3	13	12	4	53
Medium Low	Housing units	426	603	809	510	509	476	313	3,646
	block group(s)	6	8	11	7	7	6	4	49
Low	Housing units	585	399	485	571	520	407	221	3,188
	block group(s)	16	10	12	15	13	11	7	84
Very Low	Housing units	139	106	211	161	140	76	50	883
	block group(s)	30	13	24	20	22	11	9	129
Grand Total	Housing units	1,889	4,327	6,482	3,481	6,137	3,894	1,097	27,307
	block group(s)	57	50	73	53	72	46	24	375

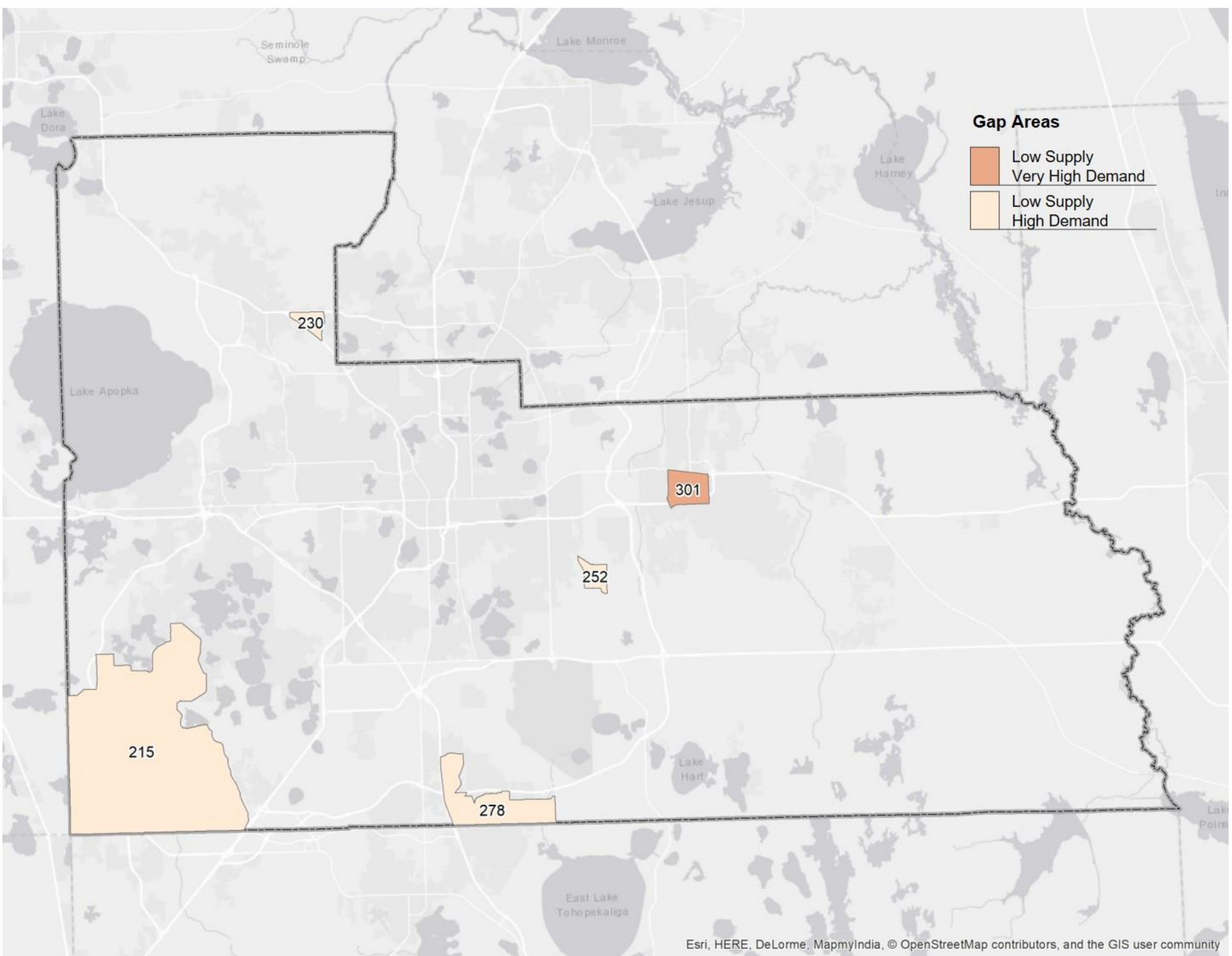


Figure 4-14. Fixed Route Service Gaps for Housing Units without a Vehicle

4.3.2 Gaps of Flexible Route Service for Individuals with Disabilities

- **Supply**

To create the flexible route supply layer, the model used Interplex Transportation for the Orlando service area, the Orange County street network, destinations, and census block groups as input data. Figure 4-15 and Table 4-8 show the spatial distribution of transportation supply for the flexible route service and populations impacted in the study area. 39.92% (24,511 people) of individuals with disabilities in Orange County have poor accessibility (categories 'very low' and 'low').

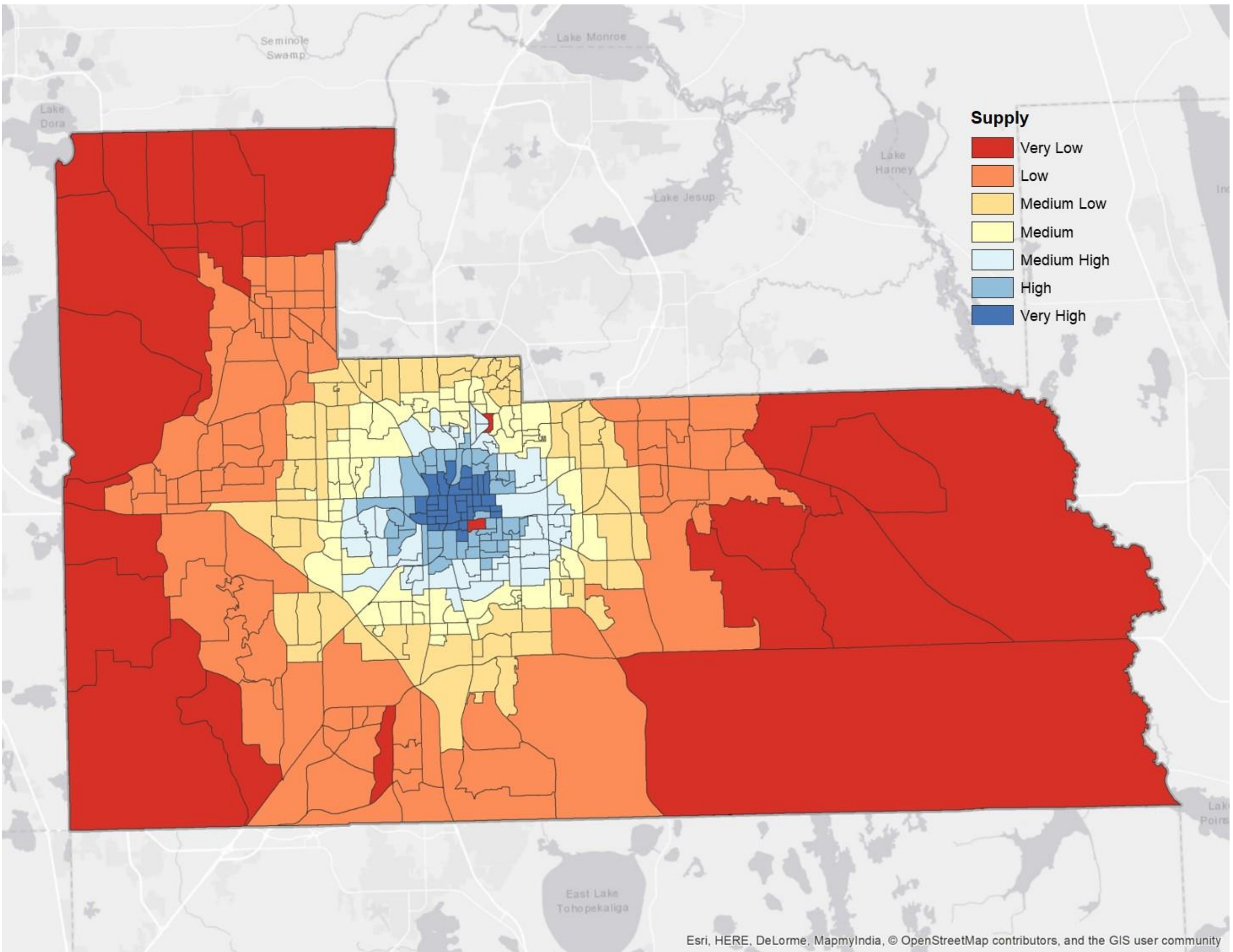


Figure 4-15. Supply Layer (Flexible Route: Interplex Transportation)

- **Demand**

Figure 4-16 and Table 4-8 show the spatial distribution of the transportation demand and populations impacted. 18.94% (11,630 people) of individuals with disabilities in Orange County have high transportation need (categories 'very high' and 'high').

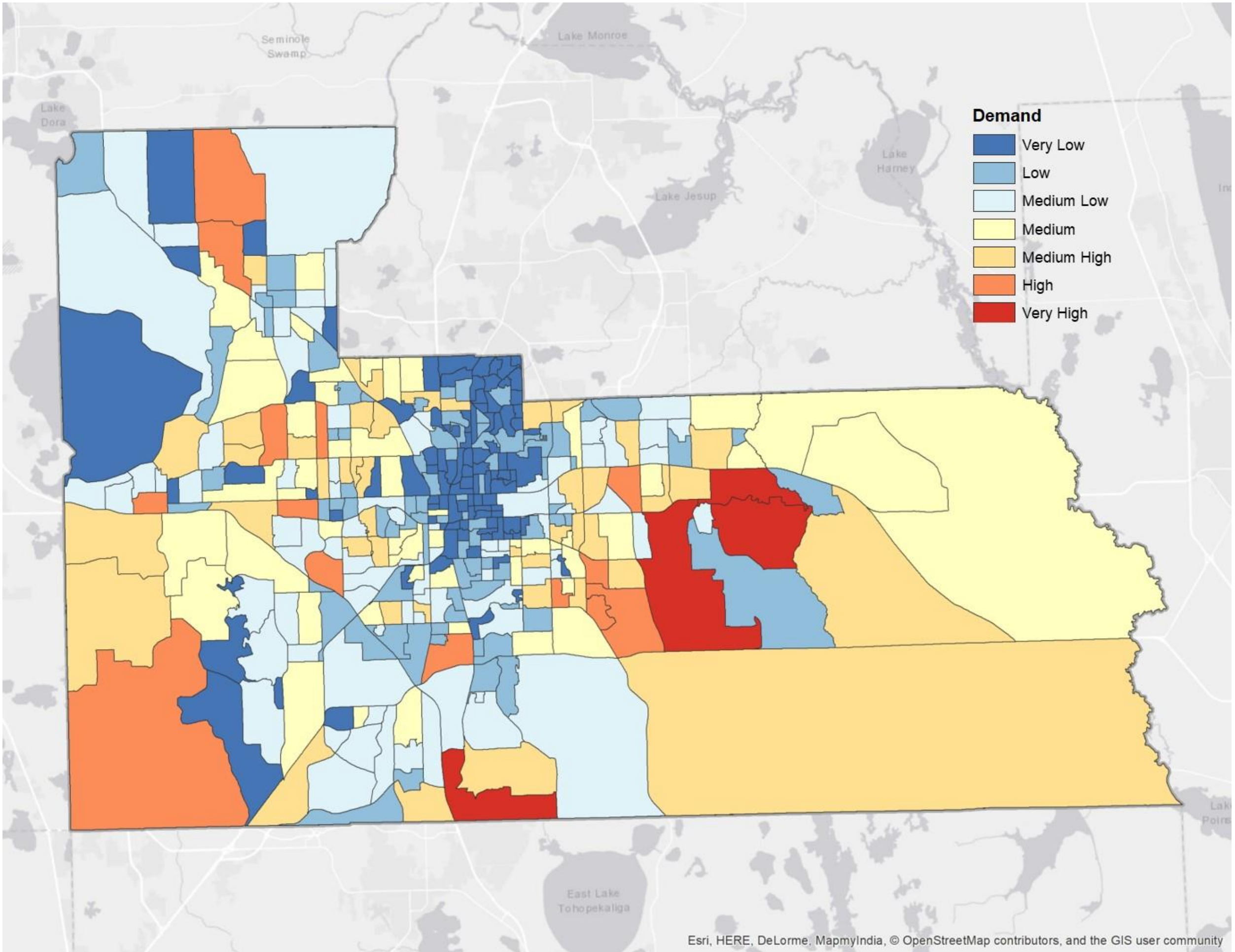


Figure 4-16. Demand Layer (Individuals with Disabilities)

- **Gaps**

Based on the matrix (Table 4-8), we can see one census block group located in areas with 'very low' supply and 'very high' demand. This census block group has 902 individuals with disabilities. In the second highest deficient category, there are three census block groups ranked as 'very low' in supply and 'high' in demand. They have 1,635 individuals with disabilities. The bottom two deficient areas contain eight census block groups with 'low' supply but 'very high' and 'high' demand. They contain 4,455 individuals with disabilities. Figure 4-17 illustrates the spatial distribution of flexible route service gaps for individuals with disabilities.

Table 4-8. Supply-Demand Matrix: Flexible Route for Individuals with Disabilities

Demand \ Supply		Very Low	Low	Medium Low	Medium	Medium High	High	Very High	Grand Total
Very High	Disabilities	**902**	**2,767**						3,669
	block group(s)	**1**	**3**						4
High	Disabilities	**1,635**	**1,688**	3,492	1,146				7,961
	block group(s)	**3**	**3**	6	2				14
Medium High	Disabilities	1,504	4,114	2,858	5,114	2,195			15,785
	block group(s)	4	11	8	14	6			43
Medium	Disabilities	464	3,945	3,296	1,548	2,066	438	219	11,976
	block group(s)	2	16	13	6	9	2	1	49
Medium Low	Disabilities	1,000	4,662	2,123	2,240	1,828	869	171	12,893
	block group(s)	6	29	14	14	12	6	1	82
Low	Disabilities	309	1,185	1,191	1,514	1,384	750	500	6,833
	block group(s)	4	13	15	18	17	10	7	84
Very Low	Disabilities	159	177	221	347	222	533	619	2,278
	block group(s)	6	8	11	16	9	25	24	99
Grand Total	Disabilities	5,973	18,538	13,181	11,909	7,695	2,590	1,509	61,395
	block group(s)	26	83	67	70	53	43	33	375

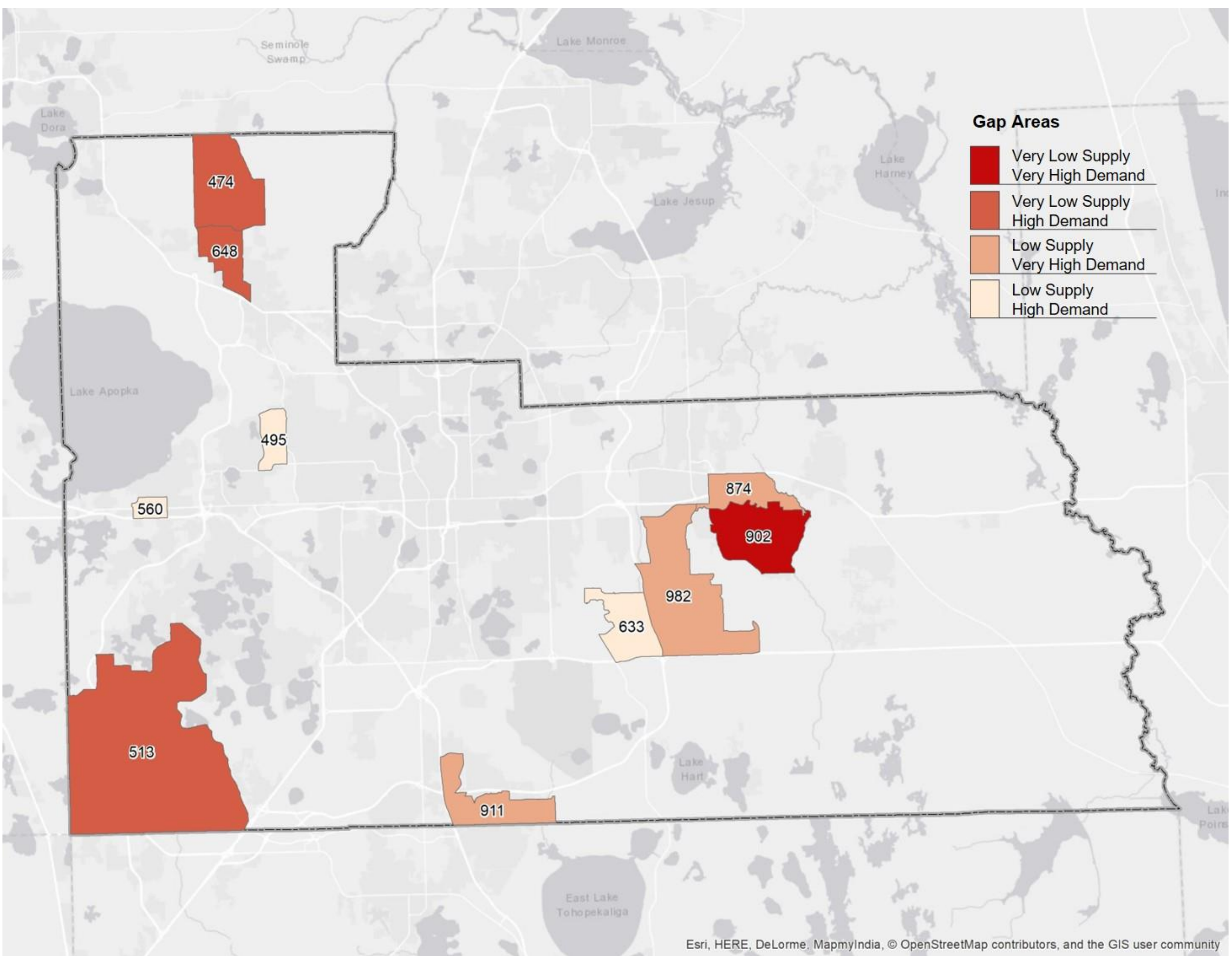


Figure 4-17. Flexible Route Service Gaps for Individuals with Disabilities

4.3.3 Gaps of Door-to-door Service for Older Adults

- **Supply**

To create the door-to-door supply layer, the model uses Diamond cab company (Service area: Orange), the Orange County street network, destinations, and census block groups as input data. Figure 4-18 and Table 4-9 show the spatial distribution of transportation supply (Door-to-door) and populations impacted in the study area. 26.93% (33,007 people) of older adults in Orange County have poor accessibility (categories 'very low' and 'low').

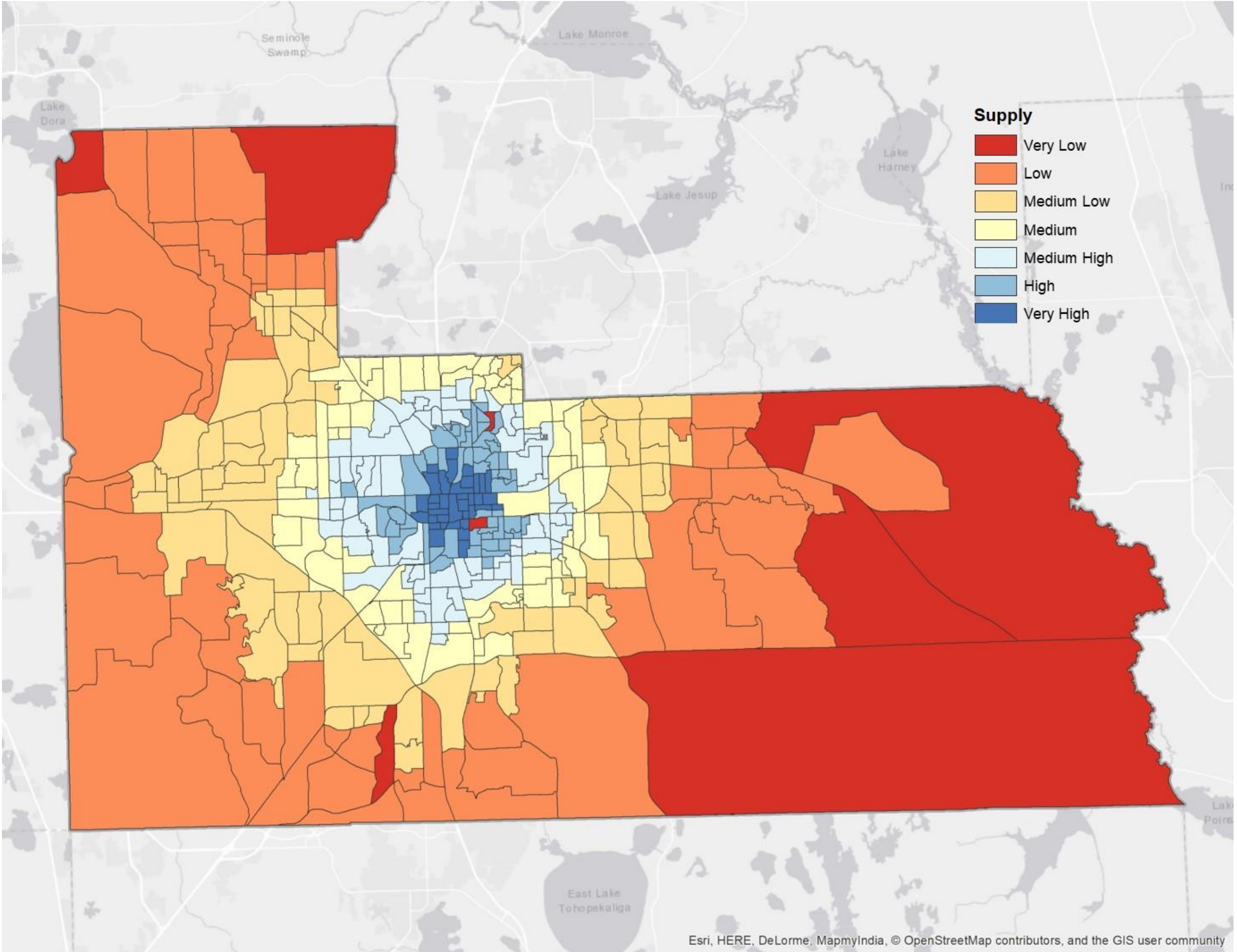


Figure 4-18. Supply Layer (Door-to-door Service: Diamond Cab Company)

- **Demand**

Figure 4-19 and Table 4-9 show the spatial distribution of transportation demand and populations impacted. 29.68% (36,375 people) of older adults in Orange County have high transportation need (categories 'very high' and 'high').

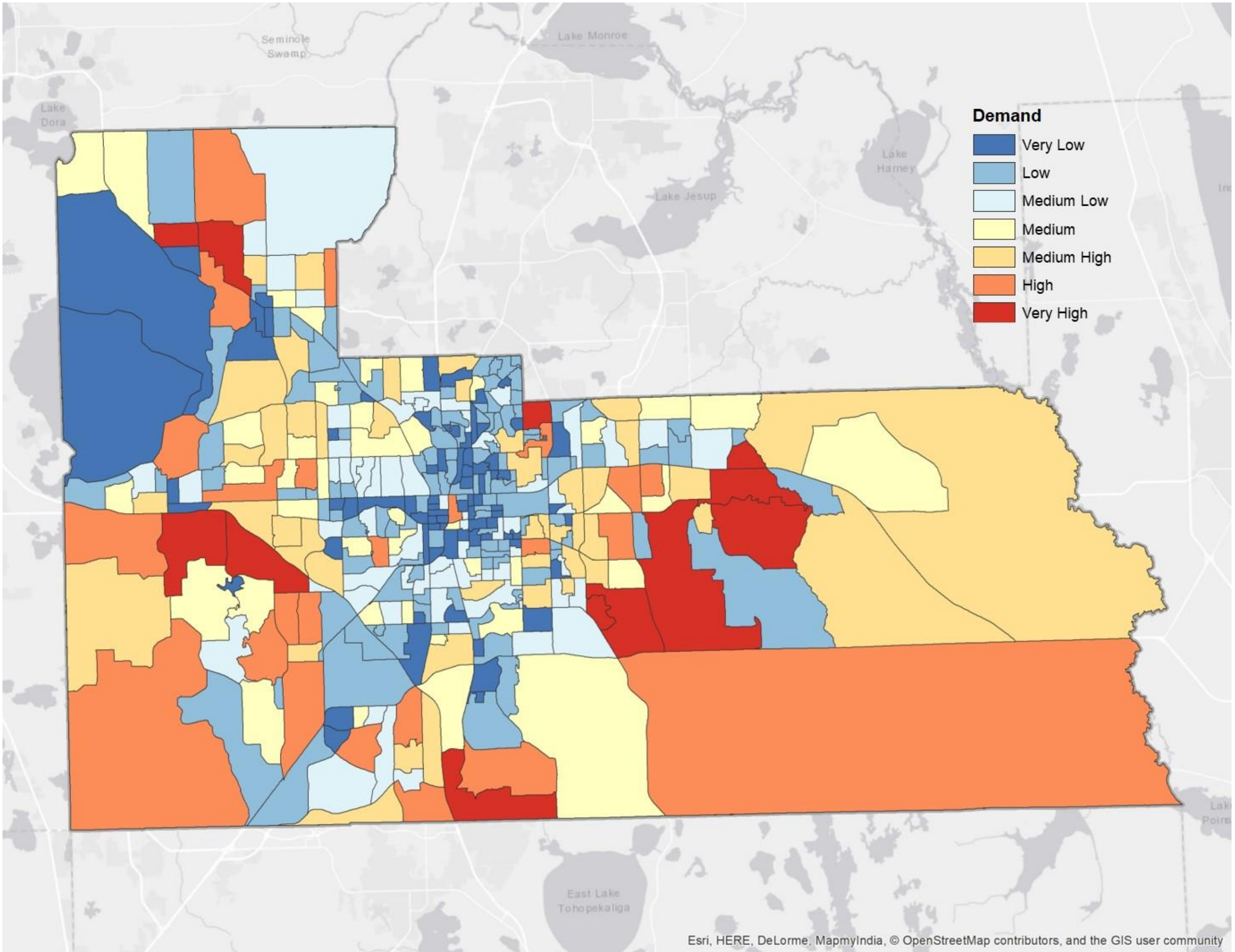


Figure 4-19. Demand Layer (Older Adults)

- **Gaps**

Based on the matrix (Table 4-9), we can see one census block group located in areas with 'very low' supply and 'high' demand. This census block group has 928 older adults. The other deficient areas contain 17 census block groups with 'low' supply but 'very high' and 'high' demand. They comprise 18,995 older adults. Figure 4-20 illustrates the spatial distribution of flexible route service gaps for individuals with disabilities.

Table 4-9. Supply-Demand Matrix: Door-to-door for Older Adults

Demand \ Supply		Very Low	Low	Medium Low	Medium	Medium High	High	Very High	Grand Total
Very High	Older Adults		**10,978**	3,296	1,268				15,542
	block group(s)		**8**	3	1				12
High	Older Adults	**928**	**8,017**	7,616	1,041	2,486		745	20,833
	block group(s)	**1**	**9**	9	1	3		1	24
Medium High	Older Adults	1,346	3,871	8,063	8,272	4,626			26,178
	block group(s)	2	7	13	14	8			44
Medium	Older Adults	373	2,880	6,104	4,516	2,589	759	396	17,617
	block group(s)	1	7	14	10	6	2	1	41
Medium Low	Older Adults	546	1,748	2,628	2,987	7,579	1,853	1,043	18,384
	block group(s)	2	6	9	10	25	6	4	62
Low	Older Adults	138	1,804	3,150	4,112	3,809	3,752	2,124	18,889
	block group(s)	1	11	19	25	24	24	12	116
Very Low	Older Adults	38	340	714	722	887	1,447	947	5,095
	block group(s)	1	5	10	10	10	22	18	76
Grand Total	Older Adults	3,369	29,638	31,571	22,918	21,976	7,811	5,255	122,538
	block group(s)	8	53	77	71	76	54	36	375

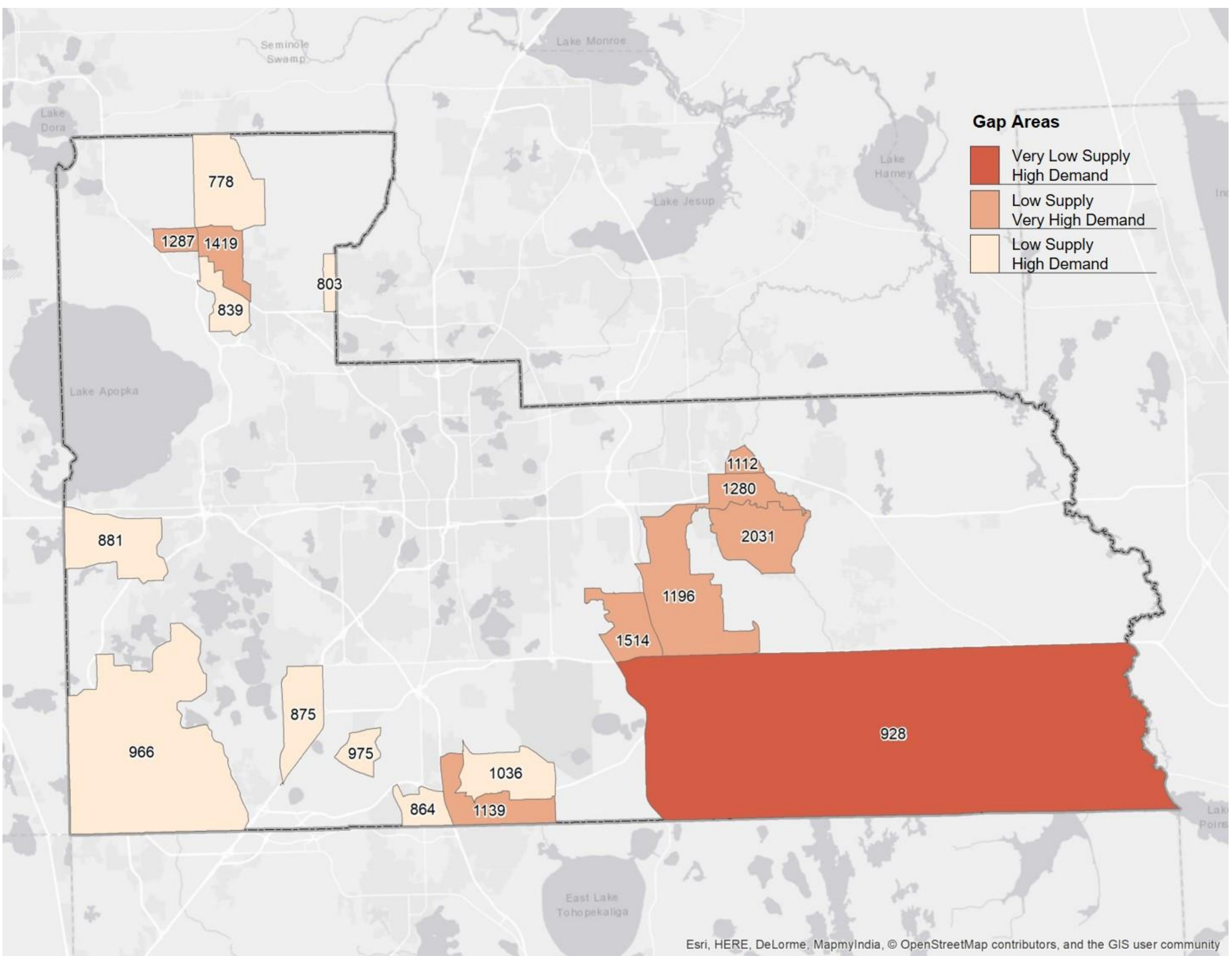


Figure 4-20. Door-to-door Service Gaps for Older Adults

5. CUSTOMIZATION OF THE GEOSPATIAL MODEL VARIABLES AND ANALYSIS EXTENTS

In chapter 4, we developed the methodology for identifying geographic areas and respective vulnerable populations that are not adequately provided with alternative transportation options. In this chapter, we look at customizing the variables of the model to allow the necessary flexibility to run the model for specific needs. Variables include vulnerable populations, user types that need alternative transportation, and the geographic area of analysis. For example, the model can be set up to find service gaps for older adults (a user type) in any given county (a geographic area), or it can be set up to find services gaps, considering door-to-door service for a FDOT district.

Based on the methodology developed in chapter 4, this chapter presents the development of the user interface to provide flexibility for users of the model. The user interfaces are developed by following the supply and demand modeling approach.

On the demand side, the interface allows for selection of target populations—older adults, individuals with disabilities, or people who do not own an automobile. Transportation supply is measured by calculating the transportation accessibility. We add the geographic extent, as a required input of the model to provide the users of the model the flexibility to analyze different regions for various purposes.

5.1 Customization Framework

Figure 5-1 describes the conceptual process and inputs to identify spatial gaps. As a first step, the model selects analysis extent, such as county, MPO, district, or another geographic extent. Next comes the selection of the eligible users, which determines the proper demographic profile of populations as well as the relevant transportation service providers. These first two steps are the parts that need to be customized to provide the flexibility for the needs of explicit users or specific geographic areas.

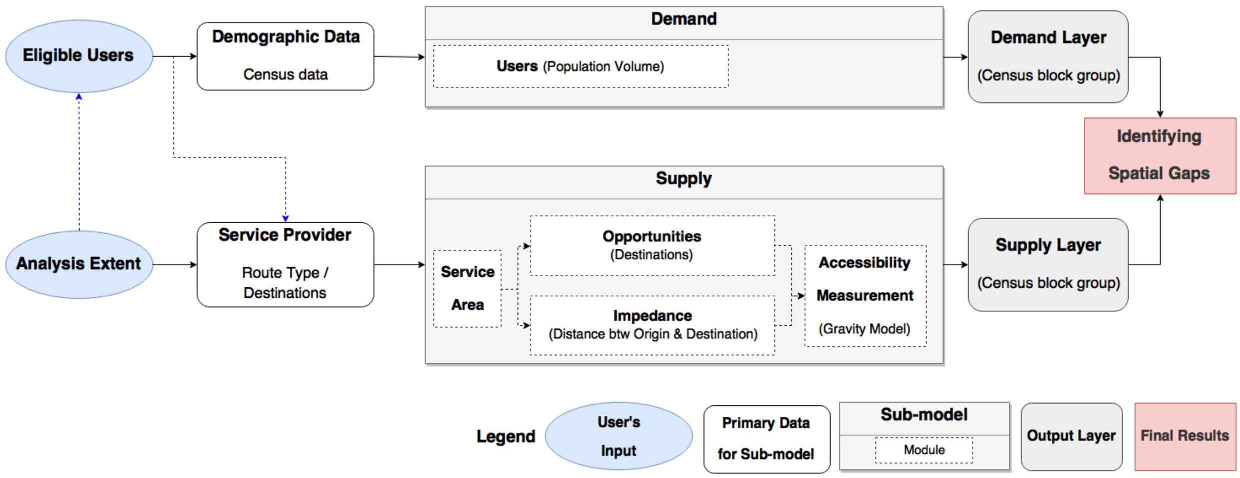


Figure 5-1. User Inputs and Process to Detect Service Gaps

Once the users and geographic extents are selected, the supply model executes several modules including service areas, opportunities, impedance, and accessibility measurement module. The result is a single index that represents transportation supply based on the selected transportation service providers. The demand model computes the needs of the users by calculating population volume of the users. Based on supply and demand, the final step of the model determines service gaps.

5.2 **Customizing the Geospatial Model**

5.2.1 The Demand Model

- **The User Interface of the Demand Model**

Figure 5-2 illustrates how the demand model selects eligible users and the related demographic data. Eligible user categories include older adults, individuals with disabilities, and housing unit without a vehicle. Other inputs include the demographic data and location to store the resulting output later.

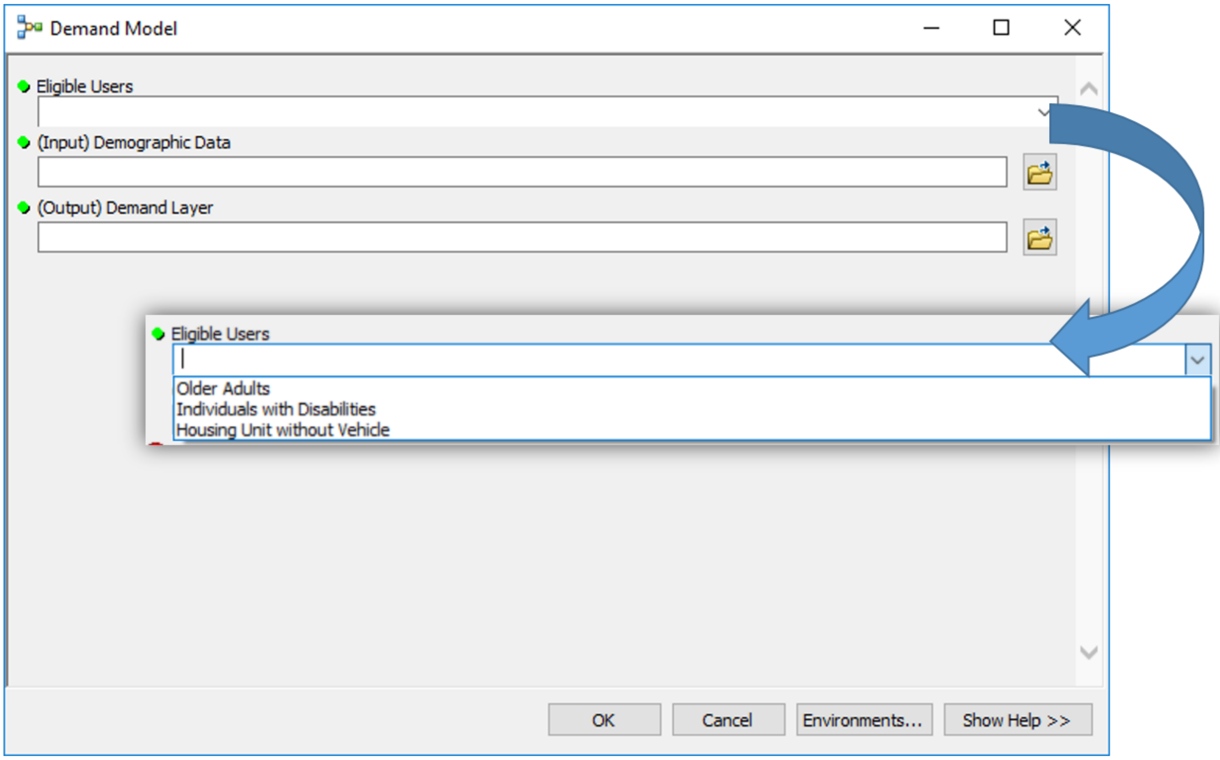


Figure 5-2. Demand Model Interface

The output values consist of a standardized score on a scale of 0 to 1 with zero indicating no transportation needs and 1 representing the highest transportation needs.

Figure 5-3 shows an example of the demand model for older adults, using Orange County census data as the demographic layer.

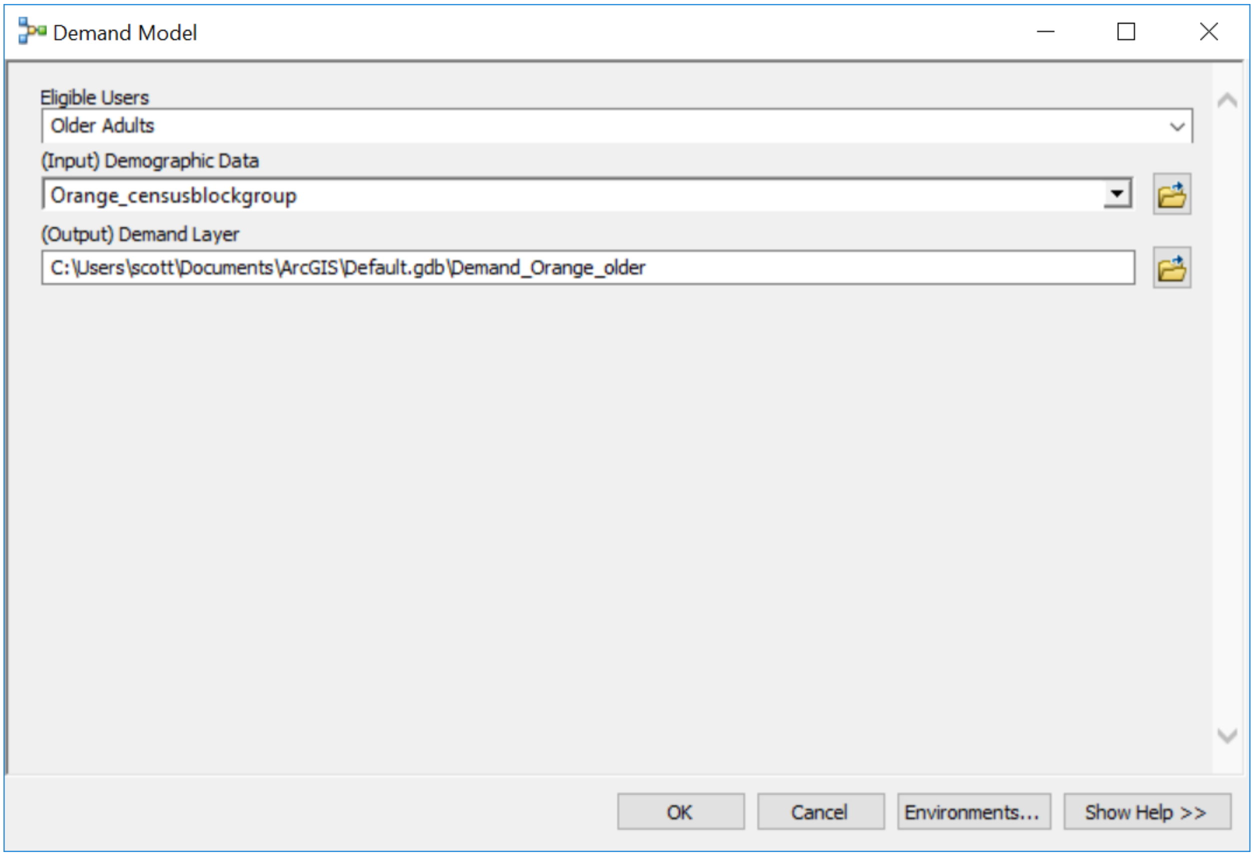


Figure 5-3. Running the Demand Model (Example: Older Adults in Orange County)

Figure 5-4 shows the results of execution of the example in Figure 5-3. The demand for older adults is standardized on a scale of 0 to 1 with zero indicating no transportation needs and 1 representing highest transportation needs.

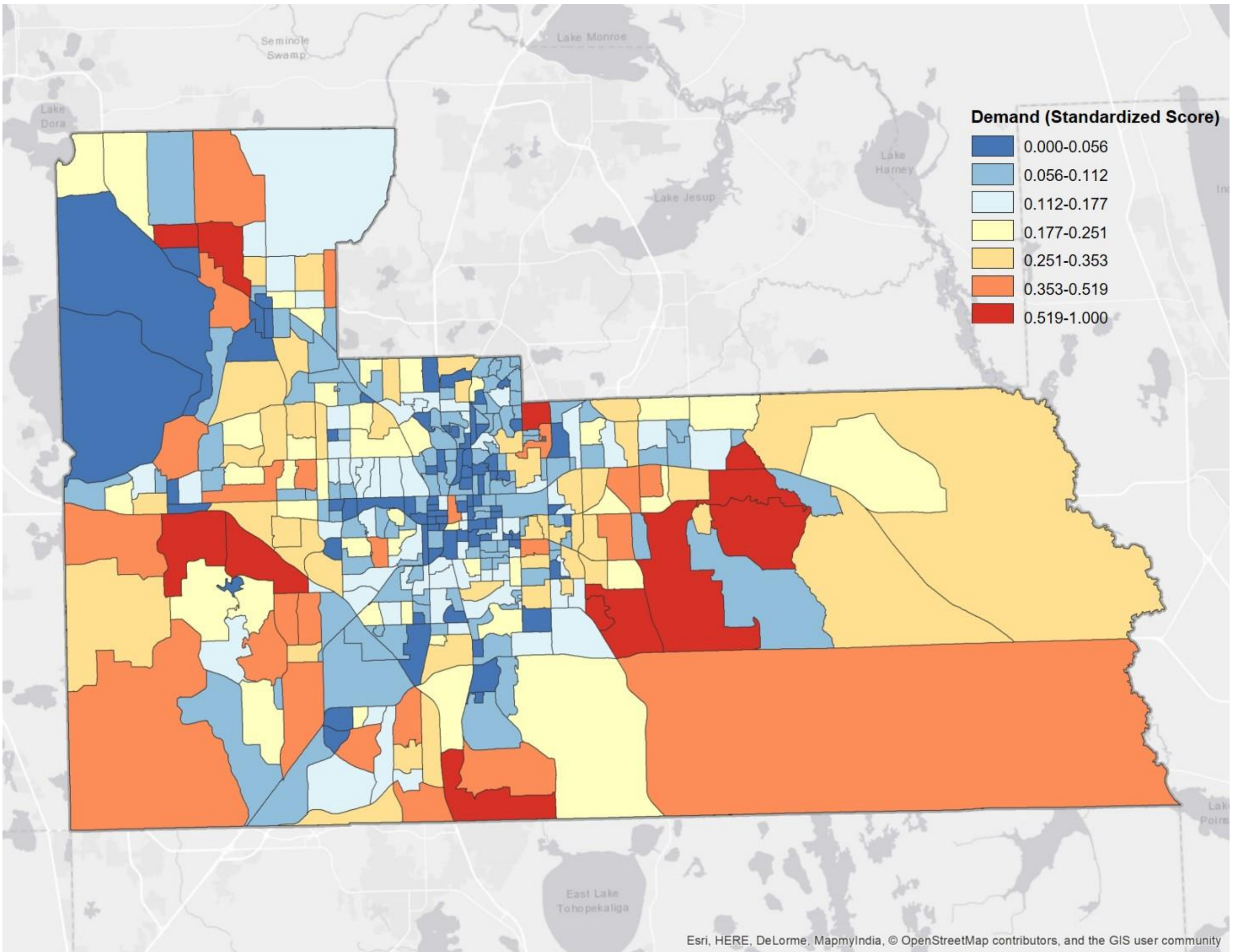


Figure 5-4. Demand Layer (Example: Older Adults in Orange County)

5.2.2 Supply Model

The supply model generates the standardized accessibility scores by calculating opportunities at the destination and the impedance between origin and destination within the service areas. Given the variation of inputs, outputs, and calculation methods, there are three modules, one for each route type.

- **Customization Options for the Fixed Route Model**

Based on the model developed in chapter 4 and Appendix A, Figure 5-5 illustrates the user interface to create the supply layer for a fixed route. Inputs include location of the model workspace, analysis extent, bus stops and the street network data. Typically, ¼ mile (about 400 meters) is recognized as an acceptable walking distance, but this distance could be changed by users' physical condition. Thus, the walking distance is set as a modifiable variable. Also, to calculate opportunities and impedance, this model requires destination data and service provider route information. Destinations can be specified by category if desired e.g. educational, medical, non-medical, or work. All destinations will be used if no category is specified. The last step is to name the supply layer. The output of this model is a standardized accessibility score ranging from 0 to 1, with zero indicating no accessibility and 1 representing maximum accessibility.

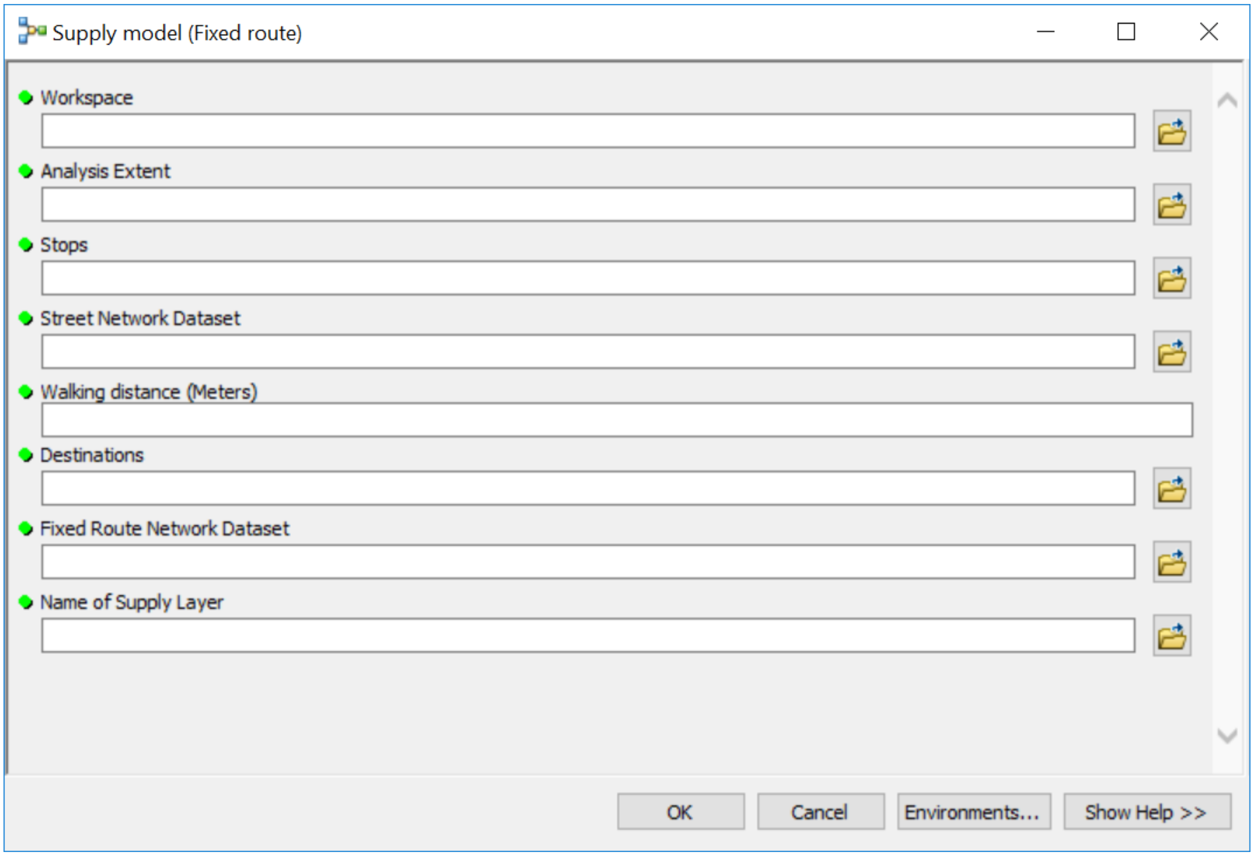


Figure 5-5. Supply Model Interface: Fixed Route

Figure 5-6 shows an example. Specifically, “Analysis Extent”, “Walking distance (Meters)”, and “Destinations” can be customized. In this example, we utilize Orange County’s census block group data for the analysis extent; second, we set 300 meters as the walking distance; and last, we included all destinations. The rest of the input data was prepared prior to executing the model.

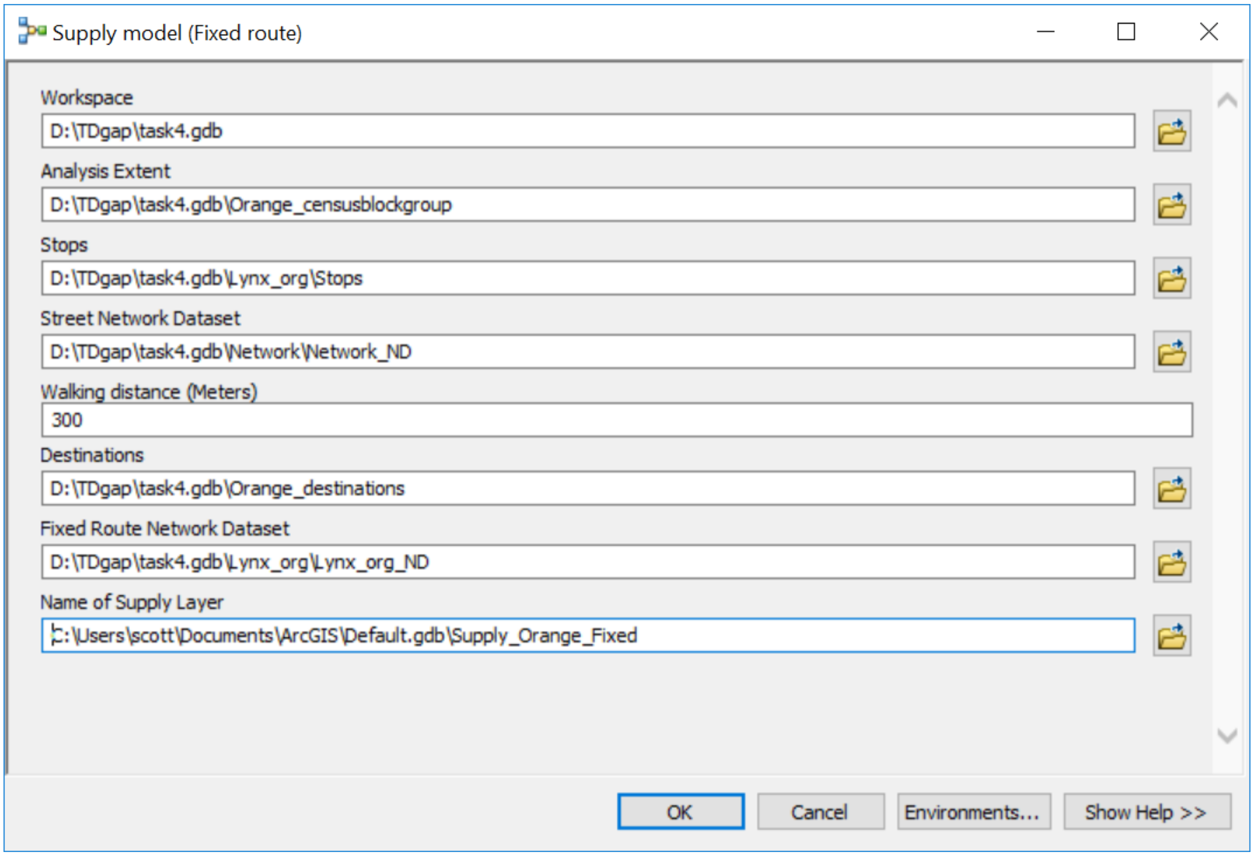


Figure 5-6. Running the Supply Model (Example: Fixed Route in Orange County)

Figure 5-7 shows an example of the resulting supply layer for a fixed route in Orange County. The accessibility for the fixed route is standardized on a scale of 0 to 1 with zero indicating no transportation accessibility and 1 representing the highest transportation accessibility.

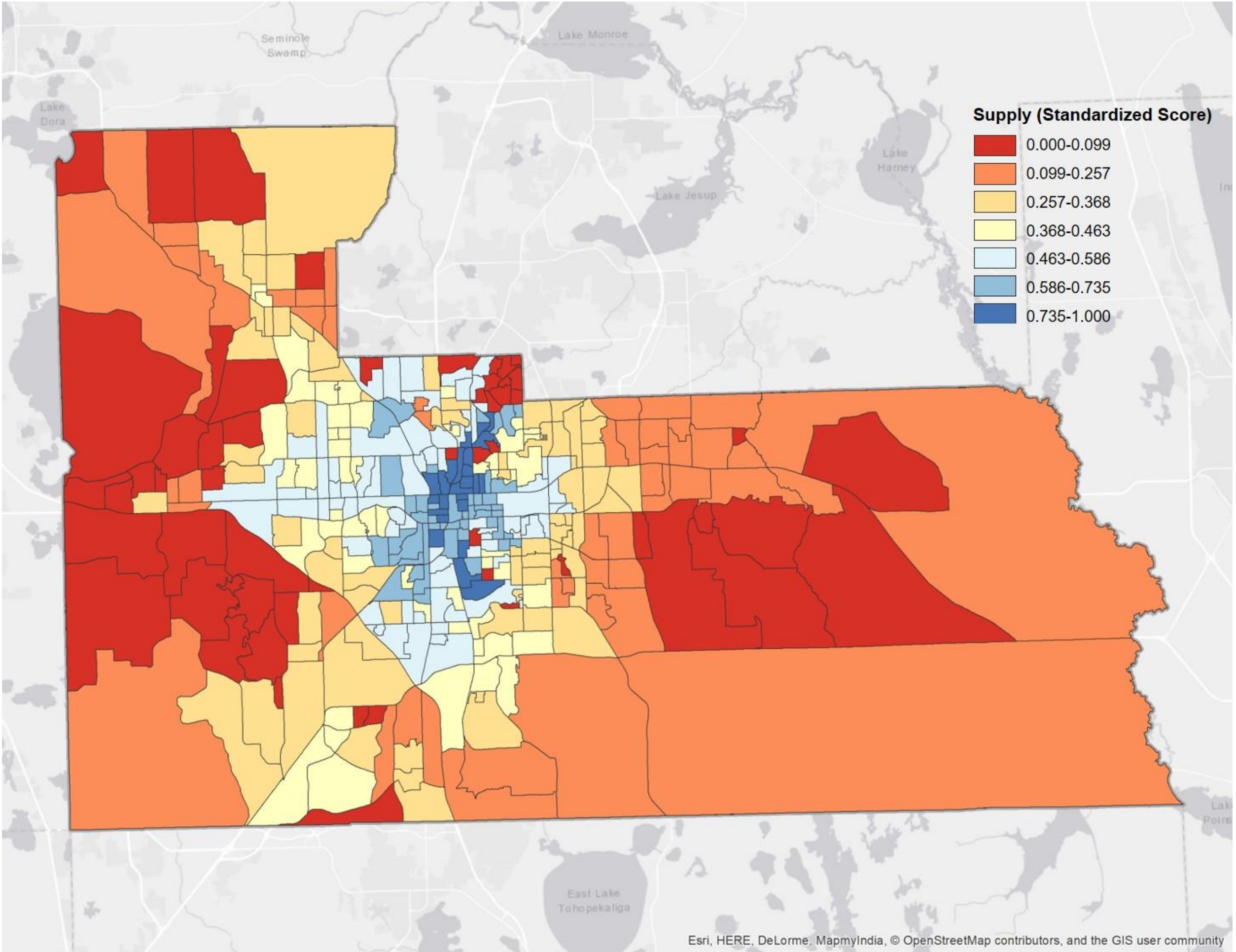


Figure 5-7. Supply Layer (Example: Fixed Route in Orange County)

o Customization Options for the Flexible Route Model

Based on the model developed in chapter 4 and Appendix B, Figure 5-8 illustrates the user interface to create the supply layer for a flexible route. To run the flexible route model, the required datasets include analysis extent, destinations, and street network dataset. The provider's service area geographic boundary is set as optional currently, due to the lack of the providers' service area information in a spatial data format. At present, provider's service areas are set the same as analysis extent if no specific service area is provided. Destinations can be specified by category if desired, e.g., educational, medical, non-medical, or work. All destinations will be used if no category is specified. The last step is to name the supply layer. The output of this model is a standardized accessibility score ranging from 0 to 1, with zero indicating no accessibility and 1 representing maximum accessibility.

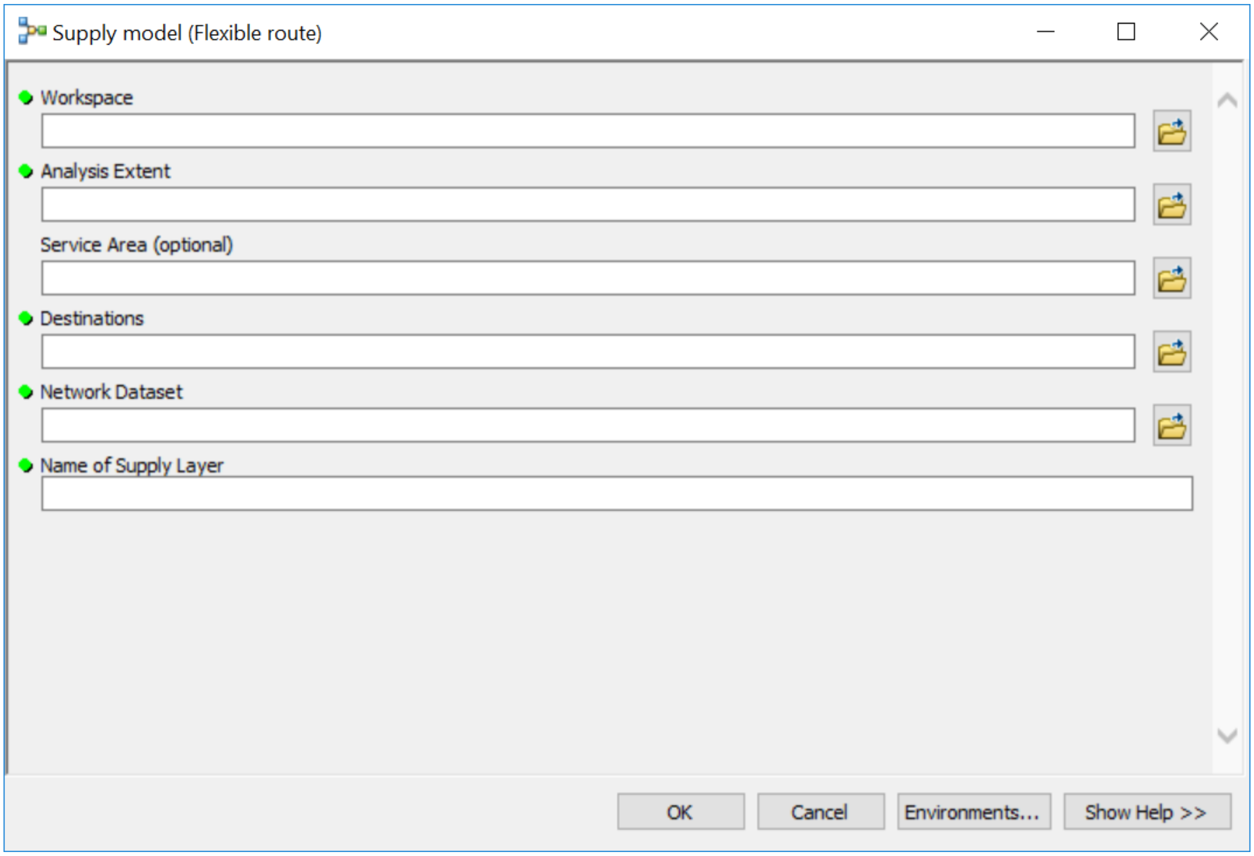


Figure 5-8. Supply Model Interface: Flexible Route

Figure 5-9 shows an example. Specifically, "Analysis Extent" and "Destinations" can be customized. In this example, inputs include Orange County's census block group data for the analysis extent, all destinations, and the city of Orlando as the service area. The network data set was prepared prior to executing the model.

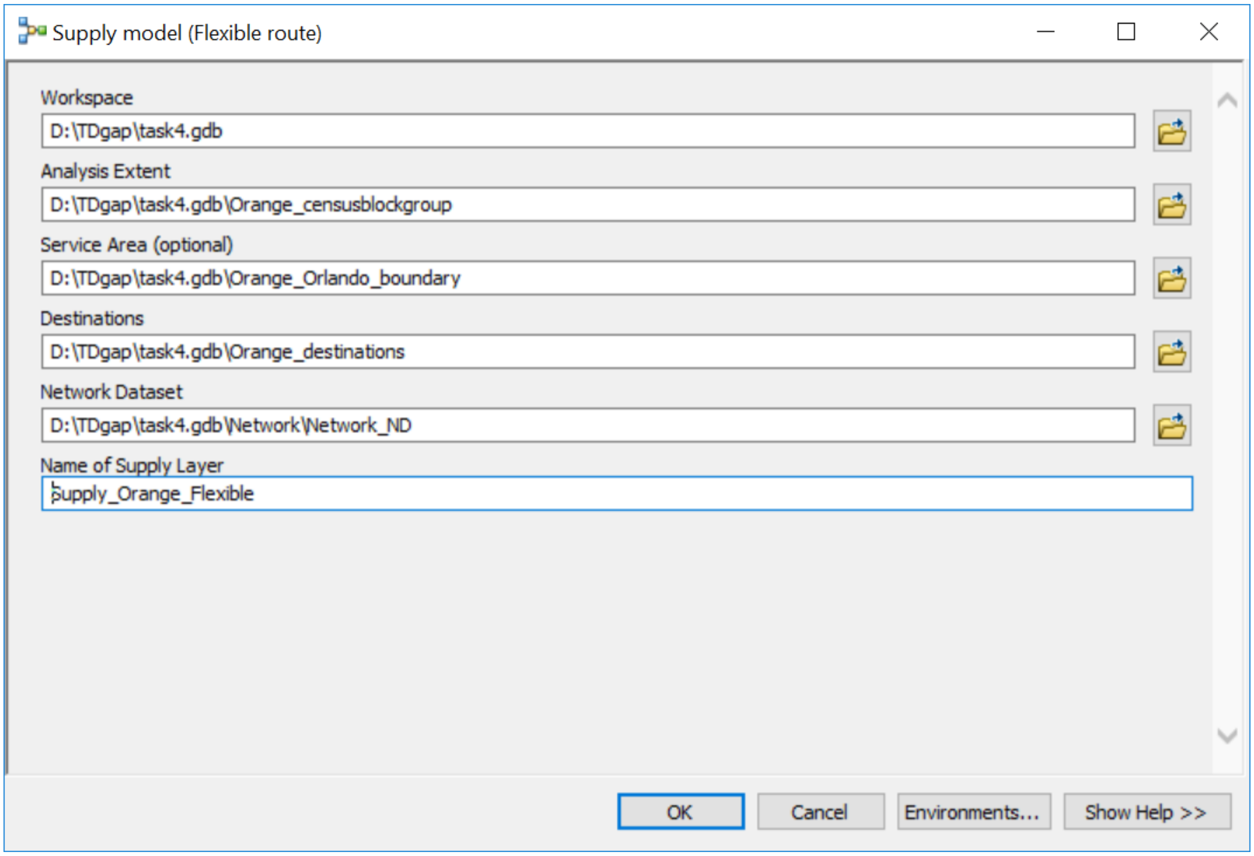


Figure 5-9. Running the Supply Model (Example: Flexible Route in Orange County)

Figure 5-10 shows the resulting supply layer for a flexible route in Orange County. The accessibility for the flexible route is standardized on a scale of 0 to 1 with zero indicating no transportation accessibility and 1 representing the highest transportation accessibility.

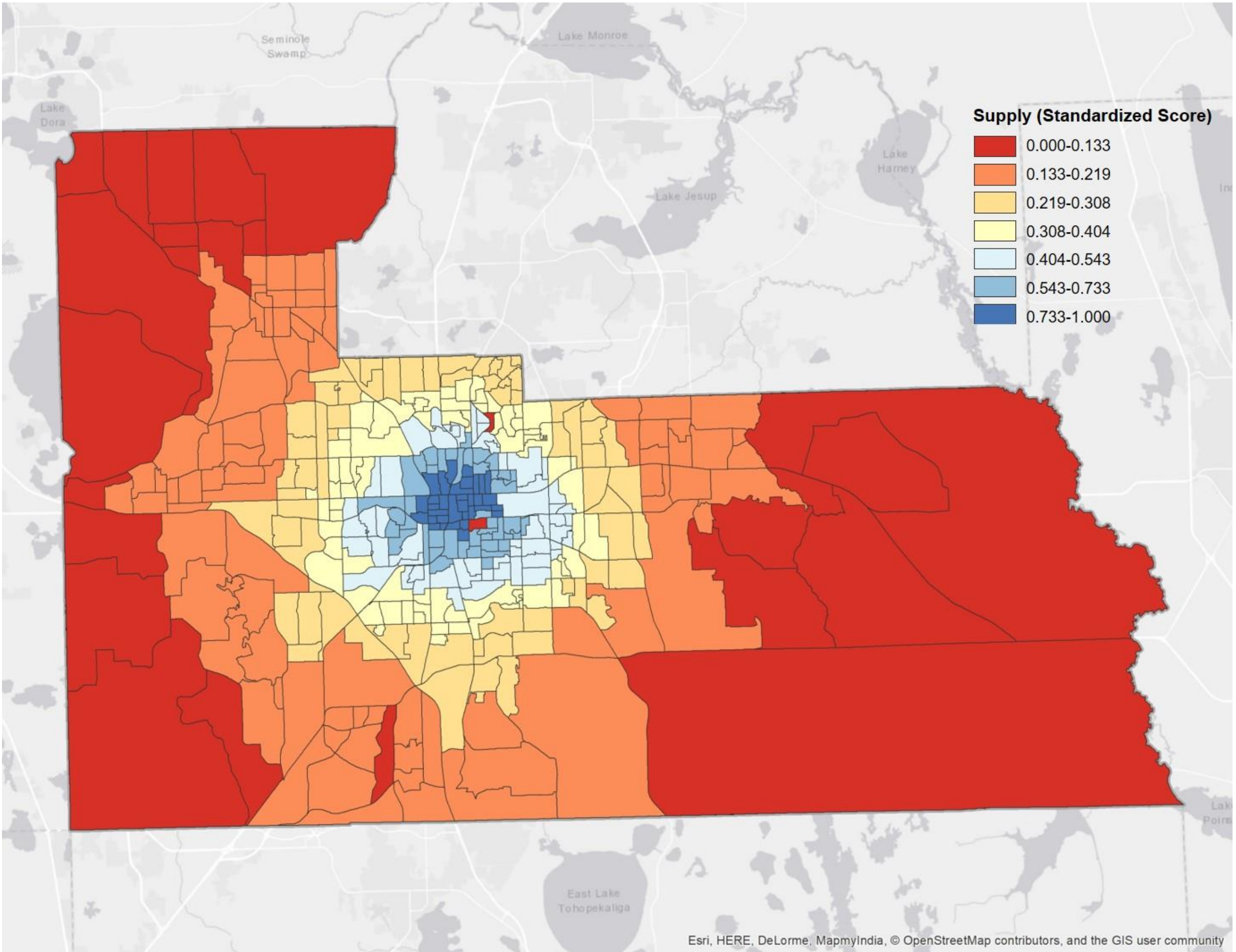


Figure 5-10. Supply Layer (Example: Flexible Route in Orange County)

- **Customization Options for the Door-to-door Model**

Based on the model developed in chapter 4 and Appendix C, Figure 5-11 illustrates the user interface to create supply layer for the door-to-door service. Similar to the flexible route model, the required datasets include analysis extent, destinations and the network dataset. Currently, the service area is set as optional due to lack of service area spatial data. If no specific boundary for service area is selected, the model uses the analysis extent for the service area. Destinations can be specified by category if desired e.g. educational, medical, non-medical, or work. All destinations will be used if no category is specified.

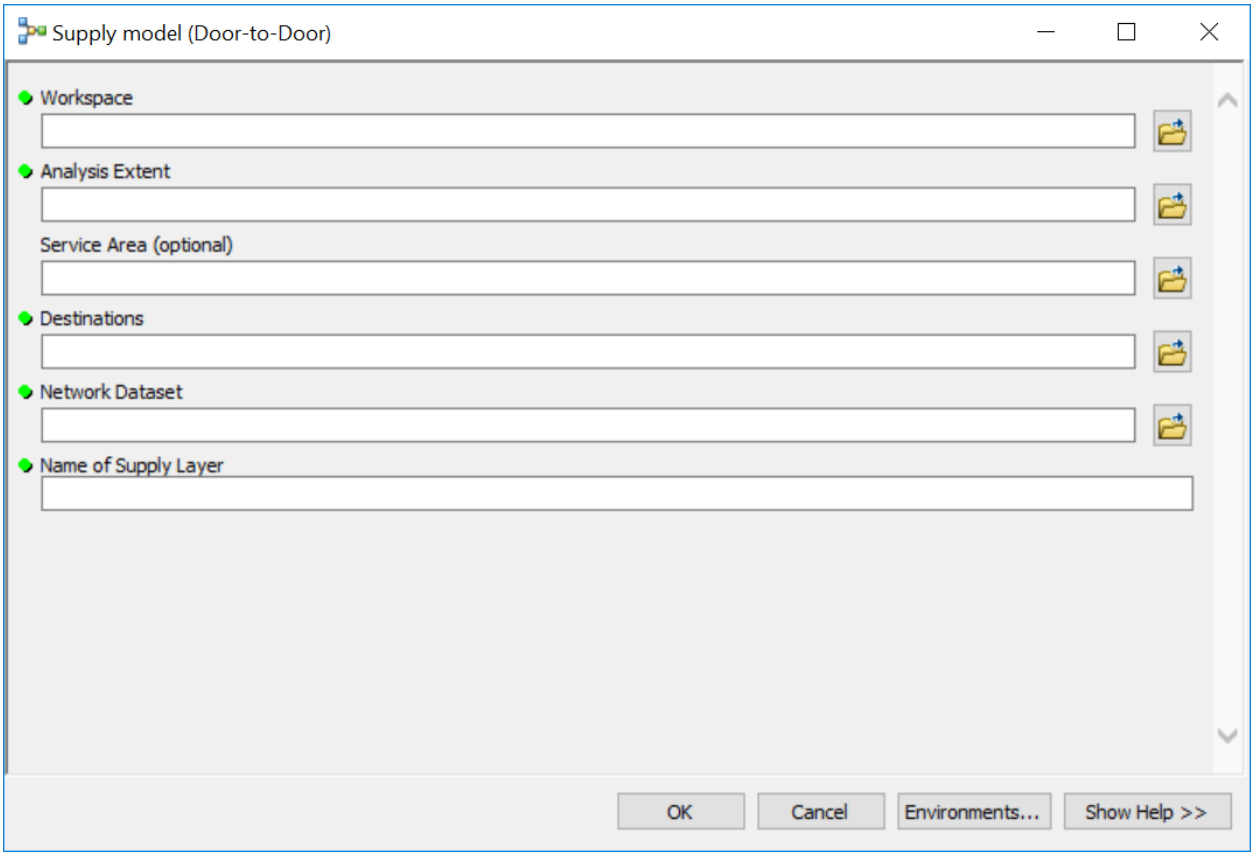


Figure 5-11. Supply Model Interface: Door-to-door Service

Figure 5-12 shows an example applied to Orange County using the Diamond Cab company which which provides door-to-door service. Specifically, "Analysis Extent" and "Destinations" can be customized. In the example, inputs include Orange County's census block group data for the analysis extent, all destinations, and Orange County as the service area – same as the analysis extent. The network dataset was prepared prior to executing the model.

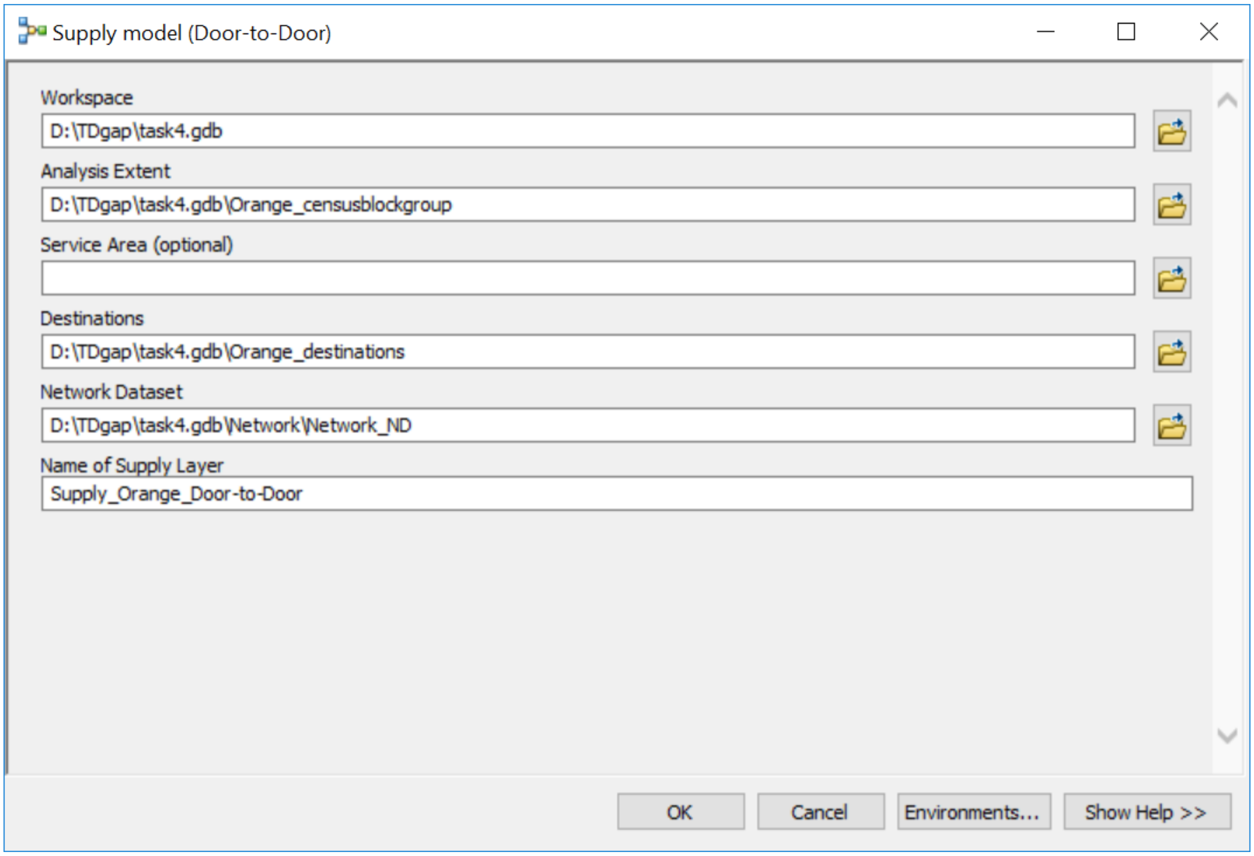


Figure 5-12. Running the Supply Model (Example: Door-to-door Service in Orange County)

Figure 5-13 shows the resulting supply layer. The accessibility for door-to-door service is standardized on a scale of 0 to 1 with zero indicating no transportation accessibility and 1 representing the highest transportation accessibility.

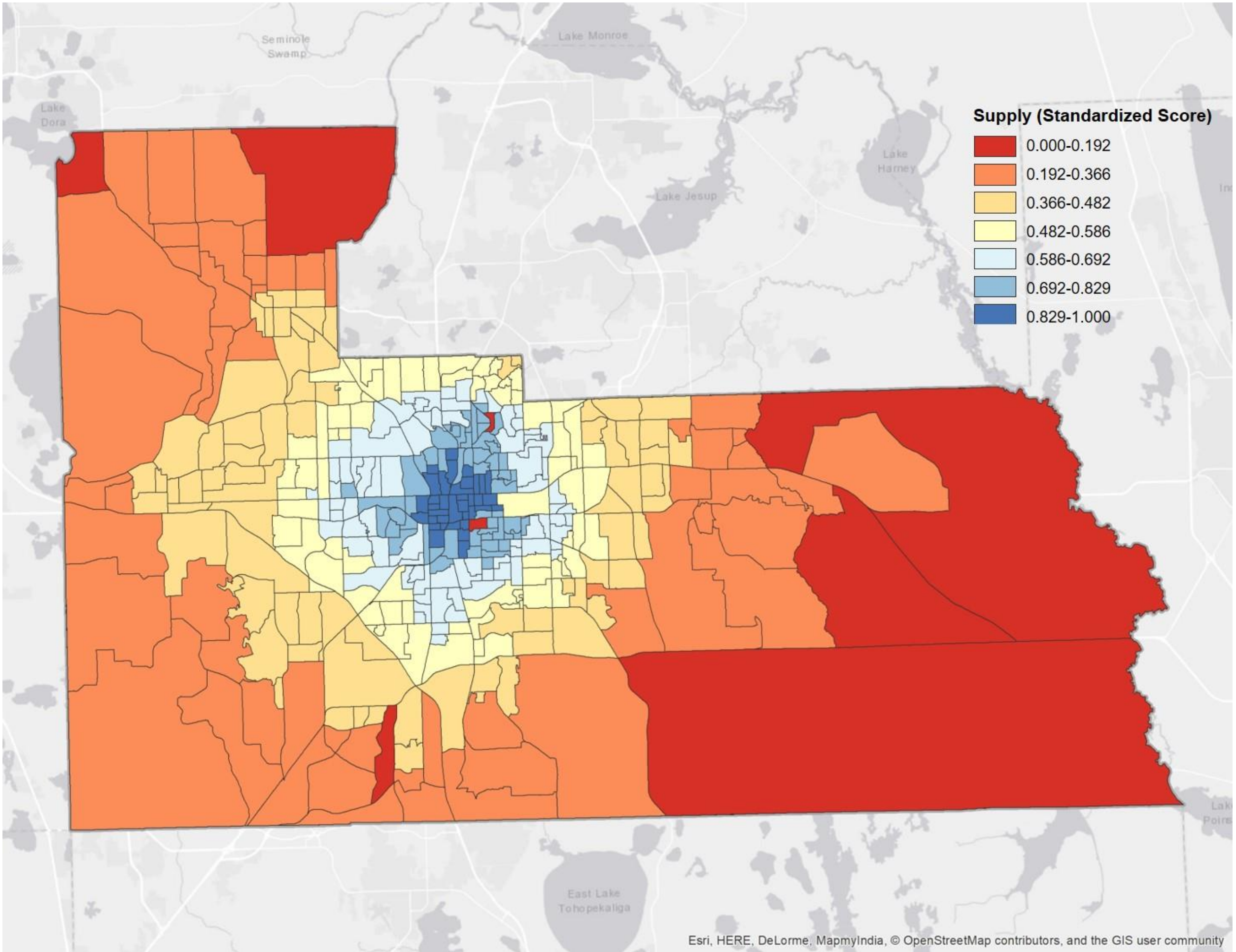


Figure 5-13. Supply Layer (Example: Door-to-door Service in Orange County)

6. FUTURE VISON AND MODEL AUTOMATION

In chapter 5 we explored options for customizing the model. In this chapter we propose a method to automate, package and manage the model in the long term, as well as a vision on how to disseminate Gap Maps produced by the model. It is expected that this model will be used to guide planning of effective alternative transportation options to reduce service gaps for Florida's vulnerable populations. It is important that the future vision for the model is placed in the broader framework of the vision of FDOT and Safe Mobility for Life Coalition. In this context, we propose a future vision of the model that serves as the basis for the recommendations on how to maintain and use this model for the improvement of transportation services for vulnerable populations. To support the future vision, this chapter addresses options for packaging the model for effective use and maintenance, model automation and user interface for the interactive selection of parameters.

6.1 Future Vision of the Model

The FindaRideFlorida.org provides transportation service information to vulnerable populations such as older adults, individuals with disabilities, and those who are low-income in Florida through FDOT's Safe Mobility for Life Program and Coalition. This research developed a model for identifying gaps in these services. The model can be used to develop gap maps that can serve as a resource to inform decision makers of potential improvements that can be made to increase transportation accessibility for Florida's vulnerable populations, and ultimately, help narrow the gaps.

Although the FindaRideFlorida.org and the transportation gaps model (referred from here on as the Gaps Model) use the same transportation provider database, at present they are not directly connected. Linking them is beneficial because it could provide up-to-date information to stakeholders, such as state, county, and agency officials, to improve transportation options for vulnerable populations and relevant information to anyone who needs transportation services. In that respect, we see the FindaRideFlorida.org, the Find-a-Ride Florida database and the Gaps Model as components of a larger framework that we are referring to here as the Find-a-Ride Framework. This does not imply the creation of an entirely new system but rather serves as a way to identify a larger framework that links or integrates the existing FindaRideFlorida.org, its supporting the database and the Gaps Model developed in this research project.

6.1.1 Find-a-Ride Framework

Figure 6-1 illustrates the components and functions of the Find-A-Ride Framework and its interaction with the end users. The sections that follow provide more information about the components of the framework and how they link to each other.

- **Find-a-Ride Florida database**

In addition to the service provider's information, the Find-a-Ride Florida database would contain various datasets to support the Gaps Model, such as street network, census data, and destinations data. Additionally, this database would contain the results of the gap modeling (referred from here on as the Gap Maps). Furthermore, the database would be enhanced by the spatial coverage areas of transportation service providers displayed in map format. The map delineation of the service areas will simultaneously produce more accurate Gap Maps and provide users of the FindaRideFlorida.org with more accurate listings of available transportation service providers. The need for map-based service areas has already been identified as a future improvement for the database.

- **FindaRideFlorida.org**

The FindaRideFlorida.org, in addition to the updated information of the transportation service providers, it could show routes, destinations, and spatial coverage areas of each service provider. This will require that transportation service providers update their spatial service areas in a map form. We propose that in the future, the FindaRideFlorida.org enables transportation service providers to update their information (currently done separately) through a page or a link within the site. Service provider access management has been already in place for a few years and does not need to change.

- **Gap Maps**

The Gaps Model would produce Gap Maps of transportation services for vulnerable populations within the ArcGIS environment. These maps need to be disseminated to stakeholders involved in improving transportation for Florida's vulnerable populations. The FindaRideFlorida.org could be enhanced through additional functions accessible as additional pages such as Gap Maps. Below we explore a few options to deliver the Gap Maps. The maps could then serve as a broad resource for planning and policy actions to examine specific users and transportation options in a local context. FDOT should consider if these maps should be open to the public or only available to relevant stakeholders. Regardless, several options can be considered for dissemination of the Gap Maps.

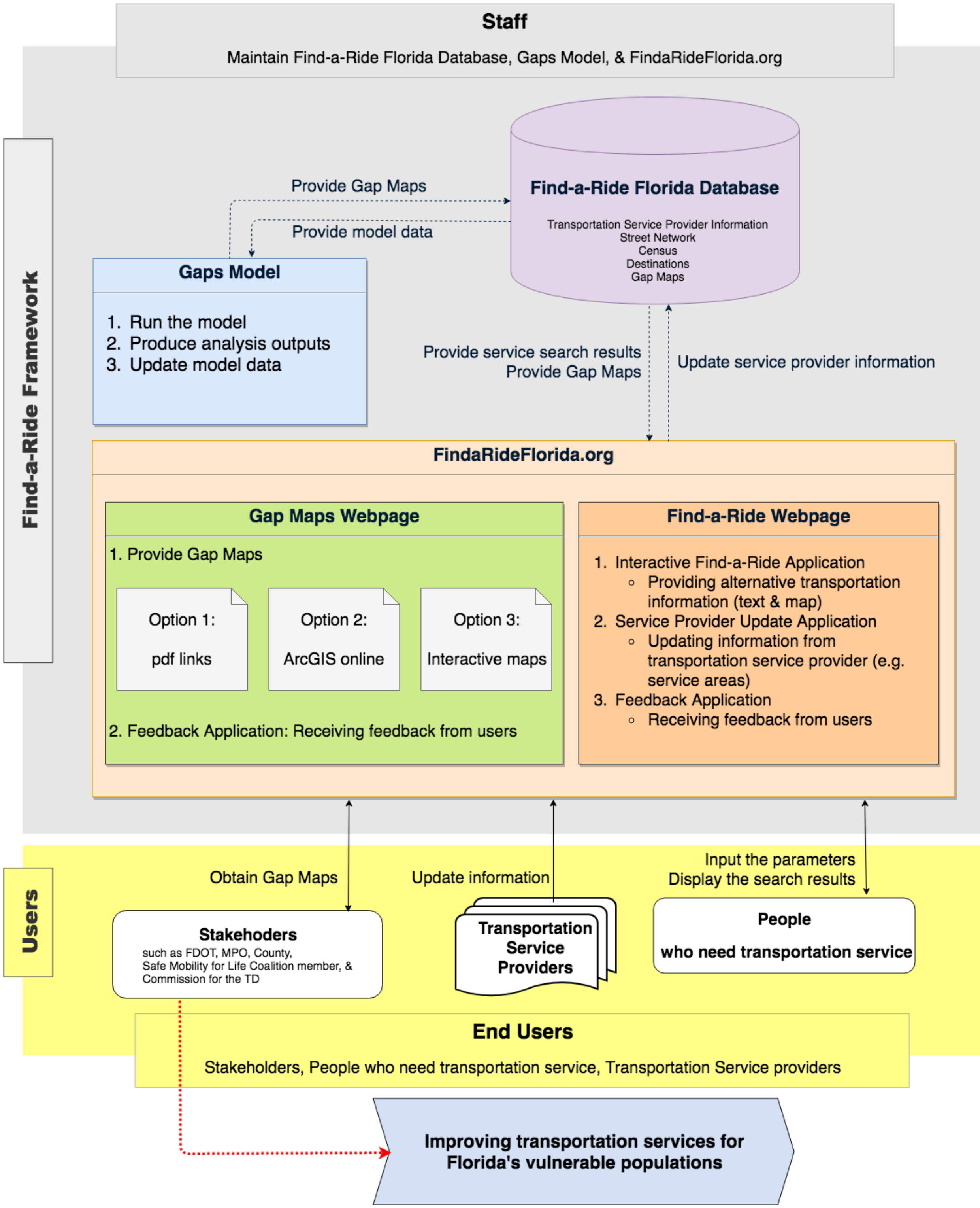


Figure 6-1. Future Vision for the Model

1. Via Email: stakeholders would request Gap Maps for their area of interest by emailing the staff member who manages/maintains the model. The staff would produce the map by the running the model and email the resulting maps in PDF format to the stakeholders.

2. Via a Webpage: Several options of this concept are shown in Figure 6-1. The current FindaRideFlorida.org website () could be enhanced or expanded through additional pages used to post previously created Gap Maps. This page could be linked from the Coalition's main website (www.flsams.org). Below are some options that to consider for this solution.

1) A new page could be dedicated to posting Gap Maps, and it could be hosted within the FindaRideFlorida.org or the Coalition's website. Regardless of where the page would be hosted physically, it could be linked from the coalition's home page. This page could provide PDFs of Gap Maps produced and updated annually for the geographic area and interested agencies. The end users could simply download these PDFs from the webpage. This page could be public or password protected. This option, although simple to develop and maintain, would require preparation and posting of a wide range of Gap Maps for various geographic extents and population types in order to cover a wide diversity of needs of various stakeholders.
2) Another option is to publish the Gap Maps on the free ArcGIS Online site. ArcGIS Online offers interactive tools for map viewing, data export, and printing. The ArcGIS Online page hosting the Gap Maps can be linked from the Coalitions' main website. The administrator of the ArcGIS Online page could control the level of access based on the user types.
3) A new page can be dedicated to posting interactive Gap Maps. This would be similar to the ArcGIS Online solution except that it can allow for more content flexibility and user friendliness. This webpage could include additional functions such as the ability to support charts, tables, discussion blogs etc. This page can be linked from the Coalition's website, and it can be hosted physically under the Find-a-Ride server. Compared to the ArcGIS Online solution this option would take a much bigger effort to develop but would allow much more flexibility in content customization and usability. For example, the ability to support discussions would encourage dialogue among stakeholders, creating a forum that would help lead to a reduction of transportation gaps.

- **Role of Staff**

The staff associated with the maintenance of the Gaps Model is expected to perform a variety of duties including running the model and producing the Gap Maps, updating the model data, updating the model itself as necessary based on user feedback, and communicating with the Safe Mobility for Life Coalition, FDOT, MPOs and other organizations interested in the Gap Maps. Depending on how the Gap Maps are distributed, the staff would be responsible for posting the results on a web page as outlined above (i.e., posting pdf links, feature layers on the ArcGIS Online website, or updating the gap layers within the interactive page). The staff would also monitor discussions if the Gap Maps web pages are used by stakeholders as discussion forums.

The Gaps Model is currently developed and managed by UF staff. Operational knowledge of ArcGIS and ability to process and manage GIS data is a necessary skill needed for managing and maintaining the Gaps Model in the long run.

- **Users and Access**

We envision three end-user categories for the Find-a-Ride Framework: stakeholders (e.g., FDOT, MPO, Safe Mobility Life Coalition members, Commission for the Transportation Disadvantaged, and county governments), transportation service providers, and users in need of transportation services. A user who needs to find transportation options would visit the FindaRideFlorida.org. A service provider would use the website to update their information stored in the Find-a-Ride Florida database. A stakeholder may need to review, download or print gaps maps, review transportation service providers' coverage areas, and so on. If FDOT chooses to provide Gap Maps only to stakeholders, the Gap Maps page needs to be password protected as would service provider access to update their information. Therefore, different levels of access need to be applied to various pages of the site based on user type and a user management application would become necessary to authorize user's access to the system.

6.1.2 Propose Phasing Plan

Figure 6-2 shows the steps to achieving the vision proposed above. In phase 1—the present phase—we developed the Gaps Model and launched the new FindaRideFlorida.org. Phase 2 would focus on selecting and implementing one of the options for dissemination of the Gap Maps and provide education/training for stakeholders and transportation service providers. In phase 3—the long-term phase—efforts would be focused on maintaining the Find-a-Ride Florida database, the FindaRideFlorida.org, the Gaps Model and the Gap Maps.

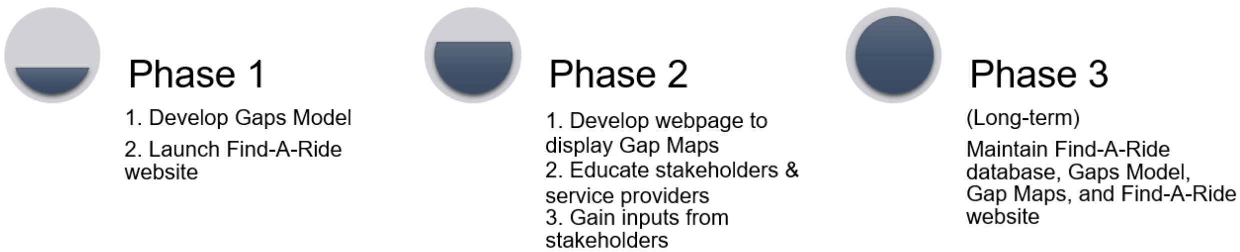


Figure 6-2. Proposed Phasing Plan

The Find-A-Ride Framework will serve as an effective mechanism for presenting and maintaining information on the actual gaps in transportation services for the transportation disadvantaged and for storing updated information from the transportation service providers. The FindaRideFlorida.org is expected to increase the productivity and shorten the time needed by the stakeholders and transportation service providers to take targeted steps and plan resource distribution to address the problems and maximize the transportation services for the vulnerable populations.

6.1.3 Scenarios for Operation, Maintenance, and Dissemination of Gap Maps

This section provides a comparison of the tasks expected to host and maintain the Gap Maps webpage and operate and maintain the Gaps Model. Three scenarios are considered: first, the Gap Maps webpage is hosted by FDOT at www.safemobilityFL.com) and the Gaps Model is operated and maintained FDOT; second, the Gap Maps webpage is hosted by FDOT but the Gaps Model is operated and maintained by UF; third, the Gap Maps webpage is hosted by UF at FindaRideFlorida.org) and the Gaps Model is operated and maintained by UF.

Table 6-1 shows the tasks required for each option when the Gap Maps webpage is hosted by FDOT and the Gaps Model is maintained and operated by FDOT. For the Gaps Model, regardless of the option, FDOT must have the necessary staff qualified to manage and operate the Gaps Model including updating and managing the relevant data in the ArcGIS environment. For the Gap Maps each option requires different skillsets. In the first option – static PDF maps - the Gap Maps webpage contains links to PDF reports; the staff should be able to update the webpage and replace the PDF files on the server each time new Gap Maps are created. For the second option - ArcGIS Online - the staff needs to maintain and update the GIS layers each time new Gap Maps are create. Finally, for the third option - interactive map webpage - the staff must possess operational knowledge of interactive map-based website development, ability to use ArcGIS Server, and ability to update GIS layers and maintain them on a server database.

Table 6-1. Scenario 1: Gap Maps Webpage and Gaps Model by FDOT

Options	Maintenance & Operation		Requirements
	Gaps Model by FDOT	Gap Maps webpage by FDOT	
PDFs	○ Maintain and update the data. ○ Maintain and update the ArcGIS model. ○ Create and update PDF Gap Maps using the ArcGIS model.	○ Update the PDFs and update the PDFs links and when new Gap Maps are generated. ○ Manage user account (if applicable). ○ Communicate with users.	✓ Need staff or contractor who has operational knowledge of ArcGIS and ability to process and manage GIS data. ✓ Need staff or contractor to prepare PDF of Gap Maps and ability to post to the webpage.
ArcGIS online	○ Maintain and update the data. ○ Maintain and update the ArcGIS model. ○ Create the Gap Maps layers using the ArcGIS model.	○ Update the GIS layers when new Gap Maps are generated. ○ Manage user account (if applicable). ○ Communicate with users.	✓ Need staff or contractor who has operational knowledge of ArcGIS and ability to process and manage GIS data. ✓ Need staff or contractor to prepare Gap Maps layers and post to ArcGIS online page.
Interactive map	○ Maintain and update the data. ○ Maintain and update the ArcGIS model. ○ Create the Gap Maps layers using the ArcGIS model.	○ Update the GIS layers once new Gap Maps are generated. ○ Update charts and tables related to the new Gap Maps. ○ Manage user account (if applicable). ○ Communicate with users.	✓ Need staff or contractor who has operational knowledge of ArcGIS and ability to process and manage GIS data. ✓ Need staff or contractor who has operational knowledge in interactive map-based webpage development. ✓ Need staff or contractor who can maintain the interactive map webpage.

Table 6-2 shows the essential tasks for each option when the Gap Maps webpage is hosted by FDOT but the Gaps Model is maintained and operated by UF. The FDOT role remains the same as in the first scenario except for the Gap Maps. UF will update and generate the maps and provide them to FDOT. Specific tasks are summarized in the table.

Table 6-2. Scenario 2: Gap Maps Webpage by FDOT and Gaps Model by UF

Options	Maintenance & Operation		Requirements
	Gaps Model by UF	Gap Maps webpage by FDOT	
PDFs	○ Maintain and update the data. ○ Maintain and update the ArcGIS model. ○ Create and update PDF Gap Maps using the ArcGIS model.	○ Update webpage with PDF Gap Maps generated by UF. ○ Manage user accounts (if applicable). ○ Communicate with users.	✓ *UF:* Need staff who has operational knowledge of ArcGIS and ability to process and manage GIS data. ✓ *FDOT:* Need staff or contractor to update the webpage.
ArcGIS online	○ Maintain and update the data. ○ Maintain and update the ArcGIS model. ○ Create the Gap Maps layers using the ArcGIS model.	○ Update the GIS layers for the Gap Maps generated by UF. ○ Manage user account (if applicable). ○ Communicate with users.	✓ *UF:* Need staff who has operational knowledge of ArcGIS and ability to process and manage GIS data. ✓ *FDOT:* Need staff or contractor that can post and update GIS layers to ArcGIS online page.
Interactive map	○ Maintain and update the data. ○ Maintain and update the ArcGIS model. ○ Create the Gap Maps layers using the ArcGIS model.	○ Update the GIS layers for the new Gap Maps generated from UF. ○ Update charts and tables related to new Gap Maps. ○ Manage user accounts (if applicable). ○ Communicate with users.	✓ *UF:* Need staff who has operational knowledge of ArcGIS and ability to process and manage GIS. ✓ *FDOT:* Need staff or contractor who has operational knowledge of interactive map-based webpage development ✓ *FDOT:* Need staff or contractor to prepare web page components (e.g., Gap Maps, charts, tables) and post the updates to interactive map page.

Table 6-3 shows the various tasks for each option when the Gap Maps webpage is hosted by UF and the Gaps Model is maintained and operated by UF. The tasks related to operating and maintaining the Gap Model are the same as in the second scenario above. The tasks for the Gap Maps webpage are shown in the table.

Table 6-3. Scenario 3: Gap Maps Webpage and Gaps Model by UF

Options	Maintenance & Operation		Requirements
	Gaps Model by UF	Gap Maps webpage by UF	
PDFs	○ Maintain and update the data. ○ Maintain and update the ArcGIS model. ○ Create and update PDF Gap Maps using the ArcGIS model.	○ Update the PDFs and update the PDFs links for the new Gap Maps. ○ Manage user accounts (if applicable). ○ Communicate with users.	✓ Need staff who has operational knowledge of ArcGIS and ability to process and manage GIS data. ✓ Need staff to prepare PDF Gap Maps and post to the webpage.
ArcGIS online	○ Maintain and update the data. ○ Maintain and update the ArcGIS model. ○ Create the Gap Maps layers using the ArcGIS model.	○ Update the GIS layers for the new Gap Maps. ○ Manage user accounts (if applicable). ○ Communicate with users.	✓ Need staff who has operational knowledge of ArcGIS and ability to process and manage GIS. ✓ Need staff to prepare Gap Maps layers and post them to ArcGIS online page.
Interactive map	○ Maintain and update the data. ○ Maintain and update the ArcGIS model. ○ Create the Gap Maps layers using the ArcGIS model.	○ Update the GIS layers for the new Gap Maps are generated. ○ Update charts and tables by new Gap Maps. ○ Manage user account (if applicable). ○ Communicate with users.	✓ Need staff who has operational knowledge of ArcGIS and ability to process and manage GIS data. ✓ Need staff who has operational knowledge of interactive map-based webpage development. ✓ Need staff to prepare web page components (e.g., Gap Maps, charts, tables) and post them to the interactive map page.

Each scenario and related options have their advantages and disadvantages in terms of resources needed and the quality of services provided to the end-users. The appropriate solution should be chosen by taking into consideration the long-term vision of FDOT and Safe Mobility for Life Coalition.

6.2 **The Model Automation**

This section proposes a method for model automation including the user interface, selection of input parameters and streamlining of the model components and their integration.

6.2.1 The User Interface

Based on the customization results and the user interface developed in chapter 5, we have developed an advanced user interface that includes both the supply and the demand model. The interface consists mainly of three required parameters—geographic extent, eligible users, and route type (Figure 6-3). Destinations is included as an optional parameter. Choices for geographic extent include a county, an FDOT district, a metropolitan planning organization (MPO), or a metropolitan statistical area (MSA). However, other geographic boundaries, such as transportation disadvantaged regions, can be added if relevant data are available. The user can also choose one or more eligible user types for the service, such as older adults, individuals with disabilities, or low income persons. As with geographic boundaries, further eligible user classes can be added (e.g., veterans, cancer patients, or Medicaid recipients) if the relevant data are acquired and updated. Finally, the user can select one or more route types based on available transportation service providers. They include fixed routes, flexible routes, and door-to-door service. The destination parameter is included to allow specific analysis to determine gaps by destination type if necessary. Using parcel data, the available destinations at this time include medical, education, and other. As mentioned in chapter 4, the work destination is currently unavailable due to lack of data at the parcel level. More research should be dedicated in the future to identify, evaluate and utilize work-related data in the model.

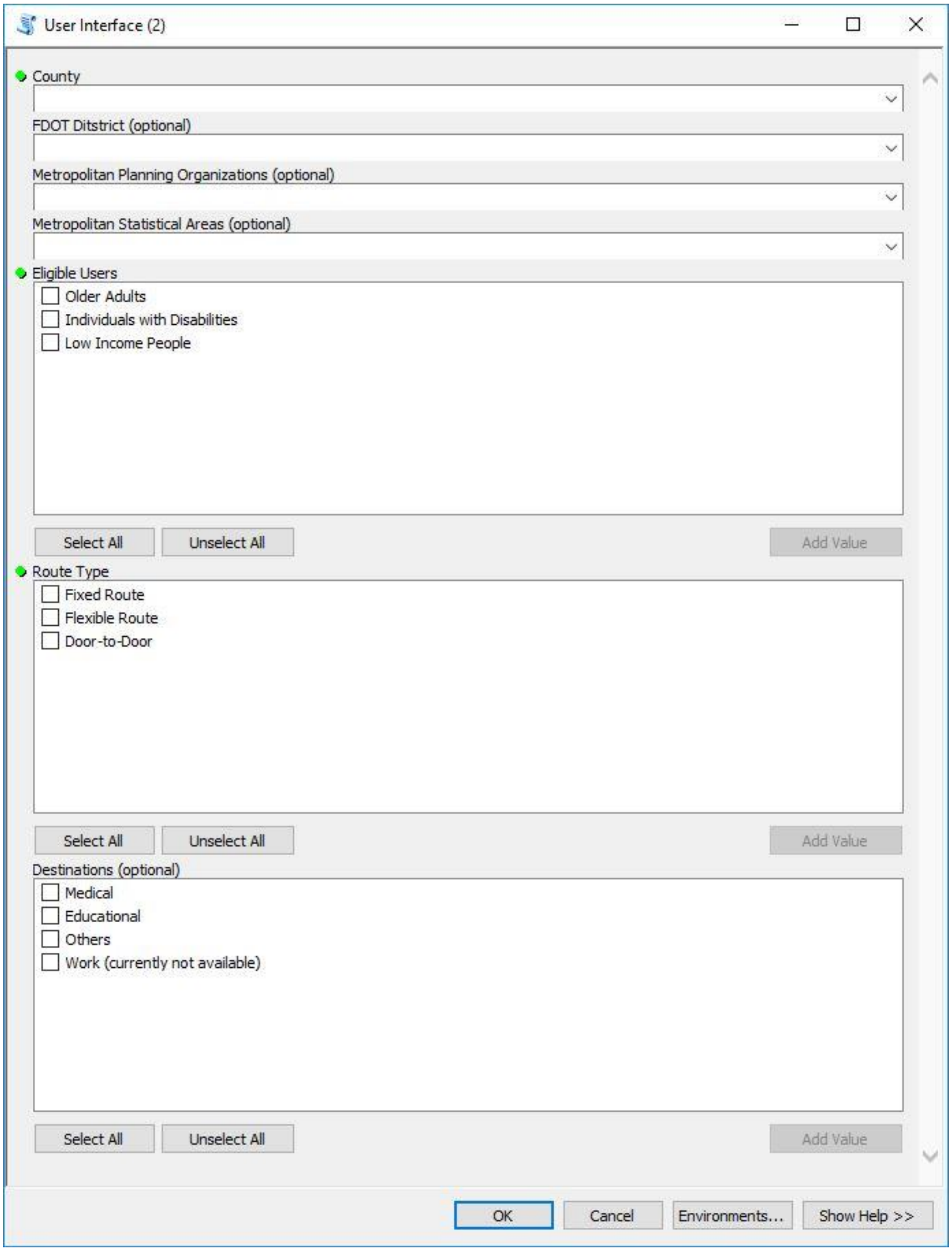
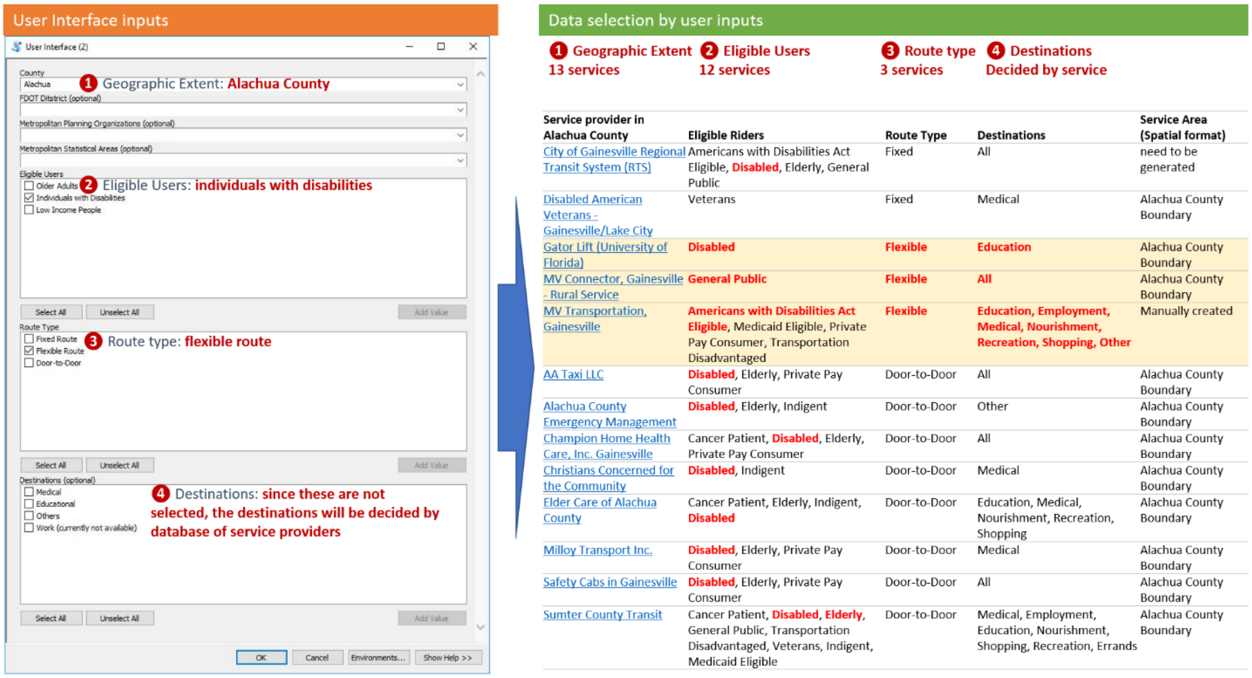


Figure 6-3. User Interface

- ### Linking of Parameters to the Data

Figure 6-4 illustrates how the model parameters correspond to the actual dataset. For demonstration purposes, we have used transportation service providers in Alachua County.



Service provider in Alachua County	Eligible Riders	Route Type	Destinations	Service Area (Spatial format)
City of Gainesville Regional Transit System (RTS)	Americans with Disabilities Act Eligible, **Disabled**, Elderly, General Public	Fixed	All	need to be generated
Disabled American Veterans - Gainesville/Lake City	Veterans	Fixed	Medical	Alachua County Boundary
Gator Lift (University of Florida)	**Disabled**	**Flexible**	**Education**	Alachua County Boundary
MV Connector, Gainesville - Rural Service	**General Public**	**Flexible**	**All**	Alachua County Boundary
MV Transportation, Gainesville	**Americans with Disabilities Act Eligible**, Medicaid Eligible, Private Pay Consumer, Transportation Disadvantaged	**Flexible**	**Education, Employment, Medical, Nourishment, Recreation, Shopping, Other**	Manually created
AA Taxi LLC	**Disabled**, Elderly, Private Pay Consumer	Door-to-Door	All	Alachua County Boundary
Alachua County Emergency Management	**Disabled**, Elderly, Indigent	Door-to-Door	Other	Alachua County Boundary
Champion Home Health Care, Inc. Gainesville	Cancer Patient, **Disabled**, Elderly, Private Pay Consumer	Door-to-Door	All	Alachua County Boundary
Christians Concerned for the Community	**Disabled**, Indigent	Door-to-Door	Medical	Alachua County Boundary
Elder Care of Alachua County	Cancer Patient, Elderly, Indigent, **Disabled**	Door-to-Door	Education, Medical, Nourishment, Recreation, Shopping	Alachua County Boundary
Milloy Transport Inc.	**Disabled**, Elderly, Private Pay Consumer	Door-to-Door	Medical	Alachua County Boundary
Safety Cabs in Gainesville	**Disabled**, Elderly, Private Pay Consumer	Door-to-Door	All	Alachua County Boundary
Sumter County Transit	Cancer Patient, **Disabled**, **Elderly**, General Public, Transportation Disadvantaged, Veterans, Indigent, Medicaid Eligible	Door-to-Door	Medical, Employment, Education, Nourishment, Shopping, Recreation, Errands	Alachua County Boundary

Figure 6-4. Example of Data Linked to User Input

In the example above, the user has selected Alachua County as the geographic extent of the analysis, individuals with disabilities as eligible users, and flexible route as the route type. Because the user does not select destinations, the selected destinations will be decided by the destinations supported by the transportation service providers.

The following is the sequence used to select the relevant information from the Find-a-Ride Florida database: First, the model selects thirteen transportation service providers within the Alachua County boundaries. Second, the model eliminates one of the providers because only twelve of them serve the eligible users - individuals with disabilities. Third, the model narrows this group down to three providers because only three providers provide the user selected flexible route service. Fourth, because the user did not select a specific destination, the model selects destinations supported by transportation service providers. In the instance of the Gator Lift service, the model selects only education-related destinations, but for the MV connector and the MV transportation, the model uses all the destinations in the database because these services can reach all destination types.

- **Input, Data and Model Flow Integration**

Figure 6-5 shows the integration of user input, data and model flow.

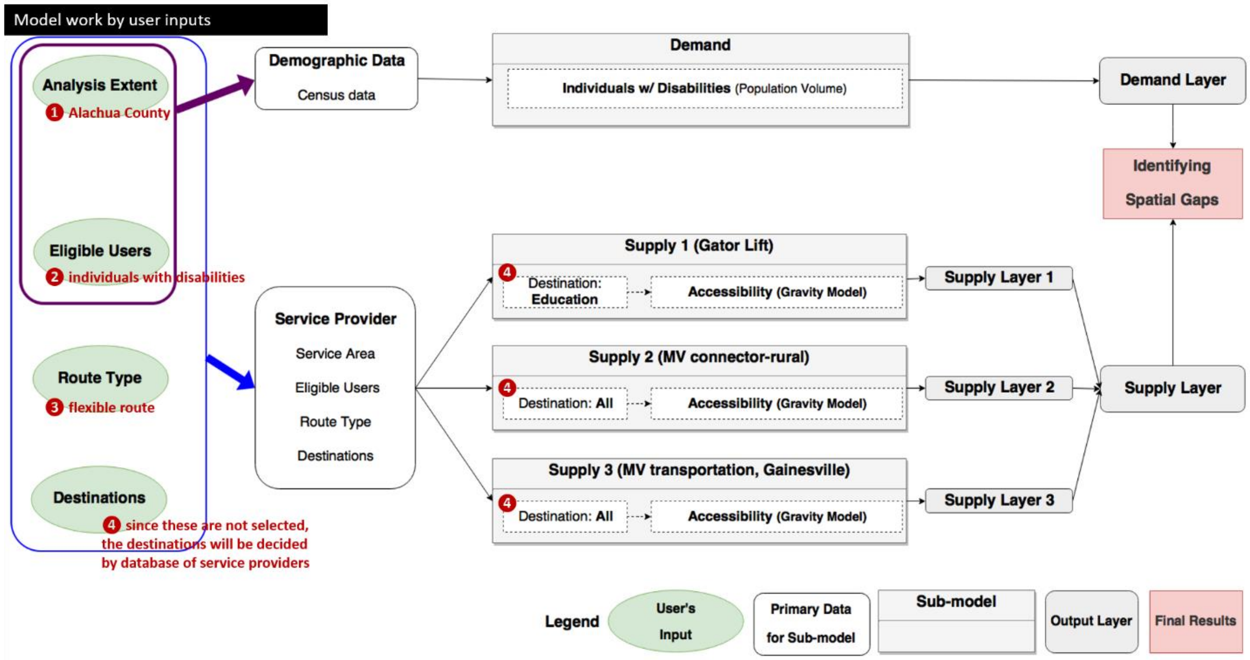


Figure 6-5. Example of Input, Data, and Model Flow Integration

First, based on the selected Alachua County geographic extent, the demand sub model selects the census block group layers within Alachua County and generates a "Demand Layer" of population of individuals with disabilities. Second, the supply sub model generates a "Supply Layer", for each of the three services on the based on the user type input. For Gator Lift, the model generates "Supply Layer 1" using education destinations. For the MV connector and the MV transportation service, it generates "Supply Layer 2" and "Supply Layer 3" respectively, using all destinations. These individual layers represent the transportation accessibility provided by each service provider. Next, the model combines them into a single layer to generate the transportation accessibility using flexible route services for individuals with disabilities within Alachua County. Lastly, using the "Demand Layer" and the "Supply Layer", the model generates gaps in flexible route service for individuals with disabilities in Alachua County.

6.2.2 Model Execution Sequence

This section describes the detailed sequence of model execution based on the automation process depicted in Figure 6-5. This process employs the supply and demand models developed in chapter 4. The purpose of this section is to describe the sequence and relevant aspects such as workspace, model flow, and input and output of each process with specific parameters by users. This sequence serves as a framework for model automation.

First, the model creates workspaces for the demand and the supply layers and selects the data layers based on user parameters such as geographic extent, user type, route type, and destinations. The subsequent process continues as follows:

(1) Select census block groups by geographic boundary layer and copy the selected census block group layers to the demand workspace (input: census block group layer; output: census block group layer within the boundary).

(2) Select transportation service providers within the selected geographic boundary (input: transportation service providers; output: transportation service providers within selected geographic boundary).

(3) Select transportation service providers by the eligible user (input: transportation service providers within selected geographic boundary; output: transportation service providers by user type).

(4) Select transportation service providers by route type (input: transportation service providers by user type; output: transportation service providers by route type).

(5) Copy the demand layer to the supply workspaces according to the number of transportation service providers selected. Three transportation service providers were chosen in this example, so the model generates three supply layers: "Supply Layer 1" for "Gator Lyft" service, "Supply Layer 2" for "MV connector" service, and "Supply Layer 3" for "MV transportation" to compute the accessibility of each service.

(6) Select destinations by each service provider (input: destinations; output: destinations supported by service provider)

(7) Select and copy destinations by user's input (input: destinations by service provider; output: destinations by user's input). If the user does not select any destinations, the model skips this step and copies the destinations from the previous step. It should be noted that the destinations layer is created using the number of transportation service providers selected. In this example, the model creates three destination layers: "destination layer 1" for Gator Lyft, "destination layer 2" for the MV connector service, and "destination layer 3" for the MV transportation service.

Next, the model calculates the accessibility of each service provider and adds standardized scores to supply layers 1, 2, and 3 accordingly. Based on the model developed in chapter 4, the model generates the accessibility scores by calculating opportunities at the destination and the impedance between origin and destination within the service areas. The supply model generates the accessibility scores by calculating opportunities at the destination and the impedance between origin and destination within the service areas (input: supply layers, street network, destinations; output: supply layers with accessibility scores). More details can be found in chapter 4.

Then, the model combines the supply layers from the previous step to generate a single “Supply Layer” with standardized scores and classified accessibility results (i.e., very high, high, medium high, medium, medium low, low, very low) using natural break classification. As a result, each census block group gets a standardized accessibility score and classification result (input: supply layers with accessibility score; output: Supply Layer with the standardized score and classification result).

Then, the model generates a “Demand Layer” with standardized scores and classification results (i.e., very high, high, medium high, medium, medium low, low, very low) using natural break classification. Each census block group gets a standardized score for the demand and the classification results (input: the demand layer; output: the demand layer with standardized score and classification result).

Finally, the model overlays the “Demand Layer” and the “Supply Layer” and identifies problematic census block groups with higher demand and lower supply, categorized as “very high and high” demand and “very low and low” supply (input: the demand layer and the supply layer; output: combined supply and demand layer showing the gap areas).

7. CONCLUSIONS AND RECOMMENDATIONS

A summary and the conclusions of the research are presented below followed by some recommendations for long-term model maintenance and data management.

7.1 Summary and Conclusions

The goal of this study was to develop a model to help identify transportation gaps for Florida's vulnerable populations by using a comprehensive geospatial approach that considers all available transportation service providers at a fine geographic unit.

To achieve this goal, the research started by examining the literature of existing methods in practice and in academia to identify the gaps between transportation needs and transportation supply. Next, the research conducted an in-depth review of the transportation service provider database by examining their characteristics such as service type, route type, schedule type, user eligibility, and travel destinations. This review was conducted in close coordination with the FDOT Project Manager and the Safe Mobility for Life Coalition's Transitioning from Driving team for guidance and information about the providers, and to finalize the categorization. The findings from the review of literature and transportation service provider categorization were used as a guide to support the development of the geospatial model for identifying the transportation service gaps.

Based on the results of reviewing existing methods to identify transportation gaps and categorization of transportation service providers, the team developed GIS model which takes a supply-demand approach using Alachua County data. Transportation supply for the vulnerable populations is calculated by quantifying the transportation accessibility of each census block group based on a gravity model. The model computes accessibility scores by considering the number of destinations and the travel impedance to them within each service area, by route type. For a fixed route service, accessibility score considers the number of destinations and travel impedance to them while traveling using transit routes and walking to and from transit stops along transit routes. For flexible route and door-to-door services, accessibility score considers the number of destinations within the service area and the travel impedance is calculated by applying the OD network analysis technique within the service areas of each service provider. Transportation demand is computed by calculating the volume of the vulnerable population—older adults, individuals with disabilities, and people who do not own an automobile. Using the calculated supply and demand scores, each block group is characterized by the level of supply and demand. Finally, spatial gaps, defined as areas of low supply and high demand, are determined by identifying spatial differences between transportation supply and demand using a supply-demand overlay comparison matrix.

The model was tested using three different scenarios that combined specific users with selected service types in Orange County. The testing showed the ability of the model to determine the gaps for any given combination of users and service type, and to support customization that allows creation of gap maps for the needs of given user categories and for geographic areas of choice.

Finally, the research team explored the role of the model as a tool to assist with planning of effective alternative transportation options to reduce service gaps for Florida's vulnerable populations. It concluded that the model should be considered an integral part of the future vision of FDOT and Safe Mobility for Life Coalition. In this context, we propose a "Find-a-Ride Florida Framework", which includes transportation provider database, Find-a-Ride Florida website, and Gap Maps model. The FindaRideFlorida.org will serve as a resource for people who need transportation services. Also, the website would include a webpage where the Gap Maps could be easily accessed and explored by any stakeholder. Thus, the Framework will serve as an effective mechanism for presenting and maintaining information on the actual gaps in transportation services for the transportation disadvantaged and the latest information from the transportation service providers.

7.2 **Recommendations**

The main challenge for long-term model maintenance is related to the data availability and update frequency. The data expected to change over time include transportation service providers, travel destinations, the street network, and population demographics. This section provides recommendations for the long-term maintenance of the required data.

7.2.1 Data and Update Frequency

- **The Essential Data Required for the Model**

The following data is critical to maintaining the model: transportation service providers, fixed route services, destination layers, street network, demographics, and various geographic extents.

<u>Transportation service providers.</u> The model depends on the service provider's attributes such as service area, eligible users, service destinations, and route types.

<u>Fixed Route Service.</u> This model is designed to use the GTFS data to determine service areas covered by fixed router service. We considered GIS data from the Florida Transit Information

System (FTIS) but found that some of the data do not contain the required attributes to run the model, e.g. departure or arrival time information. In addition, the FTIS data lack attribute consistency across geographic areas which prevent the use of a single unified model for the entire state of Florida. Therefore, we concluded that GTFS data is a more suitable data source for this model. Another benefit of using GTFS data is that the data is updated frequently and reflects most recent public transportation data.

Destinations. Destination layers should include the spatial location of each destination and its category type such as medical, non-medical, education, or work.

Street Network. GIS street network requires street length and speed limit for the accessibility calculation.

Demographics. The demographic data should contain the geographic boundary and population volumes such as the number of older adults and the number of individuals with disabilities. Additionally, demographic data are used for calculation of accessibility and for identifying the transportation gaps.

Geographic Extents. The model requires various geographic extents such as county boundaries, MPO, MSA, and FDOT district boundaries.

- **Update Frequency**

Data update is one of the most critical factors to ensure long-term usefulness of the model as the data changes over time. Here we provide considerations for data updates organized by the key data attributes, data source, expected update frequency, and important use notes (See Table 7-1).

Table 7-1. Required Model Data

Data	Source	Key Attributes	Expected update frequency	Note
Service Provider	Find-A-Ride	Service area in spatial format, eligible users, destinations, service type, service schedule, route type	Ideally, whenever their information is changed but at least once a year	Need to develop interface for transportation service providers input Need to educate transportation service providers

Table 7-1. Continued

Data	Source	Key Attributes	Expected update frequency	Note
Service Provider (fixed route)	FTIS (GTFS)	stop, route	Updated periodically but not in a consistent reliable schedule. Annual updates assumed.	Need to preprocess to use in the model
Destinations	FGDL (FDOR)	Categorization (Medical, Non-medical, Education, Work), description	Every year	Parcel data, need categorization field
Street Network	Open Street	Street network, sidewalk	Varies from daily up to every 6 months	Need to preprocess to use in the model
Demographic	FGDL (US Census)	Number of older adults, Number of individuals with disabilities, Number of low income people	Annually (American Community Survey, BEBR)	Census block group level
Geographic extents	FGDL	Spatial boundary	Every few years	Most relevant boundaries don't change

Transportation service provider information must be updated regularly. As proposed in the future vision of the model, it should be updated whenever their information is changed because it directly affects the accuracy of results in the FindaRideFlorida.org. For both the Gaps Model and the FindaRideFlorida.org, it is strongly recommended that for best results the service area boundaries should be in spatial format. This can allow the model to accurately pinpoint the service gaps. Additionally, as we suggested in chapter 3, service provider attributes should include the criteria for eligible users, destinations, service type, or route type. Table 7-2 below provides a template to guide the service provider's data update. We used two transportation service providers to demonstrate how to use this table as an example.

Table 7-2. Template for Updating Information of Transportation Service Provider Database (Example)

ID Service Provider Name		567 Disabled American Veterans: Gainesville / Lake City	12 Elder Care of Alachua County
Service Area	Spatial Format		
Service Type	Public Transportation Paratransit Specialized Transportation Vehicles for Hire	 Y	 Y

Table 7-2. Continued

ID		567	12
Service Provider Name		**Disabled American Veterans: Gainesville / Lake City**	**Elder Care of Alachua County**
Route Type	Fixed Route	Y	
	Flexible Route		
	Door-to-door		Y
Schedule	Fixed Schedule		
	Call-in-advance	Y	Y
	On-demand		
User Eligibility	General Public		
	Older Adults		Y
	Low income		Y
	Individuals with disabilities	Y	Y
Destinations	Medical	Y	Y
	Non-medical		Y
	Education		Y
	Work / Volunteering		
Service Hours	Monday	8:00AM - 4:30PM	8:00AM - 5:00PM
	Tuesday	8:00AM - 4:30PM	8:00AM - 5:00PM
	Wednesday	8:00AM - 4:30PM	8:00AM - 5:00PM
	Thursday	8:00AM - 4:30PM	8:00AM - 5:00PM
	Friday	8:00AM - 4:30PM	8:00AM - 5:00PM
	Saturday		
	Sunday		
Cost	Free Service	Y	Y
	Flat Fee		
	Charge by Distance		
Accommodation	Escort to/from vehicle		
	Full escort		
	Wheelchair equipment	Wheelchair Van	Wheelchair Van
Note		Service only for Veterans	Service only for people over 60 years of age

The FindaRideFlorida.org should provide a mechanism for transportation service providers to draw their service area on a map. When that is not possible, transportation service providers should add spatial information using administrative boundaries e.g. indicated the zip codes of their service areas.

The type of service for each transportation service provider should be categorized as one of the four we have established in this study. The first category is public transportation that is transportation on a bus or other vehicle available to the general public with fixed schedule and route. The second is paratransit, which includes both public paratransit service and ADA complementary paratransit service. Third is specialized transportation, which represents transportation options with specific users and purpose including senior transportation, specialized disability transportation, specialized medical transportation, non-emergency medical transportation, emergency evacuation transportation, and airport / seaport shuttle. Finally 'vehicles for hire' is another service provider type that users pay for the service and providers charge by travel distance. However, vehicles for hire might offer limited mobility options due to lack of affordability or support for special equipment for a certain segment of population.

Regarding the route type, we have established three categories. First, it is the fixed route service which has predefined routes and stops. Second, it is the flexible route, which use a flexible route based on the requests of the users. And the third is the door-to-door service which picks users up at the front door and drops them off at specified destinations upon request.

In our model there are three schedule types. The first is fixed schedule - the provider sets the times when customers can board. The second, call-in-advance - the vehicle schedule is set in advance by the rider. The third, on-demand service, is arranged for a single trip to be made as soon as possible.

Regarding the eligible users, the following shows the results from chapter 3. The Find-a-Ride Florida database should use the same consistent definition for eligible users of each service provider.

- Older adults: The U.S. Census Bureau defines the term older population as the population 65 years and over (Werner, 2011). For this project, we consider age 60 above as an older adult and expect to further detail older adults in sub categories (e.g., 60 to 64, 65 to 74, 75 to 84, and above 85) with the input from the project manager and the transition from driving team.
- Physically disabled: The Americans with Disabilities Acts (ADA) defines a person who has a physical or mental impairment that substantially limits one or more major life activities, a person who has a history or record of such an impairment, or a person who is perceived by others as having such an impairment (U.S. Department of Justice, 2009). The Social Security Administration (SSA) considers someone disabled if the person cannot do work that they did before. However, SSA decides if the individual cannot adjust to other work because of a medical condition(s). Additionally, the disability must have lasted or is expected to last for at least one year or to result in death (SSA, 2017). Although each service provider uses different standards for deciding the eligibility of persons as being classified disabled, the Department of Transportation (DOT) defines the eligibility to use ADA paratransit service. Federal Transit Administration (2017) explains in Appendix D to 49 C.F.R. Section 37.125: "The substantive eligibility process is not aimed at making a medical or diagnostic

determination. While evaluation by a physician (or professionals in rehabilitation or other relevant fields) may be used as part of the process, a diagnosis of a disability is not dispositive. What is needed is a determination of whether, as a practical matter, the individual can use fixed route transit in his or her own circumstances.” However, each transit agency, with input from the surrounding communities, defines the specifics of their individual eligibility processes.

- Low income: Low-income individuals may be defined in various ways. The U.S. Census Bureau determines poverty status by comparing pre-tax cash income such as wages and salaries, Social Security benefits, interest, dividends, pension, or other retirement income against a threshold that is set at three times the cost of a minimum food diet in 1963 in today’s price and adjusted for family size, composition, and age of householder (U.S. Census Bureau, 2013).

We have established four categories of destinations: medical, education, non-medical, and work. Medical destinations include medical, dental, or mental health treatment or other similar professional services. Hospital, primary care providers, and outpatient clinics are also included in this category. Places that are medically related other than the primary medical destination, such as pharmacies, labs, and physical therapy locations are also included in the medical destinations category. The education category includes schools, places to attend religious activities, libraries, daycares, and before or after-school care. The non-medical category includes recreation or social destination, which covers a place to engage in exercise, a place for a social event, a place to take a vacation, and a place for entertainment (e.g., theater, sports event place, and bar), historical site, museum, park, and library. Also, this destination category includes a place to get and eat a meal, a snack or drink as well as places to buy goods (e.g. groceries, clothing, hardware store), places to buy services (e.g. dry cleaning, post office, car service, bank, and pet care), gas stations, and shopping malls. The work destination category includes a place to work or volunteer.

In addition to destination categories each service provider could input service hours, cost, and accommodations. In the notes section of the database, the service provider can add comments or additional information about the service.

While service provider information should be updated by each service provider, the other datasets depend on external sources. For the fixed route data, which comes from GTFS, the data is frequently updated by the GTFS administrator. However, to use GTFS data for the model, it is necessary to process the raw GTFS data. Destinations require preprocessing to include destination categories (i.e., medical, non-medical, education, work) in the dataset. The Open Street dataset is frequently updated, but that update is not on a set schedule. Using the

US Census data, FGDL updates census block group data every year. Analysis geographic extent typically do not change frequently. This includes counties, FDOT districts and MPOs.

7.2.2 Dissemination of Gap Maps

The research team recommends a webpage with an interactive map as the most effective method for the dissemination of Gap Maps. Regardless the method of implementation, whether via ArcGIS online or as a custom developed map, the interactive maps can dynamically present the latest information regarding transportation service options status and the gaps in service using various demographic profiles, which in turn becomes a resource for planners to make further improvements.

7.2.3 Future Research

Recommendations for next steps and future research would focus on selecting and implementing one of the options for dissemination of the Gap Maps and provide education/training for stakeholders and transportation service providers.

- **Develop Transportation Service Provider Information Interface**

Currently, transportation service provider information is not updated through the FindaRideFlorida.org. To ensure better integration with FindaRideFlorida.org and better database consistency we recommend development of an interface for transportation service providers to update their information through FindaRideFlorida.org.

- **Develop Webpage for the Gap Maps**

Gap Maps need to be disseminated to stakeholders involved in improving transportation for Florida's vulnerable populations. The FindaRideFlorida.org could be enhanced through additional webpages to show Gap Maps. The maps could then serve as a broad resource for planning and policy actions to examine specific users and transportation options in a local context.

- **Implement Interactive Gap Maps**

Gap Maps should be generated for various geographic extent e.g. counties, MPOs, DOT districts and should be made available as interactive maps to FDOT's Safe Mobility for Life Program and other stakeholders to support transportation programs for Florida's vulnerable populations.

- **Support Gap Studies with Local Agencies**

Before the Gap Maps can be successfully used to support transportation improvements, further and closer studies of the gaps in the local context are necessary to fully understand the gaps including a comparison of the model results with evidence on the ground. This can be implemented as a pilot study with a local agency that is interested to apply the Gap maps and is willing to participate in validation of the results of the gap model. Eventually the findings can bring new information that can lead to future improvements of the gaps model.

- **Disseminate the Gaps Model**

An important next step is to educate stakeholders such as Safe Mobility for Life Coalition members, local planners and policy makers by presenting the model to meetings and by conducting training webinars. The outreach to stakeholders has also the benefit of stakeholders' feedback which in return can be a valuable resource to improve the model and the gap maps in the future.

- **Improve the Gaps Model**

At present the model weights destinations equally when calculating accessibility. However, attractiveness to destinations can be different depending on their size and function. For example, a grocery supermarket attracts a higher volume of shoppers than a convenience store. Therefore, in the future the model should be improved to increase the accessibility accuracy by considering both the number of destinations and their attractiveness weight.

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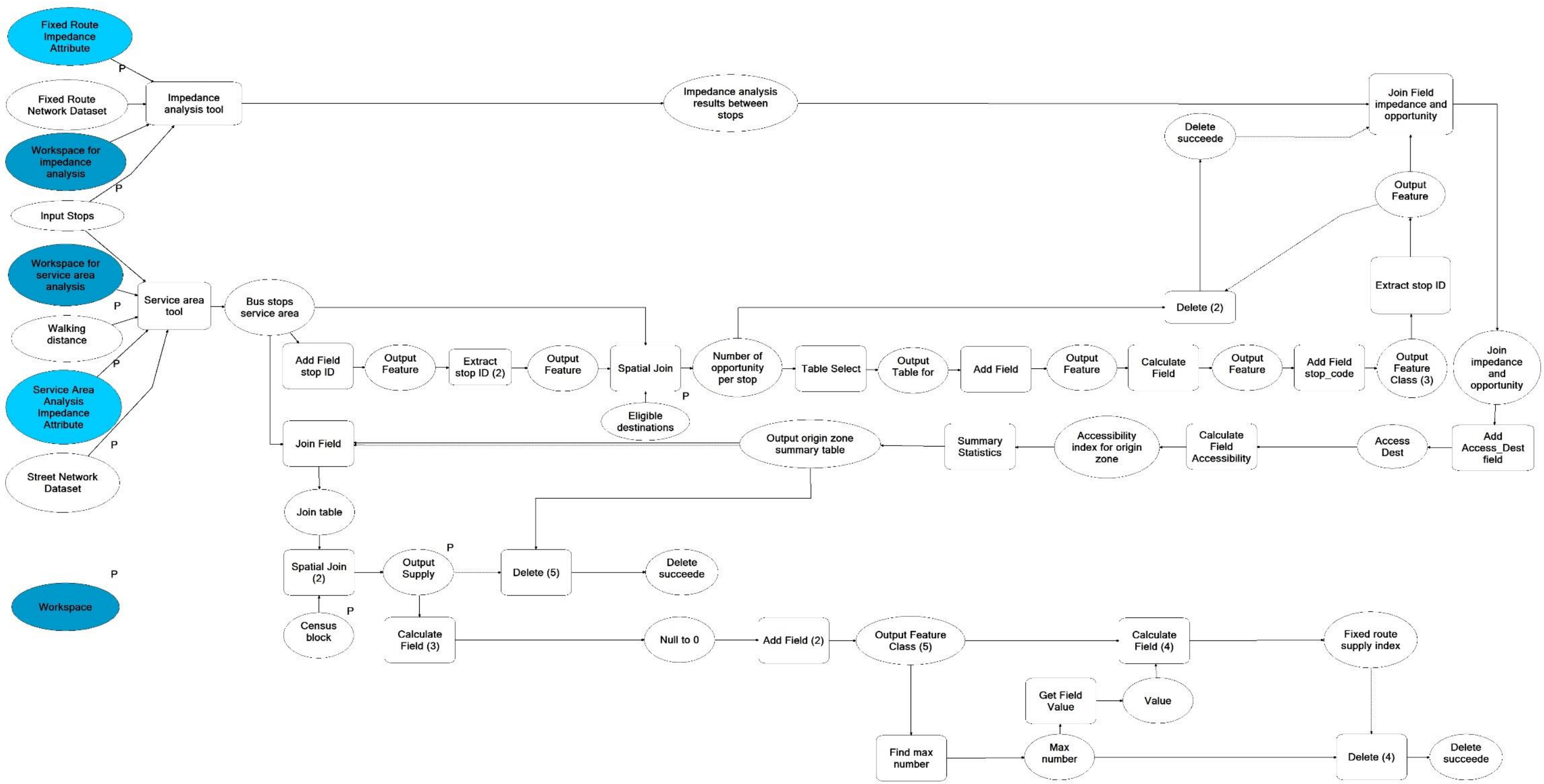
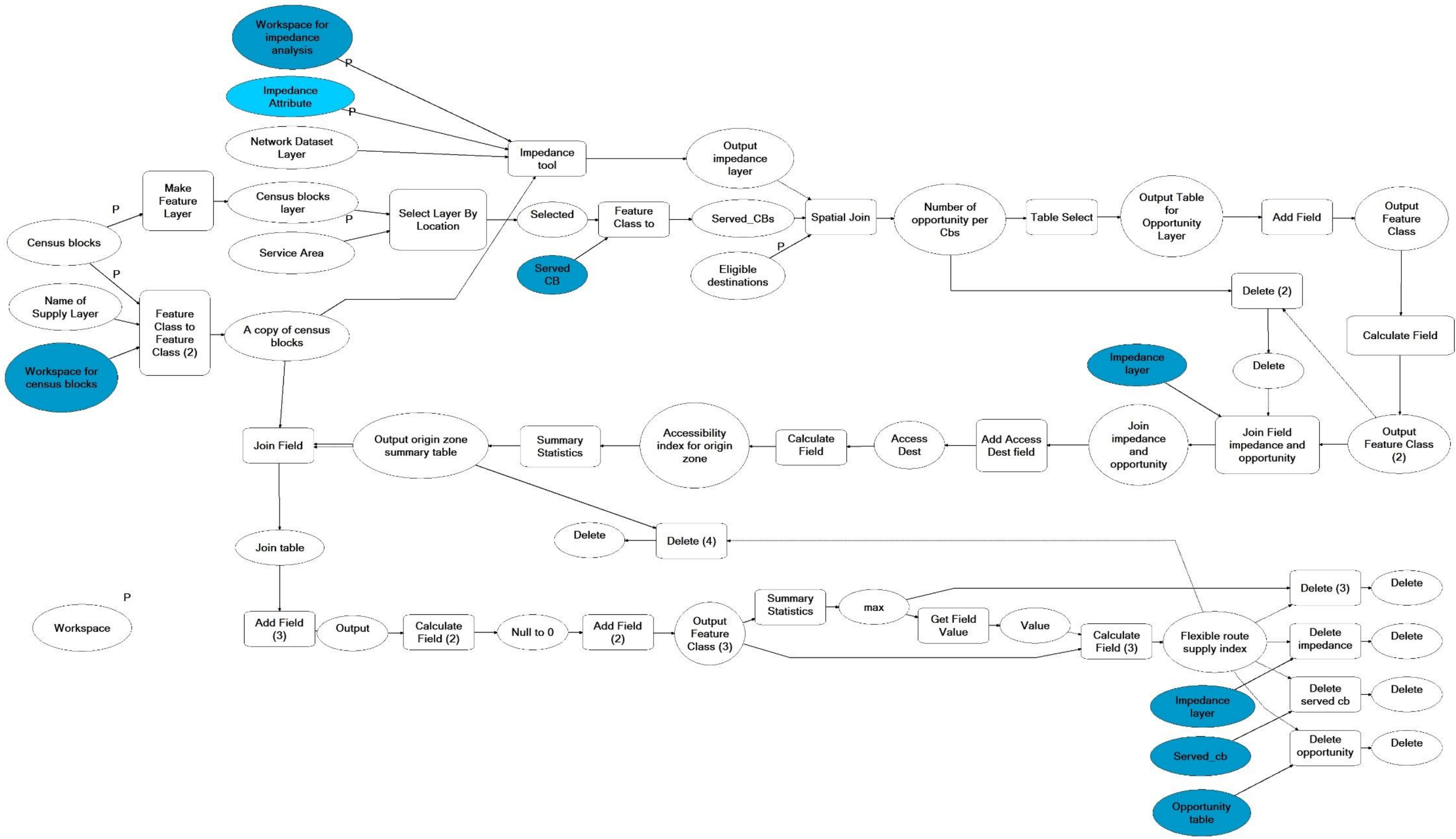
APPENDIX A: GIS MODEL FOR FIXED ROUTE SERVICE



APPENDIX B: GIS MODEL FOR FLEXIBLE ROUTE SERVICE



APPENDIX C: GIS MODEL FOR DOOR-TO-DOOR SERVICE