Creating a Transit Supply Index

Andrew Keller
Regional Transportation Authority and University of Illinois at Chicago

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Introduction

This master's project explores the creation of a transit supply index (TSI) based on the frequency of transit service. The index is created using data supplied by transit agencies through the General Transit Feed Specification (GTFS). The paper will describe the methodology and sources consulted to create this index and perform analysis using northeastern Illinois as its study area. The paper will also describe the challenges in creating the index while exploring its limitations as a level of service tool.

The goal for this project is to create a supply index using GTFS data that can be duplicated for any transit area with data available in the same format. The geographic area used for this study are traffic analysis zones provided by the Chicago Metropolitan Agency for Planning. The service area of the Regional Transportation Authority (RTA) of northeastern Illinois serves as the model for this project, but the methods used can be applied to any transit agency which supplies transit data to the GTFS data exchange.

This paper discusses some of the possible uses for GTFS data in measuring level of service for transit. The goal is to replicate measures of level of service using the tables provided by GTFS feeds. The first part of this paper will contain a brief literature review of the sources consulted for level of service measurements with a description and explanation of the methods used for this project. The next section will apply these methods to the RTA's service area, while the last section will included a detailed description of the methodology.

Sources

This project is based on three main sources, which formed the framework for the index and the set of standards to measure the results. The following section describes the relevant sections of the sources and their contribution to the methodology of this project.

The Transit Supply Index is based on a methodology created for an assignment I completed while studying at the University of Illinois at Chicago. The assignment is to create a level of service index based on frequency of service at CTA rail stations. The frequency score represents the product of transit trips per week and population served, or net person served (NPS). The figure is normalized by total population within the analysis zone to create an average NPS. The score is based on block level data, aggregated to the level of the census tract, then graded based on scores relative to other tracts. Frequency scores for stations are based on manual counts, and coverage area is defined as block centroids within a half mile of a station. The assignment's methodology and scoring system are based on literature from the <u>Transit Capacity and Quality of Service Manual, Part 5: Quality of Service</u>. (TRB, 2003)

Figure 1: Formula for average NPS

$$LOS_j = \frac{\sum_k (p_k \times n_k)}{population_j}$$

k = number of transit stops within the analysis area j.
LOS_j = transit level of service index for the analysis area j
p_k = population within the market shed of the transit stop k
n_k = total number of transit services per day (or week) at the transit stop k

Source: (Kawamura, 2011)

Transit Capacity and Quality of Service Manual (TCQSM)- The guidelines for availability of service are based on frequencies and coverage area as recommended by the TCQSM. The manual measures quality of service from the passengers perspective and assigns letter grades based on average headways during the peak period of transit, usually between 8-9 am. The grades shouldn't be read as an assessment of the transit agency, and not all communities should expect "A" level service. For smaller communities a LOS grade "C" may be an appropriate threshold for minimum service levels. For large transit agencies, ten-minute headways may not provide enough transit supply to meet demand, leading to vehicle crowding and a lower overall quality of service, despite "A" level service based on headways. (TRB, 2003)

The grades are based on the attractiveness of transit to passengers based on the average time between transit vehicles along a route. Figure 1 shows the grading scale, along with comments describing the perception of this level of service to a passenger.

Figure 2: Service Frequency Level of Service Measurements (TRB, 2003)

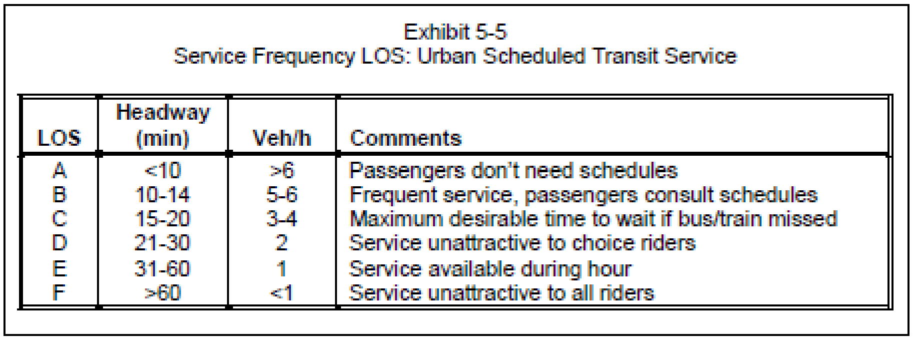

Exhibit 5-5
Service Frequency LOS: Urban Scheduled Transit Service

LOS	Headway (min)	Veh/h	Comments
A	<10	>6	Passengers don't need schedules
B	10-14	5-6	Frequent service, passengers consult schedules
C	15-20	3-4	Maximum desirable time to wait if bus/train missed
D	21-30	2	Service unattractive to choice riders
E	31-60	1	Service available during hour
F	>60	<1	Service unattractive to all riders

The TCQSM contains suggestions on service coverage areas based on transit service type and street design surrounding a transit stop. The literature suggest a quarter-mile buffer around bus stops and a half-mile buffer around rail stations. These buffers are based on willingness to travel studies that have found that these buffers tend to represent 75 to 80 percent of all pedestrians willing to walk to a transit stop. While this buffer is widely used and accepted, the manual is aware of its limitations and has suggestions for creating buffers that more accurately represent the catchment area for a transit stop. An aerial buffer cannot take into account the impact of street design on the actual walking distances required to access a transit stop. One alternative suggestion is to alter the size of the aerial buffer based the level of street interconnectivity using the network connectivity index, as measured by the ratio of intersections to street segments.

General Transit Feed Specification (GTFS)- The main source of data is the General Transit Feed Specification (GTFS), which contains data tables with station location, routes, trips along routes, and stop times for trips at transit stations. The GTFS tables are updated to reflect current service. The data is presented as a series of text (txt) files, each table containing a unique area set of data, with one mutual column shared with another table, allowing tables to be joined for analysis. The data tables can be used to analyze service both spatially and non-spatially.

Methodology

The TSI is created to best approximate the measures and methodology described by the sources, but some modifications and interpretations were made to accommodate for a multi-modal measure and the utilization of GTFS data to calculate station level frequency.

For smaller transit agencies, route frequency can be manually counted and transit stops manually placed into a Geographic Information Systems (GIS) shapefile, but for large transit agencies there are too many routes, trips and transit stops. To enable automatic frequency the GTFS data tables are utilized to measure station frequencies and spatial data to project transit stops in GIS.

GTFS data are an open source resource with data provided by the transit service boards for use in such applications as Google Transit. This data is updated on a regular basis and provides accurate station data that can be projected for GIS-based analysis. GTFS data is available from the transit agencies website individually or through the GTFS data exchange.[1] For this project the data was downloaded from the agency website's development pages. The data is in the form of a series of text files (txt), each with a different set of data points. For this analysis, the text files were imported to a Microsoft Access database, where the data can be sorted, filtered, and joined to created dbf files for use in ArcGIS.

Basic Framework- The TSI is constructed using Microsoft Access and ArcGIS. The geographic regions are traffic analysis zones (TAZ) provided by the Chicago Metropolitan Agency for Planning (CMAP). Creating the TSI is a three-step process. The first step involves using Microsoft access to sort and join text files for use in ArcGIS. Next, data is projected in ArcGIS and a coverage zone based on station buffers and frequencies is created. The coverage area is joined to a geographic zone and a score based on percentage of coverage and frequency is created. The process is repeated for each route in each zone, and all routes within the same zones have their scores summed to create a total TSI score for all routes with service for that zone.

GTFS data are a series of text tables with a different series of data contained in each table. The tables can be joined based on matching columns allowing the data to be manipulated using a database management program such as Microsoft Access. In Access, the txt tables are joined and queried to create a single database file (dbf). The GTFS contains data for

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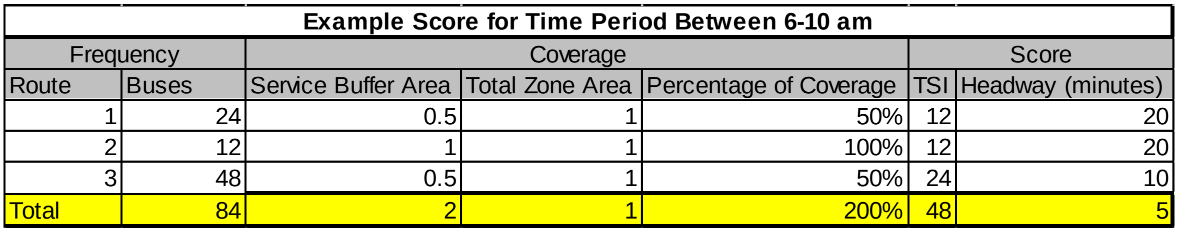
[1] chttp://pacebus.com/sub/about/data_services.asp,
http://metrarail.com/metra/en/home/about_metra/obtaining_records_from_metra.html

http://data.cityofchicago.org/Transportation/CTA-Views/gzmt-5k8a each transit trip occurring at every stop over a period of a week by stop, route, direction, day of the week and time of day. Using the query tool in Access filters all records, saving only records relevant for the day of the week, time period and direction. The remaining records are exported as a dbf for analysis using ArcGIS.

ArcGIS is used to project station locations to create a service buffer based on route and frequency for each transit stop. The dbf contains a record for each stop occurring along a route at a particular station. Using a statistical summary tool in GIS, all records for matching routes and transit stops are summarized creating a frequency count by route for each transit stop. These records are then projected using the latitude and longitude data from the GTFS tables. After the data is projected, a buffer is placed around each transit stop based on route and frequency.

This establishes a service coverage area which can be applied to a geographic zone based on frequency and percentage of coverage within that zone. The service coverage layer and the geographic zone are joined using a union tool, and a new record is created for each portion a route's coverage that occurs within each individual geographic zone. The area of the coverage area within the zone is divided by the area of the zone, to create a weight field. The frequency of service for the route is multiplied by the weight field, to create a weighted frequency score for the portion of the route within each individual zone. The weighted frequency scores for each route in a zone are totaled to create the TSI for each zone. This figure represents the average frequency of transit service available for each geographic zone.

Figure 3: Sample Calculation of the TSI



Example Score for Time Period Between 6-10 am						
Frequency		Coverage			Score	
Route	Buses	Service Buffer Area	Total Zone Area	Percentage of Coverage	TSI	Headway (minutes)
1	24	0.5	1	50%	12	20
2	12	1	1	100%	12	20
3	48	0.5	1	50%	24	10
Total	84	2	1	200%	48	5

Issues, Modifications, and Versions- While the general framework for the TSI is designed to be as straightforward and simple as possible a number of issues arise when translating the guidelines of the <u>Transit Capacity and Quality of Service Manual</u> guidelines to a regional scoring system. Three main questions emerged to adapt the TCQSM standards to a regional model, scored by geographic zone. These questions involve the correct size for service buffers, how to score areas with overlapping buffers, and how to measure transit vehicle frequencies.

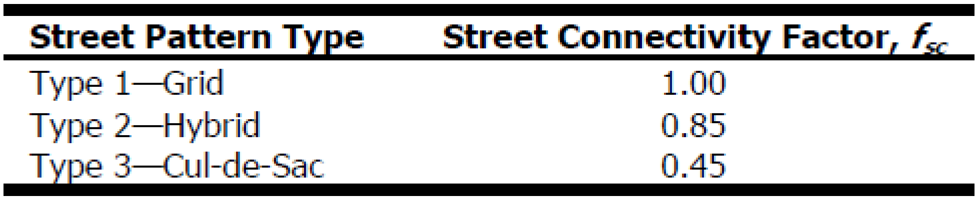
Service Buffers- The goal for service coverage measures is to create a service buffer for the areas surrounding a station that best represents an area that matches the actual area of usage for transit users. However, a regional model also demands a level of simplification in order to limit the number of calculations required to measure large areas. For the models presented in this analysis a quarter-mile Euclidean buffer is placed around each bus stop and a half-mile Euclidean buffer is placed around rail stations. These buffers are based on studies that have concluded that 75 to 80 percent of bus users walk an average of a quarter mile, or about 5 minutes, for bus stops. Rail passengers are willing to walk roughly twice that amount for an average of a half mile. (Transportation Research Board, 2003)

For many reasons the Euclidean buffer does not serve as the most accurate measure for service coverage. The physical layout of the space surrounding a transit station plays a large role how far pedestrians are willing to walk and how much ground can be covered within the time they are willing to walk. A GIS-based network analyzer could simulate a more accurate 5-minute walking buffer based on actual street distance walked compared to a Euclidean-based distance estimate. While this level of accuracy would be ideal, it is not practical for a transit region with a large number of stations, as each network simulation is data intensive. Network analyst tools tend to be extensions and not available to all GIS users.

The TCQSM recommends a less data-intensive approximation using data on the number of street segments and intersections. The more connected the street pattern the higher the proportion of street segments to intersections, the greater the interconnectivity of the pattern. Based on this ratio, TCQSM suggests maintaining the quarter-mile buffer for grid patterns, while reducing the buffer to less than one-eighth of a mile for cul-de-sac streets. The city of Chicago, for example, has a predominately grid-based layout while many of the suburbs feature cul-de-sacs. The adjustments suggested in the TCQSM would not change the coverage for Chicago, but would significantly reduce the coverage areas for many suburban transit stops.

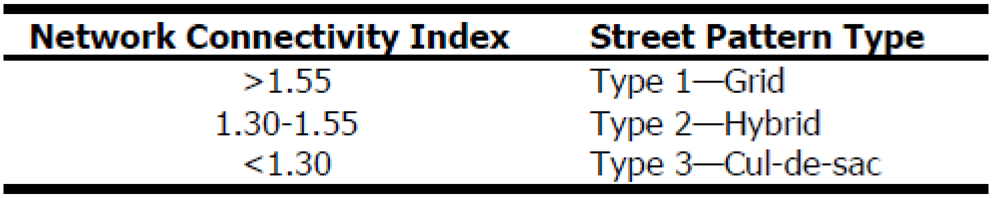
As shown in the Figures 2, the TCQSM recommends no change for streets with grid patterns, while shrinking the buffer more than one half its radius. Figure 3 shows the ratio thresholds for altering buffers based on intersections to street segments.

Figure 4: Street Connectivity Factor (Transportation Research Board, 2003)



Street Pattern Type	Street Connectivity Factor, f_{sc}
Type 1—Grid	1.00
Type 2—Hybrid	0.85
Type 3—Cul-de-Sac	0.45

Figure 5: Network Connectivity Index (Transportation Research Board, 2003)



Network Connectivity Index	Street Pattern Type
>1.55	Type 1—Grid
1.30-1.55	Type 2—Hybrid
<1.30	Type 3—Cul-de-sac

Overlapping Buffers- The Transit Capacity and Quality of Service Manual recommends both buffer sizes for coverage by area and frequency, but does not combine the two. One issue that arises are overlapping service buffers. Transit stops, buses in particular, are often located in close proximity to each other, and a quarter-mile buffer around each station along a route will lead to overlaps. When the overlapping service buffers are joined to the underlying geographic zone, the route frequency for that area will be counted for both stops, leading to double counting and overestimation of service.

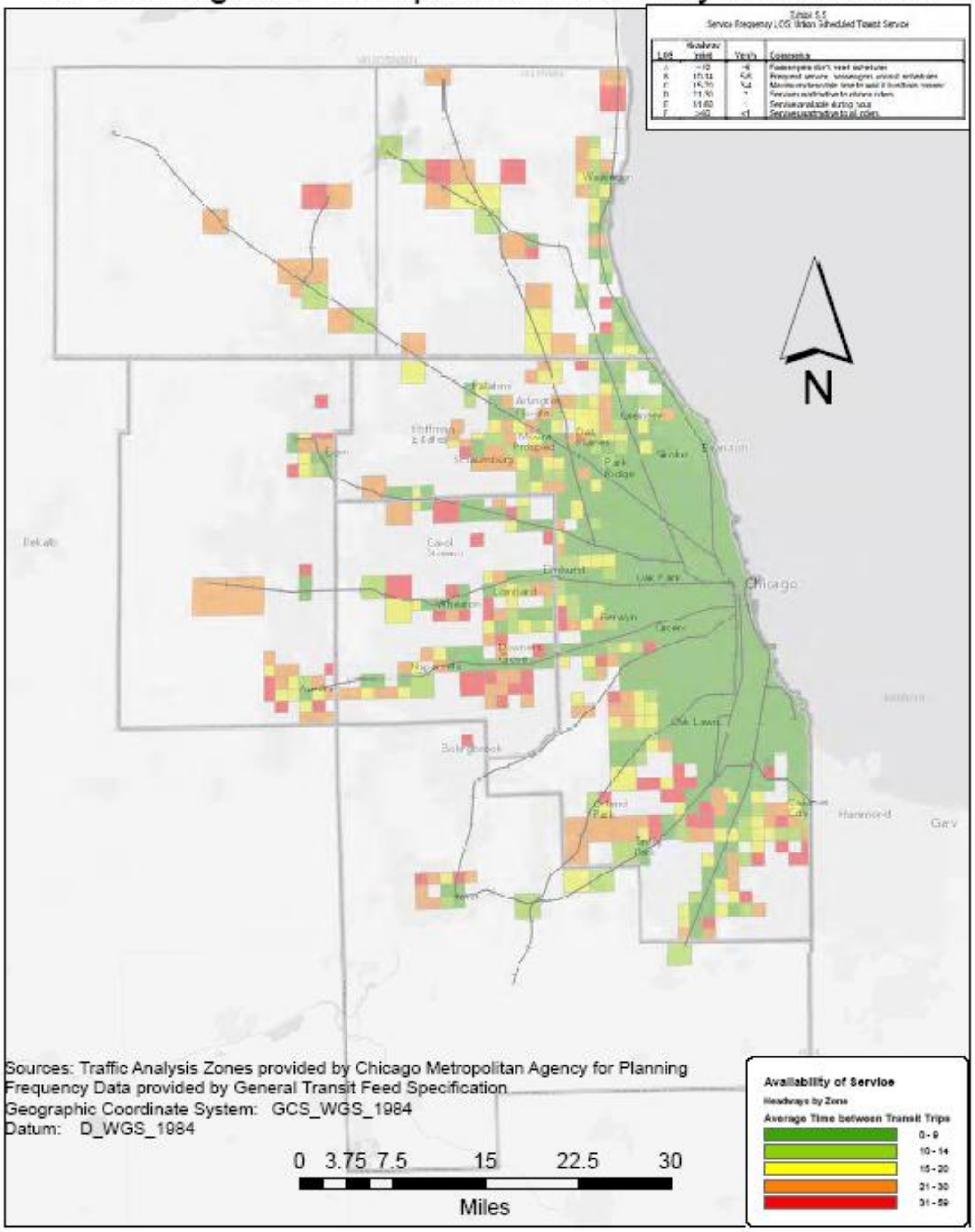
These overlaps occur largely along CTA bus routes, Pace bus routes, and along loop area CTA rail stations. Accommodating for buffers requires consideration for service from the user's perspective. Along many CTA bus routes a stop exists on nearly each block corner. A user may fall into the buffer zone for more than one bus stop. If this bus stop is along the same route, and has the same number of stops, the overlap zone would count the access to four trip for each stop under each buffer for a total score of 8 trips. But this would not truly be the case. The user could not get on the same bus twice at two different stops. However, if a user had access to buses from different stations or along different routes, those should be counted cumulatively since this does offer the user a different opportunity.

To eliminate double counting, all buffers are based on route and frequency. All areas that are under a service area with the same route and frequency are merged into one continuous buffer rather than a series of overlapping buffers. While this is effective if routes have identical frequencies, many routes have variations in station frequencies along routes. Buses often short cut routes to allow for higher frequency in higher demand areas, rail has trunk and branch lines, and many transit routes have areas where vehicles run express.

This creates a different overlap problem. In this scenario a user along the same route has access to six trips at one transit stop, and access to eight trips at another stop along the same route. The overlapping buffers allot a total of fourteen rides to the user. For this model I assigned the higher of the two frequencies to the area under the shared buffer zone. The model assumes a passenger has the choice to use the stop with higher frequency and assigns that value to the overlap portions, eliminating the other record.

Analysis by TSI

Availability of Transit for AM Peak (6-10 am) in Peak Flow for the Regional Transportation Authority Service Area



Sources: Traffic Analysis Zones provided by Chicago Metropolitan Agency for Planning
Frequency Data provided by General Transit Feed Specification
Geographic Coordinate System: GCS_WGS_1984
Datum: D_WGS_1984

The TSI can be used in a variety of ways to measure frequency based on time of day, day of the week, and direction and can be joined to any underlying series of geographic zones. As an example, the six-county area of northeastern Illinois representing the service area of the Regional Transportation Authority (RTA) serves as the test area for the TSI. The version of the TSI prepared for the analysis is frequency of all transit vehicle trips occurring during the am peak between 6-10 am. The data is analyzed at the level of the traffic analysis zone (TAZ) as provided by the Chicago Metropolitan Agency for Planning (CMAP). The analysis looks at the total number of TAZ within each county and the grades assigned to each TAZ within the county.

The accompanying map and tables describe the availability of transit for residents of northeastern Illinois. The score allocated to each TAZ represents the average wait time between transit vehicles travelling in the direction of peak flow for the morning peak period of travel (6-10 am). Based on the thresholds for availability from the Transit Capacity and Quality of Service Manual, transit is more attractive to passengers as the wait time between vehicles decrease. The highest grade "A" represents headways less than 10 minutes. At this level of service, the passenger is comfortable arriving at a transit stop without consulting a schedule. At the lower end of service, grade "F" service has headways greater than one hour and service is considered attractive to no one.

Looking at the two tables, it's clear that Cook County has both the greatest number and the greatest percentage of grade "A" service compared to the other counties, while Lake County has the second highest level of service. Over 90 percent of both Will and McHenry counties have a level of service "F", meaning that the average wait times are greater than an hour between transit trips.

Figure 7: Total Number of TAZ with Grades for Each County

Level of Service Based on Headways- Total by County							
Level of Service	***County***						***Total***
	Cook	***DuPage***	***Kane***	***Lake***	***McHenry***	***Will***	
A	471	34	8	21	0	3	537
B	53	9	2	11	2	4	81
C	66	15	9	12	0	2	104
D	60	22	14	15	6	5	122
E	29	18	10	6	1	3	67
F	173	126	102	110	95	171	777
Total	852	224	145	175	104	188	1,688

Figure 8: Total Number of TAZ with Grades for Each County

Level of Service Based on Headways- Percentage by County							
Level of Service	***County***						***Total***
	Cook	***DuPage***	***Kane***	***Lake***	***McHenry***	***Will***	
A	55	15	6	12	0	2	32
B	6	4	1	6	2	2	5
C	8	7	6	7	0	1	6
D	7	10	10	9	6	3	7
E	3	8	7	3	1	2	4
F	20	56	70	63	91	91	46

While this analysis can be useful on its own, the numbers would be more meaningful if analyzed in conjunction with a demand index, or against minimum coverage thresholds. The score would also have more meaning if connected to a measure of accessibility which would more accurately rate the attractiveness of transit based on both frequency and access.

Conclusions

The strength of the TSI is its ability to be calculated from public sources in a matter that is automated and allows for frequent updates, for both accurate up to date measurements of service, or as a regular process of analysis that can be used to track historical trends in level of service. It can be easily adapted to different geographic zones and the ability to weight coverage based on percentage of a zone. This is useful for lower-density areas with larger zones where a centroid-based coverage zone would lack accuracy. While the process of creating the TSI for a large, multi-modal transit region such as the Chicago metropolitan region can be data intensive and convoluted, the process should be much simpler for smaller transit regions, making this analysis more accessible to smaller transit agencies, or other interested parties, who may or may not be transit analysts.

Because the TSI can be measured in average headways, it creates a metric that can be understood by both transit experts and non-experts, which allows the TSI to be a tool for people outside of the transportation field. For example, retailers may want to consult the

TSI score for areas where they are considering opening a new store. An area with a higher level of service may be more attractive than one with a lower level of service. Government agencies may seek to build service centers in areas with high mid-day frequency of transit, as many seniors and other transit dependent populations would be likely to use during the mid-day off peak hours.

Calculating the TSI at the census tract level can be a useful measure for parties interested in transit equity issues. Comparing the TSI score of census tracts in a community could give a sense of fairness in transit service. It could also be used by communities to set minimum thresholds to ensure they are meeting their minimum standards for service.

The TSI should be calculated at the smallest level of geography that is allowed by the dataset that will be matched to a TSI score. For example, if analysis is being conducted for census tracts and the data is also available at the block level, create the TSI at the block level, then aggregate to the level of the census tract. The TSI gives coverage in terms of percentage of a zone and assumes an even distribution of population within the zone, when most zones have uneven concentrations of population throughout the zone. By assessing TSI at the block level first, the variances in population density will more accurately be reflected.

While the TSI is a useful tool that can be used to calculate quality of service based on frequencies, it is not a complete tool, and further exploration could yield a more complete TSI taking into account accessibility by route and station, and creating a full day score that takes into account time of day, giving larger weight to trips during periods of high demand.

The TSI assumes that all transit trips are created equal, counting a trip on a commuter rail trip the same as a bus trip, despite the wide difference in destinations reached and the time required to reach them. While passengers value frequency of transit trips, there are other issues that are important to passengers. A transit trip is only useful to a passenger if it can take them to his or her destination. A measure for accessibility at the stop level would easily integrate with the TSI to form an accessibility and availability index that would more accurately measure attractiveness to passengers.

The TSI does not take into account the size of the transit vehicle, which can be an issue in areas where demand can exceed supply. For an area where bus capacity is an issue, a train running every ten minutes is a more attractive option than a bus. An alternative version of the TSI is the Transit Capacity Index (TCI) which weights frequency by transit vehicle capacity. While this index may be of use for planning agencies, it should not be used as a replacement for the TSI, as it would imply greater frequency of transit trips for larger capacity vehicles, and overstate their attractiveness.

The morning and evening peak periods represent the time of day with the highest demand, but other passengers rely of transit during other periods of day. An improved TSI would look at transit supply to create a full day score. The score could be as simple as counting all transit trips in all directions for a 24-hour period, or could utilize a scoring system based on periods of time of day (early morning, morning peak, mid-day, afternoon peak, evening, late night) weighted to peak periods more heavily than the non-peak periods.

WORKS CITED

There are no sources in the current document.