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AHP Approch based E-Bike Sharing Station Identification for BRTS Corridor-1 of Surat City

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Abstract: This study employs Analytical Hierarchy Process (AHP) methodology to identify the suitability of locations for E-Bikeshare stations from a planning perspective. The Analytical Hierarchy Process (AHP), a multi-criteria decision-making technique widely used in urban planning and resource allocation. By examining factors like proximity to transit nodes, population density, land use characteristics, and environmental considerations, the research systematically assesses the appropriateness of potential station sites. Through the amalgamation of stakeholder preferences and expert insights, the investigation seeks to pinpoint the most suitable locations for E-Bikeshare stations. This endeavour aims to enhance last-mile connectivity, smooth traffic flow, and advocate for Urban transportation solutions.

Keyword: E-bike Station location selection, multi-criteria decision analysis.

I. Introduction

In recent years, rapid urbanization and increased population density in Indian cities have posed significant challenges for transportation infrastructure and mobility management. With mounting concerns over traffic congestion, air pollution, and carbon emissions, promoting sustainable transportation modes has become imperative. E-Bikeshare systems, offering electric bicycles for short-term rental, emerge as a promising solution. However, their success hinges on strategically locating docking stations. By integrating multiple criteria and expert judgments, AHP offers a structured approach to identify optimal locations that align with the diverse needs of stakeholders (Jones et al., 2018). By integrating various criteria, including population density, land use, and environmental factors, the research aims to develop a comprehensive framework for informed decision-making by urban planners and policymakers (Kumar et al.,2018). This approach is crucial for promoting sustainable urban transportation and improving last-mile connectivity in Indian cities, addressing unique challenges and fostering future mobility solutions. The primary objective of this research is to evaluate the suitability of locations for E-Bikeshare stations along the Udhna-Sachin GIDC BRTS corridor in Surat City, employing the Analytical Hierarchy Process (AHP). The study aims to provide valuable insights for effective placement of E-Bikeshare infrastructure to enhance last-mile connectivity and promote sustainable urban transportation in the specified corridor. This research will identify various factors including population density, land use patterns & transportation infrastructure considerations to identify optimal locations for E-Bikeshare stations in Udhna – Sachin GIDC BRTS Corridor. The study will employ AHP methodology to prioritize potential station sites and inform urban planning decisions.

II. Literature Review

E-Bikeshare systems have emerged as effective solutions to tackle urban mobility challenges in Indian cities, offering sustainable and convenient transportation choices. Various studies have delved into different aspects of E-Bikeshare implementation, including the evaluation of appropriate station locations. (Gupta et al., 2019) utilized Geographic Information Systems (GIS) and mathematical modelling to pinpoint optimal E-Bikeshare station locations, considering factors like population density, land use, and transportation infrastructure. Similarly, (Sharma and Singh, 2020) used multi-criteria decision-making methods to prioritize station sites based on accessibility, demand density, and environmental impacts. (Patel et al., 2021) underscored the importance of integrating E-Bikeshare systems with public transit networks to improve last-mile connectivity. Their study emphasized the strategic placement of stations to enhance system efficiency and user accessibility within Indian cities. (Kumar et al., 2018) showcased the efficacy of the Analytical Hierarchy Process (AHP) in evaluating station location suitability for bicycle-sharing systems. They focused on criteria such as accessibility, safety, and user preferences, offering valuable insights into AHP's application for transportation planning in urban areas like Delhi, India.

While existing literature has provided valuable insights, there's a need for further research specifically exploring the AHP approach for assessing station location suitability in Indian cities. This study aims to fill this gap by applying AHP methodology to analyse suitable locations for E-Bikeshare stations. By integrating criteria like population density, land use, and transportation infrastructure, the research seeks to develop a comprehensive framework for strategic station placement, ultimately contributing to the advancement of sustainable urban transportation initiatives in Indian cities.

III. Study Area

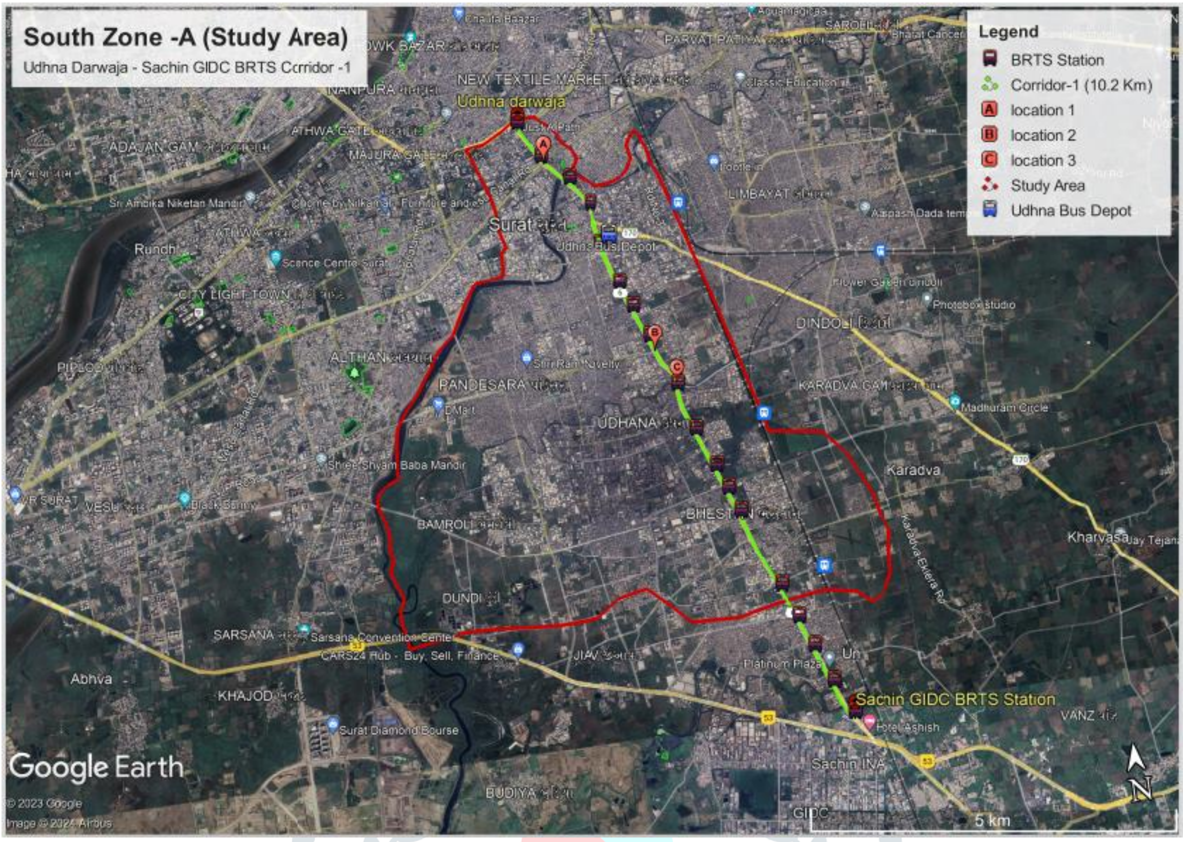

Figure 1 Selected Stretch

Source: (Google Earth)

The decision to choose Corridor 1, stretching from Udhana Darwaja to Sachin GIDC Naka, as the study area for the implementation of e-bike sharing is rooted in a comprehensive assessment of various factors. The study area is located in the south zone -A of Surat City, having a high demand for transportation. This corridor serves as a crucial link within the existing Bus Rapid Transit (BRT) system, facilitating transportation between important residential, commercial, and industrial areas.

IV. Multi-Criteria Decision Making (MCDM) method

Multi-Criteria Decision Making (MCDM) methods aim to support decision-makers in situations where multiple conflicting criteria need to be considered. Analytic Hierarchy Process (AHP) is one of the most popular MCDM methods, developed by Thomas L. Saaty in the 1970s. AHP provides a systematic approach to deal with complex decision problems by breaking them down into hierarchical structures and pairwise comparisons.

4.1 Analytic Hierarchy Process (AHP):

Analytic Hierarchy Process (AHP) is a widely used MCDM method developed by Thomas L. Saaty in the 1970s. It provides a structured approach for decision-makers to evaluate and prioritize alternatives based on multiple criteria. AHP involves breaking down a complex decision problem into a hierarchical structure of criteria and alternatives, followed by pairwise comparisons to determine the relative importance of criteria and alternatives.

Table 1 Saaty's scale of relative importance

Intensity of Importance	Definition
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate values between two adjacent judgments

The consistency ratio of pairwise comparisons was calculated using the equation 1 & 2:

$$C_r = \frac{CI}{ri}$$

Where Cr is consistency ratio index, Ci is consistency index, ri is random consistency index. While the consistency index (Ci) is derived using the following formula.

To determine the consistency ratio, divide the consistency index by the random index. The random index is dependent on the number of criteria, as shown in below table.

$$C.I. = \frac{\lambda_{max} - n}{n - 1}$$

Where n is the criteria number and λ max is the maximum value of eigenvector.

Table 2 Scale of the Relative Importance

n	1	2	3	4	5	6	7	8	9	10
Random Index (R.I.)	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

4.2 AHP Method to Determine Most Significant Criteria's

I have selected 4 main criteria and sub-criteria for each of those main criteria in the Analytical Hierarchy Process. Expert opinion surveys were conducted to determine the intensity of various parameters for accurate analysis in the pairwise comparison. Manual calculation is being utilized for Multiple-Criteria Decision Making (MCDM) to determine the most significant criteria for site selection for e-bike station.

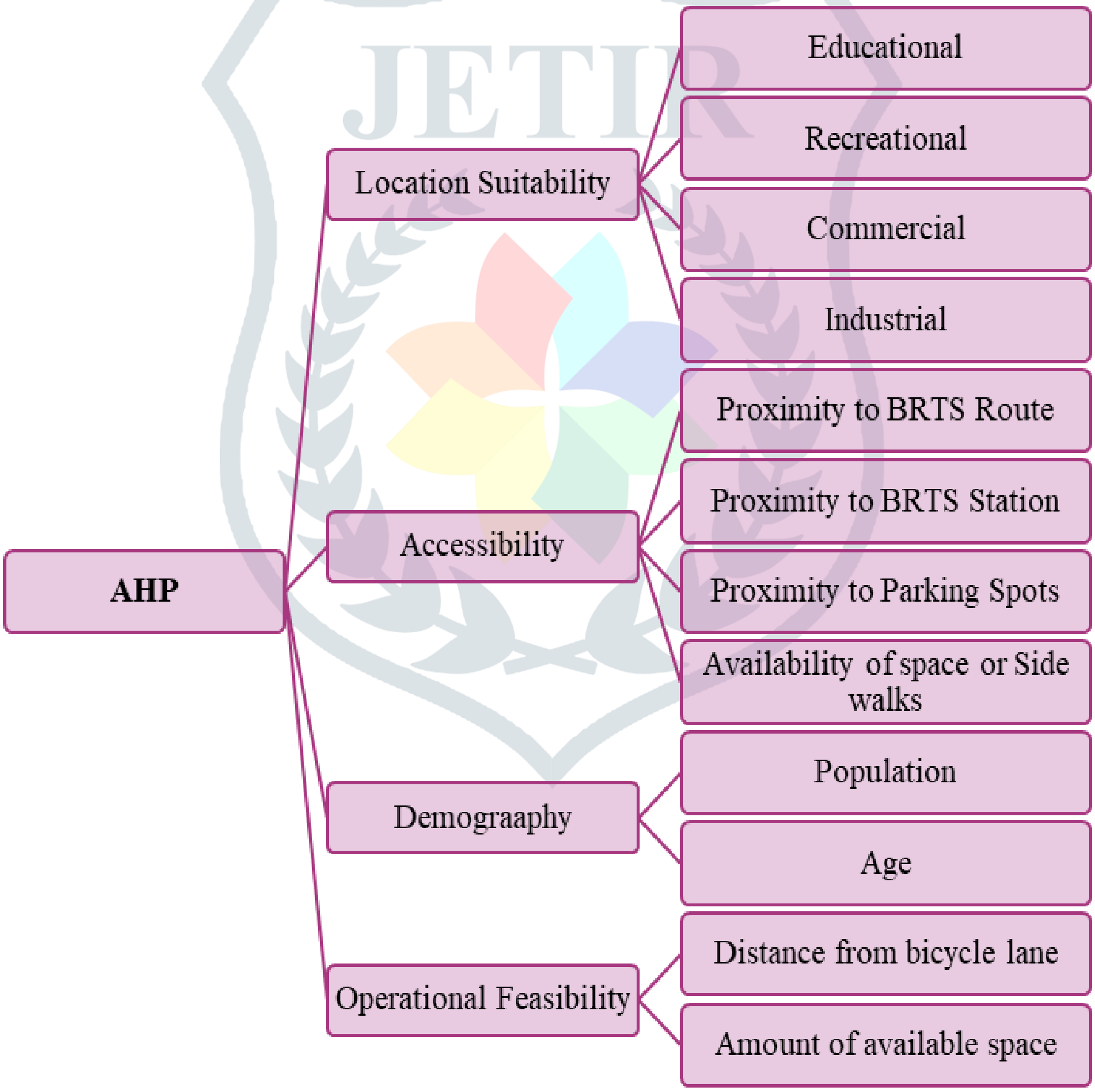

Figure 2 Hierarchy of Criteria & Alternative

4.3 Data Analysis

These are the main criteria for pairwise comparison carried out by the experts and they give the scaling for each other. Scaling is between 1 to 9 as per Saaty's scale of relative importance. The Fractional value is converted into the decimal value for better calculation and sum of each value in the column is calculated.

Table 3 Simplified the Pairwise comparison matrix

Criteria	Location Suitability	Accessibility	Demography	Operational Feasibility
Location Suitability	1.00	1.00	3.00	3.00
Accessibility	1.00	1.00	2.00	2.00
Demography	0.33	0.50	1.00	1.00
Operational Feasibility	0.33	0.50	1.00	1.00
Sum	2.66	3.00	7.00	7.00

Table 4 Calculation of weighted sum

Criteria	Location Suitability	Accessibility	Demography	Operational Feasibility	Sum weight	Criteria weight	Avg.
Location Suitability	0.3915	0.3201	0.4332	0.4322	1.5769	0.3915	4.0280
Accessibility	0.3915	0.3201	0.2888	0.2881	1.2885	0.3201	4.0257
Demography	0.1305	0.1600	0.1444	0.1441	0.5790	0.1444	4.0100
Operational Feasibility	0.1292	0.1600	0.1444	0.1441	0.5777	0.1441	4.0096

There are three stages to apply in order to compute the consistency ratio (CR) as follows:

Compute the Eigenvalue first (λmax). By multiplying the right of judgement matrix by the priority vector or eigenvector and generating a new vector, one may determine the eigenvalue (max). λmax Calculate by the average of all (weighing sum/ Criteria weight) values.

$$\lambda_{max} = \frac{0.45 + 0.23 + 0.17 + 0.13}{4}$$

$$\lambda_{max} = 4.219$$

Calculate the consistency index (CI);

$$C.I = \frac{(\lambda_{max} - 4)}{4 - 1}$$

$$C.I = \frac{(4.219 - 4)}{4 - 1}$$

$$C.I = 0.0716$$

Lastly, determine the consistency ratio (CR). The formula may be used to determine the CR. Using Table, choose RI = 0.89 as the suitable random index (RI) value for the four-matrix size.

$$CR = \frac{CI}{RI}$$

$$CR = \frac{0.0716}{0.89}$$

The consistency ratio (CR) is the 0.0341. The judgements are valid since the CR value is less than 0.1. The judgement matrix is inconsistent if CR > 0.1. Judgments should be examined and revised in order to establish a consistent matrix.

Table 5 Final weightage of AHP

Criteria	Main Criteria Weight	Code	Sub Criteria	Criteria weight	Final Weight	Ranking
Location Suitability (A)	0.3915	A1	Educational	0.4170	0.1632	1
		A2	Commercial	0.2502	0.0979	4
		A3	Industrial	0.2224	0.0871	7
		A4	Recreational	0.1105	0.0433	11
Accessibility (B)	0.3201	B1	Proximity to BRTS Route	0.3205	0.1026	3
		B2	Proximity to BRTS Station	0.4038	0.1292	2
		B3	Proximity to Parking Spots	0.1703	0.0545	8
		B4	Availability of space or Side walks	0.1055	0.0338	12
Demography (C)	0.1444	C1	Population	0.667	0.0963	5
		C2	Age	0.333	0.0481	9
Operational Feasibility (D)	0.1441	D1	Distance from bicycle lane	0.667	0.0960	6
		D2	Amount of available space	0.333	0.0480	10

The table provides insights into the weightage assigned to each criterion and its corresponding sub-criteria. For instance, under the criterion of Location Suitability (A), sub-criteria such as Educational (0.1632) and Commercial (0.0979) factors receive higher weights compared to others like Industrial and Recreational factors. This weighting indicates the relative importance of each sub-criterion in determining the suitability of a location for e-bikeshare stations.

V. CONCLUDING REMARK

In recent years, as Indian cities rapidly urbanize, tackling transportation challenges has become a top priority, with a focus on encouraging sustainable mobility options. E-Bikeshare systems have emerged as a promising solution to improve last-mile connectivity and ease traffic congestion. However, the success of these systems largely depends on strategically positioning docking stations. This study employs the Analytical Hierarchy Process (AHP) methodology to systematically evaluate potential station sites along the Udhna-Sachin GIDC BRTS corridor in Surat City. By considering various factors like population density, land use patterns, and transportation infrastructure, the research aims to create a comprehensive framework to assist urban planners and policymakers in making informed decisions. Through engagement with stakeholders and experts, the study aims to pinpoint the most suitable locations for E-Bikeshare stations, advocating for sustainable transportation solutions and enhancing urban mobility in Indian cities.

This study seeks to address this gap by applying the AHP methodology to analyze potential station sites along the Surat BRTS corridor. By building on existing knowledge and leveraging the systematic approach of AHP, the research aims to provide a nuanced understanding of station location selection, tailored to the unique characteristics of Indian cities. The AHP analysis gives important information about what factors are important when deciding where to put E-Bikeshare stations. They look at things like how close the stations are to transit stops, access to the BRTS, how many people live nearby, and if it's possible to actually put a station there. By ranking these factors, it helps city planners make better decisions, focusing on making transportation sustainable and easy for everyone. This research helps put E-Bikeshare stations in the right places in a city, making it easier for people to get around and making transportation in the city more sustainable.

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