Evaluating Transportation Sustainability in Ajmer, Rajasthan: An Indicator-Based Approach

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Abstract- In October 2016, the High-Level Advisory Group on Sustainable Transportation, appointed by the Secretary-General of the United Nations, presented a landmark report titled "Mobilizing Sustainable Transport for Development." This pivotal report highlighted the urgent need for both national and local governments to establish comprehensive frameworks for monitoring and evaluating sustainable transportation practices. The role of transportation in the socio-economic advancement of urban areas cannot be overstated, as it is essential for maintaining long-term sustainability and improving quality of life.
This study focuses on the city of Ajmer in Rajasthan, applying an indicator-based framework to assess its transportation sustainability. By selecting indicators that align with local circumstances, available data, and measurability, our analysis has revealed a Transport Sustainability Index (TSI) value of 50.49 for Ajmer. This score provides a snapshot of the city's current sustainability status, highlighting both strengths and areas needing improvement. The TSI is more than just a number; it serves as a valuable tool for policymakers, researchers, and stakeholders. It aids in making informed decisions that can drive transformative initiatives aimed at enhancing the transportation systems in Ajmer. In a broader context, the TSI can guide sustainable development efforts across India, contributing to the holistic improvement of the country's urban environments. Ajmer's moderate TSI score underscores the critical need for targeted strategies to enhance sustainability in transportation. These strategies include reducing emissions, improving public transport accessibility, and fostering economic investments in infrastructure. By addressing these areas, Ajmer can set an example for other cities striving to achieve sustainable urban growth.

Keywords: Sustainable transportation, indicator framework, Transport Sustainability Index, Ajmer, sustainable development.

1. INTRODUCTION

India, known for its vibrant cultural diversity and rapid economic growth, is also grappling with unprecedented urbanization challenges. As the most populous country globally, India has seen its urban population expand approximately 14 times from 1901 to 2011 [1]. This significant increase, while economically beneficial, has not been regionally skewed, leading to uniform urban development pressures across the nation.

The high cost of living and escalating house rents in metropolitan areas deter business investments in major cities, making small and medium towns attractive alternatives for settlement and economic activities [2]. These "next billion" markets are crucial for India's economic advancement, offering a viable solution to the saturation faced by larger metropolitan centers [3].

Urbanization, while a driver of economic growth, brings about critical challenges, particularly in transportation. Increased vehicle emissions and reliance on fossil fuels contribute significantly to environmental degradation [4]. The pursuit of meeting mobility demands through natural resource consumption results in unsustainable urban growth patterns. Notably, transportation accounts for 23% of global energy-related Greenhouse Gas (GHG) emissions, predominantly from road transport [5]. Additionally, around half a million people in developing countries die prematurely due to air pollution from road transportation [6] . Increased car dependency exacerbates traffic congestion, noise pollution, higher accident rates, and declines in urban ecological quality.

In response, many developing countries are shifting towards integrated public transit networks, promoting public transport as a sustainable alternative to private cars [7]. This global movement underscores transportation's vital role in societal

growth and well-being, significantly impacting financial progress by improving access to jobs, goods, and services, thereby enhancing overall community welfare [8]The Centre for Sustainable Transportation (CST) in Canada defines sustainable transportation as meeting the basic access and development needs of individuals, businesses, and societies in ways that ensure safety and are consistent with human and ecosystem health [9]. Sustainable transportation promotes intergenerational equity, cost-effectiveness, fairness, and efficiency, offering diverse transport options and supporting a competitive economy and balanced regional development. It collaborates with other sectors to manage emissions and waste within the planet's capacity, uses renewable resources sustainably, minimizes non-renewable resource use, and reduces land use impact and noise generation.

Indicators play a crucial role in this framework, helping to quantify, evaluate, and assess the sustainability of transportation systems. They set standards, identify trends, predict challenges, evaluate options, set goals, and monitor specific areas [10]. However, capturing the complex nature of transportation requires numerous indicators [11]. Developing comprehensive indicator initiatives is challenging as these initiatives, while sharing common starting points (like criteria for selecting indicators) and the same ultimate goal (assessing progress towards transport sustainability), vary due to different influencing factors.

This study analyzes several sustainable transport indicator projects selected after extensive literature review, identifying key findings and highlighting similarities and differences. A detailed examination of the selected indicators and various visualization methods was conducted to derive insightful conclusions, ultimately leading to the development of new indicator initiatives. Initially, descriptive statistics were applied to the key elements of the evaluated indicator initiatives.

2. LITERATURE REVIEW

Addressing the sustainability of transportation systems is a multi-faceted challenge that requires a comprehensive understanding of various indicators and their impacts. As cities like Ajmer continue to grow, so does the complexity of quantifying and managing sustainable transportation. The necessity for a robust framework to measure transport sustainability has been underscored by numerous scholars and institutions. Sustainable transportation, as defined by the Centre for Sustainable Transportation (CST) in Canada, aims to meet the basic access and development needs of individuals, businesses, and societies in ways that ensure safety and align with human and ecosystem health [9]. This definition highlights the importance of intergenerational equity, cost-effectiveness, and efficiency, emphasizing the need for diverse transport options that support economic competitiveness and balanced regional development. Sustainable transportation also involves collaborating with other sectors to manage emissions and waste within the planet's capacity, utilizing renewable resources sustainably, and minimizing non-renewable resource use [9]. Indicators are vital tools for quantifying, evaluating, and assessing the sustainability of transportation systems. They help establish standards, identify trends, predict challenges, evaluate options, set goals, and monitor specific areas [10]. However, capturing the complex nature of transportation requires a multitude of indicators. Zhou et al. [11] emphasize the importance of a mathematical programming approach to construct composite indicators that can encapsulate this complexity.The United Nations' 2030 Agenda for Sustainable Development integrates transport sustainability into several Sustainable Development Goals (SDGs), including SDGs 3, 7, 9, 11, and 12. These goals encompass reducing road traffic fatalities, improving energy efficiency, building sustainable infrastructure, ensuring equitable access to transportation, and promoting sustainable production and consumption practices [12]. One of the primary challenges in measuring transport sustainability is the interpretability of the numerous indicators required. As noted by [13] , it is crucial to ensure that these indicators align closely with the issues they are intended to tackle. This alignment helps in assessing advancements over time and provides significant insights into the performance of transportation systems in relation to environmental, social, and economic sustainability.

Developing comprehensive indicator initiatives is a complex task. These initiatives, while sharing common starting points (such as criteria for selecting indicators) and the same ultimate goal (assessing progress towards transport sustainability), vary due to different influencing factors. For instance, the characteristics of metropolitan cities in India might necessitate unique indicators that are not applicable elsewhere [10]. Several studies have provided valuable insights into the application of sustainable transport indicators. For example, [13] developed a transport sustainability index for Melbourne, Australia, highlighting the importance of a quantitative approach to measuring sustainability. Similarly, [14] proposed a Sustainable Transportation Attainment Index, which uses multivariate analysis to evaluate transport sustainability in selected Indian states and the National Capital Territory of Delhi.

In the context of developing countries, the importance of integrating public transit networks has been emphasized. Public transportation is promoted as a sustainable alternative to private vehicles, aiming to reduce traffic congestion, emissions, and reliance on fossil fuels [7].

The literature underscores the need for continuous development and refinement of sustainable transport indicators. Effective measurement and evaluation frameworks are essential for policymakers, researchers, and stakeholders to make informed decisions that promote sustainable transportation. Future research should focus on enhancing the precision and applicability of these indicators, particularly in diverse urban settings like Ajmer.

3. METHODOLOGY

Evaluating transportation sustainability in Ajmer required a multifaceted approach, integrating quantitative and qualitative data to create a comprehensive picture of the city's transport dynamics. The methodology encompassed several critical phases, ensuring a thorough and nuanced assessment.

Literature Review and Indicator Selection

The foundation of this research was an extensive review of existing literature on sustainability indicators in transportation. This review focused on identifying relevant indicators that reflect environmental, social, and economic dimensions of sustainability. Previous studies have highlighted the complexity of urban transportation systems and the necessity for diverse indicators to capture this complexity accurately [10] [11] . The indicators were selected based on their relevance to local conditions, availability of data, and measurability, following globally accepted criteria [14].

Data Collection

Primary Data Collection:

The primary data was collected through a structured questionnaire survey designed to gather diverse perspectives on Ajmer's transportation network. The questionnaire was meticulously developed to cover a broad range of indicators, ensuring comprehensive data collection. Respondents included local residents, transport professionals, government officials, students, business stakeholders, and the general populace. This diversity ensured a well-rounded perspective on the city's transportation dynamics.

A total of 112 individuals participated in the survey, providing valuable insights into various aspects of transportation sustainability. The questions were designed to be clear and straightforward, ensuring that respondents could provide accurate and relevant information. The survey covered indicators such as air quality, noise levels, public transport accessibility, commute times, and transportation costs.

Justification of sample size:

We selected a sample size of 112 respondents from a total population of 542,321 to ensure our results are statistically significant and representative. This size allows us to achieve a 95% confidence level with a 9% margin of error, balancing the need for precision with practical constraints like time, budget, and resources. By stratifying the sample, we ensured diverse representation across different demographic groups, which enhances the reliability of our findings. Furthermore, similar studies and successful pilot testing support the adequacy of this sample size, confirming its ability to provide meaningful and robust insights into the transportation sustainability of the selected Indian cities.

Secondary Data Collection:

Secondary data was gathered from governmental records, research institutions, industry publications, and public databases. This included data on vehicle emissions, fuel consumption, public transport usage, road infrastructure, and government expenditure on transportation. The combination of primary and secondary data ensured a robust and comprehensive dataset for analysis.

Indicator Framework and Weighting

The selected indicators were categorized based on their primary focus: environmental, social, and economic sustainability. This categorization helped streamline the data analysis process and ensured that each dimension of sustainability was adequately represented.

Weighting and Data Homogenization:

To ensure each indicator's impact was appropriately reflected in the overall assessment, an equitable weighting methodology was applied. Each indicator was assigned a weight based on its relative importance, which was determined through expert consultations and literature guidelines [15], [16]. The data was then homogenized to transform varied measurements into a common index value, allowing for meaningful comparisons and mathematical operations [17].

Data Analysis and Sustainability Index Calculation: After collecting the necessary data, the analysis phase involves homogenizing utility values to standardize diverse indicators, which allows for meaningful comparisons. Indicators with positive impacts retain their measured values, while those with negative impacts are adjusted using the formula: Homogenized Utility Value = 10 - Measured Utility Value. Each indicator within the

environmental, social, and economic categories is assigned an equal weight. The weighted individual value for each indicator is calculated using the formula

Weighted Individual Value of TSI= $\sum_{i=1}^{n} \frac{W_i U_i}{n}$ (1)

Where: W_i is the weight of 'i_{th}' indicator, U_i is the homogenized utility value of 'i_{th}' indicator. Using the weighted individual values, the scores for each category are calculated. These scores are then normalized to ensure comparability and practical interpretation. The total TSI is calculated by summing the normalized scores of the environmental, social, and economic categories.

Total TSI=Environmental Score +Social Score +Economic Score (2)

The total TSI is then scaled to a 0-100 range to provide an intuitive and standardized measure of transportation sustainability.

Scaled TSI=$(\frac{Total\ TSI}{300})\times 100$ (3)

Following data collection and homogenization, statistical analyses were conducted to interpret the results. Descriptive statistics provided insights into the key elements of the evaluated indicators. Visualization techniques such as graphs and charts were used to present the findings, making it easier to identify trends, strengths, and areas needing improvement.

The comprehensive analysis of the data culminated in the development of the Transport Sustainability Index (TSI) for Ajmer, which serves as a valuable tool for policymakers, researchers, and stakeholders. The methodology employed in this study ensures a detailed and accurate assessment of transportation sustainability in Ajmer. By integrating diverse data sources and applying rigorous statistical methods, the study provides a robust framework for evaluating and improving transportation systems in similar urban settings across India.

4. STUDY AREA AND DATA COLLECTION

Ajmer, a city nestled in the heart of Rajasthan, India, holds a unique blend of historical significance, cultural heritage, and economic activity. Known for its religious importance, Ajmer attracts millions of pilgrims annually to the Ajmer Sharif Dargah and Pushkar, creating a substantial demand on its transportation system [18]. With a population of approximately 542,321 as per the 2011 Census, Ajmer is steadily growing, placing increasing pressure on its infrastructure [19].

Ajmer's economy is diverse, encompassing tourism, education, and trade, which further underscores its importance. The presence of renowned institutions such as Mayo College and the Central University of Rajasthan contributes to the city's vibrant daily commuter traffic. Ajmer's strategic location within Rajasthan makes it a crucial transportation hub, facilitating significant freight movement and intercity connectivity [20].

Figure 1: Map showing study area of Ajmer

The evaluation of Ajmer's transportation sustainability involved a structured and comprehensive data collection process. The primary data was collected through a meticulously designed questionnaire survey, which was distributed among a diverse group of respondents, including local residents, transport professionals, government officials, students, and business stakeholders. This diversity ensured a well-rounded perspective on the city's transportation dynamics.

The questionnaire was tailored to gather detailed information on various indicators of transportation sustainability, categorized into environmental, social, and economic dimensions. The environmental indicators focused on factors such as noise and air pollution, greenhouse gas emissions, and energy consumption. Social indicators evaluated elements like accessibility, public health, safety, and social equity, while economic indicators concentrated on aspects such as efficiency, cost-effectiveness, employment generation, and economic growth related to transportation [10].

To supplement the primary data, secondary sources such as governmental records, research reports, and public databases were utilized. This comprehensive approach ensured a robust and reliable dataset, which is crucial for accurate analysis and interpretation.

Table 1: Indicators chosen for the comprehensive assessment of the sustainability index

Sustainability dimension	Name of the parameter	{Measured utility value, Homogenized utility value}
Environmental Indicators	Air Pollution	[4.16, 5.84]
	Transportation Emissions	[4.42, 5.58]
	Effect of Transportation on Global Climate Change	[4.84, 5.16]
	Noise Pollution	[4.98, 5.02]
	Townscape Quality	[5.04, 5.04]
	Land Used for Road Transportation	[4.92, 4.92]
	Fuel Consumption in Daily Trips	[4.54, 5.46]
Social Indicators	Average Daily Trip Time	[4.77, 5.23]
	Impact of Transportation on Health Due to Motor Vehicle Pollution	[4.44, 5.56]
	Level of Service of Public Transportation	[4.58, 4.58]
	Quality of Roads	[5, 5]
	Quality of Public Transportation for Disadvantaged People (Disabled, Child, Low Income)	[4.5, 4.5]
	Accessibility to Metro Station	[5.8, 4.2]
	Accessibility to Bus Stop	[7.17, 2.83]
	Contribution Of Transport Sector In Employment	[5.28, 5.28]
	Private Car Ownership In City	[5.63, 4.37]
Economic Indicators	Transport Demand	[5.94, 5.94]
	Cost of the Trip	[6.44, 3.56]
	Availability of Public Transportation	[5.65, 5.65]
	Financial Feasibility of Public Transportation	[5.03, 5.03]
	Vehicle and General Cost of Accident	[4.75, 5.25]
	Occupancy of Public Transportation	[5.37, 5.37]
	Average Age of Vehicle Fleet	[5.6, 5.6]
	Government Expenditure on Infrastructure to Improve Transportation Sustainability	[5.53, 5.53]

Following the data collection, an equitable weighting methodology was applied to analyze the data from each category of indicators. These weighted assessments were then integrated to compute a final Transportation Sustainability Index (TSI) for Ajmer, providing a comprehensive measure of the sustainability performance of the city's transportation systems [11].

Ethical guidelines were rigorously adhered to throughout the data collection process. Informed consent was obtained from all participants, ensuring that they were fully aware of the purpose and scope of the study. Confidentiality was strictly maintained to protect the privacy of respondents, and data was anonymized to prevent any potential identification.

This humanized approach to data collection and analysis aims to provide a nuanced understanding of Ajmer's transportation sustainability, offering valuable insights for policymakers, urban planners, and stakeholders committed to enhancing the city's transportation infrastructure.

5. RESULTS AND DISCUSSIONS

Ajmer's Transportation Sustainability Index (TSI) has been determined to be 50.49, reflecting a moderately sustainable transportation system. This score combines the city's performance across three key sustainability dimensions: environmental, social, and economic. The following sections discuss the implications of these scores in detail.

Ajmer's environmental sustainability score of 52.89 indicates a city grappling with significant challenges. Factors such as air quality, noise levels, and transportation emissions critically impact this score. Despite positive initiatives like efficient land use, Ajmer faces substantial air pollution and high fuel consumption from daily commutes, suggesting a need for more robust strategies to mitigate these issues [21].

Air pollution, primarily from vehicular emissions, remains a significant concern. Studies have shown that urban air quality directly affects public health, contributing to respiratory and cardiovascular diseases [22].

With a score of 46.17, social sustainability in Ajmer reveals several areas needing improvement. Factors such as commute duration, health impacts from vehicle emissions, and public transport accessibility are critical contributors. Public transportation, while available, often falls short in inclusivity and convenience for all population segments, including marginalized communities [14].

Commute duration and accessibility are particularly pressing issues. Long commute times can diminish quality of life and reduce time available for personal and family activities [23]. Enhancing the efficiency and reach of public transportation could significantly improve these metrics. Additionally, improving infrastructure for pedestrians and cyclists can promote healthier lifestyles and reduce vehicle dependency [24].

Ajmer performs relatively well in economic sustainability, scoring 52.41. This score is driven by strong demand for transport services, the availability of public transportation, and substantial government investments. High usage rates of public transport and a relatively young vehicle fleet contribute positively to this score [25].

However, economic sustainability can be further enhanced by addressing trip costs and vehicle accident expenses. Lowering these costs can increase accessibility and safety, thereby boosting overall economic productivity [26]. Continued investment in infrastructure, particularly in public transportation, is crucial for maintaining and improving economic sustainability [22] .

Ajmer's environmental score highlights the city's need for improved air quality and reduced fuel consumption. The negative health impacts of air pollution underscore the importance of stringent emission controls and cleaner fuel initiatives. Additionally, the city should invest in sustainable urban planning and green infrastructure to mitigate environmental degradation [21], [22].

The social sustainability score indicates areas for significant improvement, particularly in public transportation efficiency and accessibility. Long commute times and health impacts from emissions suggest a need for better public transport services and infrastructure for non-motorized transport. Prioritizing these improvements can enhance quality of life and promote social equity [23], [24] .

Ajmer's relatively strong economic sustainability score reflects effective demand for transport services and substantial investments in public transportation. However, reducing trip costs and vehicle accident expenses can further improve economic outcomes. Ensuring affordable and safe transportation options is crucial for sustainable economic growth [25], [26].

Ajmer's TSI of 50.49 reflects a moderately sustainable transportation system with strengths in economic aspects and areas for improvement in environmental and social dimensions. By adopting targeted strategies to enhance air quality, public transportation, and infrastructure, policymakers can significantly improve the city's overall transportation sustainability. These findings provide valuable guidance for other cities in India striving to create sustainable urban transportation systems.pillars and overall T.S.I.

6. CONCLUSIONS

The journey towards sustainable transportation in Ajmer reflects broader challenges and opportunities faced by urban centers worldwide. This study's comprehensive evaluation methodology, which integrates environmental, social, and economic dimensions, offers a nuanced understanding of the city's current transportation sustainability standing.

Ajmer's Transport Sustainability Index (TSI) score of 50.49 reveals a moderately sustainable transportation system, marked by notable achievements and significant areas for improvement. The environmental sustainability score of 52.89 underscores the city's efforts in efficient land use and managing ecological impacts. However, challenges such as significant air pollution and high fuel consumption persist, necessitating targeted interventions to enhance air quality and reduce emissions [22].

Social sustainability, with a score of 46.17, highlights the critical need for improved accessibility, public health initiatives, and inclusivity in transportation services. The average commute duration and health impacts from vehicle emissions are areas that require urgent attention to improve the quality of life for all residents, especially marginalized communities [27].

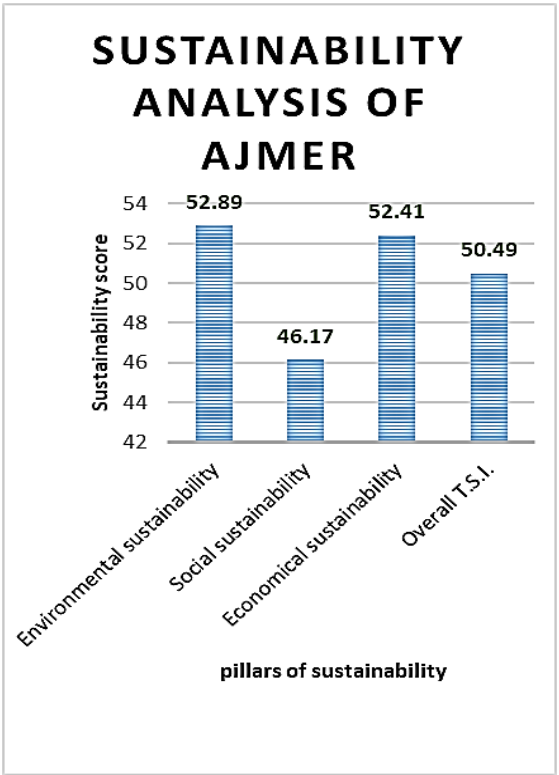

Figure 1. Graphical representation of results obtained in the respective

Economically, Ajmer shows promise with a score of 52.41, driven by robust demand for transportation services and significant government investments in infrastructure. Nonetheless, addressing the economic efficiency of transport, reducing trip costs, and minimizing vehicle accident expenses remain pivotal to enhancing overall economic sustainability [3].

The findings from this study not only offer valuable insights for Ajmer but also provide a replicable framework for other cities striving to achieve sustainable urban transportation. The integration of comprehensive indicators and the use of a multi-criteria analysis approach have proven effective in

capturing the complexities of urban transport systems.

Moving forward, policymakers and stakeholders in Ajmer must focus on implementing targeted strategies that address the identified gaps. Enhancing public transportation accessibility, promoting eco-friendly transport alternatives, and investing in sustainable infrastructure are crucial steps toward achieving a fully sustainable transportation system. Collaborative efforts between government agencies, private sector stakeholders, and the community are essential to drive these initiatives forward [25].

In conclusion, while Ajmer has made commendable progress towards transportation sustainability, continued efforts and strategic planning are necessary to overcome existing challenges and build a more inclusive, efficient, and environmentally friendly transportation network. The insights gained from this study serve as a guiding light for policymakers, urban planners, and stakeholders committed to fostering sustainable development in urban areas.

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