Mass Transportation Accessibility in Atlanta, GA

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Abstract

The mass transportation system in Atlanta, GA, provides a crucial service to its residents and businesses. Although efforts have been made in the past to unify the Atlanta area's multiple disparate transit lines, little progress has been made. GIS provides the framework to analyze the mass transit system for inadequacies and identify specific problem areas so that they can be addressed by the local government. The objectives of this study are to map the availability of public transportation options, create a mass transit walkability map, and identify areas in need of greater public transportation options. To accomplish this, publicly available GIS data will be analyzed using a Need Index based on population density, socioeconomic characteristics, and a Walkability Accessibility Index. The results will focus on discussing areas, at the census tract level, with inadequate public transportation access and their characteristics, as well as challenges faced in completing the analysis. The results from this study will be useful for planners in charge of Atlanta's public transportation system to prioritize areas to expand in. The methods used here will also be applicable for assessing transportation system needs in other cities.

Background

Over 430,000 people use public transportation on an average weekday in Atlanta, GA (American Public Transportation Association, 2015). While this number seems substantial, MARTA – the Metro Atlanta Rapid Transit Authority – does not directly connect to three of its five neighboring counties, and few metro rail stops mean that public transportation increasingly relies on buses. Atlanta automobile commuters spend nearly 71 hours in traffic a year in a city with the fourth worst traffic conditions in the country (INRIX, 2016).

State and Primary City	Transit Agency	Mode	Average Weekday (000's)
GA Atlanta	Metro Atlanta Rapit Tr Auth	Demand Response	2.2
GA Atlanta	Metro Atlanta Rapit Tr Auth	Heavy Rail	231.7
GA Atlanta	Metro Atlanta Rapit Tr Auth	Bus	199.0
GA Atlanta	Metro Atlanta Rapit Tr Auth	TOTAL	432.9

Figure 1. MARTA average weekday ridership (American Public Transportation Association, 2015)

To complicate matters further, the history of public transportation in Atlanta is inextricably intertwined with the history of race relations. This study seeks to find out where public transportation is not adequately available in the Atlanta metro area and to identify historically underserved communities who still have need for public transportation connections. This study is not meant to provide a comprehensive proposal for alleviating Atlanta's transportation crisis, but rather to identify specific areas of bus and rail opportunity for the city to focus priorities on. While automobile traffic data will be used to inform this paper, analysis will not be done on car use – rather the scope will be limited to bus and rail.

Transportation is a broad term, encompassing a large range of options such as bus, rail (including commuter, mono, light, and heavy), trolley, bike, walking, automobile, and ferries, to name a few (American Public Transportation Association, 2015). Which transportation option commuters choose is influenced by multiple factors, including employment (Sanchez, 1999), cost (Litman, 2004); availability and destination (Sanchez, 1999); overcrowding and reliability (Cantwell, Caulfield, & O'Mahony, 2009); access to a vehicle (Litman, 2004); and traffic or congestion (Gatersleben & Uzzell, 2007). Each of these will now be examined in a bit more detail.

Employment. Many jobs are moving out to the suburbs, which tend to have fewer – or more widely spaced – mass transit stops, which make it more difficult for urban commuters to get to work (Sanchez, 1999). Without access to affordable public transportation options jobs will go unfulfilled, particularly low-income jobs.

Cost. The price of tickets or gas can significantly impact commuter transportation choice. Atlanta transit fares are higher than the nationwide average - $1.83 for bus and $2.21 for rail (American Public Transportation Association, 2016). Low income commuters often afford ridership by “foregoing basic necessities, risking arrest, and relying on welfare workers and the generosity of household members, coworkers, and friends” (Perrota, 2017). Other associated costs are taken into account as well. For example, increased parking prices make public transit more appealing to automotive commuters (Litman, 2004).

Availability. It is perhaps obvious, but commuters are more likely to choose more readily available transportation options. For example, the closer a commuter is to a bus or rail stop the more likely they are to utilize it (Sanchez, 1999). Many studies have used a radius of approximately ¼ of a mile to determine streets and residents who have easy access to transit systems (Lei & Church, 2010).

Destinations. One of the great appeals of owning a car is that the commuter has virtually unlimited places they can travel to. Conversely, by their nature public transit options have limited numbers of destinations. If the public transit network provides insufficient coverage, riders will not use it because it cannot get them where they want to go (Sanchez, 1999).

Overcrowding. If transit options are overcrowded and uncomfortable, this may decrease satisfaction and increase stress, leading to fewer people using that transit option (Cantwell, Caulfield, & O'Mahony, 2009). For example, overcrowded trains can discourage commuters from repeating that transit experience and instead push them to an alternative method.

Reliability and frequency. Most commuters have a regular and recurring need for the same transportation in order to reach their job. Public transit which is on-time and rarely breaks down – in other words, has few service interruptions – has higher commuter satisfaction and is more appealing as a transport option (Cantwell, Caulfield, & O'Mahony, 2009). If the commuter cannot trust a transport option to get them to work on time, most of the time, then they will either have to find another choice or get a different job.

Access to a vehicle. Once a commuter makes the switch to driving an automobile it is much more difficult to get them to switch back to public transport (Litman, 2004). This is in part due to associated positive psychological effects from owning and using a car, including producing feelings of “autonomy, protection, and prestige” – feelings not usually produced by public transport (Gatersleben & Uzzell, 2007).

Traffic and congestion. As a counterpoint to the previous factor, drivers who are often stuck in traffic feel great frustration and do not feel in control (Gatersleben & Uzzell, 2007). The Atlanta metro area has seen enormous increases in travel delays due to increasing traffic without accompanying increasing traffic capacity (Metro Atlanta Chamber of Commerce, 2007). High-occupancy vehicle (HOV – lanes limited to use by vehicles with two or more passengers) lanes have been created within the city limits in order to ease congestion. However, once the highways leave the city limits, they transition to high-occupancy toll (HOT) lanes, which permit vehicles with three or more passengers to use them for free or vehicles with fewer passengers to pay a toll (ranging from a few dollars to nearly twenty per trip) in order to use them. The common-sense implication of these HOT lanes is that commuters with higher incomes are better able to afford to use them on a regular basis (Hart, 2013). And regardless, the introduction of HOV/HOT lanes has not prevented Atlanta's traffic problem from getting worse, as the average commuter spends more time in traffic every year (INRIX, 2016).

In Atlanta, the primary provider of mass transit in Atlanta is MARTA, which was first created in 1965. Originally, it was planned to connect the city of Atlanta with its five surrounding counties: Clayton, Cobb, DeKalb, Fulton, and Gwinnett. Out of those five counties only DeKalb and Fulton supported MARTA, and to this day none of the other counties are connected to Atlanta through a unified mass transit system (Monroe, 2012). Although attempts have been made to connect to the remaining counties, this has failed twice, once in 1990 and more recently in 2012 (Hart, 2012). Neither the MARTA rail system nor buses connect to Clayton, Cobb, or Gwinnett counties, rather commuters must transfer from MARTA transport options to local bus systems, or utilize the GRTA Xpress regional bus lines, which were created by the Georgia Regional Transportation Authority after its inception in 1999 by then-governor Ray Barnes in order to combat air pollution in the Metro Atlanta area (Trelstad, 2000).

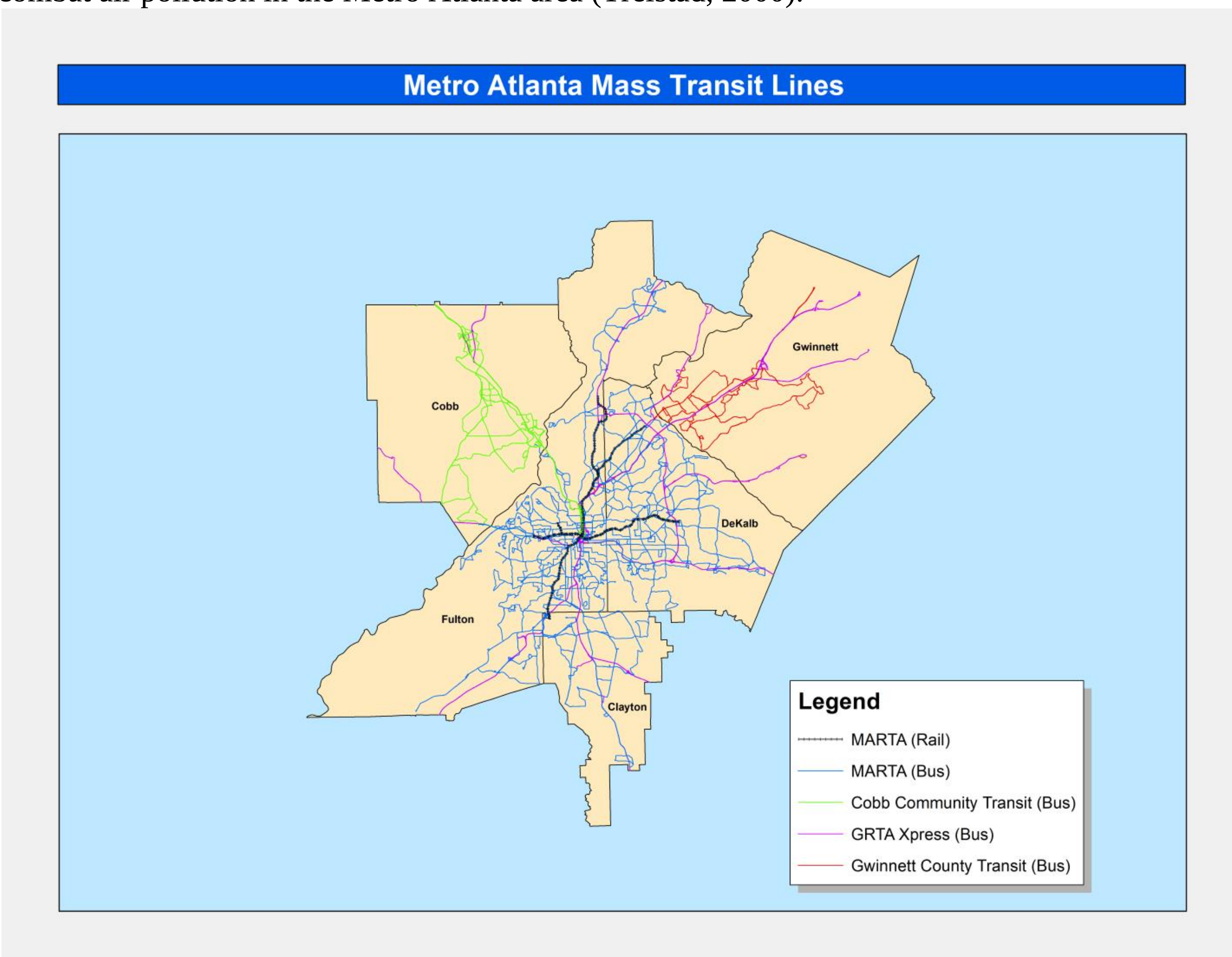


Figure 2. Metro Atlanta mass transit lines

Although the aforementioned factors affect the demand and use for public transportation there are additional complexities. Studies have also shown that commutes with transfers (as well as public transport overcrowding) generate high levels of stress and job strain (Cantwell, Caulfield, & O'Mahony, 2009).

While many metropolitan areas have employment opportunities, city residents often do not have the necessary education to take advantage of those opportunities, and instead find their jobs moving further and further out into the suburbs (Sanchez, 1999). These jobs moving out into the suburbs also tend to be "dispersed", rather than concentrated, and urban public transport is designed to operate in highly concentrated areas and subsequently "do a poor job of serving dispersed trip origins and destinations." (Sanchez, 1999) To put it another way, people living in "fringe" and "regional" areas as opposed to urban centers experience greater transport barriers to employment and leisure activities (Delbosc & Currie, 2011). Therefore, the innate challenges facing public transport are only exacerbated when surrounding areas refuse to connect to the system, instead creating an ad hoc coalition of different public transport systems which then must all coordinate and cooperate with each other.

Several studies have examined Atlanta's transportation issues using a Geographic Information System (GIS). These studies have focused on HOT/HOV lane use (Southern Environmental Law Center, 2013), health impacts of automobile use (Friedman, Powell, Hutwagner, Graham, & Teague, 2001; Frank, Andresen, & Schmid, 2004), economic impacts of public transportation availability (Sanchez, 1999; HNTB Corporation, 2015), how Atlanta mass transit is closely intertwined with racism and anti-urbanism (Henderson, 2006), and finally a Need Index assessment of potential mass transit expansion (Yao, 2007). Several of these studies will be summarized in greater detail below in addition to related studies focusing on other cities.

Yao's 2007 Need Index study examined demand potential for public commuter transit in Atlanta. He compared a Need Index (NI) method with a self-organizing map (SOM) method. The NI inputs land-use and socioeconomic characteristics as well as network structure to assign each spatial unit a NI value. The SOM on the other hand utilizes the same inputs but runs them through a machine-learning algorithm

Yao found that many areas identified by the NI as having high potential demand were expanded into by the Atlanta mass transit systems in 2005, although gaps remained. However, the main purpose of the study was to compare complex mathematical methods, so the results were not examined in greater detail (Yao, 2007).

In 2011 a case study of Meriden, Connecticut utilized three different methods for analysis: Local Index of Transit Availability, Transit Capacity and Quality of Service Manual, and the Time-of-Day Tool. The researchers found that the results varied widely across methods, which were each designed for a different audience, and had to create a method to weight each tool to create usable data. The researchers only considered commuters within a quarter-mile buffer of transit stops, and thus found their study to have limited utility in other more general contexts (Al Mamun & Lownes, 2011).

Another 2011 case study examined New Haven, Connecticut, and used a composite transit accessibility index compared against transit need. The transit need was measured using the percentage of the population which were Transit Disadvantaged Workers (TDWs), and the Service Gap was measured as the difference between the accessibility index score and the need index score. The characteristics used to determine the TDW population were: Forced Car

Ownership, Zero Car Ownership, Low Income Earners, Workers over 65 Years Old, and Disabled Workers. This method of using TDWs to measure need was found to be useful and allowed analysis of a narrower swath of the population (Mamun, 2011).

Mavoa et al. completed a study in 2012 of Auckland, New Zealand, where they examined transit accessibility using a Public Transit and Walking Accessibility Index (PTWAI) combined with a transit frequency measure. Transit time was measured from every land parcel to 17 different destinations and then each parcel was given an accessibility score based on travel time.

The researchers found the PTWAI to be a useful too, as it combines multiple measures for a more comprehensive accessibility scale. Unfortunately, given the high resolution used it is extraordinarily resource intensive, and study results will heavily depend upon which destinations are chosen to measure for each land parcel (Mavoa, Witten, McCreanor, & O'Sullivan, 2012).

In the study by the Southern Environmental Law Center in 2013, over 1.5 million HOT transactions were analyzed to determine whether or not income level correlate with HOT lane use. The analysis resulted in a statistically significant correlation between median income and HOT lane use. However, with a Correlation Coefficient of R=0.44, median income is not the only influencing factor. Yet, it remains an important one (Southern Environmental Law Center, 2013). This study suggests that automotive attempts to alleviate congestion are disproportionately used by higher-income demographics, meaning that those with lower incomes do not benefit as much from these efforts.

Several studies have examined the specific health risks of Atlanta's traffic, including a 2001 study which found that when efforts were made to curb traffic congestion in downtown Atlanta during the 1996 Olympic Games, the reduced traffic congestion "was associated with a prolonged reduction in ozone pollution and significantly lower rates of childhood asthma events" (Friedman, Powell, Hutwagner, Graham, & Teague, 2001). A 2004 study found that Atlanta residents' risk of obesity increased by 6% for ever hour per day spent in the car, and that the risk was reduced by 4.8% for every kilometer per day walked (Frank, Andresen, & Schmid, 2004). These studies underscore the public health benefits of a robust public transportation network as it can reduce car use and increase the amount of walking done by commuters, even by a small amount.

In "The Connection Between Public Transit and Employment: The Cases of Portland and Atlanta", Sanchez examined impacts on employment from mass transit stop proximity. In Atlanta, there is a "strong association between proximity to a bus stop and employment level" as seen in Figure 3. For every half-kilometer away from a bus stop one went the number of weeks worked by nonwhites dropped by 1.9. Access to rail lines also has a statistically significant relationship to employment level, although not as significant as access to a bus stop. However, a "causal relationship" between higher access to public transit and higher employment was not observed. One important potential explanation for this unintuitive result is that public transit lines may not go to where the jobs are or may be too expensive for low-income households to use (Sanchez, 1999).

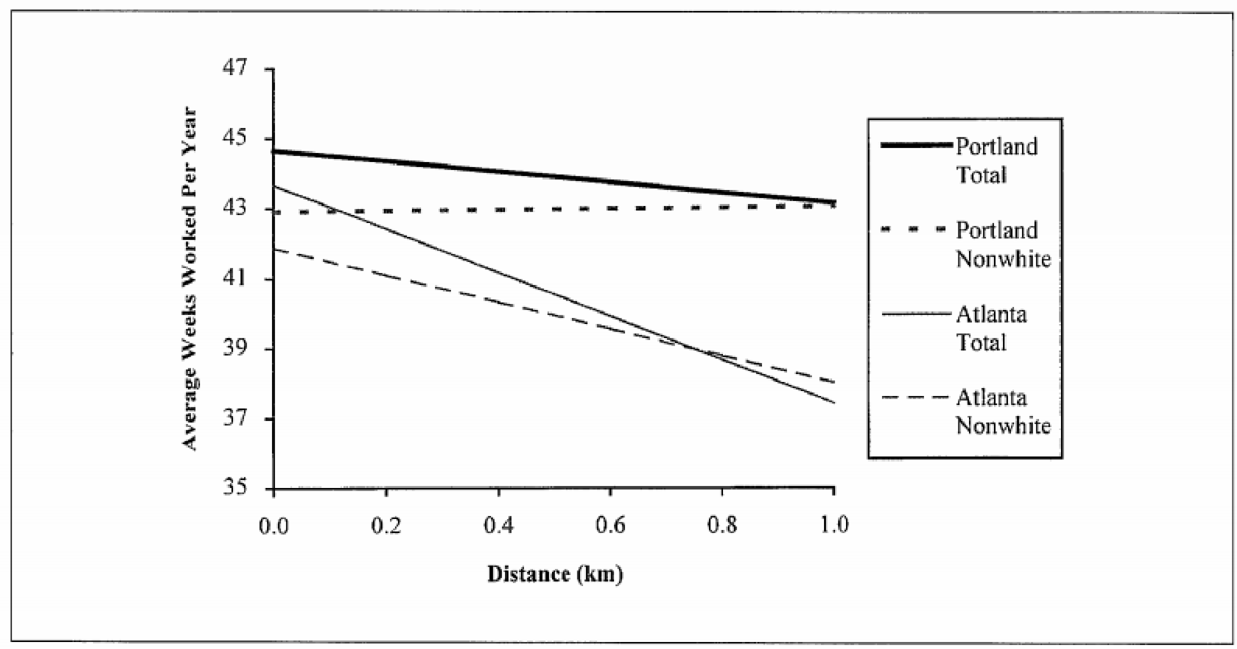


Figure 3. Distance to bus transit and employment levels, taken from "The Connection Between Public Transit and Employment: The Cases of Portland and Atlanta" (Sanchez, 1999).

Purpose

The purpose of this project is to create a transportation availability map for Atlanta, GA and its neighboring counties, based on demographics (including race and income level).

This project's goal is to create a series of maps with the following three objectives:

1. Summarize currently available public transportation (bus and train) options connecting the city of Atlanta with its five surrounding counties: Clayton, Cobb, DeKalb, Fulton, and Gwinnett
2. Create a Walkability Index to measure population accessibility to public transport stops
3. Identify areas in need of public transportation by integrating accessibility and availability with population information to create a Need Index

Methodology

The data used will include at least the following types:

- County/city boundaries
- Mass transit stops and lines
- Demographic data

A variety of sources will need to be used. Primary sources will be the US Census Bureau, Atlanta city, and surrounding county websites and GIS repositories. Preprocessing of the table data to connect it to spatial polygon data will need to be completed. The following table lists each data source to be used.

Data Table

	Type	**Description**	**Source**
Boundaries	Polygon	Published: 2016 Scale: 1:500,000	https://www.census.gov/geo/maps-data/data/cbf/cbf_counties.html
Transit Stops	Point	Published: 2016	http://opendata.atlantaregional.com/datasets/transit-stops-2016
Transit Lines	Line	Published: 2016	http://opendata.atlantaregional.com/datasets/dd084d56fb994651b85699b9807e1f45_146
Schedule data	Table	Published: 2018	http://www.itsmarta.com/, https://cobbcounty.org/index.php?option=com_content&view=category&id=427&Itemid=2073, https://www.gwinnettcounty.com/portal/gwinnett/Departments/Transportation/GwinnettCountyTransit/RoutesandSchedules, http://www.xpressga.com/
Census tracts	Polygon / Table	Published: 2016 (5-year estimates from 2010 – 2015) Scale: 1:500,000 Attributes: population, income, commuter type	https://www.census.gov/geo/maps-data/data/tiger-data.html

The data will need to be processed and some will need to be digitized in order to be used in the analysis. The preprocessing necessary for each is listed below:

	Data Preprocessing
Boundaries	Clip to desired county boundaries Ensure data is in correct projection
Transit Stops and Lines	Ensure data is in correct projection
Schedule Data	Generate tables from data scraped from the various transit agency websites
Census tracts	Clip to desired county boundaries Join to boundary data Remove unnecessary data columns
Commuting data	Remove unnecessary data columns Join to boundary data

Additionally, a crucial step will be to ensure that the correct cell size is used so that the raster analysis can be completed correctly. The cell size must be equal to that of the dataset with the coarsest resolution.

Analysis

(A) Availability of public transportation options: Capture available public transportation (bus and rail) lines connecting the city of Atlanta with its five surrounding counties: Clayton, Cobb, DeKalb, Fulton, and Gwinnett.

The boundary data was clipped to show only Cobb, Fulton, DeKalb, Gwinnett, and Clayton counties. The transit line data was joined with the schedule data table in order to add service frequency, fare, and travel time attributes to each line. Finally, the transit lines were dissolved to obtain their total network length.

The first map, Atlanta Area Transit Agencies, was by overlaying the transit line data (displayed by agency) over the census tract data showing population density. Fare and network length information were then incorporated into the legend.

The second map, Maximum Cost and Travel Time, overlays the county boundary data (displayed by fare cost to Atlanta) with the transit line data, displayed by maximum scheduled travel time from one end of the line to the other.

(B) Walkability map: Accessibility to public transport based on walking distance to transport nodes/stations.

A series of intermediate buffer raster layers were created around the transit stop data at 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 6, 7, 8, 9, and 10 km intervals. Two sets were created, one with interval distance as the value and the other with service frequency as the value. The interval distance rasters were then reclassified with their values as walking time for that distance in minutes, calculated from the below table.

The service frequency rasters required additional steps. Given limitations in hardware processing capacity, each raster had to be individually reclassed with negative values, which were then subtracted from the next level up service frequency raster (i.e. 0.5 negative value raster subtracted from the 1 negative value raster) to create a band of data which does not overlap with any of the other bands. All these intermediate band rasters were then combined into a single raster with the raster calculator.

Realistic Travel Times	
Walking	5 km/h
Driving	40 km/h
Bus	20 km/h
Rail	43 km/h

(British Heart Foundation, n.d.; Couture, Duranton, & Turner 2016; NTD, 2016)

Score	Walkability Index
A	< 15 min
B	15 – 30 min
C	30 – 45 min
D	45 – 60 min
F	> 60 min

The final Walkability Index values were created by combining the total walking time plus half the service frequency time to represent the average amount of time a commuter would need to wait for service once arriving at the stop. Thus, the scores in the table above represent the amount of time it takes for a commuter to leave their front door and step on a bus or train. Areas further than 10 km from the closest transit stop were ignored.

(C) Identify areas in need of public transportation: Integrate accessibility and availability with population information to determine what areas are most in need of public transportation and the populations most affected.

A Need Index was created by calculating the percentage of the population comprised of Transit Disadvantaged Workers (TDWs). In order to be considered a TDW, the worker must fall in to one of the following categories:

- ≥ 65 years old
- < $30,000 annual income
- Commute by car without owning a car
- Disabled

Each census tract was then assigned a score based on the percentage of population which fell into these four groups.

Score	Need Index
A	> 40%
B	30 – 40%
C	20 – 30%
D	10 – 20%
F	< 10%

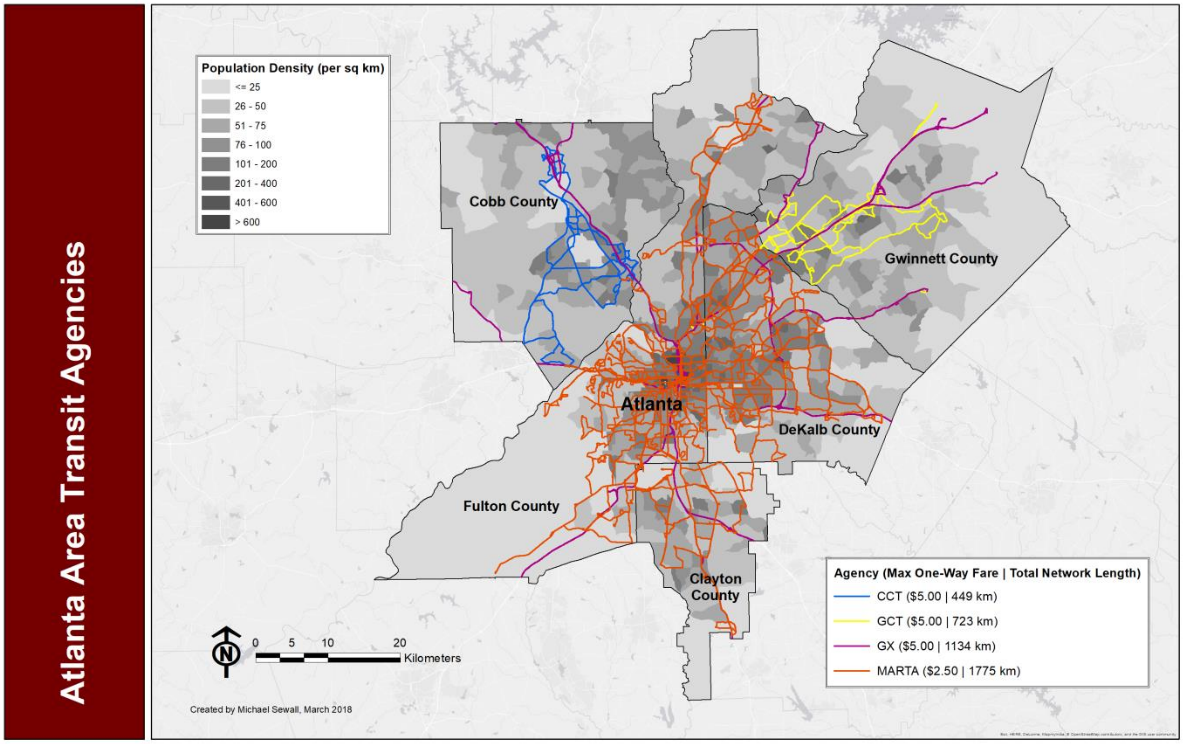
In order to make the next step easier, the highest Need Index grades correspond to the tracts with the *highest* need, matching the grades for the Walkability Index which correspond to the *highest* level of service.

Finally, a Service Gap map was created at the census tract level by subtracting the Walkability Index grade from the Need index grade. A Service Gap value was then assigned based on the difference between the grades.

Service Gap	Grade Difference
No Gap	≤ 0
Low	1
Average	2
High	≥ 3

Results

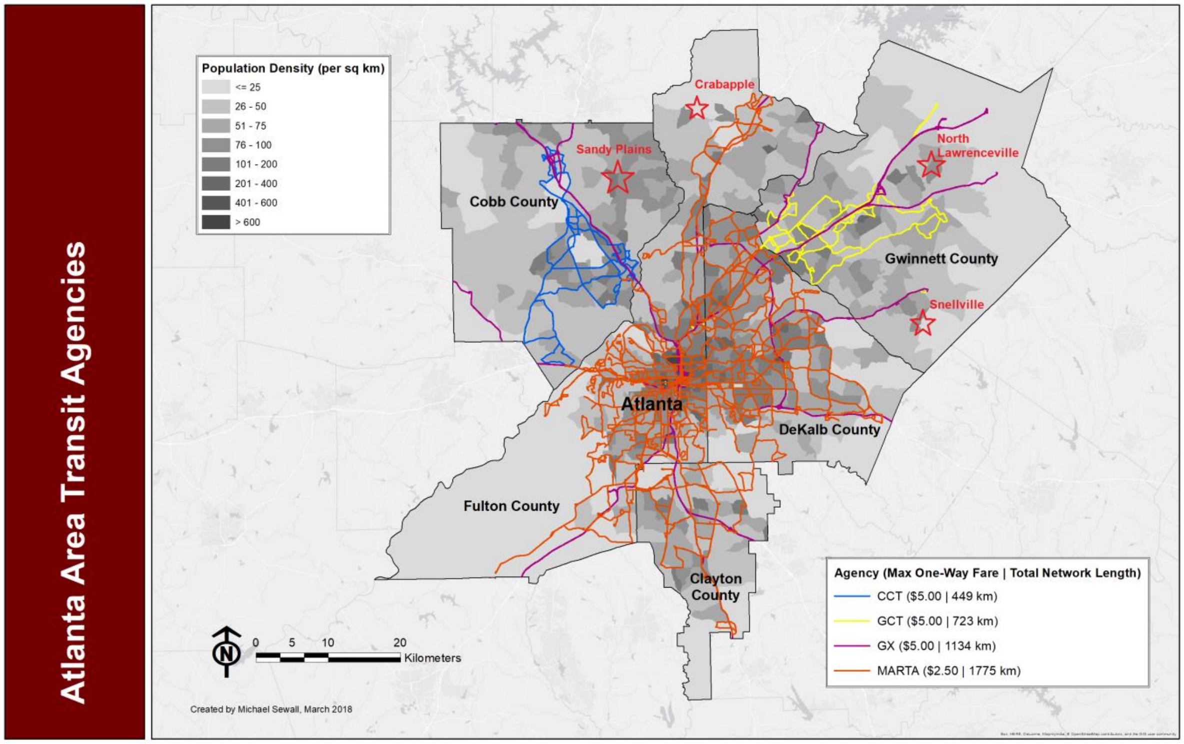
(A) Availability of public transportation options: Summary of all public transportation options and availability



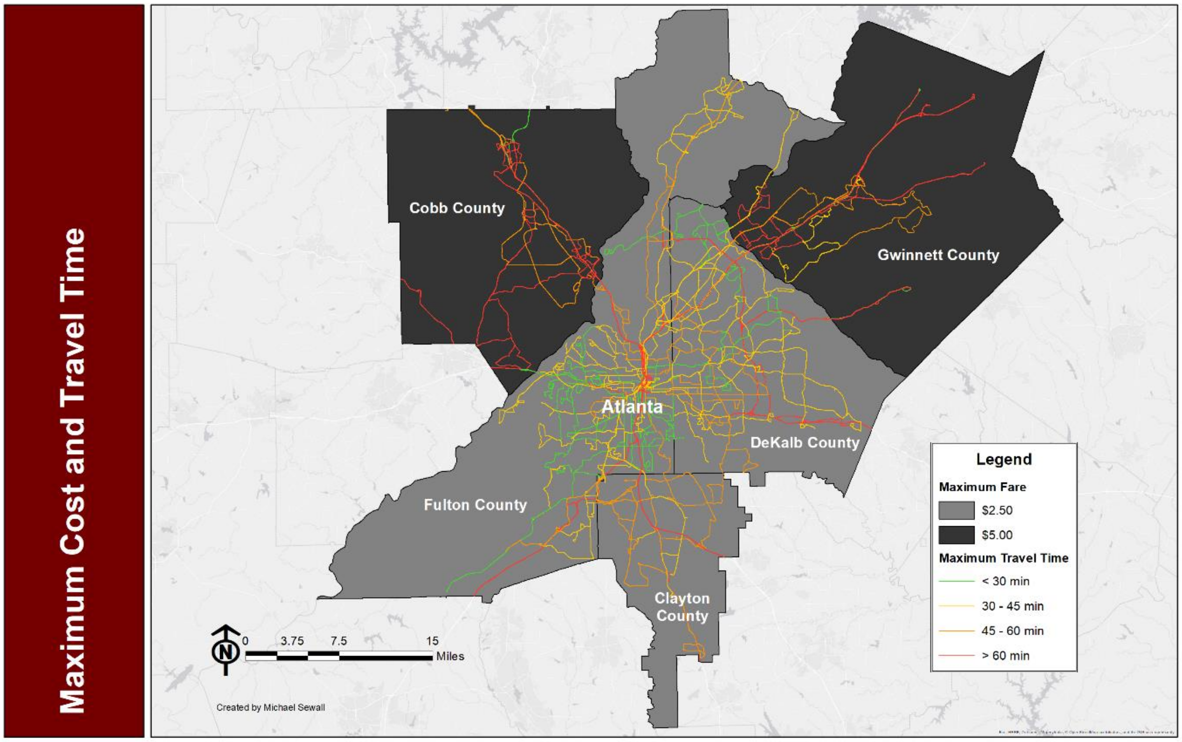
This map shows population density by census tract and the transit agencies which service the metro Atlanta area (excluding the Atlanta streetcar and private shuttles). The data is supplemented by network fare and size information. There are several inferences which can be drawn from this map.

First, MARTA provides service over twice the area of the local CCT and GCT agencies at half the cost. It is important to note that local fares within Cobb County for CCT and Gwinnett County for GCT are $2.50, but if you want to cross county lines the fare increases to $5.00 as you will need to take a GRTA Xpress line operated either by GRTA Xpress or by CCT/GCT. MARTA has a flat fare cost for both rail and bus, and provides service in a significantly larger area. The effects of the refusal of Cobb County and Gwinnett County to connect to and help fund MARTA since 1965 are clearly shown in the way the transit agencies have developed. The GRTA Xpress lines (created by mandate of the state government) are the only direct ways to get from either of those two counties to downtown Atlanta. It is worth noting that agreements have been established to allow CCT and GCT to operate several of the GRTA Xpress lines, but this makes no difference in cost for commuters.

Second, there are obvious gaps in coverage, which is obvious even without further analysis. Several of these locations are marked in the map below.

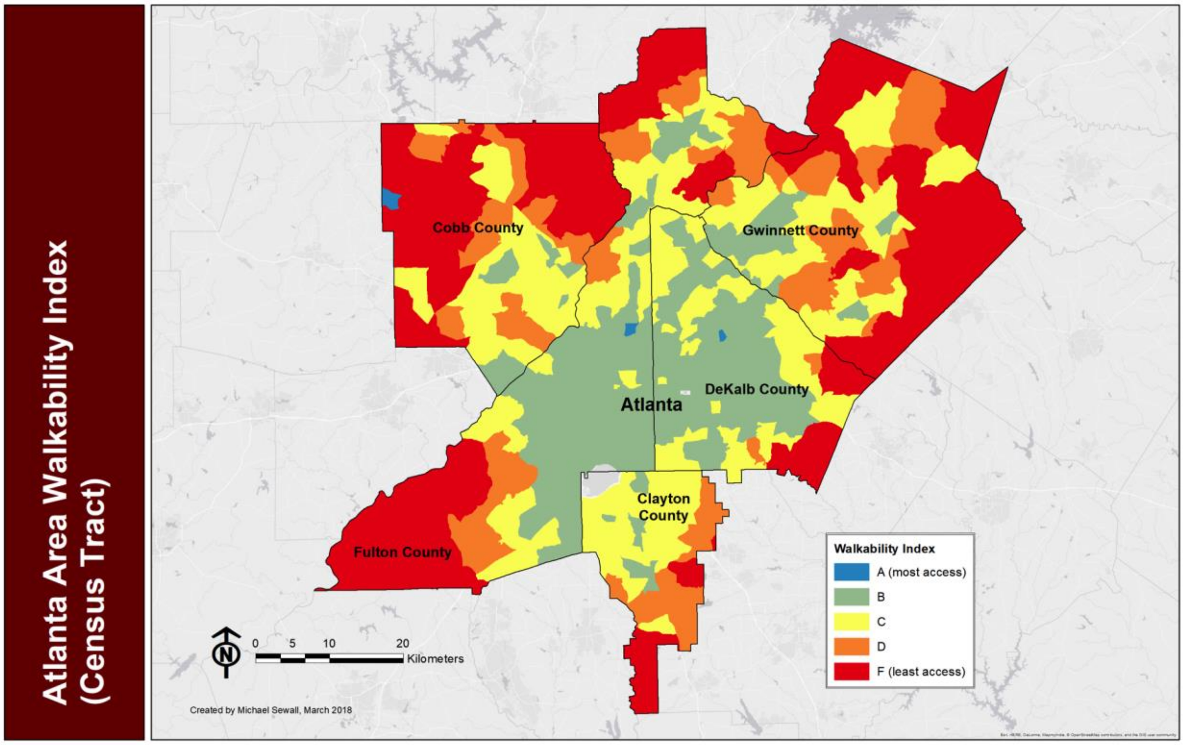


Almost the entirety of west Cobb County has virtually no mass transit service. Sandy Plains, an affluent suburb of Marietta, as well as the rest of northeast Cobb County, also has no service. Crabapple, another affluent area, is somewhat unique in Fulton County in that it has insufficient service. It's also hard to miss the large blank area in southwest Fulton County, near Palmetto. While much less dense, this area also is much less affluent than the areas previously discussed. In Gwinnett County, North Lawrenceville has a fairly significant population, but lies awkwardly between two express lines and as such utilizing the mass transit lines actually requires driving a car to get to the bus. Snellville is another area which is underserviced, with a single express line connecting it to downtown Atlanta, and a notable lack of any local lines connecting it to the rest of its own county.



The Maximum Cost and Travel Time map also shows the fare cost, except this time summarized by county. It's important to note that Fulton, DeKalb, and Clayton counties can utilize the GRTA Xpress lines which are more expensive, but this is not necessary to cross county lines or reach downtown Atlanta. The travel time is the maximum scheduled travel time from end to end of the line, so its accuracy for a particular commuter will vary based on which stop they board and which stop they disembark. Factors which can influence the travel time are the number of stops on a line (which can be indicative of an overtaxed line) and the distance, which is particularly noticeable on the Xpress lines. It is interesting to note that even the local CCT and GCT lines have a longer travel time than the local MARTA lines do, which suggests that on the whole they do not provide as efficient of service as MARTA does.

(B) Walkability map: Accessibility to public transport based on walking distance to transport nodes/stations



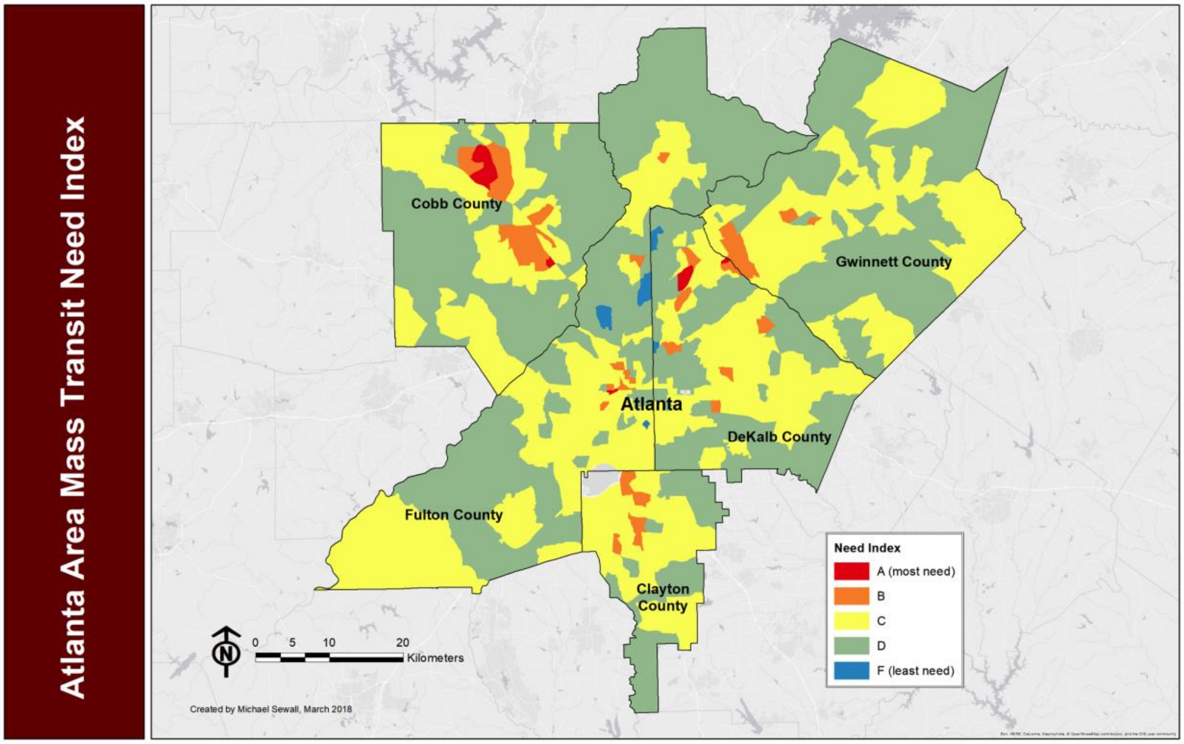
The Walkability Index was created by combining the walking time from each cell to its closest transit stop with the average time between service for each stop. In other words, it is a "from house door to bus board" measure, so it does not include travel time while on mass transit and walking time from the stop to the place of employment.

Only 2% of the five-county area has the most desirable index of 1, meaning it takes less than 15 minutes on average to walk to and board a bus. Less than 27% falls into the next category, a time between 15 and 30 minutes. Over 35% of these counties takes between 30 and 60 minutes to walk to and board a bus, while another 31% take longer than 60 minutes. There are areas of no data, which represent land further than 10 km from the closest transit stop. This area accounts for 3.44% of the total.

These results support the initial analysis results gleaned from the previous maps. Almost all of west and northeast Cobb County (Sandy Plains) would require an hour or more to walk to and board the closest bus. Most of Gwinnett County, including North Lawrenceville and significant areas around Snellville, take just as long. Northwestern and southwestern Fulton County also have the least desirable Index score, while a large chunk of southwestern Fulton has no mass transit accessibility at all. Central Fulton County, where the city of Atlanta is located, as well as most of DeKalb County have large percentages of relatively good accessibility.

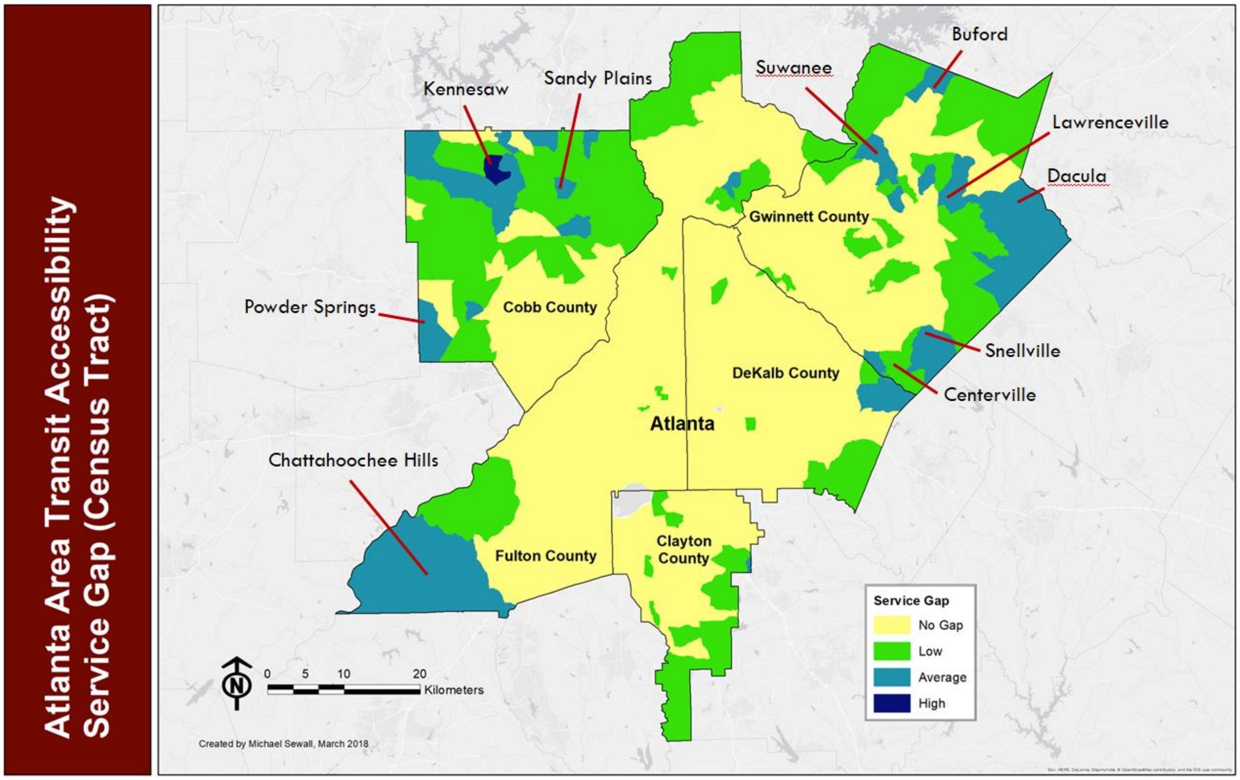
Overall, only approximately a third of the area of these counties has easily accessible mass transit, a third has moderately accessible mass transit, and another third has little or no mass transit available whatsoever.

(C) Identify areas in need of public transportation: Integrate accessibility and availability with population information to determine what areas are most in need of public transportation.



The Need Index results show that there are clusters of higher need where more TDWs live, but that most census tracts have a lower need. It is still important to meet that need, so that the TDWs who do live in census tracts with lower need still have access to mass transit options.

It is interesting that the largest pockets of need are in Cobb County, which is not connected to the surrounding counties through MARTA and instead have sparse connections through GRTA Xpress lines.



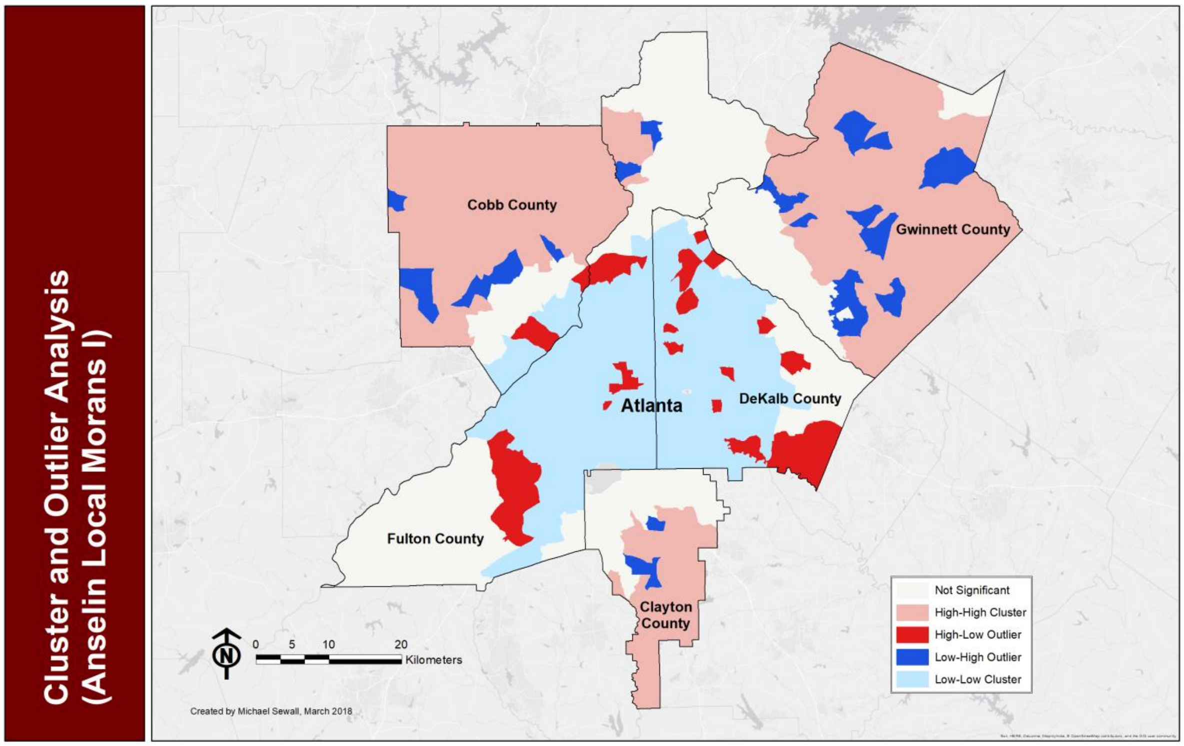
Overall, the closer you are to downtown Atlanta, the better the service level and the lower the service gap. The service gap increases towards the fringes of the Atlanta area. The greatest average service gap is in Cobb and Gwinnett counties, neither of which are part of the MARTA system. Fulton County does have a large area in the southwest, where Chattahoochee Hills is located, where there is an Average service gap. This can be explained by the rural nature of these census tracts, with only a single MARTA line providing service to the southeastern part of that block.

One important point to keep in mind is that several of these communities with service gaps are actually quite wealthy, like Sandy Plains, for example. Historically, there has been some hesitancy in Cobb and Gwinnett counties to connect to the broader regional mass transit system, and that is reflected on a smaller scale within specific communities in these counties.

Conclusion

Several conclusions can be drawn from these analyses.

Perhaps the most obvious conclusion is that service gaps remain in the Atlanta metro area, with many census tracts lacking suitable access to mass transportation for Transit Disadvantaged Workers. It is important to note that closer you are to the downtown Atlanta area, the better the service is, while for the most part the regions without adequate service lie on the periphery. This may be a common-sense result, but it is important for transportation planners to know definitively so that efforts can be made to focus expansion along the periphery. For the most part, mass transportation accessibility is good enough or better for most of the downtown area.



Another important point to note is that the largest service gaps are in counties not serviced by MARTA: Cobb and Gwinnett counties. Both of these counties have historically lagged significantly behind Fulton, Clayton, and DeKalb counties in providing mass transit access to their population. MARTA was created in 1965, and it wasn't until 1989 that Cobb county created a mass transit system, and Gwinnett did not create one until 2000. GRTA Xpress, which runs express regional lines, was not created until 1999. Combined, all these agencies have a daily ridership of about 28,500, a mere 7% of MARTA's daily ridership. Multiple attempts have been made to extend MARTA to these two counties, with the most recent in 2012. The long-term effects of opting out of the regional transport network are obvious in the map results, with large gaps in service apparent.

Continued work is necessary to meet underserved populations throughout this region. First steps have already occurred, with agreements between the transit agencies allowing for fare transference and a common fare card. Cobb Community Transit and Gwinnett County Transit are now also operating a few GRTA Xpress lines to provide service to downtown Atlanta. However, in recent years the focus has been more on adding toll lanes to major highways, which as has been discussed earlier disproportionately benefit wealthier commuters without positively impacting TDWs – perhaps those who most need assistance. Greater efforts need to be made to reach those commuters who *cannot* make use cars, or who find driving prohibitively difficult for a variety of reasons.

More work is needed to provide a more complete picture, as this study looks at a subset of the whole.

Further studies would benefit from extending this analysis to the Atlanta-Sandy Springs-Roswell Metropolitan Statistical Area, a 21 county area encompassing the region as a whole. This analysis would show connections between urban centers and not just from suburbs to a single urban center. It would also be helpful to conduct the analysis at a finer resolution than census tract, to more accurately locate areas in need of increased service.

Conducting the analysis for broader population profiles would provide a more complete picture as well. This study focused on Transit Disadvantaged Workers, but extending the analysis to all commuters, as well as mass transit users who are not commuters, would allow for better planning.

Finally, this data should be provided to regional transit authorities and planning agencies – the Atlanta Regional Commission, for example. This would allow for a practical application of this project, and impetus to further this research.

Bibliography

Al Mamun, S., & Lownes, N. E. (2011). A Composite Index of Public Transit Accessibility. *Journal of Public Transportation, 14*(2). Retrieved October 23, 2017, from http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1121&context=jpt

American Public Transportation Association. (2015). *APTA Public Transportation RiderShip Report.* Washington, DC: American Public Transportation Association. Retrieved October 9, 2017, from http://www.apta.com/resources/statistics/Documents/Ridership/2015-q4-ridership-APTA.pdf

American Public Transportation Association. (2017). *2016 Public Transportation Fact Book.* Washington, DC: American Public Transportation Association. Retrieved October 23, 2017, from http://www.apta.com/resources/statistics/Documents/FactBook/2016-APTA-Fact-Book.pdf

Atlanta Regional Commission. (2014). *2014 Transportation Fact Book.* Atlanta: Atlanta Regional Commission. Retrieved October 23, 2017, from http://documents.atlantaregional.com/transportation/TFB_2014_v17.pdf

British Heart Foundation: Walks and treks FAQs. (n.d.). Retrieved September 25, 2017, from www.bhf.org.uk: https://www.bhf.org.uk/get-involved/events/training-zone/walking-training-zone/walking-faqs

Cantwell, M., Caulfield, B., & O'Mahony, M. (2009). Examining the Factors that Impact Public Transport Commuting Satisfaction. *Journal of Public Transportation, 12*(2), 1-21. Retrieved August 27, 2017, from http://scholarcommons.usf.edu/jpt/vol12/iss2/1/

Couture, V., Duranton, G., & Turner, M. (2016). *Speed.* University of California, Haas School of Business, Berkeley. Retrieved October 23, 2017, from http://faculty.haas.berkeley.edu/couture/download/Couture_Duranton_Turner_unp2016.pdf

Delbosc, A., & Currie, G. (2011). The spatial context of transport disadvantage, social exclusion and well-being. *Journal of Transport Geography, 19*(6), 1130-1137. doi:10.1016/j.jtrangeo.2011.04.005

Frank, L. D., Andresen, M. A., & Schmid, T. L. (2004). Obesity relationships with community design, physical activity, and time spent in cars. *American Journal of Preventive Medicine, 27*(2), 87-96. doi:https://doi.org/10.1016/j.amepre.2004.04.011

Friedman, M., Powell, K., Hutwagner, L., Graham, M., & Teague, W. (2001). Impact of Changes in Transportation and Commuting Behaviors During the 1996 Summer Olympic Games in Atlanta on Air Quality and Childhood Asthma. *JAMA*, 897-905. doi:10.1001/jama.285.7.897

Gatersleben, B., & Uzzell, D. (2007). Affective Appraisals of the Daily Commute: Comparing Perceptions of Drivers, Cyclists, Walkers, and Users of Public Transport. *Environment and Behavior, 39*(3), 416-431. doi:10.1177/0013916506294032

Hart, A. (2012, August 1). *Voters reject transportation tax*. Retrieved August 18, 2017, from The Atlantic Journal-Constitution: http://www.ajc.com/news/state--regional-govt--politics/voters-reject-transportation-tax/fZB3UVE1IM5jMVlhZvpruN/

Hart, A. (2013, August 25). *I-85 HOT lane: 'Lexus Lanes' or an option for all?* Retrieved August 18, 2017, from The Atlantic Journal-Constitution: http://www.myajc.com/news/local/hot-lane-lexus-lanes-option-for-all/KP1x8msX0gp36ir0LB0I1I/

Henderson, J. (2006). Secessionist Automobility: Racism, Anti-Urbanism, and the Politics of Automobility in Atlanta, Georgia. *International Journal of Urban and Regional Research, 30*(2), 293-307. doi:10.1111/j.1468-2427.2006.00662.x

HNTB Corporation. (2015). *Economic Benefits of Investing in Transit.* Atlanta: Metro Atlanta Chamber. Retrieved October 18, 2017, from http://www.mymidtownmojo.com/wp-content/uploads/2016/12/Marta-MAC-brochure20.pdf

INRIX. (2016). *INRIX Global Traffic Scorecard*. Retrieved from inrix.com: http://inrix.com/scorecard/

Johnson, M. (2010, March 16). *Average schedule speed: How does Metro compare?* Retrieved September 25, 2017, from ggwash.org: https://ggwash.org/view/4524/average-schedule-speed-how-does-metro-compare

Lei, T. L., & Church, R. L. (2010). Mapping transit- based access: integrating GIS, routes and schedules. *International Journal of Geographical Information Science, 24*(2), 283-304. doi:10.1080/13658810902835404

Litman, T. (2004). Transit Price Elasticities and Cross - Elasticities. *Journal of Public Transportation, 7*(2), 37-58. Retrieved August 27, 2017, from http://scholarcommons.usf.edu/jpt/vol7/iss2/3/

Litman, T. (2015). *Evaluating Accessibility for Transportation Planning: Measuring People's Ability to Reach Desired Goods and Activities.* Victoria: Victoria Transport Policy Institute. Retrieved August 21, 2017, from https://pdfs.semanticscholar.org/f825/8c66401bf0b0737602bbc63b1d04539142e8.pdf

Mavoa, S., Witten, K., McCreanor, T., & O'Sullivan, D. (2012). GIS based destination accessibility via public transit and walking in Auckland. *Journal of Transport Geography, 20*, 15-22. doi:10.1016/j.jtrangeo.2011.10.001

Metro Atlanta Chamber of Commerce. (2007, February 6). *Georgia Association of Railroad Passengers.* Retrieved August 28, 2017, from garprail.org: http://www.garprail.org/documents/macoc_transportation.pdf

Monroe, D. (2012, August 1). Where It All Went Wrong: If Only We Could Undo The MARTA Compromise Of 1971. *Atlanta*. Retrieved August 18, 2017, from http://www.atlantamagazine.com/great-reads/marta-tsplost-transportation/

National Transit Database. (2016). *2016 Service.* Washington, DC: Federal Transit Administration. Retrieved October 23, 2017, from https://www.transit.dot.gov/ntd/data-product/2016-service

Perrotta, A. F. (2017). Transit Fare Affordability: Findings From a Qualitative Study. *Public Works Management & Policy*, *22*(3), 226-252. doi:10.1177/1087724X16650201

Roberts, B., Povich, D., & Mather, M. (2013). *Low-Income Working Families: The Growing Economic Gap.* The Working Poor Families Project. Retrieved October 23, 2017, from http://www.workingpoorfamilies.org/wp-content/uploads/2013/01/Winter-2012_2013-WPFP-Data-Brief.pdf

Sanchez, T. W. (1999). The Connection Between Public Transit and Employment: The Cases of Portland and Atlanta. *Journal of the American Planning Association*, *65*(3), 284-296. doi:10.1080/01944369908976058

Southern Environmental Law Center. (2013). *A Highway For All? Economic Use Patterns For Atlanta's Hot Lanes.* Atlanta. Retrieved August 18, 2017, from https://www.southernenvironment.org/uploads/publications/selcatlantahotlanereport.pdf

Trelstad, B. (2000). Georgia Regional Transportation Authority: A Case Study of an Innovative Regional Planning Institution. *Berkely Planning Journal*, *14*(1), 23-45. Retrieved October 18, 2017, from http://escholarship.org/uc/item/3gq047nw

Yao, X. (2007). Where are public transit needed - Examining potential demand for public transit for commuting trips. *Computers, Environment and Urban Systems*, *31*(5), 535-550. doi:https://doi.org/10.1016/j.compenvurbsys.2007.08.005