Deana Baron GTECH733

Literature Review

The purpose of this paper is to establish a running literature review of the project; a coverage model of transportation accessibility in terms of Beeline bus stops in Westchester County, NY. This paper cites other literature in which the topics of public transportation accessibility and equity is addressed, along with two models that others have developed. The overall goal is to establish a solid foundation for which the model being developed can be built on.

Transportation accessibility is becoming a particular topic of interest in the transportation geography community as urban areas shift toward public transportation as the main method of transportation. To begin with defining transportation accessibility and how it manifests and can be measured in an urban area, we start with a dissertation by Hunter College graduate Maxwell Siegel (2016), who attempts to quantify transit accessibility in New York City and develop an index to identify spatial and social patterns in public transportation. Siegel discusses how there is only a finite number of resources that planners and municipalities can put into transportation, and there are a multitude of factors that go into establishing the best public transportation network for an area. Accessibility and mobility are two concepts that are commonly brought up for the overall goals of a government agency’s transportation system. There are a myriad of definitions for both. Mobility is generally identified as an efficiency measure of movement to, from, and within a system. Accessibility is identified as more flexible depending on its application, but generally is the idea of availability of goods and services. These concepts are different, however cannot be separated in such a study.

Siegel’s study area was New York City, in which he set out to quantify transit accessibility across multiple different public transportation networks. He established that accessibility can be a measure of social equity, and attempted to understand and break down what different factors differ among different demographics which would result in public transportation disparities. Siegel a total transit accessibility index, which is based on three sub-indices. The Bus-Service and Subway-Service indices were based on three factors: distance to the nearest station/stop, the number of intersecting lines/routes, and the availability of express service. The Disabled-Access index shows just distance from a disability accessible station. The resulting index shows that Manhattan is very accessible, while the outer boroughs are much less accessible. Although Siegel’s index heavily favors subways, it’s useful to determining what factors can be used in determining public transit accessibility (Siegel 2016).

Establishing a measure for public transportation accessibility is important and there are multiple ways to do so. Many of the models set out to measure accessibility use a different measure of travel time, like Tribby and Zandbergen (2012), who set out to design a high resolution spatio-temporal model for public transit accessibility. While accessibility can be thought of as a social measure, implementing this into a network requires some other factors. Tribby and Zandbergen use travel time from origins to destinations using walking times, waiting times, and bus travel times to measure transportation accessibility in this network. The study area was Albuquerque, New Mexico, where at the time of the article, two new bus routes were added to the Albuquerque bus service system. These routes did not replace existing bus routes but expanded the coverage of bus service in the Albuquerque area. The goal was to decrease travel time to the Downtown area of Albuquerque in implementing these routes. The stops on these routes are spread farther apart, but the decreased travel time and increased capacity of the buses make it an attractive option for commuters. Tribby and Zandbergen also establish that different regions of Albuquerque have large demographic disparities, with the Northwest part of the study area being much more affluent and older. In general, the west side contains many more houses than jobs, which would mean many people who live in this region commute across the Rio Grande for work. The authors set Downtown Albuquerque as a catch-all destination based on the amount of economic activity is located within the Downtown region.

This model was built and developed in ArcGIS, and analyzed using the Network Analyst extension. This network was multimodal, and combines a walking network and a bus route network. The walking network was constructed from streets, and were deemed “suitable” for walking if they had sidewalks. The bus route network was constructed from bus routes, with the temporal attributes added from the published bus timetables. There were three temporal categories: morning peak time, afternoon peak time, and off-peak. The interaction between these networks was modeled with boarding and exit lines, and using the bus schedule to determine wait times. Overall, this network can be used to calculate the total travel time between walking, waiting, riding, transferring, etc. Analysis of this network for the morning rush hour from individual address points to Downtown Albuquerque was done, and the total travel time was calculated for the network before and after the addition of the two new bus lines.

The authors also set out to see if this model could be used for social justice applications. They compared the resulting travel times and the travel time savings from address points and comparing it to different socio-economic factors. The authors use weighting of different socio-economic factors to determine high public transportation need, and create an index to show a proportion of transit users in a census block group. The results show that the Northwest area had much more significant time travel savings with the new bus routes while the Southwest area had almost no travel time savings. Using the index, there appears to be a negative correlation between the proportion of transit users and the percentage of travel time savings. This is a very straightforward model, however simple, and ArcGIS Network Analyst is robust but still lacking some functionalities. Regardless, this is a great base for the model being developed, as it is quite similar in idea to what is to be done in Python (Tribby and Zandbergen 2012).

The previous model is a step forward in modeling accessibility in multimodal networks. However, transportation geography is a large and computationally intensive field. ArcGIS has features that work well out of the box without any precursor knowledge about transportation problems and formulas, but understanding these issues from a mathematical standpoint might lend itself to a different solution. It is also important to note that modeling where existing nodes along a network could be moved is a mathematical issue that ArcGIS cannot solve by itself. Although this is an older paper, Alan Murray created a coverage model for public transportation accessibility in Brisbane, Australia in his paper, “A Coverage Model for Improving Public Transit Accessibility and Expanding Access” (2003). One of the major points that Murray discusses that is not discussed in Tribby and Zandbergen is the idea of spatial efficiency of service coverage. What is the best configuration of nodes in a network that will maximize service coverage? Murray also uses origin-destination travel times as an accessibility measure in his model for bus routes in Brisbane, Australia. Unlike Tribby and Zandbergen, this is not a multimodal network.

The one detail in Murray’s paper that is not discussed in either of the other two articles is this idea of spatial efficiency of service coverage. Murray discusses stop spacing optimization for bus routes, which has a direct impact on travel time and speed as a measure of accessibility. Governments have established standards for the spacing of bus routes, usually between 200 and 600 meters. Minimizing the number of stops can improve the performance of a network, however there needs to be enough to service the area. There is also the idea of minimizing the redundancy or inefficiency of stops along a bus route, which occurs when two stops service the same area, which in turn can decrease travel speeds and increase overall costs. The concept of accessibility is abstract, however can be routed in relatively precise approaches and mathematical equations. Evaluating access to bus routes is quite simple, using a sort of spatial aggregation method found in most GIS systems. For evaluating accessibility in a network with respect to efficient bus stop placement, there is an equation using the location set covering problem (LCSP) which can be the driver for modeling. The idea of the problem is to minimize the number of stops within a network, while giving the same areas that already have service in a network continued suitable service. The latter is considered a constraint, so there’s a secondary problem called the Maximal Coverage Location Problem (MCLP), which maximizes the total percentage of the population that will continue to receive coverage with the optimization of bus stops. Both don’t deal with expanding coverage to regions that do not currently have access, which can be dealt with by applying a similar problem to areas without current coverage in the network.

The model used in this paper is a hybrid set covering problem, which allows each currently serviced area to continue to be served by at least one transit stop, and accounting for increased coverage. The study area was Brisbane, Australia, which at the time needed greater public transit needs in the South East Queensland region due to an increase in growth and population. ArcView was used for generating the problems and displaying the results of the analysis from Avenue, which is an ArcView scripting language. The problems were solved externally in ILOG CPLEX. Previous work denoted that there was already a large amount of inefficiency among Brisbane bus stops, but did not account for the optimization and expansion of those routes. There were 19,484 decision variables and 1,522 constraints total. It was found that 98.88% of the population of Brisbane could be serviced with 685 bus stops, 525 existing and 160 new stops. This is complete coverage since 17 of the 1,346 collection districts that were not currently covered can still not be covered. Murray found that since Brisbane has over 7,000 stops at the time of this paper, reducing the number of stops to 685 can have a relatively similar service coverage of the region, and targeting over 98% of the population in Brisbane. Correcting the inefficiencies can then improve travel times and speeds, while lowering costs of the network (Murray 2003).

Overall, the above articles are great starts for the drivers and factors that go into modeling accessibility of public transportation in urban regions. Siegel’s work establishes factors that would go into creating an index for measuring public transit accessibility using demographic factors as well as distance from the nearest stop. Tribby and Zandbergen create an ArcGIS model with Network Analyst that models travel times for a multimodal transit network in Albuquerque, New Mexico, which is a useful step in computationally managing accessibility besides demographic factors. Murray uses a hybrid set coverage problem to not only measure accessibility and access in a public transit network, but to also see how the network could be optimized to provide maximum coverage while also minimizing the number of stops and inefficiencies in the network. In the project at hand, it will be interesting to apply these concepts to a much more densely and highly populated commuter region (Westchester County) with a seemingly more modern transit routing.

Bibliography

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