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An Aggregated Public Transit Accessibility Measure

Md. Sha Al Mamun *
Graduate Student
Department of Civil and Environmental Engineering
University of Connecticut
261 Glenbrook Road, Unit 2037
Storrs, CT 06269-2037, USA
Phone: (001)-860-486-0586
Email: msm08014@engr.uconn.edu

Nicholas E. Lownes, Ph.D.
Assistant Professor
Department of Civil and Environmental Engineering
University of Connecticut
261 Glenbrook Road, Unit 2037
Storrs, CT 06269-2037, USA
Phone: (001)-860-486-2717
Fax: (001)-860-486-2298
Email: nlownes@engr.uconn.edu

*Corresponding author

ABSTRACT

Measuring the ease of access to the transit services is important in evaluating existing services, predicting travel demands, allocating transportation investments and making decisions on land use development. A new aggregated approach to assessing the accessibility of public transport is described to assist transit professionals in the planning and decision making process. It involves the use of readily available methods and represents a more holistic measure of transit accessibility integrating developer, planner and operator perspectives. The paper reviews previous and current methods of measuring accessibility and selects three methods for application in a case study in Meriden, CT. Inconsistencies are noted across the methods, and a consistent grading scale is presented to standardize scores and ensure a better comparison of results. Finally, this paper proposes weighting factors for individual methods to formulate an aggregated measure based on individual accessibility component measures. The approach aims to provide a robust and uniformly applicable measure of transit accessibility that can easily be interpreted by transit planners to identify shortcomings in service coverage and promote equity in transit accessibility in the community.

INTRODUCTION

Public transportation is a key component of a sustainable transportation system that improves systemic mobility without placing the economic and environmental burden of increased auto ownership on the traveling population. It assures long term sustainability in terms of resource consumption by relieving highway congestion and provides a very efficient means of moving large numbers of people with considerable flexibility to meet demand throughout an area (Armstrong-Wright et al. 1987). The provision of public transport and infrastructure will not in itself fulfill public transportation's potential. This system must be properly accessible and available to the community and connected with the rest of the transportation system. Trip makers would consider the public transit system as an option for trip making when the system is properly accessible to and from their trip origins/destinations (spatial coverage), when service is available at times that one wants to travel (temporal coverage). Another key decision in considering the transit service as an option for trip making is comfort and convenience – Is sufficient space is available on the transit at the desired time (TCQSM, TRB 2003). As a result, there is need to assess and quantify public transportation access from the passenger point of view considering the three aspects of transit accessibility- spatial coverage, temporal coverage and comfort/convenience.

Accessibility measures aid transport operators and local authorities in the development of appropriate transit service expansion plans and policies by recognizing mobility needs and identifying service gaps. For the purpose of assessing equity in transit service delivery for a region with the existing methods, consistent method is warranted. Measures with consistent grading scales can facilitate the assessment of the distribution and quality of public transport service provided within an area and an aggregated measure (properly weighted) can provide a single, more representative measure.

This paper will proceed with a literature review of the existing transit accessibility measures, highlighting their scale of analysis and the measures used in their calculation. The methodology section focuses on the three methods used in a case study for the development of the aggregated method. This section also provides a standardized scaling option for the comparison of the results. The results section presents the output of the comparative analysis and aggregated measure. The final section concludes the paper with a summary of major findings and some discussion on the future adoption of the examined method to improve the performance of accessibility measures.

LITERATURE REVIEW

The attempt to develop a public transport accessibility index has been discussed in several transport studies from the 1950 to the 1980s, and still receives growing attention in transit sector (Schoon et al. 1999). Several studies have made considerable progress on developing service indices to measure transit accessibility. Different measures have been designed to reflect differing points of view. Some of the measures of transit accessibility focused on local accessibility and considered both spatial and temporal coverage. The Time-of-Day tool developed by Polzin et al. (2002) is one of the measures that consider both spatial and temporal coverage at trip ends. In addition to the inclusion of supply side temporal coverage, this tool overtly recognizes and considers the demand side of temporal coverage by incorporating the travel demand time-of-day distribution on an hourly basis. This integration makes this tool distinctive to transit planners.

The Transit Capacity and Quality of Service Manual (TCQSM, TRB 2003) provides a systematic approach to assessing transit quality of service from both the spatial and temporal dimensions. This manual measures the temporal accessibility at the stops by using various temporal measures as shown in Table 1. Assessing spatial public transit accessibility throughout the system is carried out by measuring the percentage of service coverage area and incorporating the transit supportive area (TSA) concept. TSA identification deals with socioeconomic and demographic data of a study area. The calculation of service coverage area used GIS software's buffer area calculation option and outlined the results in terms of level-of-service (LOS).

The transit level-of-service (TLOS) indicator developed by Ryus et al. (2000) provides an accessibility measure that uniquely considers the existence and eminence of the pedestrian route connected to stops. It also combines population and job density with different spatial and temporal features (Table 1) to measure transit accessibility. This tool emphasisizes various aspects (i.e. walking distance and access to the stops, wait time at stops, and the availability of service at the user's required time) in the consideration of accessible transit service by a person. Revealing the association of the safety and comfort of the pedestrian route to the stops makes this method distinctive measure in the evaluation of transit accessibility.

Another measure that considers the space and time dimensions of local transit accessibility is the public transport accessibility level (PTAL) index developed in 1992 by the London Borough of Hammersmith and Fulham. This index measures the density of the public transport network at a particular point, using walk access time and service frequency. It measures the accessibility level for a specific point (origin) considering the accessibility index (AI) for all available modes of transport from that point. The inclusion of total access time to measure the level of accessibility is the striking feature of this method.

Fu et al. (2005) proposed an O-D based approach called Transit Service Indicator (TSI) to evaluate transit network accessibility by combining the various temporal attributes (as shown in Table 1) into one composite measure. To develop the Transit Service Indicator (TSI) for a single O-D pair, they used the ratio of the weighted door-to-door travel time by auto (WTA) to the weighted door-to-door travel time by transit (WTT). This study considered the walk, wait, transfer, and in-vehicle travel times in the calculation of door-to-door travel time. Schoon et al. (1999) formulated another set of Accessibility Indices (travel time AI and travel cost AI) for different modes (i.e. bus, car and bicycle) between an O-D pair. Travel Time AIs for a particular mode were calculated by using the ratio of the travel time of a particular mode to the average travel time across all modes. Cost AIs were calculated in much the same way. For bus, the one way travel fare was considered the travel cost and for private cars an average out-of-pocket operating cost and, when applicable, parking fees were considered as the travel costs. The travel cost for private car was divided by the car occupancy rate to obtain the per-occupant travel cost consistent with the measure of travel cost for the bus.

Hillman and Pool (1997) described a measure to examine how a database and public transport planning software (ACCMAP) comprising of GIS can be implemented to measure accessibility for Local Authorities and Operators. This software measured the local accessibility as the Public Transport Accessibility Level Index (PTAL) using the combination of walk time to a stop and the average waiting time for service at that stop. Network accessibility was measured by ACCMAP as total travel time along the network between an origin and destination including walk time from the origin to the transit stop, wait time at the stop, in-vehicle travel time, wait time at interchanges, and time spent walking to the destination.

There were few studies that paid attention to the comfort and convenience aspect of transit service. The Local Index of Transit Availability (LITA), developed by Rood (1998), measures the transit service intensity, or transit accessibility in an area by integrating three aspects of transit service: route coverage (spatial availability), frequency (temporal availability), and capacity (comfort and convenience). The route coverage score incorporates the available number of stops in a zone and the land area of this zone. The frequency score measures the number of available transit vehicles for the zone but the most important component is the capacity score as it includes the comfort and convenience aspect.

Bhat et al. (2006) described the development of a customer-oriented, utility-based Transit Accessibility Measure (TAM) for use by the TxDOT and other transportation agencies. Two types of indices were included in this manual to identify patterns of inequality between transit service provision and the level of need within a population: transit accessibility indices (TAI) and the transit dependence index (TDI). The TAI reveals the level of transit service supply and considers various elements of the utility measures (i.e. spatial, temporal, others) of transit service. The most significant attribute of this utility-based measure is its ability to aggregate the elemental measures over multiple dimensions, such as origins, destinations, population groups, and trip purposes. The transit dependence index (TDI) measures the level of need for transit service as a function of socio-demographic characteristics of potential transit users. This helps the transit agencies to identify the users who need service the most by comparing the level of service supply with the demand level of the transit user.

A new approach to identify the geographical gaps in the quality of public transport service for a community of transit users was developed by Graham Currie (2004). This ‘Needs Gap’ approach assesses the service of public transport by comparing the distribution of service supply with the spatial distribution of transport needs. The supply index calculation employs several datasets, including bus and tram stop locations, train station locations, public transport service frequencies for each mode, access distance/buffer area to each stop/station, etc. To quantify the distribution of needs in the community with a single transport needs index, the approach combined socio-economic data and the transport needs related data. Another paper by Currie et al. (2007) quantifies the associations between the shortage of transport service and social exclusion and uniquely links these factors to the social and psychological concept of subjective well-being. This paper investigates the equity of transit service by identifying the transport disadvantaged groups and evaluating their travel and activity patterns.

A customer demand-oriented methodology incorporating all categories of accessibility measures is best for measuring the quantity and quality of service. Such a method should not view transit as a last-resort option, but as a service that should be available for heavily traveled corridors because it is a good option for travelers. Any method identifying service quality must consider the populations being served, meaning that one must consider the social needs of travelers. The method should be easily understandable to transport operators and contain fundamental information about the system and the community it serves. The different types of methods, their coverage of analysis, the measures they incorporate, and the most important features of the methods are summarized in Table 1.

OBJECTIVES AND ORGANIZATION

The objective of this paper is to describe a method for quantifying public transportation access that aggregates existing public transport accessibility indices to harness the positive features of each. For the development of a performance/accessibility measure, TCRP Report 88 (Kittelson & Associates, Inc. et al. 2003) identified eight categories of performance measures based on underlying goals and objectives of different transit users. The categories are overlapped in some extent and hence require some distinct broad categorization (Bhat et al. 2006). The Transit Capacity and Quality of Service Manual (TCQSM, TRB 2003) represents only two broad categories of customer-oriented performance/accessibility measures: Service availability (Spatial and Temporal coverage) measures and comfort and convenience measures. Three methods have been selected to assure that the two broad categories of accessibility measures are being considered in the development of aggregated accessibility measure. Selection of methods also considers the intended user of this product and limitation of data sources. This paper selected existing measures which can address transit accessibility from differing perspectives (i.e. transit planner, transit operator, the traveler and the property developer) and calculations that require nothing more sophisticated than spreadsheet software. The three methods, individually and in aggregate, are applied to Meriden, CT as a case study. The results are compared and contrasted for consistency, completeness, and clarity. Finally, this paper evaluates weighting schemes for individual factors for their inclusion in the aggregated measure.

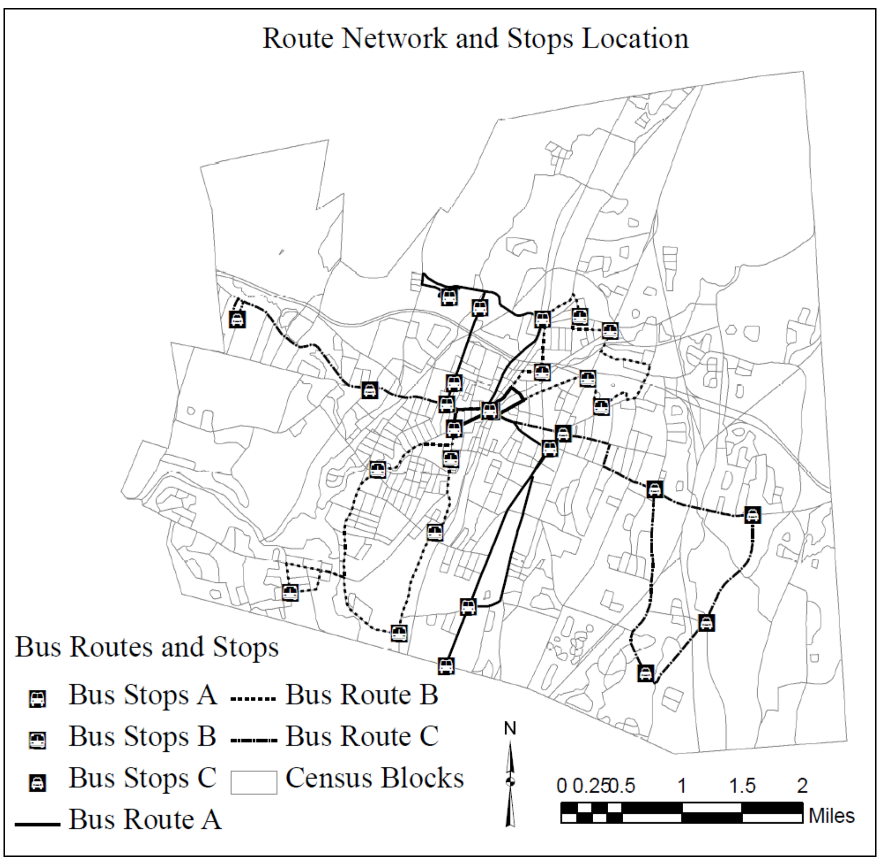

Figure 1: Three Local Bus Routes and Stop Locations of Meriden City, Connecticut

Table 1: Summary of Previous Transit Accessibility Measures

Study/ Paper	Type of Measure	Reflecting Local Accessibility		Reflecting Network Accessibility	Incorporated Accessibility Measure(s)	Important Feature	Computational Complexity	Intended Users
		Spatial Coverage	Temporal Coverage					
Polzin et al. (2002)	Time-of-Day tool (Index)	Yes	Yes	No	Service Coverage, Time-of-Day, Waiting Time, Service Frequency, Demographic data.	Time-of-Day Trip Distribution	Transportation Specialist	Transit Planner
Rood (1998)	LITA (Grade)	Yes	Yes	Yes	Service Frequency, Vehicle Capacity, Route Coverage.	Comfort and Convenience	Little Technical Skill	Property Developer
Schoon et al. (1999)	AI (Index)	No	No	Yes	Travel Time, Travel Cost	Travel Cost	Little Technical Skill	Transit Planner Transit User
TCQSM (2003)	LOS	Yes	Yes	No	Service Frequency, Hours of Service, Service Coverage, Demographic data.	LOS Concept	Some Technical Skill	Transit Operator Transit User
Hillman and Pool (1997)	PTAL (Index)	Yes	Yes	Yes	Service Frequency, Service Coverage	Agg. Travel Time between O-D pairs	Transportation Specialist	Transit Planner Transit Operator
Fu et al. (2005)	TSI (Index)	Yes	Yes	Yes	Service Frequency, Hours of Service, Route Coverage, Travel time components	Weighted Travel Time	Some Technical Skill	Transit Operator
Ryus et al. (2000)	TLOS	Yes	Yes	No	Service Frequency, Hours of Service, Service Coverage, Walking Route, Demographic data	Availability & quality of Pedestrian Route	Transportation Specialist	Transit Planner Transit Operator
Currie et al. (2004)	Supply Index & Need Index	Yes	Yes	Yes	Service Frequency, Service Coverage, Travel time, Car Ownership, Demographic data.	Transport Needs Measure	Some Technical Skill	Transit Planner Transit Operator Property Developer
Bhat et al. (2006)	TAI & TDI (Index)	Yes	Yes	Yes	Access distance, Travel time, Comfort & parking, Network Connectivity, Service Frequency, Hours of Service, Vehicle Capacity.	Transit Dependency Measure	Transportation Specialist	Transit Planner Transit Operator Transit User

METHODOLOGY

To formulate an effective quantitative measure on the basis of existing methods, three methods have been selected on the basis of several considerations. Due to the limitations of available data, this paper is looking for less data-intensive methods that can be applicable with the available datasets for the study area. For simplicity in calculation, this research stays away from the methods involving software based analysis tools and considers methods whose calculation procedures are straightforward and require some basic use of GIS software. On the basis of the review of accessibility methods, three methods, LITA, TCQSM and Time-of-Day Tool, were picked to characterize the three transit accessibility coverage aspects. These methods ensure the consideration of all imperative accessibility measures.

Analysis was conducted on the 17 census tracts of the city. Accessibility calculations were carried out for three (A, B and C) public bus routes through Meriden City provided by CTtransit. The local bus route network and stop locations for this city are shown in Fig. 1. The three methods with their data sources, reasons for the selection of these particular methods, intended users, and scales of analysis are explained below.

Method 1: The Local Index of Transit Availability (LITA)

LITA (Rood, 1998) measures the transit service intensity of an area with consideration of an area's population and size. Two basic types of data are required to calculate the LITA score: transit data and census data. Transit data includes full route maps and schedules of all transit lines serving the study area, locations of transit stops, and the transit vehicle capacities. Census data encompasses total land area, resident population, and number of employees in each tract. All transit data was collected from the transit provider and census data from U.S. Census (2000).

This method considers the comfort and convenience facet of transit service by appending the vehicle capacity measure in the calculation. The capacity measure incorporates the daily available seats of the transit service, route miles of transit line, and the total population of the area, making this score calculation quite worthy. The LITA score can be calculated for any unit of land area (i.e. census tract or TAZ) for which census data is available and measures the accessibility for the total transit system of that area. LITA score calculation is quite easy and does not require a transportation specialist. LITA scores are intended to be useful to transit planners and property developers by revealing where transit service is most intense and aiding the development of appropriate transit and land use plans and policies for areas with different level of transit accessibility.

Method 2: The Transit Capacity and Quality of Service Manual (TCQSM)

The Transit Capacity and Quality of Service Manual (TCQSM, TRB 2003) incorporates a wide range of measures to assess transit accessibility and requires the same datasets (transit and census data) as LITA. It measures the transit accessibility for bus stops using service frequency and for route segments or corridors using hours of service. Transit accessibility calculations for the entire transit system were performed by measuring service coverage area. Two methods are used to calculate the service coverage: the GIS method and the Manual (Graphical) method. For this research, the detailed GIS method was used. The concept of Transit-Supportive Areas (TSA) identification was disregarded because the household and employment density for 8 of 17 census tracts were below the TSA threshold densities. To identify the service coverage area, a 0.25 mile radius buffer area was used around the bus stops. The service frequency and hours of service measures were not considered in this study as transit service for Meriden City is not frequent and the span of service is very limited.

This method was selected for this research to account for spatial coverage in transit accessibility assessment. This manual provides the scale of accessibility measure from individual bus stops to individual routes to the entire transit system. The calculation of service coverage using GIS method requires a technically skilled person familiar with GIS tools. The Transit Capacity and Quality of Service Manual offers a comprehensive guide for use by the transit operators and transit users. Transit users can get the information on transit accessibility at bus stops and transit operators can make decisions for infrastructure enhancements and other improvement options that could enrich the overall transit system and improve service.

Method 3: The Time-of-Day Tool

The Time-of-Day tool (Polzin et al. 2002) measures transit service accessibility using time-of-day travel demand distribution and provides the relative value of transit service provided for each specific time period. This tool requires data on the temporal distribution of travel demand on an hourly basis in addition to the transit and census data required for the previous two methods. The time-of-day distribution of travel demand data and a daily trip rate of 4.09 trips per person were adopted from the 2001 National Household Travel Survey (NHTS). Tolerable wait time was defined as 10 minutes in accordance with NHTS data. The fractional distribution for each tract that falls within the 0.25 mile buffered transit route was calculated using GIS software.

The Time-of-Day tool was considered by this paper as the only tool to account for the time-of-day distribution of travel demand and reflect the temporal coverage of transit accessibility. The tool can assess the degree of accessibility of a transit system for an individual zone or at the census tract level depending on the availability of transit and census data. The calculation and interpretation of data from several different sources makes this tool more difficult to use and requires some transportation specialist personnel to execute this analysis. This tool allows transit operators to easily assess required service change (changes in coverage, frequency, and span of service) because it provides a quantitative data-based measure. This measure plays an important role to the transit planners in determining the importance of transit service provided in each time period of the day.

Scaling

One purpose of this paper is to determine how consistently the three methods rated the transit accessibility for each tract of study area. To do this, accessibility grades from each method were compared for each census tract. This presented some problems, as the results were given on three different scales.

LITA was scored to five grades, A through F (excluding E). Grade “A” corresponded to a LITA+5 rating of 6.5 or higher, indicating the highest level of accessibility. TCQSM adopted the level-of-service (LOS) concept, introduced in the HCM, for measuring the quality of transit service. Scores were grouped in six LOS, A through F. The Time-of-Day tool measures transit accessibility by the number of daily trips per capita (in each Census Tract) that are exposed to transit service. For a more consistent comparison of the accessibility results, the calculated scores for each method were standardized across all of the census tracts for relative accessibility scores. The scores were standardized by finding the difference between a specific score and the mean of the scores and then dividing that difference by the standard deviation of the scores for all tracts. For ease of interpretation, this paper develops a common grading scale with five grades A through F (excluding E). Grade “A” represents a score of +1.5 or higher, indicating the highest level of accessibility, and grade “F” represents a score lower than -0.75, indicating a poor level of accessibility.

The development of an aggregated measure on the basis of the three selected methods comprises several steps. In the first step, the raw scores were standardized for each method, as mentioned earlier. Secondly, the accessibility metrics used for calculations across the three methods were identified (Table 2). Individual weighting factor was then assigned for each of the individual measures. The summation of all weighting factors for the individual measures was assigned as the final weighting factor for each method. Three weighting schemes were considered to assign the weighting factors to the measures. Results obtained with the different schemes were compared to determine the best scheme. In Scheme # 1, measure WF was allotted according to the occurrence of a measure in the methods (i.e. if a measure is common in all the three methods then its weighting factor was assigned as 3). Scheme # 2 consigns the WF as 1 for all the common and unique measures and Scheme # 3 assigns the WF of total 1 for common measures and 1 for other all unique measures. The weighting factors of individual elemental measures and the total weighting factors for the three methods are shown in Table 2.

Table 2: Development of Weighting Factors (WF)

Methods	**Accessibility Metrics**	**Scheme # 1**		**Scheme # 2**		**Scheme # 3**	
		Metric Weight	Method Weight	Metric Weight	Method Weight	Metric Weight	Method Weight
Time-of-Day Tool	Service Coverage	3	**9**	1	**5**	⅓	**10/3**
	Service Frequency	2		1		½	
	Demographics	2		1		½	
	Travel Demand	1		1		1	
	Waiting Time	1		1		1	
LITA	Service Coverage	3	**8**	1	**4**	⅓	**7/3**
	Service Frequency	2		1		½	
	Demographics	2		1		½	
	Capacity	1		1		1	
TCQSM	Service Coverage	3	**3**	1	**1**	⅓	**1/3**

RESULTS

Table 3 depicts the accessibility results for the census tracts in the original scales for each method and combined in the standardized score. With the actual scales for individual method, one can interpret the accessibility results according to that method’s grading system. Table 3 shows that the obtained results vary greatly across the methods. To get a comparable picture of accessibility using the results of these methods, the results must be interpreted in terms of the applicable scale. Furthermore, the accessibility results of the Time-of-Day tool can not be compared with the other methods because this tool does not provide any grading or scaling system by which one can easily interpret or compare the accessibility results. Thus, for a meaningful comparison of transit accessibility between the tracts that can be easily understood, this paper standardizes the results, providing a picture of the relative difference in accessibility between methods. The results of the standardized scores shown in Table 3 provide unswerving results across methods. The grades for these standardized scores are shown in Table 4.

Table 3: Comparison of Results in the Raw Scores and Standardized Scores for the Three Methods

Census tracts	Raw Scores					Standardized Scores					
	Time-of-Day Tool Score(Daily exposure per capita)	LITA Score (Rescaled overall score, Grade)		TCQSM Score(% of service area served, LOS)		Time-of-Day Tool Score, Grade		LITA Score, Grade		TCQSM Score, Grade	
1701	0.0273	12.97	A	76.89	C	1.976	A	7.973	A	1.144	B
1702	0.0229	5.46	C	62.36	D	1.44	B	0.465	C	0.668	C
1703	0.0119	3.99	D	40.94	F	0.88	C	-1.001	F	-0.032	D
1704	0.0028	3.45	F	5.23	F	-1.03	F	-1.545	F	-1.201	F
1705	0.0025	4.25	D	11.39	F	-1.072	F	-0.742	D	-0.999	F
1706	0.0062	4.83	C	21.37	F	-0.614	D	-0.161	D	-0.673	D
1707	0.0125	4.85	C	50.65	E	0.162	C	-0.146	D	0.285	C
1708	0.0097	5.25	C	29.21	F	-0.182	D	0.25	C	-0.416	D
1709	0.0196	7.69	A	83.09	B	1.036	B	2.694	A	1.347	B
1710	0.022	4.72	C	69.63	D	1.327	B	-0.272	D	0.906	B
1711	0.0065	4.20	D	17.10	F	-0.581	D	-0.792	F	-0.812	F
1712	0.0041	3.71	D	13.42	F	-0.876	F	-1.286	F	-0.933	F
1713	0.0086	4.80	C	39.53	F	-0.316	D	-0.194	D	-0.078	D
1714	0.017	8.16	A	91.28	A	0.712	C	3.164	A	1.615	A
1715	0.0133	5.42	C	83.51	B	0.2586	C	0.42	C	1.361	B
1716	0.0028	4.50	C	14.24	F	-1.03	F	-0.492	D	-0.906	F
1717	0.0007	1.97	F	2.91	F	-1.298	F	-3.023	F	-1.277	F

Table 4 presents the grades for the three methods and the grades outlined by the proposed aggregated measure for different weighting schemes. The comparative results using standardized scores show that the aggregated approach is a good indicator of the differences in accessibility between sites. The similarity of the resulting grades for the individual census tracts are shown in Table 4. The results of the aggregated score are consistent across schemes but this paper suggests employing Scheme # 2. In Scheme # 2, each individual measure is treated equally and the presence of a particular measure in all methods gives it additional weight in the aggregation process. It seems that in Scheme # 1, some measures experienced superfluous importance and the same measures are treated as less significance in Scheme # 3. Although the results are very similar, Scheme # 2 makes the most theoretical sense as a weighing option.

Table 4: Comparison of Results for Three Methods and Grades for Aggregated Measure

Census Tracts	Time-of-Day Tool Score	LITA Score	TCQSM Score	Aggregated Score Scheme# 1	Scheme # 2	Scheme # 3
1701	A	A	B	A	A	A
1702	B	C	C	B	B	B
1703	C	F	D	D	C	C
1704	F	F	F	F	F	F
1705	F	D	F	F	F	F
1706	D	D	D	D	D	D
1707	C	D	C	C	C	C
1708	D	C	D	D	D	D
1709	B	A	B	A	A	A
1710	B	D	B	C	C	C
1711	D	F	F	D	D	D
1712	F	F	F	F	F	F
1713	D	D	D	D	D	D
1714	C	A	A	A	A	A
1715	C	C	B	C	C	C
1716	F	D	F	F	F	F
1717	F	F	F	F	F	F

Results in Table 4 provide the level of accessibility of each census tract across the different methods. This table is helpful to transit providers and planners for quickly identifying the relative difference in accessibility across the tracts so that they can make decisions about the scale of improvement options for the areas experiencing different levels of accessibility. Transit service planners can model some changes (i.e. re-allocating the position of transit stops, re-alignment of transit lines etc.) to the current public transport network to increase the accessibility of public transit for the poorly-served or un-serviced areas. These comparative results provide a useful tool for evaluating transit service and ridership potential. Figure 2 maps the grades of accessibility scores across methods and illustrates the grading scale of the accessibility scores. This graphical view shows relative accessibility intensity which is helpful for the comparison of accessibility between different tracts. This graphical view also helps build a framework for property developers to identify potential development sites with high accessibility.

TCQSM considers a much smaller coverage area than the other two methods. While there is broad agreement that the best coverage is concentrated in a relatively small area (which is expected, given the service map in Figure 1), there is disagreement on that extent for the middle of the accessibility spectrum (Figure 2). LITA considers a much larger area to have moderate accessibility, but this may be due in part to its target audience: developers. LITA is designed to broadly identify good investment possibilities near transit, leaving more detailed analysis to those regions a developer may want to target. TCQSM is concerned with spatial coverage only and therefore follows the layout of lines and stops closely. The time-of-day tool considers measures of demand which reflect that some tracts that are not well covered spatially may in fact serve high demand populations. It is important to remember that these scaled versions are comparing a particular tract against the average measure for the entire system. These values are not absolute.

Figure 2: Accessibility Scores for Different Methods

These three methods calculate their scores to give emphasis to different aspects. The developed aggregated method attempts to cover all of these transport aspects to provide a better understanding of transit accessibility. This measure provides a very useful gauge to all transit spectators for their different perspectives. The incorporation of the grading system for this aggregated method makes this accessibility measure easy to understand and interpret.

CONCLUSIONS

This paper objectively examined the utility in different perspectives and the differing accessibility metrics used in different methods. The individual accessibly results were calculated to examine the inconsistency in results as well as in grading scale for different methods. The aggregated accessibility measure was developed by integrating all the differing measures across the methods, which would make this result more reliable and defendable to the stakeholders and policy officials, as it encompasses several user perspectives. This paper standardized individual raw scores and adopted a common grade scale to map accessibility level results. Several permutations of aggregated weighting scheme were tested and the best scheme identified. This paper helps planners to select a set of accessibility measures and apply this method of aggregation to produce a more defensible and robust accessibility result for their customers. The results of aggregated measure can be taken as a basis for adjusting the priorities of public transport services and to address lack of service in public transport provision. The findings should provide an excellent basis to bus service planners for informing the alteration of service frequencies and stop combinations or changing route alignment to improve accessibility.

The aggregated method provides a relative accessibility measure across tracts for which transit is reasonably available at the origin of the trip. This information is important for zonal service equity analysis and to understand how well the transit supplier provides transit services to the community. Aggregated accessibility results could enhance the coordination among different stakeholders (i.e. property developers, transit agencies, land use planners) which eventually is required in implementing Transit Oriented development (TOD) principles.

However, further development and refinement of the measure would be useful in several areas. In addition to those accessibility measures in this study, a needs gap (Currie 2004 and Bhat et al. 2006) assessment in transit service would be a good addition to the metric, addressing the transportation disadvantaged population and its relationship to systematic spatial coverage. Further, the authors' are interested to the decisions planners make based on transit accessibility measures, and the reasons behind the selection of their transit accessibility measure.

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