1 The Effectiveness of Walkability Index for Social Sustainability in Developing Countries Using Geographical Information System and Space Syntax

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Abstract:

Walking is greatly significant to achieve good health, and ultimately, social sustainability. There have been numerous walkability indices developed to measure the effectiveness of walking. Limited number of these indices have been developed objectively in the context of developing countries. The current research is focused on developing a walkability index objectively, as well as finding a comparison between non-gated and gated neighborhoods, and to see how the developed walkability index is associated with walking in developing countries. The study area for this research is Karachi, Pakistan. The walkability index has been developed by utilizing entropy index for land-use-mix and Space Syntax for street connectivity, while gross housing density was considered. In order to measure the walking at neighborhood level, a questionnaire (n=1042) was used. Binary logistic regression analysis and Independent sample t-test were used for attaining results. The results show that the walkability of non-gated neighborhoods is higher than gated and there is a positive correlation between walkability and walking. The study concludes that an objectively measured walkability index can be developed in even those areas where a central database doesn't exist. Furthermore, the promulgation of walking at neighborhood level doesn't necessitate the policy of promoting the gating of neighborhoods.

2 Introduction

Sustainability is a well-known concept in many disciplines and is getting much attention amongst researchers. Sustainable development comprises of three key components, which is also known as triple bottom line: environmental, economic, and social. Past research have given much attention to the environmental issues and their interaction with the economic aspect; but, have hardly examined the social issues making it the least described aspect. This research focuses on this third aspect in detail, specifically, the walkability effect on the health of the residents of the two types of neighbourhoods i.e. gated and non-gated. Walkability is an important component of social sustainability. Walking is an essential activity for achieving good health and sustainable development outcomes. Different guidelines are available for different age groups to stay physically active. As per the recommendations of the World Health Organization (WHO), a 30-minute moderate level walk for 5 days a week, which achieves 600 Metabolic Equivalent of Task (MET), is essential for maintaining one's health.

In the recent years, the association between built environment components and walking has been gaining much attention in urban and transport planning as well as public health research (1; 2). The built environment data measures used for calculating the walkability of neighborhoods are divided in three categories, which include: perceived measures obtained through telephonic or in-person interviews, or paper-based questionnaires filled by the respondents themselves; observational measures obtained through methodical measurement; and archival datasets, which are often analyzed with geographical information system (GIS). The GIS-derived measures, which include population density, land-use mix, and access to recreational facilities and street patterns; are known as the three dimensions (3D's) i.e. design, diversity and density of neighborhoods (3). These 3D's are widely investigated in the literature of transportation planning, and it is generally concluded that these components of built environment affect travel behavior (4), for example, the density, land-use diversity, and pedestrian oriented designs generally reduce the number of trips of motorized travel and encourage the non-motorized ones. In another study, it was reported that 3D's along with the daily route choice (3Ds + R) can serve as an important method to calculate neighborhood walkability.

Four components of built environment have been widely used to objectively develop indices to examine the walkability of neighborhoods. The components of street connectivity, land-use mix (LUM), and housing density have been used through GIS database to calculate the walkability indices objectively in several studies e.g. NQLS, USA (5); PLACE, Australia (6); BEPAS, Belgium (7); and SNAP, Sweden (8). Moreover, retail floor area has also been used as a component in addition to the above three components of walkability index in a few studies (5; 6; 9). However, most of the studies in Europe have used only three of the four components, leaving out the retail floor area due to the unavailability/scarcity of data on it (8; 7). Of the three components, housing density is generally estimated as the number of residential units per acre. The street connectivity is calculated by counting the number of intersections or intersection densities in a 1 km2 area. The areas having greater than 30 intersections are considered as well-connected areas. The land-use mix is analyzed by charting how even the distribution of commercial, residential, recreational, and official land utilization is. It is measured on a 0-1 scale. The researchers who use the above three components generally give the street connectivity a weight of 1.5, whereas those using the four components generally give the street connectivity a weight of 2.0.

There have been various types of walkability indices reported in literature. For example, the effects of the walkability of a neighborhood are considered to be different on children, therefore, a different type of walkability index was developed to investigate the physical activity among children from age 2-9 years. The components used in this index were intersection density, public transport density, land-use mix, playground density, and the density of open public space. Land-use mix was found to be negatively associated with the physical activity of children, whereas the playground density was the most associated component (10). Another study investigated the walkability of neighborhoods along with the walking for transportation behavior and leisure-time physical activity of children in low and high socio-economic status (SES) neighborhoods in Belgium. It was found that in low-SES neighborhoods, while walkability contributed positively towards transportation/utilitarian walking, it affected negatively on sports during leisure time; whereas, in high SES neighborhoods, the children's physical activity was not related to walkability. The components of walkability index consisted of street connectivity, housing density, and land-use mix (11). Another walkability index around primary schools was calculated through street connectivity and dwelling density in different income groups of urban areas in Scotland as a whole and at local level. Positive association of walkability was reported with walking to access transportations (12). The objectively measured walkability of a neighborhood using the components of land-use mix, distance to public transport, retail land-use ratio, public transport density, distance to the nearest transit, and public park density in 14 cities worldwide was investigated along with walking among adults 18-66. Mixed land use and the distance to the nearest public transport point were reported to have no relation with physical activity (13).

A set of theories and techniques to analyze spatial patterns known as Space Syntax, was developed by Bill Hillier's team in late 1970s to early 1980s (14). A walkability index was developed for the urban areas of Adelaide, Australia by Koohsari, et al. (15), using Space Syntax and the same was compared to the walkability index developed by Lesliea, et al. (6) through GIS. The population density of the area along with the integration values which were generated through Space Syntax utilizing vector data from Google maps were used by the present researchers. The researchers attained similar results to those obtained by Lesliea, et al. (6), thus, they concluded that Space Syntax can also be used as a tool to develop walkability indices especially where there is either no GIS database available or it is not accessible. Built environment configuration also effects body mass index of older adults as was reported after investigating destination accessibility and street connectivity through Space Syntax method for older adults in Tehran, Iran. It was reported that direct routes (less turns) encourage walking at neighborhood level (16). Walkability index through GIS could only be possible if the availability of central data base (GIS) for cities is assured. On the other hand the strength of Space Syntax method for developing walkability index is that the necessary geographic data is easily accessible through Google maps (Vector data) or redrawn data in a GIS software, such as Arc GIS, ERDAS, QGIS etc. which is compatible with the software used in Space Syntax method (15).

The development of walkability index objectively has been discussed above along with different methods, and components of built environment, which can be used therewith. At the same time, only few researches have compared the walkability in gated neighborhoods with that in the non-gated ones. Gated neighborhoods are advanced form of neighborhood design, separated by walls and fences from the surrounding neighborhoods. The gated communities are of three types, including lifestyle, prestigious and security zone gated communities (17; 18). The prestigious gated communities are for high class people such as football and film stars, while the lifestyle gated communities are developed to attract young retired people by providing more physical activity facilities, while security zone gated communities are for security purpose. These neighborhoods are found in suburban areas of cities as well as in high density inner city development such as in China (19). These neighborhoods have less street connectivity and Land-use mix, therefore less walking (20; 21) and more physical activity facilities (22). The growth of gated neighborhoods is very fast around the globe, especially in Asian developing countries; the gated neighborhoods there have all the three aspects combined in them i.e. prestige, security and life style (23). Some other aspects of gated communities have been investigated such as the crime level and its effects on gated and non-gated neighborhoods in Karachi, Pakistan (24). The effects of neighborhood walking behavior on different demographics in gated and non-gated neighborhoods (25).

3 Research problem, assumptions, objectives, the importance of research, and the limits

It has also been reported that maximum number of the neighborhoods will be gated in the city of Karachi, Pakistan by 2030 for safe and healthy lifestyle (26), which is one of alarming problem for the cities of Asian developing countries such as Karachi, Pakistan. Therefore, this research objectives of this study are, firstly to formulate a walkability index, secondly to distinguish the walkability index between gated and non-gated communities, and in the end to check the correlation of walkability with walking in Asian developing countries while choosing Karachi, Pakistan as the study area. The importance of this is study is that through this type of studies in the developing countries the neighborhoods in cities can be designed for the people to be physically active through mixing the land use, connecting different neighborhoods together and through increasing housing densities. This study can help policy maker to take decisions for people according to WHO guidelines for human beings to be physically active through walking at neighborhood level.

4 Methods

This study has used two types of methods such as objective and subjective methods. The objective method has been used for calculating Land-use Mix, Street connectivity and housing density while the subjective method has been used to investigating the walking level of people in a week through using the International questionnaire for physical activity (walking part). The objective methods which were used for calculating land use mix was GIS software (27) while for connectivity the Space Syntax (DepthMap X) method has been used (28).

4.1 Selection of the study area

Karachi is the biggest metropolitan city of Pakistan. This city was preferred as the study area due to its largest size (3,527 km2) and heterogeneous population (29). In Karachi city, two main types of developments: planned and unplanned. The planned developments are further divided in to two types: single family and multifamily. The multifamily developments include walk-ups (5 stories) and high-rises (16 stories). There are 18 towns, 5 districts, 216 union councils, and 4 development authorities in the city. The districts include; Karachi East, Karachi South, Karachi West, Karachi Central, and Malir (Figure 1). There are some cantonments, which are areas with their own administrative setup separate from these districts. The Karachi West and South districts were not part of this study due to very little or no gated neighborhoods there.

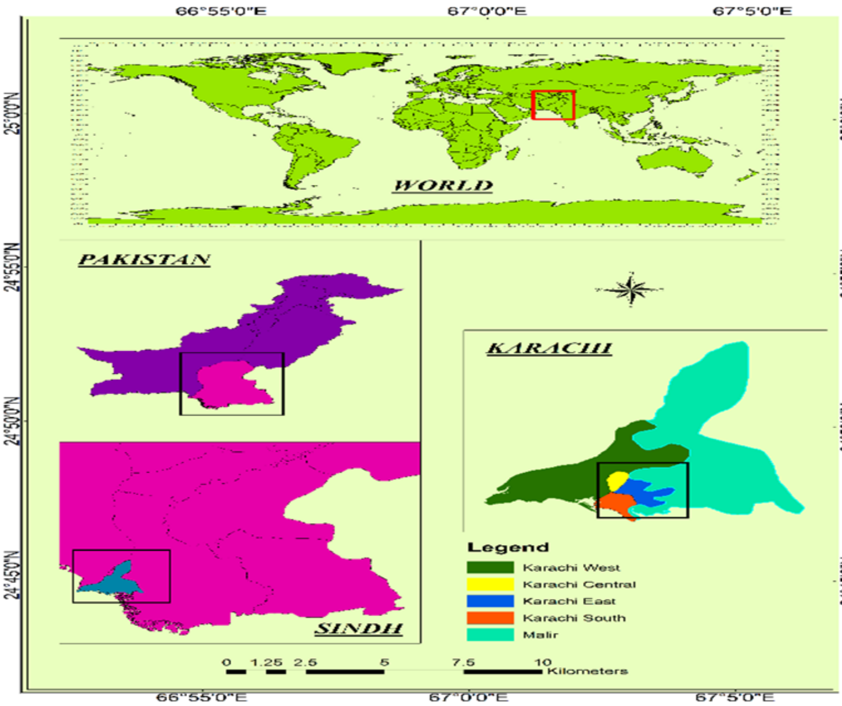

FIGURE 1. Study Area

For the selection of neighborhoods, some other important factors were also considered including population density, income group, and the area. The income-based selection of neighborhoods ranged between upper-middle to high-income groups (Rs.65, 000 to Rs.250, 000 per month, which is approx. $650–$2,500 per month). This income bracket was selected for the reason that the gated communities mostly belong to these income groups. All the selected non-gated neighborhoods also lie in a similar income group. The second important characteristic for selection was population density (demographic indicator). The neighborhoods with a similar population density were selected in each category. Population density was estimated as the product of the average size of a household in Karachi (29) and the gross housing density of that particular neighborhood. Furthermore, for each gated neighborhood, a counterpart non-gated neighborhood was selected that had a similar gross population. The neighborhood area was the fourth significant aspect that was considered during the selection of neighborhoods (Figure 2). Neighborhooods with the area between 0.5 to 1 km2 were selected, because this range is considered a suitable size for the inhabitants to access Physical Activity Facilities (PAF). Moreover, most of the gated neighborhoods of Karachi were between 0.5 to 1.5 km2, limited by the presence of walls and gates; therefore, the non-gated neighborhoods were also selected to be as close in area as possible.

4.2 Study sample

This was a cross-sectional study carried out by matching gated neighborhoods with their counterpart non-gated neighborhoods. A total of four neighborhoods were selected from each dwelling type i.e. single family and multi-family in gated neighborhoods and their counterparts in non-gated, yielding a grand total of 16 neighborhoods.

Simple random sampling method was applied by utilizing the Cochran (1963) formula of sample size. A total of 1200 respondents who met the inclusion criteria were selected (75 from each neighborhood) for the current study. The inclusion criteria were based on (1) reading and writing skill of individual either in English or Urdu, (2) staying duration in neighborhood shouldn't less than 3 months, and (3) without a serious impairment that may restrict their ability to do physical activity. A total of 1,042 individual responses were considered for analysis after excluding the missing data.

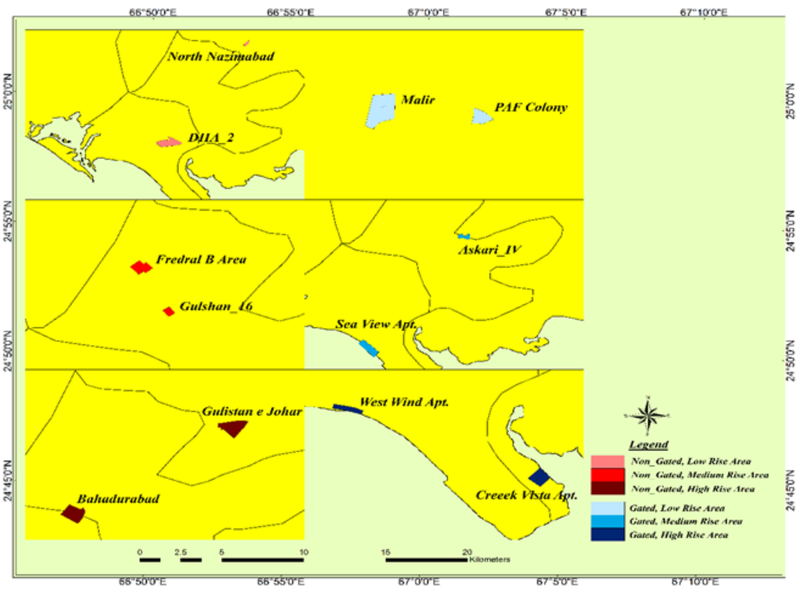

Figure 2. Sample sites

4.3 Data collection and analysis

The total walking was a dependent variable in this study which includes both practical and recreational walking. The data was collected with the help of Neighborhood Physical Activity Questionnaire (NPAQ) (30). Practical walking includes walk for multiple purpose e.g. to access the transportation or any utility whereas recreational walking includes walk for health benefits or leisure purposes. The standard MET value is for Practical walking is 4 and that for recreational walking is 3.5 (31). At first, the questionnaire asked the respondents if they did any walking in any given week. If they answered yes to that question, then they were given different destination options to choose the suitable one from, for example, options for practical walking included walk to school, shop, religious building, bus station, and work. The destination options for recreational walk included walk to the neighborhood park, a friend's place, coffee shop, and walk on neighborhood pathways and trails without any destination. An open option was also given in which the respondents can specify their own destination if it was different from all the options given. They were asked the durations (time of return trip)/ per day and days/ week. Then the time was multiplied with the standard MET values of 4 for the practical walk destinations and 3.5 for the destinations of recreational walk. The total MET was obtained in this way for each respondent for each type of walking. Later, both types of walking were added to analyze statistically the differences and association of total walking with walkability in the two types of neighborhoods through Independent sample t test and binary logistic regression analysis.

Walkability was used as independent variable for this study and is calculated through land-use mix (LUM), street connectivity and housing density. The data for LUM, housing density and street connectivity was obtained from the relevant development authorities in the form of aerial maps (AutoCAD drawings and hard copies), which were later re-digitized in GIS and converted into vector maps.

The statistical analysis was performed using a software (SPSS). The analysis was divided into two parts; the first part consisted of independent sample t-test to relate walkability and total walking in the neighborhoods. Secondly, binary logistic regression analysis was done to investigate the association of walkability with walking. For binary logistic regression, the walkability was divided into quartiles while the activity of walking was dichotomized into people who achieve above 600 MET minutes of walking in a week, and people who do not. This is the guideline to become physically active according to the WHO.

5 Results

5.1 Development of walkability index

In order to develop walkability index, three components of neighborhood built environment were calculated including (1) street connectivity, (2) LUM and (3) housing density, partially built on earlier described HHI (5). The current study introduced a modified method for the calculation of walkability index with the street connectivity measured by the Space Syntax method. The entropy index method was used to calculate LUM. The concept of entropy index was previously used for such calculation of LUM by Bordoloia, Motea, Sarkab, & Mallikarjuna (32); and Peiravian, Derrible, & Ijaz (33). Street connectivity has been calculated via Space Syntax method and the housing density has been computed from gross density. The Equations used in study are presented in Table 1.

TABLE 1 EQUATIONS FOR WALKABILITY INDEX

Measures	Definitions	Scale of measurement	Equation	Data source
LUM	Measurement of how evenly the square footage of a neighborhood is distributed among different types of lan-use	blocks of 1x1 km and entire gated neighborhoods	$\text{Entropy} = \sum_j \left[P_j \times \frac{\ln(P_j)}{\ln(J)}\right]$ where, P_j is the proportion of land area of j^{th} land-use category and J is the total number of land use categories considered	Land-Use maps from the relevant development authorities
Street Connectivity	Axial Line Analysis		Space Syntax (Axial Line Analysis) through the software of Depth Map X and AJAX light	AutoCAD drawings/ GIS
Housing Density	Number of housing units per unit area		$\textit{Number of Dwellings} = \left(\frac{\textit{Number of dwellings}}{\textit{site area in hectares}}\right)$	Aerial maps (Google Maps) and Surveys of the areas

5.2 Components of walkability index

5.2.1 Land-use mix (LUM)

The term "Land-use mix" is used for the distribution of all categories of land use e.g. commercial, recreational, residential and public buildings. The public buildings category includes education and health facilities. Instead of computing LUM around the participant's houses in a 1 km2 buffer area, this research used the gated neighborhoods of the size as close to 1km2 as possible, and blocks of similar size of non-gated neighborhoods. For example, the spatial scale for Askari Phase-IV (a gated neighborhood) is 1:10,000; and it is 1:15,000 for North Nazimabad blocks C, D and E (non-gated neighborhoods). The parcel level data was obtained from department of Urban Engineering, NED University of Engineering and Technology, Karachi; and concerned development authorities. The detailing of neighborhoods under study has been done with the help of aerial maps (AutoCAD drawings and Google maps) and land-use maps obtained from the development authorities. The overall calculation of LUM was normalized, with 0 indicating a single use and 1 indicating that the floor area is evenly distributed among all the 4 uses.

5.2.2 Street connectivity

Street Connectivity was computed by Space Syntax method. Space Syntax consist of techniques and theories to analyze the spatial patterns. This method was developed by Bill Hillier and colleagues at The Bartlett, University College London around 1980. The purpose behind this development of this system was to facilitate the urban planners in simulating the possible social effects their designs might have (34). It works by breaking the spaces under consideration into multiple components before analysis. Space Syntax observes the spatial structure of neighborhoods and cities in two ways, first by modeling the spaces or the land uses which are non-built-up, e.g. squares, streets, parks, and pedestrian paths (35). These space components are referred to as networks of choice and are represented through graphs and maps explaining their comparative connectivity and integration. There are three central notions used by this system, which include axial map lines, visibility graphs, and convex spaces. The axial maps are utilized to compute integration and connectivity. These maps connect the spaces by axial lines which are the longest and fewest lines and it covers all the spaces in a layout and shows their mutual connections. Basically, the axial lines are presumed as sight lines for the people moving about in a particular spatial network. These lines may be hand-drawn or with the help of freely available software's e.g. AJAX and Depthmap X etc, The values transferable into different spatial and statistical programs e.g., SPSS, GIS– for additional analysis.

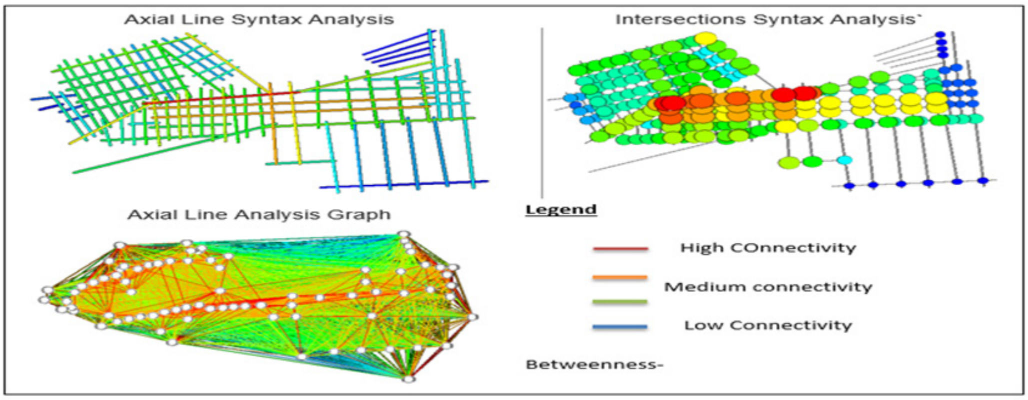

Figure 3. Visualization of streets according to their connectivity. Note: A spectral colour legend with smooth transition from blue to red is used for visualization. The red lines indicate the highest connectivity and blue lines show the lowest connectivity.

This study has used Depthmap X software to calculate the street connectivity. The street center lines maps were imported from ArcGIS and converted into axial maps at first stage in Depthmap X. The graph analysis of the axial maps has been done, the include choice (between-ness) has been selected. Street-level between-ness is a measure of street network connectivity (36; 37). Spectral colors were used to visualize the streets with red representing the highest connectivity and local integrations, and blue representing the lowest end. The attributes summary provides three values: minimum, average and maximum for connectivity. The average values for connectivity were selected for further investigation in this study.

5.2.3 Housing density

The Housing density was computed with the help of gross density where the number of housing units per unit area was estimated. The housing density calculation equation is given in Table 1. Lesser than 17 houses per 100 hectares were categorized as low density, in between 17 to 45 were considered medium density, and above 45 falls in high density (38). The Google maps and Land-use maps have been used to compute gross density at each individual neighborhood level.

5.3 The Resulting Walkability Index

The results of the objectively measured walkability index are given in Table 2, which shows the average values for LUM, street connectivity and housing density, which were calculated through entropy index, Space syntax method, and gross density, respectively, as discussed in detail above. Then Z-scores for all the three components were calculated by dividing the corresponding component value e.g. housing density of a particular neighborhood by the standard deviation (SD) of housing density calculated from all the neighborhoods. The Z-scores signify how much a particular component differs from the average value in that particular category. Mathematically, using the case of LUM, the Z-score is given as:

$$Z\_i=LUM\_i-LUM\_avg/SD$$

Where, Z_i is the Z-score for i^th neighborhood, LUM_i is the LUM for i^th neighborhood, and LUM_avg is the average LUM for all the neighborhoods in that category.

Thus, the developed walkability index is a scale from 0 to 10, with 0 representing not-walkable at all and 10 representing the most-walkable.

TABLE 2 CALCULATION OF WALKABILITY INDEX

S.No.	Category	Sub-Categorization	Neighbourhoods	Avr. LUM	Avr. Connectivity	Housing density	Walkability Index
1.	Gated	Single-Family	Malir Cantonment	0.601295472	3.24	14	4.92
2.			PAF-Falcon Housing Society	0.493690677	3.21	13	3.70
3.			Chapal Suncity	0.380821139	3.04	45.1	5.52
			Askari Phase IV	0.106661728	3	36.7	1.88
5.		Multifamily	Agha khani Housing Society Karimabad	0.570806634	2.54	51.2	7.28
6			Sea View Apartments	0.39604184	2.8	17.1	2.51
7.			Creek Vista Apartments	0.437096676	2.12	64.6	6.65
8			West Wind Apartments	0.40621617	2.1	35	3.36
Average				0.42	2.75625	34.5875	4.4775
9	Non-Gated	Single Family	Gulshan – e - Maymar	0.67118826	3.67	12	6.06
10			DHA Phase VI	0.401	3.6	16.24	8.04
11.			North Nazimabad Blocks C,D and E	0.554438343	3.14	25.4	5.44
12.			Nazimabad Block-5	0.455970166	4.29	17.26	5.36
13.		Multifamily	FB Area Block-3	0.605509988	3	65.8	9.78
14.			Gulshan-e- Iqbal Block-16	0.221276246	2.7	96.1	8.52
15.			Bahadarabad Chowrangi	0.376554336	2.55	17.85	2.02
16.			Gulistan -e - Johar Block-16	0.305588758	2.5	23.65	1.81
Average				0.5	3.18125	34.2875	5.87875

5.4 Comparison of Walkability between Gated and Non-gated Neighbourhoods

An independent sample t-test was performed to find the association between walkability and walking in both types of neighborhoods. The results show a substantial variance in the walkability of non-gated neighborhoods (M-5.92 and SD-2.84) and gated neighborhoods (M-4.2 SD-434); conditions (t=-14) = 1.47 and p-0.000. Furthermore, the results of the components of walkability index in the two types of neighborhoods also show quite significant difference in land-use mix and street connectivity, but there is no substantial difference in the housing density. That is because the selection of neighborhoods was done on the basis of development type and similar development type neighborhoods were selected in both categories. At the same time the results of walking in both neighborhoods show a major difference in walking in gated (M-434 SD-490) and the same in non-gated (M-633 SD 674), under the conditions of t-937.106 =-11.21 and p-0.000. Based on these results, it is concluded that: as the LUM and street connectivity increase, the walkability in neighborhoods will also increase, which can encourage more walking. The results of independent sample t-test and group statistics are given in Tables 3 and 4.

TABLE 3 GROUP STATISTICS

Neighbourhoods		**Mean**	**Std. Deviation**	**Std. Error Mean**
Walkability Index	Gated	4.2710	1.84187	.08245
	Non-Gated	5.9233	2.84444	.12207
LUM	Gated	2.0982	.62445	.02795
	Non-Gated	2.2762	.69069	.02964
Street Connectivity	Gated	2.7735	.39669	.01776
	Non-Gated	3.0674	.49522	.02125
Housing Density	Gated	33.6599	15.43068	.69077
	Non-Gated	36.0839	29.15573	1.25119
Walking	Gated	434.1727	490.75411	27.01512
	Non-Gated	633.4950	674.57966	38.75359

TABLE 4 INDEPENDENT t-TEST

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
Dependent and Independent Variables		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Walkability Index	Equal variances assumed	93.667	.000	1.470	14	.000	-1.65235	.14987	-1.94644	-1.35826
	Equal variances not assumed			-11.217	937.106	.000	-1.65235	.14731	-1.94144	-1.36327
LUM	Equal variances assumed	39.550	.000	-.310	14	.000	-.17805	.04092	-.25833	-.09776
	Equal variances not assumed			-.310	13.998	.000	-.17805	.04074	-.25799	-.09810
Street Connectivity	Equal variances assumed	31.353	.000	-1.545	14	.000	-.29394	.02795	-.34878	-.23909
	Equal variances not assumed			-1.545	12.781	.000	-.29394	.02769	-.34828	-.23959
Housing density	Equal variances assumed	231.717	.000	-.024	14	.098	-2.42398	1.46360	-5.29592	.44796
	Equal variances not assumed			-.024	11.734	.090	-2.42398	1.42921	-5.22924	.38127
Walking	Equal variances assumed	13.230	.000	-4.275	631	.000	-199.32232	46.62318	-290.87770	-107.76695
	Equal variances not assumed			-4.219	548.034	.000	-199.32232	47.24042	-292.11679	-106.52786

5.5 Association of Walkability with Total Walking

Binary logistic regression analysis was done to investigate the effectiveness of walkability of neighborhood for walking. People who reported any walking were included for investigation only and it was dichotomized into under 600 MET minutes and over 600 MET minutes per week. The values of walkability index have been divided into quartiles. The scaled data for components of walkability index were used including the data for street connectivity, LUM, and housing density. Walkability index and its components were considered independent variables and dichotomized Walking was deemed as the dependent variable. The results show a significant increase in walking between third and fourth quartiles of walkability than the reference quartile (lowest) with the p-value of 0.0001. The increase in third quartile is 3.4 time higher than reference quartile with (CI-2.0-5.6) and it is 4.3 times higher in quartile four with (CI-2.7-7.1). The components of walkability index result shows that LUM (p-0.007), street connectivity (p-0.018), and housing density (p=0.019) have significant positive association with walking in Asian developing countries. The results are presented in Table 5.

TABLE 5 BINARY LOGISTIC REGRESSION BETWEEN CATEGORICAL WALKABILITY INDEX, SOCIO-DEMOGRAPHICS AND TOTAL WALKING

								95% C.I.for EXP(B)	
		B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Step 1[a]	Walkability			32.858	3	.000			
	Q-1					Ref			
	Q-2	.357	.259	1.903	1	.168	1.429	.860	2.375
	Q-3	1.228	.253	23.582	1	.000	3.414	2.080	5.604
	Q-4	1.469	.257	32.638	1	.000	4.344	2.624	7.189
	LUM	.512	.190	7.213	1	.007	1.668	1.148	2.423
	Street connectivity	.385	.163	5.553	1	.018	1.470	1.067	2.025
	Housing Density	.014	.009	2.424	1	.019	1.014	1.096	1.032
	Constant	-1.950	.293	44.404	1	.000	.142		
Significance					0.0001				
Nagelkerke R Square					.167				
Overall percentage					82.2%				

a. Variable(s) entered on step 1: Walkability, LUM, street connectivity, housing density

6 Discussion and Conclusion

The development of a walkability index objectively, utilizing Aerial maps (AutoCAD) and Space Syntax methods is the key achievement of the current study. This walkability index could be used worldwide even in case of absence of central database for land use. Finding the difference in the walkability between gated and no-gated neighborhoods is another significant contribution of current study. This study has inspected the association of the objectively developed walkability index with walking in Asian developing countries. The results show a substantially positive relation, which is in agreement with the existing literature including the studies of (NQLS) (5) in the USA, (PLACE) (6) in Australia, (BEPAS) (7) in Belgium, and (SNAP) (8) in Sweden.

The results show a significant difference of walkability and walking between the two types of neighborhoods i.e. gated and non-gated; the walkability of non-gated neighborhoods is significantly higher than gated neighborhoods. This result agrees with the findings of Burke & Sebaly, (2001) and Miao, (19). They reported that due to the lack of connectivity of the streets of gated neighborhoods, both within and near to the boundary walls; these neighborhoods are less walkable. The results of the present study highlight the same fact that due to the less street connectivity and LUM, the gated neighborhoods have less walkability as compared to their non-gated counterparts.

This study has developed a walkability index objectively for developing countries with the help of Aerial maps and land use maps (AutoCAD drawings). This walkability index can be used as guideline by policy makers for designing physically active neighborhoods in future to meet the challenge of sustainable development. This walkability index can also guide policy makers not to encourage the gated neighborhoods in cities because these neighborhoods are sealed and separated from the surrounding areas which not only creates fragmented areas but also have a negative impact on the walking habits of people. Walking habits are of many types, such as walking to shops, mosques, bus stops, schools and hospitals of their neighborhoods as well as surrounding areas. The walkability index developed here is based on three components. Future studies can include other important components as well, such as the retail floor area ratios, etc.

This study concludes that: if there is a high walkability in terms of LUM and street connectivity, the walking ratio will be higher. Moreover, the gated neighborhoods, which separate the neighborhoods from each other by walls, should not be encouraged at policy for promoting neighborhood level physical activity.

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GATED COMMUNITIES PYSICAL ACTIVITY (GC-PA)

a) SECTION 2: PHYSICAL ACTIVITY

Think about the entire vigorous, moderate physical activities and walking inside as well as outside your neighborhood that you did in the last 7 days.

Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal

Moderate activities refer to activities that take moderate physical effort and make you breathe harder than normal

Walking is divided into two categories like Transportation walk and Recreational walk.

(I.e. Transportation walk is like walking to work or public transport stations or walking for any utility while Recreational walk is walk for leisure and health benefits)

Inside Neighborhood means walking within 1kmsq or walking for 10-15 minutes while Outside Neighborhood means walking beyond your gated neighborhood or walking for 15-20 minutes from your home.

A. Vigorous Physical Activity (VPA)

Think about all the vigorous activities that you did in the last 7 days. Vigorous physical activities (i.e. sports, working out in gym) refer to activities that take hard physical effort and make you breathe much harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time

1. During the last 7 days, on how many days did you do vigorous physical activities like sports, working out in gym)?

_____ Days per week

No vigorous physical activities (Skip to question 3)

2. How much time did you usually spend doing vigorous physical activities on one of those days?

_____ Minutes per day

Don’t know/Not sure

B. Moderate Physical Activity (MPA)

b) Think about all the moderate activities that you did in the last 7 days. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time. (I.e. cycling, jogging)

3. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ Days per week

No moderate physical activities (Skip to question 5)

4. How much time did you usually spend doing moderate physical activities on one of those days?

_____ Minutes per day

Don’t know/Not sure

C. Walking INSIDE neighborhood

This part is about walking IN AND AROUND your neighborhood or gated community - we mean everywhere within a 10-15 minute walk of your home. Part D is about walking OUTSIDE your neighborhood.

5. In last 7 days, did you walk in or around your neighborhood or gated community to get to or from somewhere (such as walking to public transport or shops) or for recreation?

- Yes
- No (Skip to question 8)

6. Tick all the places where you have walked as a means of transportation and leisure in or around your neighborhood in last 7 days and write the numbers of return trips as well as time in minutes of one way

Walking destinations		**Tick**	**Number of return trips/week**	**Time in minutes /walk (one way)**	**Distance though GPS by interviewer**
1) To or from work [or study]	Practical walk				
2) To or from Mosque					
3) To or from public transport					
4) To or from shops					
5) To or from café or restaurant					
6) To or from friend’s or relative’s house	Recreational walk				
7) Beach/Natural landscape					
8) Parks					
9) Around the neighborhood using the streets/footpaths (no specific destination)					
10) Somewhere else (Please write where)					

D. Walking OUTSIDE Neighborhoods

This section is about walking OUTSIDE your neighborhood or gated community - we mean everywhere further than a 15-20 minute walk from your home. (For example, somewhere you walk to in the next neighborhood).

7. In the last 7 days, did you walk outside your neighborhood or gated community to get to or from somewhere (such as walking to a shop or to public transport) or for recreation?

- Yes
- No (Skip to Section 2)

8. Tick all the places where you have walked as a means of transportation or recreational walk outside your neighborhood in last 7 days and write the numbers of return trips as well as time in minutes of one way

Walking destinations		Tick	Number of return trips/week	Time in minutes /walk (one way)	Distance though GPS by interviewer
1) To or from work [or study]	Practical walk				
2) To or from Mosque					
3) To or from public transport					
4) To or from shops					
5) To or from café or restaurant					
6) To or from friend's or relative's house	Recreational walk				
7) Beach/Natural landscape					
8) Parks					
9) Around the neighborhood using the streets/footpaths					
10) Somewhere else (Please write where)					