Assessing Spatial Accessibility to Bus Stops in an Urban Road Corridor Using GIS

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Abstract: Accessibility plays a vital role not only for drivers but also for pedestrian. Better accessibility creates low congestions, low travel distance and lower the transit time. Public transport plays a key role in the sustainability of urban environments. Therefore, establishing accessible public transport networks for pedestrians at a reasonable distance is much more important. Based on an assumed average walking speed of about 1.3 m/s, 5 minutes of walking is considered reasonable in urban areas. Therefore, about 400 meters is concerned as average comfortable walking distance from one bus stop to another for pedestrians. In the current planning methods, to design the bus stops location some parameters are only considered as such the distance from origin/destination trip to the bus stop and the walking time. In this research suggest a methodology to measure the accessibility of a bus stop through the surrounding road network using GIS.

Keywords: Accessibility, Public transport, Surrounding pedestrian road network, Actual access coverage, Ideal access coverage of a stop

1. INTRODUCTION

1.1 Background of the Research

Accessibility can be defined in several ways. It can be described as "The ease and convenience of access by means of a choice of travel". Further definition of accessibility by Grey is "A measure of the relative access of an area and zone to population, employment opportunities and community services"(Kalaanidhi & Gunasekaran, 2013). Public transport plays a key role in the sustainability of urban environments. It helps to enhance the economic and environmental performance of cities by connecting resources to destinations effectively and facilitating mass mobility.

Public transportation is gaining its share in many cities due to the growing congestion, rise in the fuel price and the better awareness of the transport-related environmental impacts(Nurul & Hawas, 2017). Therefore, establishing accessible public transport networks for pedestrians at a reasonable distance is identified as a prominent factor that affects the overall travel time of the transit trip.

In the current planning methods, to design the bus stops location some parameters are only considered as such the distance from origin/destination trip to the bus stop and the walking time. In Sri Lankan context, bus stop locations and spacing are decided by National Transport Commission (NTC) while planning of road transport sector is govern by Road Development Authority (RDA).

Therefore, it’s quite clear that there is mismatch between Policy makers and infrastructure builders. Most transit firms consider 400meters as an acceptable access/egress standard(Ammons, 2001). In Columbus, Ohio, it is stipulated that passengers do not exceed walking distances of 400m to transit stops in urban areas(Central Ohio Transit Authority, 1999). Many of tools have been developed for specific cities by different countries to assess the accessibility of bus stop. All these tools have discussed under literature review.

1.2 Research Problem

In general, this study focuses on “Finding nature of spatial accessibility of bus stop locations in western province and the analyzing the service level of them”. Therefore, this study measures spatial accessibility of bus stop locations in between Moratuwa to Dehiwala Junction section in Galle road, based on the interaction between the bus stop location and the actual pedestrian road network surrounding by evaluating ISAI, ASAI & SCRI indices”

2. Research Objectives

Main objective is to assess spatial accessibility of bus stop locations in between Moratuwa to Dehiwala Junction section in Galle road in Western Province Sri Lanka using GIS analysis. In this study three indices will be developed using the powerful GIS network analysis functions. Therefore, Specific objectives of this study are

- To evaluate the accessibility of bus stops in study area through the surrounding pedestrian road network and can be used to assess and compare different stop locations from a spatial perspective by using the Ideal Stop-Accessibility Index (ISAI)

- To provides a more accurate measurement of the pedestrian road network density around a bus stops in study area, using the Actual Stop-Accessibility Index (ASAI)

- To evaluate the percentage of actual access coverage of a bus stop with respect to its ideal access coverage by using the Stop Coverage Ratio Index (SCRI)

2.1 Research Scope

Galle road has been selected for analysis. In order to provide descriptive analysis Moratuwa to Dehiwala Junction Section (9.8 Km) is selected which includes significant commercial cities of Moratuwa, Ratmalana, Mount Lavinia, Dehiwala etc. There are 41 bus stops (Both sides of the roads) within the study area.

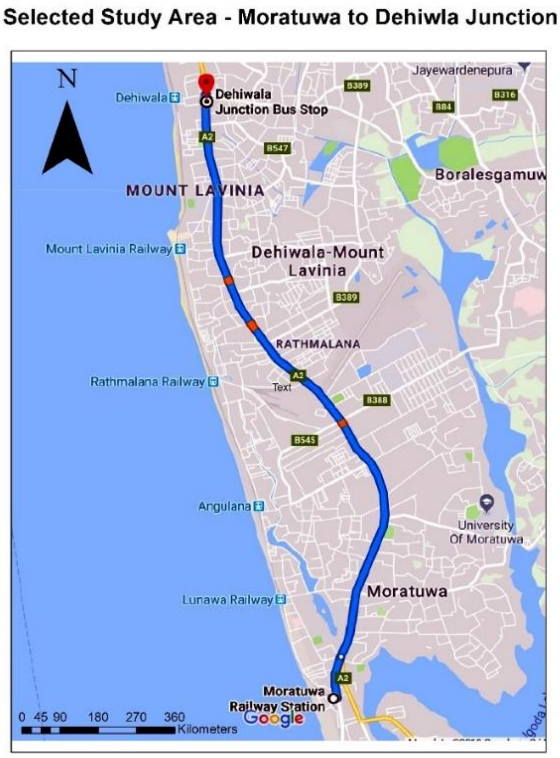


Figure 1- Selected Study Area (Moratuwa to Dehiwala Junction)

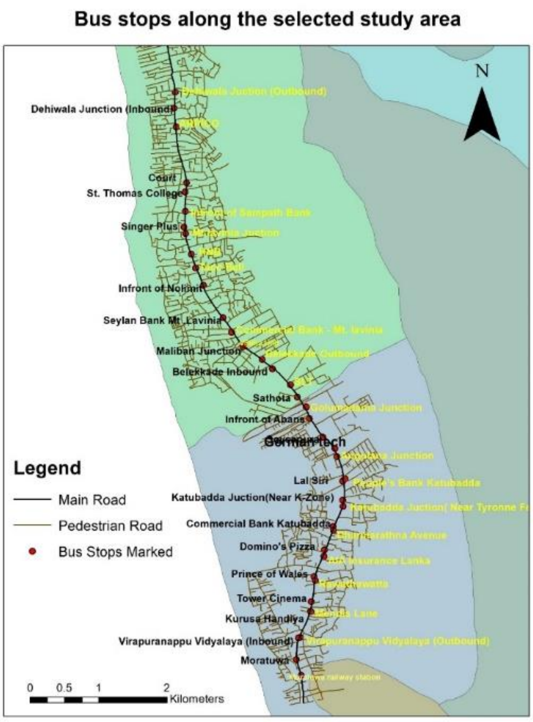


Figure 2 - Bus Stops locations along Galle Road - Moratuwa to Dehiwala Junction

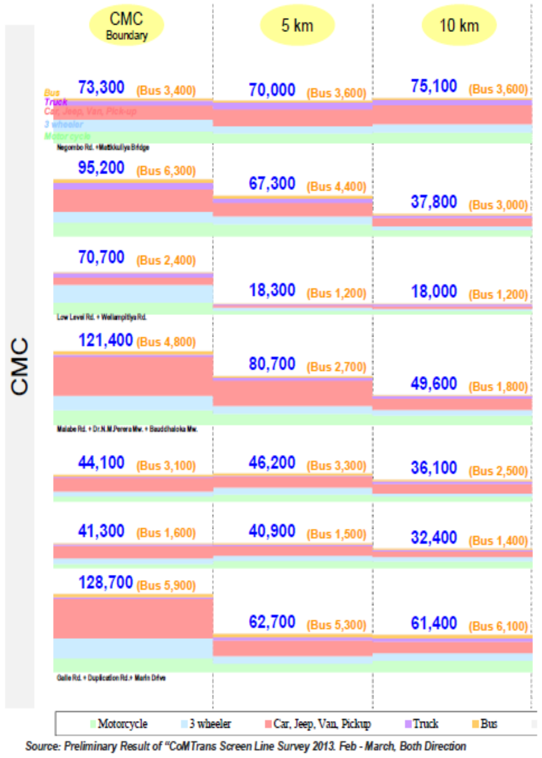
3. LITERATURE REVIEW

Previous researches have not focused on the interaction between bus stop locations and their surrounding pedestrian road networks. Bus stops access coverage had been estimated using a circular buffer analysis with a radius of the 400m (threshold distance) around the bus stop. Another approach for estimating access is by comparing the distance from the centroid of a spatial block to its nearest bus stop.

If this distance is within the threshold distance, then coverage is achieved(Al, 1998).Both approaches gave simple estimates for access coverage showing that both are unrealistic. Stops should be spaced to minimize pedestrian walking distances near major demand generators and to reduce the number of bus stoppages in order not to increase the transit trip travel time; that is, choosing a bus stop location is a tradeoff between stop spacing and travel time. Accordingly, new indices are developed to assess a bus stop location on a more spatial basis. These indices measure the accessibility of a bus stop through the surrounding road network in addition to the ratio of actual access coverage to the ideal access coverage of a stop(Foda & Osman, 2010).

Many of tools have been developed for specific cities (foreign Countries) to assess the accessibility of bus stop. (Zhu, Guo, Chen, Zeng, & Wu, 2017) Z. Zhu, X. Guo, H. Chen, J. Zeng, and J. Wu Prolonged this line of research further by developing a mathematical model based on the fundamental relationships among velocity, uniform acceleration or deceleration, and displacement, with the average bus operating speed, headway, required fleet size and potential system capacity. Some studies used a discrete model combining Geographic Information System (GIS) and dynamic programming to minimize passengers' time costs and the operating expenses of the route ("2000 optimal stop spacing, Furth & Rahbee TRR.pdf," n.d.). (Chien * & Qin, 2004) S. I. Chien * and Z. Qin proposed a mathematical model to determine the optimum number of stops and location by minimizing total cost. A realistic demand distribution based on a general street configuration was considered.

(Tirachini, 2014) A. Tirachini proposed an optimal bus stop location and spacing model to minimize the social cost of all the transport system.(Hafezi, Ismail, & Al-Mansob, 2011)estimated the average stop spacing by their model using the Bus Dispatch System (BDS) data. The aim of their design is to minimize the operating cost while maintaining a high degree of transit accessibility. (Sieger, Alliez, & Botsch, 2010)developed a model comprising non-linear programming and heuristics to optimize bus stop spacing by minimizing users' average travel time. (Alonso, Moura, dell'Olio, & Ibeas, 2011) B. Alonso, J. L. Moura, L. dell'Olio, and Á. Ibeas proposed a bi-level optimization model, which includes a modal split function at a lower level and a social cost minimization function on the upper level.



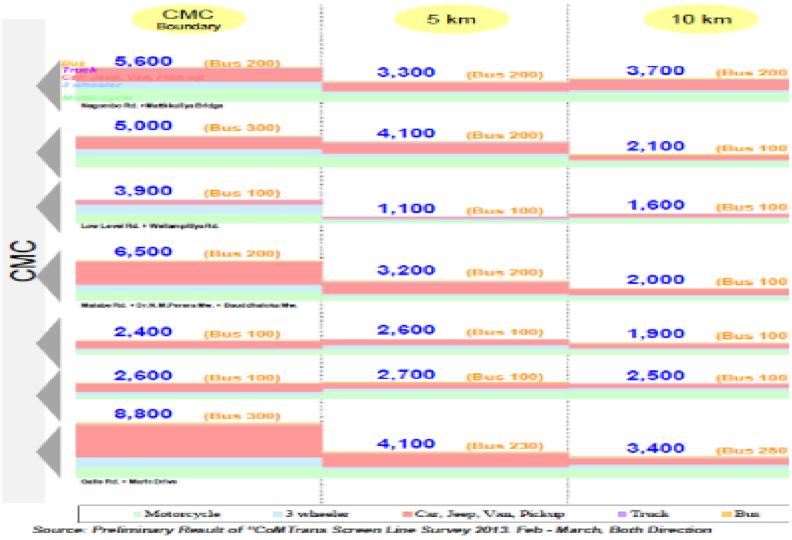
Source: CoMTrans Screen Line Survey, 2013

Figure 1- Daily Traffic Volume of Main Corridors

Most of those tools have been developed in a GIS environment, since GIS platforms have ability to give solutions by analysis of spatial patterns. New indices are developed to assess a bus stop location on a more spatial basis using GIS platforms. These indices measure the accessibility of a bus stop through the surrounding road network in addition to the ratio of actual access coverage to the ideal access coverage of a stop (Described under methodology)(Foda & Osman, 2010).

As above discussed, even though there were comprehensive qualitative or quantitative researches have been conducted regarding bus stops accessibility. There weren't local level studies regarding this topic. Therefore, it's timely important to conduct a study regarding this area. Since there were no any researches regarding spatial accessibility of bus stops in Sri Lankan transport context, this study attempts to measure bus stop access coverage is estimated based on the actual pedestrian road network surrounding the stop by using ISAI, ASAI & SCRI indices. This study could help transit planners in evaluating the locations of bus stops on a spatial basis rather than just spacing and circular access coverage, in order to select the most suitable places for locating new bus stops or for reallocating currently existing bus stops.

Moratuwa railway station to Dehiwala junction was selected as road section of the study area. Due to the high modal share for buses in that road section, it's an ideal study area for this research. According to the CoMTrans Screen Line Survey conducted in 2013, Dehiwala to Moratuwa area had high modal share for buses than CMC boundary. By comparing peak hour traffic volume data also depict that Dehiwala to Moratuwa road section has high modal share rather than CMC boundary within Galle road.



Source: CoMTrans Screen Line Survey, 2013

Figure 4- Peak Hour Traffic Volume of Main Corridor

4. METHODOLOGY

The research problems were mainly focused on

- Identifying the sequence of bus stops in terms of their accessibility
- Selecting the most suitable places for locating new bus stops or for reallocating currently existing bus stops.

This has done thorough the evaluation of both the accessibility of each bus stop through its surrounding pedestrian road network and the ratio of actual access coverage to the ideal access coverage at the stop location. As mentioned in research objectives, methodology is designed based on finding values of each bus stops regarding following indices and compare values of each bus stops.

ISAI –Ideal Stop-Accessibility Index

Total length of the pedestrian road network links lying within a walking distance of 400m measured along the network paths (km)
Area of the circular buffer layer for each bus stop (km2)

ASAI –Actual Stop-Accessibility Index

Total length of the pedestrian road network links lying within a walking distance of 400m measured along the network paths (km)
Actual travel polygon area for each bus stop (km2)

SCRI - Stop Coverage Ratio Index

Actual travel polygon area for each bus stop (km^2)

Area of the circular buffer layer for each bus stop (km^2)
According to the values getting above mentioned indices can provide comprehensive analysis regarding accessibility of the bus stops within study area including,

- Which bus stop has the maximum accessibility among the rest of the stops?
- Which bus stop has the minimum accessibility among the rest of the stops?
- How is the accessibility of each existing bus stop according above indices?

4.1 Data Collection

Collected data for this study are mentioned in Table 01.
Table 1- Collected Data

Collected Data	Source
Bus stop locations of study area	CTDroid Sri Lanka Mobile App
Main & Pedestrian Road Network Data	Google My Maps
Local demographic details (Population) and information on important facilities such as education, employment, leisure and health	Census data maps - Census & Statistics Department
Land use and Other data (Shape Files)	Survey Department

4.2 Data Analysis Method

Using Collected Bus stop location data, Road network data, Bus route data, Population data, Local demographic data, Pedestrian road network data, following tasks are done by GIS network analysis functions in ARC GIS Software.

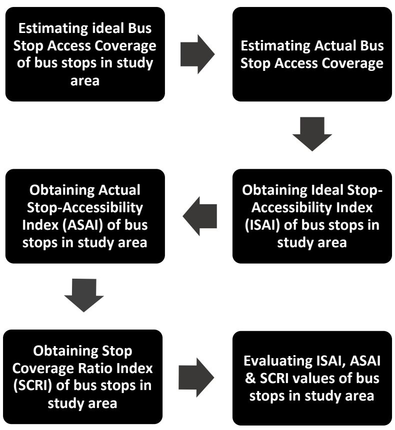


Figure 5 - Research Design

As explained earlier, Galle road corridor, one of the major corridor in the Colombo city, Sri Lanka, was selected for this the research. Locations of bus stop along Galle corridor - Moratuwa to Dehiwala Junction were identified as a case study for the proposed analysis in this research. 41 bus stops were identified serving the bus routes from Moratuwa railway station to Dehiwala Junction, as shown in Table 2 & Table 3.

Bus stops which are situated both side of the road were included in this study. Bus stops which are in left side of the road when approaching towards Colombo were called as Inbound bus stops and Bus stops which are in other side were called as Outbound bus stops.

Table 2- Outbound Bus Stops Along Galle road – Moratuwa to Dehiwala Junction

Bus Stop No	Outbound	Bus Stop Name
1	O	Moratuwa Railway station
4	O	Veerapuranappu vidyalaya (Outbound)
6	O	Mendis Lane
8	O	Rawathawatta (Outbound)
10	O	AIA Insuarance Lanka
12	O	Dharmarathna Avenue
14	O	Katubedda (Near Tyrrone Fernando Stadium)
17	O	People's Bank Katubedda
19	O	Angulana Junction
22	O	Golumadama
24	O	SLT
26	O	Belekkade (Outbound)
27	O	Vijitha Hall
29	O	Commercial Bank Mt. Lavinia
30	O	Seylan Bank Mt. Lavinia
32	O	Taco Bell
33	O	HNB
36	O	Infront of Sampath Bank
39	O	Arpico
41	O	Dehiwala Junction (Outbound)

Table 3- Inbound Bus Stops Along Galle road – Moratuwa to Dehiwala Junction

Bus Stop No	Inbound	Bus Stop Name
2	I	Moratuwa
3	I	Veerapuranappu vidyalaya (Inbound)
5	I	Kurusa Handiya
7	I	Tower Cinema
9	I	Prince of Wales
11	I	Domino's Pizza
13	I	Commercial Bank Katubedda
15	I	Katubedda (Near K - Zone)
16	I	Lal Sri
18	I	German Tech
20	I	Soysapura
21	I	Infront of Abans
23	I	Sathosa
25	I	Belekkade (Inbound)
28	I	Maliban Junction
31	I	Infront of Nolimit
34	I	Mt. Lavinia Juction
35	I	Singer Plus
37	I	St. Thomas College
38	I	Court
40	I	Dehiwala Junction (Inbound)

5. RESEARCH FINDINGS

5.1 Ideal and the Actual Access Coverage

Comparing both the ideal and the actual access coverage values clearly shows that an overestimation has occurred while calculating the access coverage on bases of circular buffer around the bus stops, as it estimates the coverage area to be 20.62 km^2 while it is only 18.91 Km2 on basis of actual coverage and considering the pedestrian's real paths. In other words, the actual bus stop access coverage was overestimated by about 1.71 Km2 (approximately 8.29 % of the route coverage).

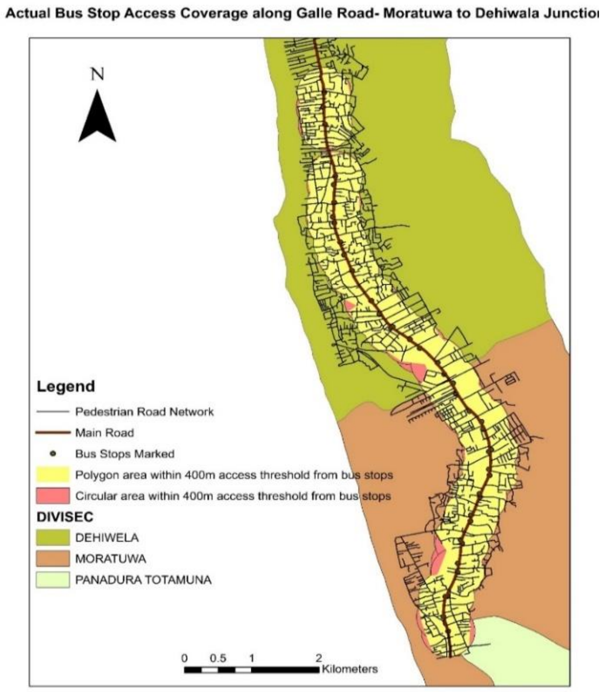


Figure 6 - Actual Bus Stop Access Coverage along Galle Road - Moratuwa to Dehiwala Junction

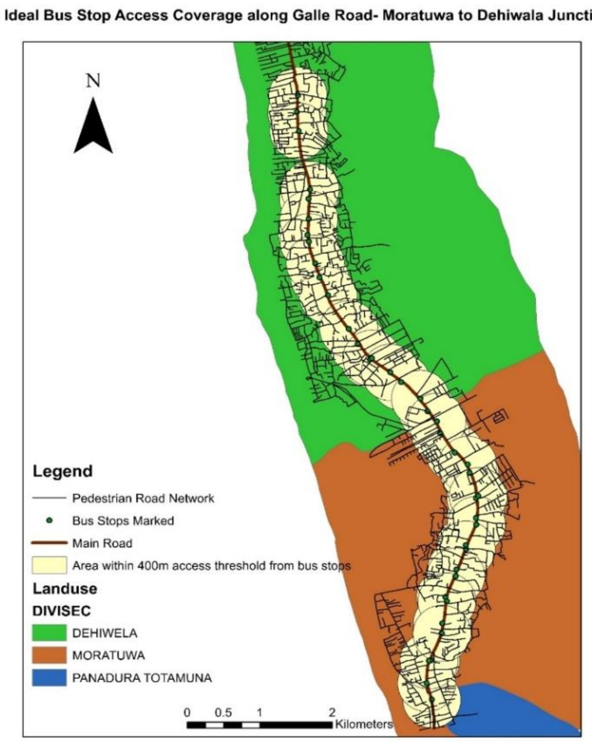


Figure 7 - Ideal Bus Stop Access Coverage along Galle Road - Moratuwa to Dehiwala Junction

5.2 Evaluating ISAI, ASAI & SCRI for study area

It can be shown that bus stop at Dharmarathna Avenue, (Bus Stop #12) has the minimum ISAI value, which means that this stop has the minimum pedestrian road network length serving it within the suitable walking standard and, hence, it is not likely to be accessible. Inversely, it can be shown that Moratuwa Railway Station (Bus Stop #1) has the maximum ISAI value, which means that this stop has the maximum accessibility among the rest of the stops. Figure 8 & 9 show the pedestrian road network diagrams within 400m circular buffer of two bus stops.

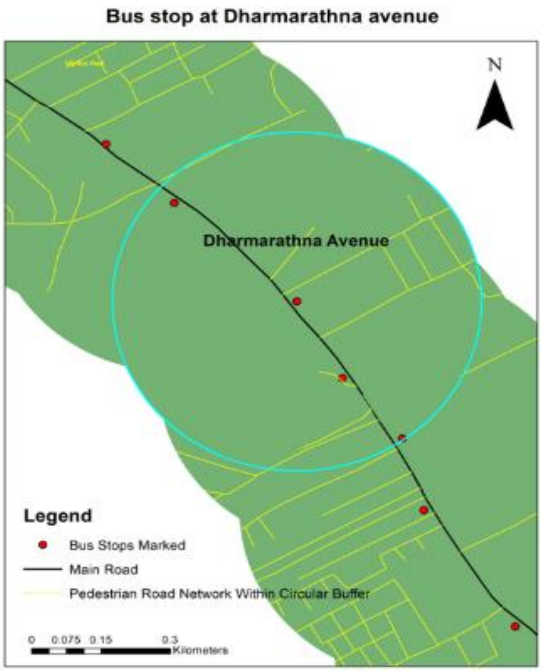


Figure 8 - Bus Stop at Dharmaratna Avenue

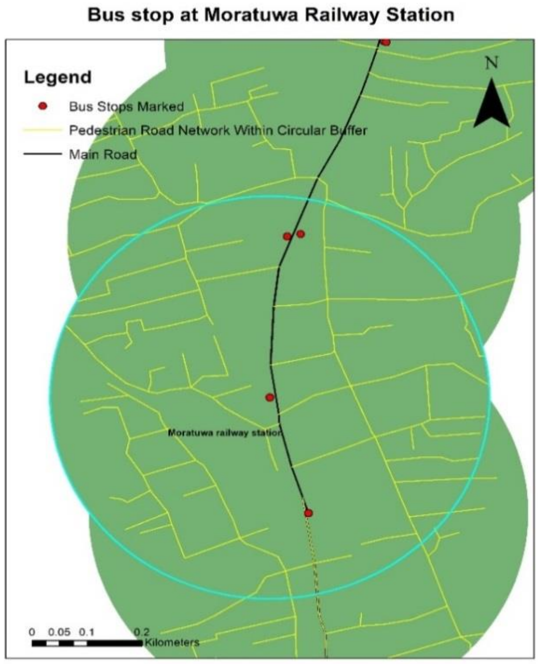


Figure 9 - Bus Stop at Moratuwa Railway

It is quite clear that the ASAI gives a more accurate value than the ISAI to the pedestrian road network density around a bus stop, where the denominator represents the actual access coverage area for the bus stop within the 400m circular buffer. When evaluating the ASAI values, it was found that again bus stop at Dharmarathna Avenue (Bus Stop #12) has the least value of the index, which means that it has the minimum actual pedestrian road network density among the rest of the stops, and, again, the Moratuwa Railway Station (Bus Stop #1) bus stop achieved the highest value of the index. it should be noted that the actual access coverage area and its shape are affected by the geometry and formation of the pedestrian road network surrounding the bus stop within the suitable walking limit and, thus, the ASAI may be misleading if used to compare the accessibility of different bus stops locations.

Finally, while evaluating the SCRI, it was shown that the SLT (Outbound- Bus Stop #24) bus stop has the least SCRI value, which means that it has the least actual access coverage area. Inversely Dehiwala Junction (Outbound - Bus Stop #41) is found to have the highest SCRI value, which means that it has the highest actual access coverage area among the stops. When comparing SCRI, it's quite clear that all SCRI values are within 0.739 – 0.974 range. It depicts that all bus stops have relatively spanned pedestrian road network with higher actual access coverage (Polygon area). Table 4 shows the results for all Bus Stops.

Table 4- ISAI, ASAI, and SCRI Values for Bus Stops

Bus Stop No	Stop Name	ISAI (m/m2)	ASAI (m/m2)	SCRI
1	Moratuwa Railway station	12048.651	13598.388	0.886
2	Moratuwa	5895.465	6541.501	0.901
3	Veerapuranappu vidyalaya (Inbound)	3015.916	3149.654	0.958
4	Veerapuranappu vidyalaya (Outbound)	6553.184	6898.365	0.95
5	Kurusa Handiya	8294.324	9897.342	0.838
6	Mendis Lane	1781.374	2312.803	0.77
7	Tower Cinema	2993.406	3928.201	0.762
8	Rawathawatta (Outbound)	2408.704	2835.996	0.849
9	Prince of Wales	7296.002	8524.27	0.856
10	AIA Insuarance Lanka	2945.321	3069.803	0.959
11	Domino's Pizza	7392.573	7905.189	0.935
12	Dharmarathna Avenue	1726.724	1799.959	0.959
13	Commercial Bank Katubedda	6685.093	7043.902	0.949
14	Katubedda (Near Tyrrone Fernando Stadium)	5886.391	6077.281	0.969
15	Katubedda (Near K - Zone)	3375.837	3722.514	0.907
16	Lal Sri	6553.033	7434.836	0.881
17	People's Bank Katubedda	3032.426	3264.407	0.929
18	German Tech	6443.692	6960.942	0.926
19	Angulana Junction	2232.827	2378.430	0.939
20	Soysapura	8594.103	9324.294	0.922
21	Infront of Abans	7547.830	8121.643	0.929
22	Golumadama	2486.259	2648.193	0.939
23	Sathosa	6536.867	7650.026	0.854
24	SLT	2690.355	3641.518	0.739
25	Belekkade (Inbound)	4839.954	5893.618	0.821
26	Belekkade (Outbound)	4931.766	5617.891	0.878
27	Vijitha Hall	8512.515	8916.959	0.955
28	Maliban Junction	6197.268	6554.533	0.945
29	Commercial Bank Mt. Lavinia	7163.451	7375.011	0.971
30	Seylan Bank Mt. Lavinia	5165.364	5550.037	0.931
31	Infront of Nolimit	7677.836	7915.624	0.970
32	Taco Bell	11133.570	11532.078	0.965
33	HNB	4129.635	4249.343	0.972
34	Mt. Lavinia Juction	2669.121	2768.479	0.964
35	Singer Plus	10196.278	10592.548	0.963
36	Infront of Sampath Bank	2897.073	3008.291	0.963
37	St. Thomas College	9176.404	9468.466	0.969
38	Court	7503.666	7839.765	0.957
39	Arpico	9251.139	9837.321	0.94
40	Dehiwala Junction (Inbound)	11201.734	11709.021	0.957
41	Dehiwala Junction (Outbound)	8350.971	8572.032	0.974

Based on the ISAI values, bus stop accessibility can be categorized in to 5 types.

Table 5- Accessibility Ranking Table based on ISAI Values

Bus Stop No	Stop Name	Pedestrian Road Network Within 400m (m)	ISAI (m/m2)
12	Dharmarathna Avenue	868.295	1726.724
6	Mendis Lane	895.776182	1781.374
19	Angulana Junction	1122.792591	2232.827
8	Rawathawatta (Outbound)	1211.233912	2408.704
22	Golumadama	1250.232986	2486.259
34	Mt. Lavinia Juction	1342.186296	2669.121
24	SLT	1352.863991	2690.355
36	Infront of Sampath Bank	1456.813224	2897.073
10	AIA Insuarance Lanka	1481.075493	2945.321
7	Tower Cinema	1505.255117	2993.406
3	Veerapuranappu vidyalaya (Inbound)	1516.574318	3015.916
17	People's Bank Katubedda	1524.876514	3032.426
15	Katubedda (Near K - Zone)	1697.56331	3375.837
33	HNB	2076.615616	4129.635
25	Belekkade (Inbound)	2433.804775	4839.954
26	Belekkade (Outbound)	2479.973083	4931.766
30	Seylan Bank Mt. Lavinia	2597.439482	5165.364
14	Katubedda (Near Tyrrone Fernando Stadium)	2960.012703	5886.391
2	Moratuwa	2964.575714	5895.465
28	Maliban Junction	3116.339588	6197.268
18	German Tech	3240.255692	6443.692
23	Sathosa	3287.109344	6536.867
16	Lal Sri	3295.238384	6553.033
4	Veerapuranappu vidyalaya (Outbound)	3295.314312	6553.184
13	Commercial Bank Katubedda	3361.645603	6685.093
29	Commercial Bank Mt. Lavinia	3602.191532	7163.451
9	Prince of Wales	3668.845769	7296.002
11	Domino's Pizza	3717.406977	7392.573
38	Court	3773.270995	7503.666
21	Infront of Abans	3795.479179	7547.830
31	Infront of Nolimit	3860.853763	7677.836
5	Kurusa Handiya	4170.858711	8294.324
41	Dehiwala Junction (Outbound)	4199.344097	8350.971
27	Vijitha Hall	4280.577536	8512.515
20	Soysapura	4321.604976	8594.103
37	St. Thomas College	4614.41895	9176.404
39	Arpico	4652.000044	9251.139
35	Singer Plus	5127.269669	10196.278
32	Taco Bell	5598.593584	11133.570
40	Dehiwala Junction (Inbound)	5632.870296	11201.734
1	Moratuwa Railway station	6058.748291	12048.651

Table 6- Accessibility Index

Accessibility Index		
	Very Low	Below 2500 ISAI Value
	Low	2500 - 5000 ISAI Value
	Moderate	5000 - 7000 ISAI Value
	High	7000 - 10000 ISAI Value
	Very High	Above 10000 ISAI Value

According to above accessibility index, 5 bus stops are identified having extremely lower accessibility for pedestrians. Bus stops near to Dharmarathna Avenue, Mendis Lane, Rawathawatta (Outbound), Angulana Junction, and Golumadama belong to this category. Main reason for this lower accessibility is these bus stops haven't spanned pedestrian network

Since these five bus stops are situated near to commercial suburban cities, bus stop locations should be rearranged in order to increase their ISAI value up to at least 7000 to 10,000. Another 11 bus stops were identified having lower accessibility for pedestrians. They were having ISAI values in between 2500 – 5000. There are 9 bus stops having moderate accessibility compared to their surrounding pedestrian road network. Therefore, these lower and moderate accessible bus stops need to be rearranged which will have higher ISAI values with better accessibility for pedestrian.

6. CONCLUSION

The analysis attempted to highlighting to assess the spatial accessibility of the bus stops. Based on the GPS and GIS data, 41 bus stops selected as the study area along the in the Galle corridor Moratuwa to Dehiwala Junction road section. The total length of the selected road segment is 9.8km. In this research, bus stop access coverage is estimated based on the actual pedestrian road network surrounding the stop. Accordingly, new indices are developed to assess a bus stop location on a more spatial basis. These indices measure the accessibility of a bus stop through the surrounding road network in addition to the ratio of actual access coverage to the ideal access coverage of a stop. Bus stops were selected both sides of the roads and three main indices were used to do GIS analysis about accessibility of bus stops. The Ideal Stop-Accessibility Index (ISAI) assesses the accessibility of bus stops through the surrounding pedestrian road network and can be used to assess and compare different stop locations from a spatial perspective. The Actual Stop-Accessibility Index (ASAI) evaluates a more accurate measurement of the pedestrian road network density around a bus stop. The Stop Coverage Ratio Index (SCRI) gives the percentage of actual access coverage of a bus stop with respect to its ideal access coverage.

6.1 Summary of the Findings

Above mentioned three indices were calculated to all 41 bus stops. As the summary, bus stop at Dharmarathna Avenue (Bus Stop #12) had the least value of the ISAI and ASAI indices, which means that it has the minimum actual pedestrian road network density and actual access coverage (polygon area) among the rest of the stops while Moratuwa Railway Station (Bus Stop #1) bus stop achieved the highest value of the ISAI and ASAI indices, which means that it has the maximum actual pedestrian road network density among the rest of the stops and actual access coverage(Polygon Area) as well. ASAI values were calculated for all bus stops and it is believed that the ASAI gives a more accurate value than the ISAI to the pedestrian road network density around a bus stop, where the denominator represents the actual access coverage area for the bus stop within the 400m circular buffer. When comparing two values (ASAI and ISAI) of particular bus stops, it's quite clear that all most same sequence is maintained.

But there are few variations where the same sequence is not maintained. Based on the ISAI values, bus stop accessibility can be categorized in to 5 types. Lower accessible bus stops are recommended to rearrange in order to increase their accessibility for pedestrians. 25 bus stops were identified as lower accessible bus stops while 16 bus stops were categorized as high accessible bus stops. Transport planner and designers should concern surrounding pedestrian road network when rearranging lower accessible bus stops.

6.2 Limitations of the Study

In this study the selected area is only a 9.8 km length corridor from Moratuwa railway station to Dehiwala Junction. There are only 41 bus stops within study area including both side of the road. With the limitation of the time and the limitations of the data collection processes the collected data only available for the above mentioned road section and bus stops. Bus stops locations were collected manually by GPS coordinators. There are slight changes when comparing locations which are already in google maps. Even though these data also collected but they were not used for this analysis. When calculating three indices mainly concern on effect of ideal access coverage and actual access coverage of surrounding pedestrian road network for accessibility of selected bus stops. The accuracy level of the result could be uplifted with the availability of more data, and also if there is an availability of population and other socio economic data of area it could strengthen the analysis of relationships. The limitation of the GIS data especially the scale of the data, classification of the data and richness of the data layers affect to the final analysis and the accuracy of the data, timely of data will directly influence to the data analysis of this research.

6.3 Recommendations

It is recommended that an extensive detailed analysis be performed for the developed indices in order to study how the geometry of the surrounding pedestrian road network could affect the values of the indices. This study could help transit planners in evaluating the locations of transit stops on a spatial basis rather than just spacing and circular access coverage, in order to select the most suitable places for locating new bus stops or for reallocating currently existing bus stops. For instance, same methodology can be developed to assess the accessibility of railway stations. AS explained in summary identified lower accessible bus stops should be rearranged in order to increase their pedestrian road network.

Five (5) bus stops from extremely lower accessible category, 11 bus stops from lower accessible category and 9 bus stops from moderately accessible category should be immediacy rearranged. This study can be extended in order to select the most suitable places for locating new bus stops or for reallocating currently existing bus stops.

6.4 Suggestions for Future Research

As explained in above, Bus stops which are already located in google maps can be also used for future researches. Since these bus stops in google map and marked locations of bus stops which are used for this study are not tally in some locations. Therefore, it’s quite good to develop the future research using both bus stops locations based on this methodology.
The Following potential areas can be used for continuing this study in future

1. Accessibility and linkage with potential users of the bus stop and using information on population densities for different urban districts and transforming it in terms of persons per km. Moreover, the effect of time on the demand variability also can be introduced through the use of appropriate data in morning/evening peak periods or even on a seasonal basis.

2. Distribution of potential users within the circular buffer zone can also addressed. For example, by creating various circles radiating from the location of the bus stop with 50m increments and locating the share of the total road network length in km within each

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