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Measuring Walkability Index along Metro Station Areas of Faridabad City

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Abstract

Mobility within cities and the role of pedestrians in the urban scene are among the main themes of debates about the problems to be faced today. In this scenario, walkability in the urban environment, understood as a dimension of the built space that prioritizes pedestrians and encourages walking as a form of displacement, is possibly the most desired feature in contemporary cities.

Walking is the imperative requirement in any urban areas because of compact development, high density, mixed use and dependence on public transport. Faridabad is a major industrial town of Haryana state. It has lots of industrial labour population which commutes and resides in the unauthorized colonies, slum area and nearby villages. Majority of people in Faridabad commute daily by means of walking or cycling. Objective of this research is to measure the features in the built environment at the major transit hubs in the Faridabad city; these measures can be replicated. This study is an objective type study for which data are measured on infrastructure such as road geometry and land-uses in the built walking environment. This research paper will investigates and evaluates the walkability of Faridabad city Metro stations area.

Keywords: mobility; compact development; transit; walkability; intersection

1. Introduction

The concept of walkability stands out as one of the properties of urban spaces that can be worked on so that they become more accessible, passable and pleasant for everyone. Walking is a sustainable mode of transportation and must be prioritized over motorized means, since it benefits the city as a whole (Jacobs, 1961 and Gehl, 1987). Within the theme of commuting on foot, the term of walkability appears by Bradshaw (1993).

Walkability was defined as “the extent that a facility provides safe, direct connectivity to destinations while minimizing travel time and effort as well as offering a comfortable and

pleasant visual environment" (Southworth, 2005). Walking has sound health benefits, and can be a pleasurable experience that requires no fuel, fare, license, nor registration (Kaseko & Nyaga, May 2017). Certain built-up infrastructure and their characteristics can act as facilitators or as barriers to walking in Faridabad city such as railway line, foot-over bridge etc.

As stated by Humberto and others, the term "walkability" was emerged in 1990's (Humberto, Laboissière, Giannotti, Marte, & Primon, 2019). After that many researchers developed metrics for evaluation of pedestrian facilities and quality of built environment at the transit station areas. As per presentation by Michalis Lambrinos on Walkable Cities, there are some cities such as Florence, Amsterdam, Dubrovnik, San Francisco and Edinburgh which are considered most walkable cities (Lambrinos, 2016). The traits of a walkable city are percentage of residential land use, land use mix, connectivity, street design and access to mass transit system.

Many researchers have evaluated the suitability of walking facilities. In this research paper various walkability indicators such as Intersection densities, mix land use, residential and commercial densities and proximity of land use to the transit are measured for Transit Oriented Development (TOD) which create more walkable environment. Simon Ng (2016) stated that "a starting point to improve a city's walkability is to measure the current state of the pedestrian environment. There is a growing consensus that good walkability will bring substantial benefits to the city and its people. These benefits include better public health, higher property values, travel time savings and greater accessibility, increased economic opportunities, as well as other environmental and social gains" (Ng, et al., December 2016). Researchers across the world have developed many tools for assessment of walkability in urban areas.

Faridabad as an industrial city has a unique urban features and characteristics, such as compact development, connection with multi modal transit and pedestrian flow, required an appropriate tool for measurement of walkability. For measuring the walkability along the transit station areas in Faridabad city, various variables of walkability needs to be evaluated. Furthermore, the urban form proved to be very relevant in terms of the mobility of people, being directly related to the factors that interfere with walkability. It is concluded, therefore, that the insertion of the form proved to be quite useful for understanding issues related to urban mobility, making it possible to provide guidelines for the policies of urban mobility and thus make cities for people, not cars (Barros & JM, September 2014).

2. Define Walkability

From a conceptual point of view, walkability is a quality of the place; the path that allows pedestrians to have good access to different parts of the city, guaranteed to children, the elderly, people with limited mobility and everyone. Thus, walkability should provide a motivation to induce more people to adopt walking as a means of effective displacement, reestablishing their interdependent relations with the streets and neighborhoods. And, for that, it must commit resources aiming at the restructuring of the physical infrastructure (adequate and attractive walks for pedestrians) and social [...]

There are several indicators to assess the walkability and quality of spaces in the city. Measuring the features of the built environment may be considered of resources significance for management and urban planning. Walkability comprises aspects such as the conditions and geometry of roads and number of intersections, land use mixes and density of the neighborhood, that have an influence on the motivation for people to walk with more often and use the urban space. Walkability focuses not only on physical elements, but also on attributes of land use and the neighborhood characteristics (ITDP, 2016).

3. Problem Statement

The developments of most of the cities in India were compact, mixed use and pedestrian friendly. Most of the residents in cities commute daily for works, schools and other activities by walking without using automobiles. Cities are expanding due to migration of people in urban areas for search of job opportunities. The land price in the city is higher and because of affordability, the millions of people prefer to reside in suburban areas. These areas lack transportation connectivity, walkable infrastructure and nonmotorised transportation choice.

Numerous factors are responsible to the failure of walkable conditions in India. Decentralized and transportation-dependent developments in past 50 years have become the norms of urban planning in India. The sector planning in Faridabad is based on the zoning regulations and the residential sectors are planned separate from commercial and industrial land use. The development plan of the city lacks mixed land use planning and integration of multi modal transit system. So, there is need to study to measure the factual position of walkability along the mass transit system.

4. Study Area

Faridabad is the largest and the major industrial city of Haryana. It has large number of manufacturing industries. Its major economy is based on industrial activities. It became the only million plus city in the state of Haryana as per the 2001 Census and has the population of 14,38,855 as per 2011 Census. The city is situated on Delhi Mathura National Highway No-2 at a distance of 32km from National Capital of Delhi. It is located in the south-eastern part of Haryana state. The accessibility of the city is high because of linkage of city with NCT Delhi through NH-42 and Delhi Mathura Railway line (Department Town and Country Planning, 2016). Faridabad Metro rail started in 2015 with 9 stations from Badarpur to Mujesar. In 2018 two more stations added in the magenta line to make connectivity upto Ballabgarh. The study area consists of metro stations namely; "Sarai, NHPC Chowk, Mewala Maharajpur, Sector 28, Badkal Mor, Old Faridabad, Neelam Chowk Ajronda and Bata Chowk, Escorts Mujesar, Sant Surdas - Sihi and Raja Nahar Singh". All the stations are located on the side of National Highway no. 2 and are connected the city to the other side of Highway with Foot Over Bridges. The metro line entered Faridabad towards Delhi from Badarpur metro station as a starting point and ended to Raja Nahar Singh metro station in Ballabhgarh. The study area is limited to 800m buffer around the transit stations in Faridabad.

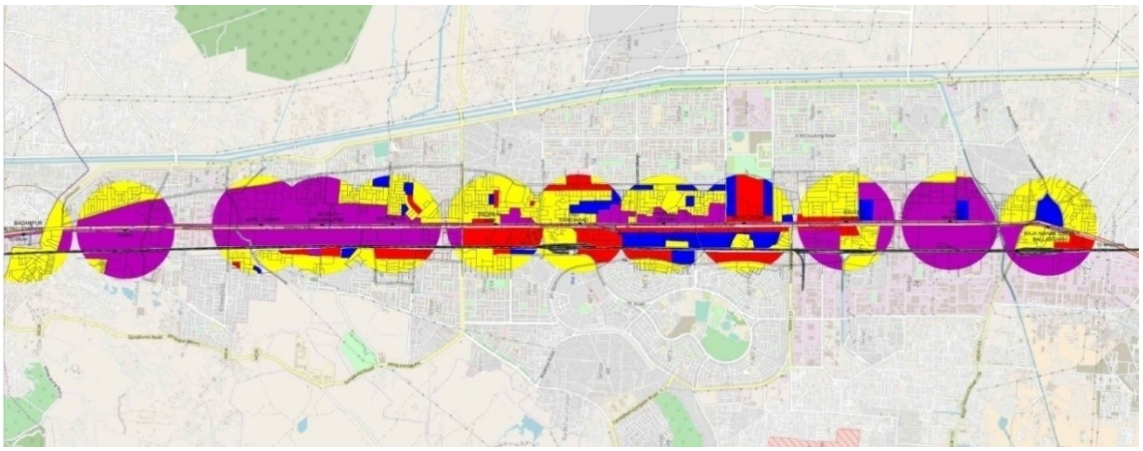

Figure 1: Land use along Faridabad Metro Station Areas

5. Research Methodology and Data Collection

Walking or walking is the most democratic mode of transport as it does not require any type of equipment nor the disbursement of money. As such, walking is the foundation for sustainable and equitable access and mobility in a city (ITDP, 2016). Walking establishes the diachronic relationship between three perspectives: the space traveled, the time spent, and the physical

principle of movement. “Walkability index” will measures the propensity of a person to walk to a destination. The result help identify which parameters should be emphasize to enhance the walkability in the metro station area in the case of Faridabad city. The present work helps in assessing the potential of TOD around metro stations for policy planners. The Urban Walkability Index, on the other hand, is the degree of adequacy of this space for walking, that is, the extent to which city sidewalks provide pedestrians with a safe, continuous and comfortable walk. The statistical and geographical data regarding land use (floor area occupied by each land use) i.e, residential, commercial, industrial, public & semi public were collected. The street network, number of intersections and pedshed area of each metro station areas were mapped. The walkability index is the integrated index of the four aspects of the built environment: residential landuse, land-use mix, access to public transit, and pedshed efficiency.

Walkability index= ∑ (Residential landuse + Land-use Mix+ Street connectivity+ pedshed efficiency).

5.1 Residential landuse:

The areas under residential land use at each metro station were mapped and computed. The image from the open street map was used as a base map and with the help of Autocad software, all the landuse use in the study area were mapped and computed. The land use data that was collected from the authority and through site visit. As per Department of Town and Country Planning and Master Plan of Faridabad, the average density of residential sectors of the city is 271 persons per hectare (PPH). The residential density of the sector along the metro transit system of study area is same, so we have considered the percentage of residential land use at each station area.

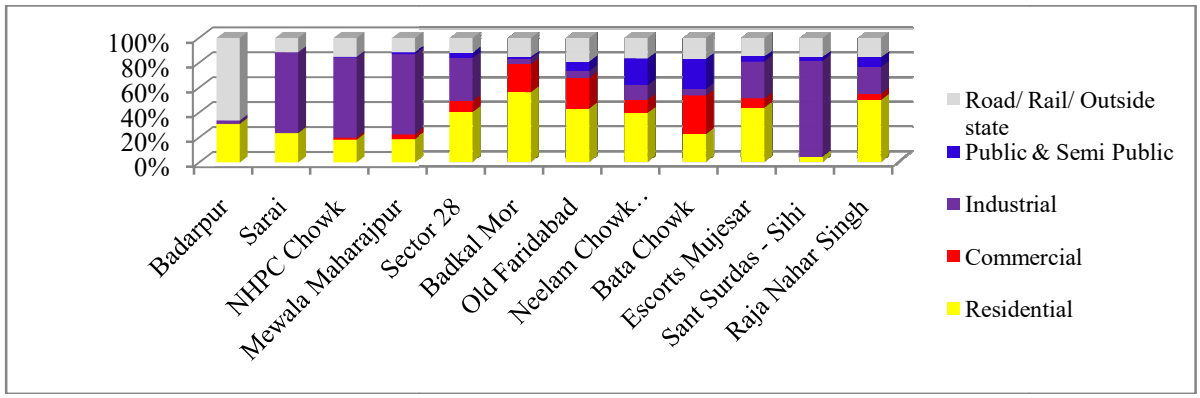

Figure 2: Land use (in percentage) of metro station area

The result indicates that the Badkal Mor metro station has the highest percentage of residential land use and Sant Surdas - Sihi metro station has the lowest percentage of residential land use at the metro station study area.

Table 1: Land use (in percentage) of metro station area of Faridabad city

	Land Use along Metro Station Area			
Name of Metro Station	Residential	Commercial	Industrial	Public & Semi Public
Badarpur	31.01%	1.00%	2.79%	1.00%
Sarai	23.65%	1.00%	64.95%	1.00%
NHPC Chowk	18.36%	1.59%	64.33%	1.00%
Mewala Maharajpur	18.80%	3.79%	64.48%	1.48%
Sector 28	39.88%	8.96%	34.92%	4.24%
Badkal Mor	55.89%	22.81%	4.41%	1.48%
Old Faridabad	42.68%	24.90%	5.61%	7.60%
Neelam Chowk Ajronda	39.16%	10.56%	11.94%	21.62%
Bata Chowk	22.00%	31.22%	5.32%	24.44%
Escorts Mujesar	43.34%	7.59%	29.91%	4.09%
Sant Surdas - Sihi	3.69%	1.00%	77.71%	3.13%
Raja Nahar Singh	49.70%	5.13%	21.57%	7.84%

Source: Analysis

5.2 Land-use mix:

It is an indicator of the mixed level of all land use types in the study area. It will be calculated by the following equation. The land use mix along the metro corridor in Faridabad city is shown in the figure 2 and table 1. The entropy formula derived from the Shannon index characterizes the land use mix in a better way. The Shannon Index is popular index to measure the land use diversity index. The Shannon Index value ranges between 0 and 1 with 1 being complete evenness. Land use mix (LUM) was calculated using an entropy formula with the following equation:

$$Entropy \quad \sum_j \frac{P_j \ln(P_j)}{\ln(J)}$$

, where Pj is the proportion of landuse in 800 m buffer in the jth use category and J is the number of different land use type classes in the area (Nasri & Zhang, 2014). This index is calculated separately for each transit station area. The resulting variable LUM is the land-use mix entropy, which varies from 0 to 1.

Table 2: Shannon Entropy Index

Name of Metro Station	Shannon Entropy (Land use Diversity Index)
Badarpur	0.2490
Sarai	0.4223
NHPC Chowk	0.3887
Mewala Maharajpur	0.4274
Sector 28	0.6317
Badkal Mor	0.4936
Old Faridabad	0.6199
Neelam Chowk Ajronda	0.6831
Bata Chowk	0.7058
Escorts Mujesar	0.6125
Sant Surdas - Sihi	0.1732
Raja Nahar Singh	0.5809

Source: Analysis

Table 3: Land Use along Metro Station Area

	Land Use along Metro Station Area				
Name of Metro Station	Residential	Commercial	Industrial	Public & Semi Public	Shannon Entropy
Badarpur	31.01%	1.00%	2.79%	1.00%	0.5232
Sarai	23.65%	1.00%	64.95%	1.00%	0.6887
NHPC Chowk	18.36%	1.59%	64.33%	0.50%	0.6697
Mewala Maharajpur	18.80%	3.79%	64.48%	1.48%	0.7633
Sector 28	39.88%	8.96%	34.92%	4.24%	1.1042
Badkal Mor	55.89%	22.81%	4.41%	1.48%	0.852
Old Faridabad	42.68%	24.90%	5.61%	7.60%	1.1074
Neelam Chowk Ajronda	39.16%	10.56%	11.94%	21.62%	1.2452
Bata Chowk	22.00%	31.22%	5.32%	24.44%	1.2559
Escorts Mujesar	43.34%	7.59%	29.91%	4.09%	1.0727
Sant Surdas - Sihi	3.69%	1.00%	77.71%	3.13%	0.3958
Raja Nahar Singh	49.70%	5.13%	21.57%	7.84%	1.0516

The results indicated that Bata Chowk metro station has higher land use diversity index (0.7058). Objectively speaking, a score of 0.7 (or higher) over a maximum possible score of 1 can be considered as a good score (Singh, Lukman, Flacke, Zuidgeest, & Maarseveen, 2017). Thus, it is

safe to suggest that Bata Chowk metro station has a high land use diversity score. Sant Surdas – Sihi metro station area has recorded a lowest diversity score of 0.1732 as shown in table 2. Due to the character of development around the area of Sant Surdas- Sihi Metro Station, the land use diversity score is observed low.

5.3 Street connectivity:

The street connectivity involves a system of streets providing multiple routes and connections to the same origins and destinations (Community Choices- Street Connectivity, 2007). It measured by the number of true intersections (i.e., intersections with three or more legs) per unit area, capturing the grain and interconnectedness of the street network; this is a measure of street connectivity. The purpose of the evaluation is to assess a specific piece (connectivity) of a larger complete streets design. There are numerous techniques and methods to measure street connectivity with transit system but the most commonly recognized model is the "Links & Nodes" calculation.

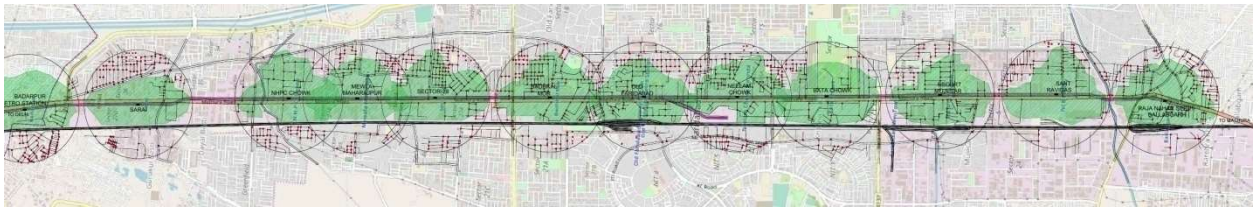

Figure 3: Intersection nodes and pedshed plan

Table 4: Intersection nodes details of metro station area

Name of Metro Station	Nodes	Percentage
Badarpur	84	41.78%
Sarai	123	61.18%
NHPC Chowk	78	38.79%
Mewala Maharajpur	100	49.74%
Sector 28	170	84.55%
Badkal Mor	194	96.49%
Old Faridabad	147	73.11%
Neelam Chowk Ajronda	172	85.55%
Bata Chowk	89	44.26%
Escorts Mujesar	106	52.72%
Sant Surdas - Sihi	104	51.73%
Raja Nahar Singh	144	71.62%

Source: Analysis

The above results indicate that the Badkal Mor metro station has the highest number of intersection nodes (194) and Badarpur metro station has the lowest numbers of intersection nodes (84) at the catchment area of the case metro. As connectivity and route options increases, the travel time & distances decrease which creating a more Accessible and Resilient system and allows more direct travel between the destinations.

5.4 Pedshed efficacy

The pedshed efficacy is computed from the area of the actual mapped pedshed polygon (ha) divided by area theoretical maximum 800m radius pedshed loci (ha) and multiplied by 100%. If the plot sizes are small, there will be higher walkability, which is associated with a higher coverage of area through walking. Areas with good accessibility and walkability have a ped-shed access ratio of >= 60% of an area within a ten-minute walk to a transit station. In this research Euclidean distance was adopted to measure the distance between the transit stations to the facilities around the transit stations.

Table 5: Pedshed area details of metro station area

Name of Metro Station	Pedshed Area	Percentage
Badarpur	0.9639	47.94%
Sarai	0.8262	41.09%
NHPC Chowk	1.0005	49.76%
Mewala Maharajpur	0.9661	48.05%
Sector 28	1.0504	52.24%
Badkal Mor	1.0312	51.29%
Old Faridabad	0.9706	48.27%
Neelam Chowk Ajronda	0.9395	46.73%
Bata Chowk	1.0639	52.91%
Escorts Mujesar	1.011	50.28%
Sant Surdas - Sihi	1.0484	52.14%
Raja Nahar Singh	1.0039	49.93%

Source: Analysis

The results indicate that the Sector 28 metro station has the highest percentage of pedshed area and Sarai metro station has the lowest percentage of pedshed area. The walkability index is then calculated from the collected data of four parameters, according to the following expression:

Table 6: Faridabad Metro Stations walking Index and Ranking

Name of Metro Station	Residential Density	Land Use Diversity	Intersection Density	Pedshed Area	Total	Rank
Badkal Mor	55.89	49.36	96.49	51.29	253.03	1
Sector 28	39.88	63.17	84.55	52.24	239.84	2
Neelam Chowk Ajronda	39.16	68.31	85.55	46.73	239.75	3
Raja Nahar Singh	49.7	58.09	71.62	49.93	229.34	4
Old Faridabad	42.68	61.99	73.11	48.27	226.05	5
Escorts Mujesar	43.34	61.25	52.72	50.28	207.59	6
Bata Chowk	22	70.58	44.26	52.91	189.75	7
Sarai	23.65	42.23	61.18	41.09	168.15	8
Mewala Maharajpur	18.8	42.74	49.74	48.05	159.33	9
NHPC Chowk	18.36	38.87	38.79	49.76	145.78	10
Badarpur	31.01	24.9	41.78	47.94	145.63	11
Sant Surdas - Sihi	3.69	17.32	51.73	52.14	124.88	12

Source: Analysis

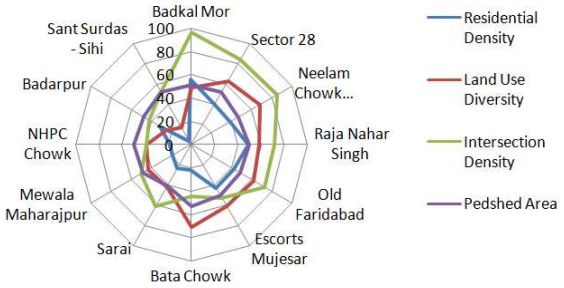

Figure 4: Faridabad Metro Stations walking Index

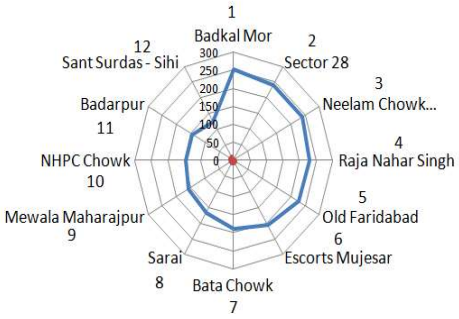

Table 5: Faridabad Metro Station Area Ranking

6. Conclusions

A walkable situation plays an important role in supporting transit supportive urban development. In this research, a comprehensive walkability index is computed using four components i.e., net residential land use, land-use mix, street connectivity and pedshed efficacy. Through this index, the walkability of Faridabad metro stations areas were computed.

The result indicates that the Badkhal Mor metro station has the highest value and Sant Surdas – Sihi metro station has the lowest score of walkability index. Results of this study are of significant importance in terms of transit oriented development for Faridabad city. In addition, the walkability model used in this study has the potential to be applied in other cities in India as a tool for urban planners, policy makers, and the public.

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