ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 10(17), DOI: 10.17485/ijst/2017/v10i17/114379, May 2017* ISSN (Online) : 0974-5645

Study of Correlation between Urban Physical Environment and Walkability for Cities of "Y" Category in Indian Context using Analytical Hierarchy Process and Simple Additive Weighing Methods of Multi Criteria Decision Making

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Abstract

This paper intends to study the correlation between urban physical environment and walkability with a view to develop a correlation model between the two which shall help the decision making authorities at local level working for the urban development in their endeavor to encourage walkability in urban pockets through urban design interventions. This paper talks about one of the commercial pockets called "Sayajigunj". Firstly the physical environment is analyzed like a conventional urban design study and the inferences are enlisted with the help of graphical illustrations and text. A theoretical frame work is prepared to enlist the parameters affecting the walkability of urban pocket based on the Global Walkability Index developed by Holly Virginia Krambeck. AHP method is used for assigning weights and determining scores for the indices and SAW method is used for final decision making. The data was collected using manual method and separate questionnaires were prepared for the experts and respondents respectively. The result is enlisted in a tabular format. The result reveals that the availability of amenities is the most important factor affecting the walkability of an urban pocket. However each criterion plays its role in holistically influencing the walkability.

Keywords: Analytical Hierarchy Process (AHP), Multi Criteria Decision Making (MCDM), Simple Additive Weighting (SAW) Process

1. Introduction

Walkability is considered to be one of the basic parameters of livability and sustainability of built environment. In an endeavor to enhance walkability of the neighborhood through urban planning interventions, it becomes extremely important to quantify the parameters associated with walkability. The policy making and setting up the priorities is easier with the quantified parameters. This study scans the urban form of a commercial pocket called "Sayajigunj" in the city of Vadodara, Gujarat, India which is a "Y" category city of India. Separate questionnaires are prepared for the experts and respondents which are the end users of this pocket. The parameters taken are based on the Global Walkability Index.

1.1 Global Walkability Index

The Global Walkability Index developed by Holly Virginia Krambeck in 2006 for the World Bank provides a qualitative analysis of the walking conditions including

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safety, security and convenience of the pedestrian environment. It consists of a field walkability survey to assess pedestrian infrastructure in four areas: Commercial, residential, educational and public transport terminals. The survey also identified pedestrian preferences and analyzes government policies and institutional setup. The methodology is qualitative but because it encompasses several key parameters, it provides a good insight into the current state of the walkability environment and enables the identification of areas for improvement. The Global Walkability Index consists of 73 indices including 6 Primary, 23 Secondary and 44 Tertiary indices. It comprehensively covers the parameters affecting walkability but the relative significance will change from site to site depending up on the Physical, Cultural and Political fabric. This study area for this research is the city of Vadodara located in the Gujarat state of India[1].

1.2 Categorization of Cities in India

The classification of "X", "Y" and "Z" categories of cities is as per the Ministry of Finance, India for consideration of House Rent Allowance. Population above 50 lakhs falls in "X" category, range between 5 lakhs to 50 lakhs falls under "Y" category and range between 1 lakh to 5 lakhs falls under "Z" category. From the pie chart it is clear that maximum share is from "Y" category. Total 8, 88 and 372 centres are covered under "X", "Y" and "Z" category respectively. The "X", "Y" and "Z" category houses 32%, 40% and 28% of the urban population in India. This makes the "Y" category the biggest of them and hence it is considered for this research.

2. Study Area

Vadodara is a city located in the central part of Gujarat state with the population of approximately 18 lakhs as per Census 2011. It is divided in to four zones and 22 wards. The city has its identity as the cultural capital of Gujarat and it is one of the four biggest cities of the state. For the larger research three urban pockets are identified from each zone having Commercial, Residential and Recreational character respectively. In this paper the commercial pocket known as "Sayajigunj" is demonstrated as pilot study.

Figure 1 shows the location of the pocket, it can be seen that the Sayajigunj area is in close vicinity of the railway station of Vadodara The street connecting Railway station and "Kalaghoda" is the spine of the area. On one side of the street the famous Maharaja Sayajirao university is housed which attracts the Students, Teaching staff and non-teaching staff along with the visitors to the university throughout the day[2]. On the opposite side of the road all high rise commercial office buildings are housed. Major commercial activities comprises of stock trading and coaching related activities making this a buzzing place during office hours.

Figure 2 contains some graphical illustration showing different layers of urban physical environment characteristics of the demonstration pocket. In the Built vs. Open layer, Black color indicated the built area; Grey is for roads, White indicates the unbuilt or ground portion out of which Green indicated the landscaped garden area. As we can see the University campus is less dense and has significant open and landscaped area but the opposite side of the road is highly dense. It is obvious to have different walkability experience in and out of the university campus.

In the Building use pattern of the neighborhood. Blue indicates the Commercial activities, Red indicates the Institutional activities and Yellow indicates the Residential portion. It is interesting to observe that with such a small portion of residential component it has a greater threat of becoming a "Ghost" neighborhood at knight as both commercial and institutional activities does not have any presence at knight. But due to the presence of railway station and the fact that the main spine of his area is one of the major connecting link between the station and the city has made sure the ghost phenomena does not become significant.

The Building height pattern Map of the neighborhood indicates that the darkest brown color indicates G+9 buildings which clearly are adding on to the effect of building density. All these high-rise buildings are totally commercial buildings, the moderately dark brown color is the G+3 to G+4 buildings; some of them are residential providing some relief to the "Ghost" threat as well as the early morning and late evening walkability. Some gentrificative measures may be thought for the retention of residence in this pocket and attracts the migrated property owners to reestablish their residential presence in this pocket.

The Hierarchy of streets in the study area where the Red indicates the primary, Blue indicates secondary and Yellow indicates the tertiary level of streets[3]. It is important to convert the blues in to red in order to divert

the traffic volume and also to avail alternative route and adding choice in to the equation.

Figure 1. Location map of the Sayajigunj area. Source: Author.

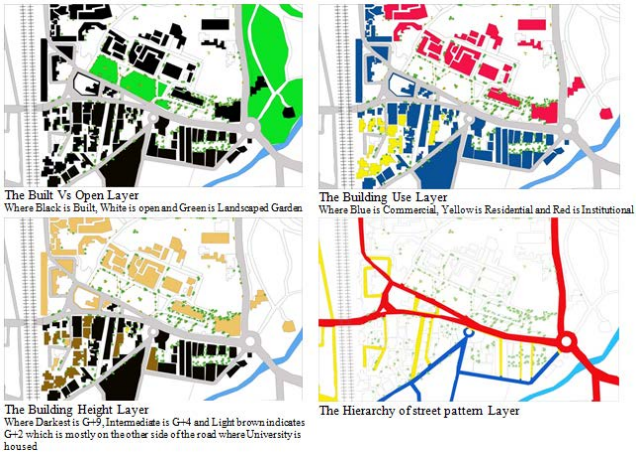

Figure 2. Graphical illustration showing different layers of urban physical environment characteristics of the demonstration pocket. Source: Author.

3. Methodology

3.1 Weight Assignment using AHP

A theoretical frame work is prepared based on the Global Walkability Index developed by Global Walkability Index developed by Holly Virginia Krambeck which consists of total 69 Indices where 6 primary , 22 secondary and 41 tertiary indices[4]. A questionnaire is prepared as per Saaty for the experts to give relative significance on the scale of 1 to 9 for each pairwise comparison as shown in Table 1. Five experts were contacted for the same. No. of experts was determined using the Delphi method

Table 1. The relative significance used in the questionnaire for experts as per Saaty scale

1	Equally preferred
3	Moderately preferred
5	Strongly preferred
7	Very strongly preferred
9	Extremely preferred
2, 4, 6, 8	Intermediate values between two adjacent judgements (When compromise is needed)

After the questionnaire is responded the pairwise comparisons are made as per AHP method. The no. of comparisons depends up on the no of parameters and the same can be obtained from Table 2.

After the pairwise comparisons the reciprocal Matrix was generated and normalized using the AHP software and the Principal Eigen Value (λmax) was determined. Screenshots of the process for Primary indices is shown in Figure 3.

Table 2. No. of pair wise comparison required For AHP method

No. of Parameters	1	2	3	4	5	6	7	n
No. of Comparisons	0	1	3	6	10	15	21	N (n-1)/2

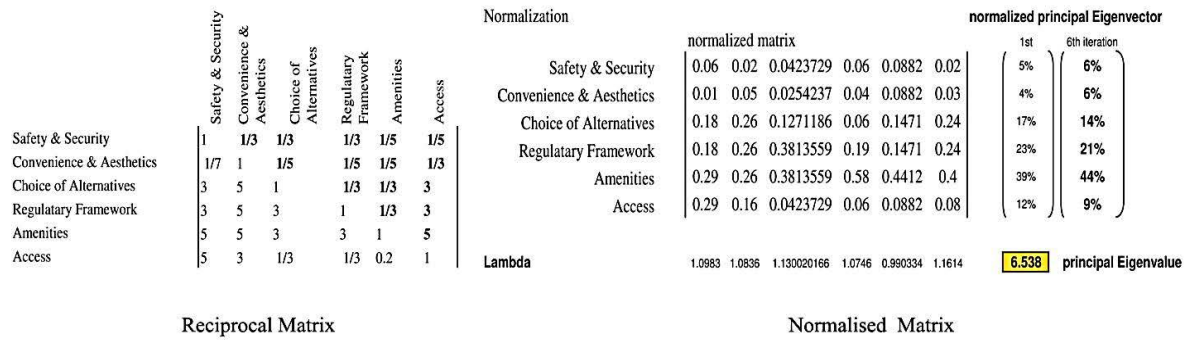

Figure 3. Screenshot of the reciprocal matrix and normalized matrix for primary indices using AHP software.

The Consistency Index (CI) was calculated from λmax using formula shown in Equation 1.

$$\text{Consistency Index CI} = \frac{\lambda max - n}{n-1}$$

Where λmax = Principal Eigen Value

and n = No of Indices (1)

The Random Consistency Index (RI) I was taken from the Table 3 which depends up on the no. of criteria (n).

Table 3. The Random Consistency Index for the no. of criteria (N)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The Consistency Ratio (CR) was calculated to check that it is smaller than 10 for the acceptability of the data using the formula shown in Equation 2. In AHP the consistency check is done for the data and that is why this method is preferred over other compensatory MCDM methods. Weights were determined using AHP software.

$$\text{Consistency Ratio CR} = \frac{\text{CI}}{\text{RI}}$$ If CR < 10 than the data is acceptable (2)

In this case the Cr was 8.7. Hence it is acceptable. The weight thus determined for all the indices are used for final evaluation using SAW method

3.2 Score Determination

A separate questionnaire was prepared for the respondents in order to determine the score. For determining the sample size Krejcie and Morgan formula is adopted which is shown in Equation 3; and 5% margin of error and 95% confidence level is considered as this is a qualitative research[5]. The population of the zone is 281626 hence 384 responses are required. Approximately 400 respondents are contacted for the same using manual method. The data was compiled using SPSS software and scores were determined.

$$n = \frac{(X^2 * N * P * (1-P))}{[(ME^2 * (N-1) + (X^2 * P * (1-P)]}$$

Where n = sample size,

X^2 = *Chi – square for the specified confidence level at 1 degree of freedom*

N = Population size.

P = Population proportion.

ME = Desired margin of Error (3)

The score thus determined for all the indices are used for final evaluation using SAW method. The data was analyzed using SPSS software.

3.3 The Application of SAW Method for Decision Making

After the weight and the scores were available the Simple Additive Weighting method was adopted for the decision making as this method is compensatory in nature it is more conducive for the qualitative research[6]. As all the criteria's are positive in nature for this study the formula shown in Equation 4 was used for the normalization of the data.

$$\text{nij} = \frac{\text{rij}}{\text{rj}*}$$

where i = 1, ……m, j = 1, …… n rj* is maximum no of r in column of j. (4)

After normalization of the data the final evaluation of each alternative was done using the formula shown in Equation 5. The results thus generated are shown in Table 4.

$$\text{Ai} = \sum wj.\ xij$$

Where xij is the score of ith alternative with respect to the jth criteria

Wj is the weighted criteria (5)

4. Application of MCDM Methods to Study of Correlation between Urban Physical Environment and Walkability

Table 4. Result of the saw decision making for each indices in a tabular format. (Own calculation)

Sr No	Code	Indices name	Relative significance value using SAW method
1	P1	Amenities	460.94
2	P1S1	Social Infrastructure conducive for active living	768.00
3	P1S1T1	Availability of Infrastructure in walkable neighbourhood.	36.78
4	P1S1T2	low noise levels and air pollution	103.24
5	P1S1T3	separation from motorized traffic	10.65
6	P2	Regulatory Framework (Policies)	232.29
7	P2S1	Planning for Pedestrian	846.00
8	P2S1T1	Degree of centralization amongst relavant agencies	80.01
9	P2S1T2	Incorporation of pedestrian planning in DP	29.60
10	P2S1T3	Presence and quality of pedestrian planning programme	15.80
11	P2S1T4	Relative importance of pedestrians in city planning	15.70
12	P3	Choice of alternative routes for walking	156.43
13	P3S1	Walking path congestion	515.73
14	P3S1T1	Pedestrian congestion LOS rating 1-5	60.00
15	P3S1T2	Availability of less congested alternative route	75.50
16	P3S2	Availability of Crossing	189.85
17	P3S2T1	Average distance between crossings as function of road width	65.00
18	P3S3	Connectivity	92.13
19	P3S3T1	Connectivity of sidewalks	134.00
20	P3S3T2	Connectivity between residence and place of work	78.00
21	P3S4	overall convenience	89.77
22	P3S4T1	pedestrian perception of convenience rating 1-5	151.00
23	P4	Access	102.30
24	P4S1	Ease of Access	678.00
25	P4S1T1	neighbourhood level accessibility	69.00
26	P4S1T2	frequency of visit	75.00
27	P5	Safety and Security	68.62
28	P5S1	Pedestrian Behavior	311.28
29	P5S1T1	Pedestrian Behavior at Non crossings/non Phase Signals	72.00
30	P5S2	Motorist Behavior	169.18
31	P5S2T1	compliance to traffic rules/Model conflict LOS	78.00
32	P5S2T2	road accidents	79.00
33	P5S2T3	traffic Speed	67.50
34	P5S3	Pedestrian signals	123.22
35	P5S3T1	Pedestrian Phase signal count as function of road length.	60.50
36	P5S3T3	Pedestrian Phase signal LOS	76.00
37	P5S4	Safety Education	93.79
38	P5S4T1	Safety education and awareness programme	68.50
39	P5S5	Safety rules and laws	76.52
40	P5S5T1	Existence of pedestrian safety rules	72.50
41	P5S5T2	Enforcement of pedestrian safety rules	69.00
42	P5S6	Crossing	56.04
43	P5S6T1	Average waiting time	61.50
44	P5S6T2	Crossing safety LOS	72.50
45	P5S7	Street Lighting	44.85
46	P5S7T1	Street Light count as function of road length.	60.00
47	P5S7T2	Adequacy of Street lights in neighbourhood.	64.00

48	P5S8	Injuries and Facilities	29.62
49	P5S8T1	proportion of road accidents resulting in serious injuries	77.00
50	P5S8T2	availability of medical infrastructure	62.50
51	P6	Convenience and Aesthetics	58.12
52	P6S1	Permanent Obstructions	353.59
53	P6S1T1	Presence of Permanent Obstruction LOS	61.00
54	P6S1T2	Inconvenience caused by Permanent Obstruction	61.50
55	P6S2	Barrier Free Environment	171.85
56	P6S2T1	LOS for Barrier free environment/universal design for differently abled citizens	141.00
57	P6S3	Quality of Maintenance	117.15
58	P6S3T1	LOS for maintenance	148.00
59	P6S4	Cleanliness	80.08
60	P6S4T1	Cleanliness of the walking path and surroundings	71.00
61	P6S4T2	presence of open dumping points	78.00
62	P6S5	Surface Material	81.63
63	P6S5T1	conduciveness of surface material for active living	70.00
64	P6S5T2	width of the walking path	72.50
65	P6S6	Foliage Trees	47.46
66	P6S6T1	Tree count as function of road length	151.00
67	P6S7	Temporary Obstructions	42.00
68	P6S7T1	Presence of temporary Obstruction LOS	75.50
69	P6S7T2	Inconvenience caused by temporary Obstruction	78.50

5. Conclusion

The result as shown in Figure 4 reveals that even though all the indices have smaller or greater impact on the walkability[7,8], the most important factor by far is the availability of the appropriate amenities for the conduciveness of walkability for a commercial neighbourhood.

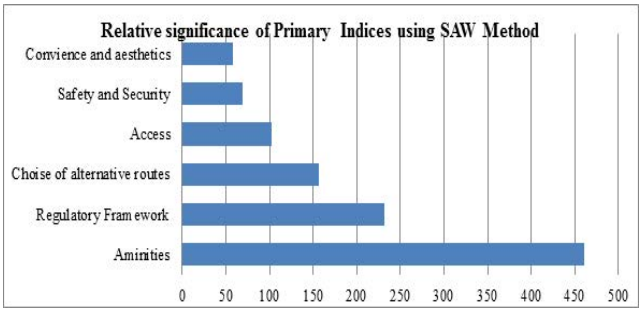

Figure 4. Bar chart showing saw result for primary indices.

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