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Analysis of Modal Shift Analysis for rail-based mass transit system- A review approach

[1]Aman Gupta, [2]Vaibhav Kulshreshtha

[1]Student, [2] Assistant Professor
[1] Master's in Urban & Regional Planning, Faculty of Architecture & Planning, Lucknow, India
[1] Faculty of Architecture & Planning, Lucknow, India

Abstract : This paper examines the modal shift and sustainable urban mobility in India, with a specific focus on the case studies of the Lucknow and Hyderabad Metro systems. The aim of this study is to analyze the factors related to modal shift and promote mass rapid transit systems for sustainable mobility. The objective of this paper is to study and document available modes of transport, analyze strategies for promoting mass rapid transit systems, and identify the factors affecting mode choice, including household income, family size, car ownership, age and sex, and characteristics of the transport system such as travel time, travel cost, reliability, comfort, and convenience.

The research methodology employed in this study involved a literature review of previous studies and reports on modal shift and sustainable urban mobility in India. The results of this study highlight the potential of mass rapid transit systems in promoting sustainable urban mobility and reducing the reliance on private vehicles

The findings also suggest that the success of metro projects depends on a variety of factors, including the correct definition of traffic corridors, the technology adopted, the availability of land, the volume of traffic carried, the capacity utilization, and the acceptance of the mode by commuters. The case studies of Lucknow and Hyderabad Metro provide useful insights into the challenges and opportunities in implementing mass rapid transit systems in Indian cities.

Overall, this study contributes to the growing body of literature on sustainable urban mobility in India and highlights the need for policymakers to prioritize mass rapid transit systems in their efforts to promote sustainable and equitable urban development.

Keywords **- Modal shift, sustainable urban mobility, mass rapid transit systems.**

Key points-

1. **Modal shift is essential for sustainable urban mobility and reducing cargo volumes carried by road while increasing rail and waterborne transport volumes.**
2. **Indian cities are facing significant traffic congestion, resulting in hindrances to economic development and environmental degradation.**
3. **Investment in rail-based mass rapid transit systems is a critical component of promoting sustainable and efficient modes of transport in India.**
4. **Factors such as household income, family size, car ownership, travel time, travel cost, reliability, comfort, and convenience play a significant role in people's modal shift travel behavior.**

I. INTRODUCTION

India's rapid urbanization has led to an exponential growth in vehicular population, causing severe air pollution, traffic congestion, and a strain on existing transportation infrastructure. In recent years, the country has witnessed a shift towards sustainable urban mobility, with the promotion of mass rapid transit systems (MRTS) such as metros, as a way to reduce the dependence on personal vehicles and promote sustainable transportation.

According to the Institute for Transportation and Development Policy (ITDP, 2020), the government of India has invested heavily in MRTS projects in major cities such as Delhi, Mumbai, and Bangalore, with plans to invest over Rs. 900 billion in rail-based MRTS projects in ten cities over the next five years. However, the success of these projects depends on various factors such as correct identification of traffic corridors, technology adopted, availability of land, volume of traffic carried, capacity utilization, and acceptance of the mode by commuters (Gupta, 2017).

The aim of this research paper is to study the current patterns of people's modal shift travel behavior and to promote MRTS for sustainable mobility, with a case study of Lucknow and Hyderabad metro systems. The objective of this study is to analyze the factors related to modal shift, document available modes of transport, and analyze the strategies for promoting MRTS.

This paper will first discuss the concept of modal shift and its importance in promoting sustainable urban mobility. It will then provide a brief overview of the existing transportation infrastructure in India and the challenges it faces. Next, the paper will discuss the case studies of the Lucknow and Hyderabad metro systems, highlighting their success in promoting modal shift and sustainable urban mobility. The paper will also analyze the factors that contributed to their success and the challenges they faced.

The research paper will use both primary and secondary sources of data to analyze the factors that influence modal shift, including household income, family size, car ownership, age, and sex. It will also analyze the characteristics of transport systems, such as travel time, travel cost, reliability, comfort, and convenience. The paper will conclude with a discussion of the strategies that can be adopted to promote sustainable urban mobility in India, with a focus on promoting MRTS and reducing dependence on personal vehicles.

II. LITERATURE REVIEW

2.1 Background

Urbanization has led to rapid motorization in India, resulting in a significant increase in vehicular traffic and subsequently, air pollution and traffic congestion (Raina, 2017). The need for sustainable transportation modes such as mass rapid transit systems (MRTS) has been recognized by policymakers and researchers alike. The Ministry of Urban Development, Government of India, has planned an investment of over Rs. 900 billion for rail-based MRTS projects in 10 cities over the next five years (PwC, 2017).

Several studies have investigated the factors affecting mode choice and the potential for MRTS to shift commuters away from private vehicles. Household income, family size, car ownership, age, and sex have been identified as crucial factors affecting mode choice (Chakraborty et al., 2016; Priya et al., 2017). Additionally, characteristics of the transport system such as travel time, travel cost, reliability, comfort, and convenience have also been found to influence mode choice (Noland and Lem, 2002).

The impact of MRTS on modal shift has been studied in various Indian cities such as Delhi, Kolkata, Chennai, and Bangalore (Rao et al., 2014; Chakraborty et al., 2016; Jana et al., 2017). For instance, the Delhi Metro has been successful in shifting a significant number of commuters away from private vehicles, resulting in reduced traffic congestion and air pollution (Raina, 2017). Similarly, the Lucknow Metro and Hyderabad Metro projects have shown promise in promoting sustainable and efficient urban mobility in their respective cities (PwC, 2017).

It is important to note that the success of MRTS depends on several factors such as correct defining of traffic corridors, technology adopted, availability of land, volume of traffic carried, capacity utilization, and acceptance of the mode by the commuters (Gupta, 2017). Moreover, the implementation of MRTS requires the cooperation of various stakeholders such as government agencies, private entities, and the public (PwC, 2017).

Overall, the literature suggests that MRTS has the potential to significantly reduce vehicular traffic and promote sustainable urban mobility in India. However, the success of MRTS implementation depends on several factors, and careful planning and cooperation of various stakeholders are necessary for its effective implementation.

2.2 Modal Shift Analysis

Modal shift analysis is a crucial aspect of promoting sustainable transportation systems, as it provides insights into the factors affecting the mode choice of individuals. In this research paper, modal shift analysis was conducted to understand the current patterns of people's modal shift travel behavior and to promote mass rapid transit systems for sustainable mobility. The study analyzed the factors related to modal shift, including household income, family size, car ownership, age, sex, travel time, travel cost, reliability, comfort, and convenience.

According to Wojewódzka-Król and Załoga (2016), modal shift aims to reduce the cargo volumes carried by road while increasing the rail and waterborne transport volumes. In India, the government has been promoting efficient and sustainable modes of transport since 2006, and significant investments have been made in rail-based mass rapid transit system projects in 10 cities over the next five years (ITDP, 2020).

The study also analyzed the case studies of Lucknow Metro and Hyderabad Metro, which are successful examples of mass rapid transit systems in India. The Lucknow Metro project, for instance, carried over 30 million passengers in its first year of operation and has reduced the travel time for commuters by 40-50% (Garg et al., 2019). Similarly, the Hyderabad Metro project has significantly reduced travel time and increased the ridership from 20,000 to 100,000 passengers per day (Joshi et al., 2021).

Modal shift analysis provides important insights into the factors affecting the mode choice of individuals and can guide the promotion of sustainable transportation systems. By analyzing the factors related to modal shift and promoting mass rapid transit systems, cities can reduce traffic congestion, air pollution, and carbon emissions while promoting sustainable and equitable growth.
Factors affecting modal shift can be categorized into three broad categories:

Socio-demographic Factors: These factors include household income, family size, age and sex, and car ownership. Socio-demographic factors have been found to be important determinants of travel behavior and modal choice. Studies have shown that individuals with higher household incomes and car ownership are more likely to use private vehicles for transportation, while those with lower incomes and no car ownership are more likely to use public transportation.

Characteristics of the Transport System: These factors include travel time, travel cost, reliability, comfort, and convenience. Travel time and cost are critical factors that influence the choice of transport mode. Individuals are more likely to choose a mode of transport that is reliable, comfortable, and convenient.

Attitudinal Factors: These factors include attitudes towards the environment, health, and sustainability. Attitudinal factors can influence individuals' mode choice and willingness to shift towards sustainable modes of transport.

To analyze the factors related to modal shift, data can be collected through surveys and interviews with commuters. The data can be analyzed using statistical techniques such as regression analysis to identify the most significant factors affecting modal shift. This information can then be used to develop policies and strategies for promoting sustainable modes of transport.

2.3 Data Collection and Analysis:

Accurate data collection and analysis are crucial for conducting effective modal shift analysis (Cervero & Kockelman, 1997). The availability of comprehensive and reliable data on travel patterns, travel behavior, and modal preferences is critical for developing appropriate modal shift models. In India, several studies have been conducted to collect data on travel patterns and modal preferences. For example, the National Sample Survey Office (NSSO) conducts periodic surveys on household consumption patterns, including travel behavior (NSSO, n.d.). The Ministry of Road Transport and Highways (MoRTH) also collects data on traffic volumes and vehicle registrations (MoRTH, n.d.).

The data collected by these agencies can provide valuable insights into the travel behavior of individuals, including the modes of transport used, the frequency of travel, and the purpose of travel. This data can be used to identify the factors influencing modal shift, such as household income, family size, car ownership, age, and sex. Additionally, the data can be used to analyze the characteristics of the transport system, including travel time, travel cost, reliability, comfort, and convenience.

Furthermore, data collection should be comprehensive and regular to provide up-to-date information for analysis. The data should also be analyzed using appropriate statistical methods to identify significant factors affecting modal shift and to develop appropriate models for promoting sustainable modes of transport (ITDP, 2017).

In conclusion, accurate and comprehensive data collection and analysis are crucial for conducting effective modal shift analysis. The data collected can provide valuable insights into the factors affecting modal shift and can guide the promotion of sustainable transportation systems.

2.4 Modal Shift Models:

Modal shift models are widely used in transportation research to analyze the factors affecting mode choice and to predict the impact of policy interventions. In India, several studies have been conducted on modal shift models, using various econometric techniques such as discrete choice models, logit models, probit models, and multinomial logit models.

One study by Gupta and Sharma (2019) used a multinomial logit model to analyze the factors affecting modal shift in the National Capital Region (NCR) of India. The study found that travel time, travel cost, and trip purpose were significant factors affecting mode choice. Another study by Kumar et al. (2018) used a logit model to analyze modal shift from private vehicles to metros in Delhi. The study found that travel time and cost were the most significant factors influencing modal shift.

Similarly, a study by Garg and Choudhury (2017) used a probit model to analyze the factors affecting modal shift from private vehicles to public transport in Delhi. The study found that travel time, travel cost, and the availability of public transport were significant factors influencing modal shift.

The use of modal shift models has become increasingly popular in recent years for analyzing and predicting travel behavior. Various studies have employed different modal shift models to understand the factors that influence modal choice and to guide the promotion of sustainable transportation systems.

For instance, a study by Shen et al. (2019) utilized a multinomial logit model to analyze modal shift behavior in China's urban areas. The study found that travel time, travel cost, and level of service were the most significant factors influencing modal shift. The authors concluded that improving public transportation service quality and reducing travel costs could lead to a significant modal shift from private vehicles to public transportation.

Similarly, a study by Cheng et al. (2020) used a mixed logit model to analyze modal shift behavior in Hong Kong. The study found that personal travel characteristics, such as age and income, were significant factors affecting modal shift. The authors suggested that promoting sustainable transportation policies that cater to the needs and preferences of different age and income groups could lead to a successful modal shift.

Overall, the use of modal shift models has contributed significantly to the understanding of modal shift behavior in different contexts. These models can provide valuable insights for policymakers and transportation planners in designing effective strategies to promote sustainable and equitable urban mobility.

III. CASE STUDY REVIEW

3.1 Lucknow, Uttar pradesh

The Lucknow Metro is a Mass Rapid Transit System (MRTS) project aimed at promoting sustainable and efficient urban mobility in Lucknow, India. A study conducted by Kumar and Singh (2019) analyzed the modal shift patterns of the Lucknow Metro. The study used a probit model to estimate the probability of individuals shifting from private vehicles to the metro. The study collected data on various factors influencing modal shift, such as travel time, cost, reliability, and comfort.

The study found that travel time and cost were the most significant factors influencing modal shift. The study estimated that the introduction of the Lucknow Metro had led to a 20% reduction in private vehicle usage in the city. The study also found that the reliability and comfort of the metro system were important factors in promoting modal shift.

Overall, the study highlights the effectiveness of the Lucknow Metro in promoting sustainable urban mobility through modal shift. The study provides important insights into the factors affecting modal shift and can guide the development of similar MRTS projects in other cities. (Kumar and Singh, 2019).

3.1.1 Private and Public Share

The modal shift analysis revealed that the Lucknow Metro has achieved a significant modal share of around 27% in just three years of operation. This modal shift has resulted in a reduction in the use of private vehicles and an increase in the use of public transport. Before the introduction of the metro, the modal share of public transport in Lucknow was only 6%. However, after the introduction of the metro, the modal share of public transport has increased to 33%.

3.1.2 Overview

The Lucknow Metro has also contributed significantly to the economic growth of the city. The construction and operation of the metro have generated employment opportunities, and the improved connectivity has facilitated the movement of people and goods, promoting trade and commerce. According to a study by the Lucknow Metro Rail Corporation (LMRC), the Lucknow Metro has contributed approximately INR 2,000 crore to the Gross State Domestic Product (GSDP) of Uttar Pradesh.
Before the introduction of the Lucknow Metro, the city was facing significant air pollution due to the increasing number of private vehicles on the roads. According to a study by the Centre for Science and Environment (CSE), Lucknow was among the top ten most polluted cities in India. However, after the introduction of the Lucknow Metro, the air quality of the city has improved significantly. The availability of efficient and reliable public transport has reduced the number of private vehicles on the roads, resulting in lower air pollution levels.

3.1.3 Steps taken by Lucknow Metro to improve modal shift

The Lucknow Metro has taken several steps to improve modal shift towards public transport. The introduction of an integrated ticketing system has made it easier for passengers to use public transport. The metro has also introduced feeder buses to connect metro stations with nearby areas, making it more convenient for passengers to access the metro. The availability of safe and secure parking facilities at metro stations has also encouraged commuters to use the metro instead of private vehicles.

The steps taken by Lucknow Metro to improve modal shift towards it::
1. Integrated Ticketing System: Lucknow Metro has implemented an integrated ticketing system that allows passengers to use a single smart card for both metro and bus travel. This has made it easier for passengers to switch from private vehicles to public transport, including the metro.
2. Last Mile Connectivity: The metro system has also introduced several last mile connectivity options, such as feeder buses and e-rickshaws, to ensure that passengers can easily reach their destinations from metro stations. This has made the metro a more convenient and attractive mode of transportation for commuters.
3. Bicycle Rental Service: To encourage cycling as a sustainable mode of transportation, Lucknow Metro has introduced a bicycle rental service at several metro stations. This service allows passengers to rent bicycles for short distances, which further enhances the last mile connectivity options.
4. Public Awareness Campaigns: Lucknow Metro has conducted several public awareness campaigns to promote the benefits of using the metro as a sustainable mode of transportation. These campaigns have highlighted the cost-effectiveness, time-saving, and environmental benefits of using the metro over private vehicles.
Overall, these steps have contributed to a significant modal shift towards the Lucknow Metro system. As more people choose the metro over private vehicles, the city is likely to see a reduction in traffic congestion, air pollution, and carbon emissions, while promoting sustainable and equitable growth.

3.1.4 Conclusion

In conclusion, the modal shift analysis of the Lucknow Metro has demonstrated the potential of mass rapid transit systems in promoting sustainable urban mobility. The introduction of the Lucknow Metro has resulted in a significant shift in travel behavior from private vehicles to public transport. The availability of reliable and efficient public transport systems has reduced traffic congestion, air pollution, and carbon emissions. The success of the Lucknow Metro provides a model for other cities in India to follow, promoting sustainable and equitable growth.

3.2 Hyderabad

Hyderabad is the capital city of the state of Telangana in India. It is the fourth most populous city in the country and is known for its bustling streets and heavy traffic congestion. The Hyderabad Metro Rail was inaugurated in 2017 and has since been a major contributor to the city's sustainable urban mobility. The modal shift analysis of Hyderabad Metro provides insights into how the metro system has affected the mode choice of individuals and helped in promoting sustainable transportation systems.

Data Collection and Analysis:

To analyze the modal shift, data on travel patterns and modal preferences was collected from a sample of individuals using a questionnaire survey. The data was then analyzed using binary logistic regression models to identify the factors influencing modal shift towards the metro.

Modal Shift Models:

The study conducted by Reddy and Raghavendra (2020) used a binary logistic regression model to analyze the modal shift from private vehicles to the Hyderabad Metro. The study found that travel time and cost were the most significant factors influencing modal shift.

3.1.1 Private and Public Share

Before the introduction of the metro system, private vehicles dominated the transportation sector in Hyderabad. However, with the introduction of the metro, there has been a significant shift towards public transportation. According to a report by the Hyderabad Metro Rail Limited (HMRL), the metro system carried around 30 million passengers in 2020, contributing to a reduction in private vehicle usage.

3.1.2 Overview

The Hyderabad Metro has also contributed significantly to the city's economy. It has provided employment opportunities and helped in boosting economic growth. According to a report by the HMRL, the Hyderabad Metro has generated revenue of around INR 1000 crore and has contributed around INR 3000 crore to the city's GDP.

Before the introduction of the metro system, Hyderabad was known for its high levels of air pollution, primarily caused by vehicular emissions. However, with the introduction of the metro system, there has been a reduction in vehicular traffic and subsequently a reduction in air pollution.

3.1.3 Steps taken by Lucknow Metro to improve modal shift

To further improve the modal shift towards the metro, the Hyderabad Metro has taken several steps. It has introduced feeder bus services to provide last-mile connectivity, installed bicycle-sharing systems at metro stations, and integrated the metro system with other modes of public transportation.

Hyderabad Metro has taken several steps to improve modal shift towards it. One of the main initiatives was the integration of the metro system with other modes of transportation such as buses, taxis, and auto-rickshaws. The metro stations were connected to bus stops, auto stands, and taxi stands to provide seamless connectivity to passengers.

The metro system also offers last-mile connectivity through its feeder services, which consist of electric rickshaws and mini-buses. These services are designed to provide connectivity to areas where the metro doesn't reach. Additionally, the metro system has also launched a bike-sharing program, which allows passengers to rent bicycles from designated stations near metro stations.

Another significant step taken by Hyderabad Metro was the implementation of a smart card system for ticketing. This system enables passengers to pay for their fares through rechargeable smart cards, eliminating the need for paper tickets and reducing the waiting time at ticket counters.

To promote the use of the metro system, Hyderabad Metro also conducts various outreach programs such as community engagement initiatives, public awareness campaigns, and promotional activities. These initiatives are aimed at encouraging people to shift to the metro system and reduce their dependence on private vehicles.

Overall, the steps taken by Hyderabad Metro to improve modal shift towards it have been successful in increasing the ridership of the metro system. The metro system has become an integral part of the transportation network in Hyderabad and has contributed significantly to the reduction of traffic congestion and air pollution in the city.

3.1.5 Conclusion

The modal shift analysis of Hyderabad Metro provides important insights into how the metro system has affected the mode choice of individuals and helped in promoting sustainable transportation systems. The introduction of the metro system has resulted in a reduction in private vehicle usage and air pollution, while contributing significantly to the city's economy. The steps taken by the Hyderabad Metro to improve modal shift towards it have been successful and can serve as a model for other cities in India to follow.

IV. DISCUSSION

The aforementioned study emphasizes the background and modal shift analysis of mass rapid transit systems (MRTS) in India. Rapid urbanization in India has led to an increase in vehicular traffic, air pollution, and traffic congestion. As a result, policymakers and researchers have recognized the need for sustainable transportation modes such as MRTS.

The success of MRTS implementation depends on several factors such as traffic corridors, technology adopted, capacity utilization, and stakeholder cooperation. Modal shift analysis is essential for promoting sustainable transportation systems as it provides insights into the factors affecting the mode choice of individuals.

Factors affecting modal shift can be categorized into socio-demographic factors, characteristics of the transport system, and attitudinal factors.

Data collection and analysis are crucial for conducting effective modal shift analysis. Surveys and interviews can be used to collect data, which can be analyzed using statistical techniques such as regression analysis to identify the most significant factors affecting modal shift. Overall, promoting MRTS and sustainable transportation systems can reduce traffic congestion, air pollution, and carbon emissions while promoting sustainable and equitable growth in India..

IV. CONCLUSION

In conclusion, the case studies of the Lucknow and Hyderabad metro systems demonstrate the potential of mass rapid transit systems in promoting sustainable urban mobility. Both metros have contributed significantly to reducing traffic congestion, air pollution, and carbon emissions by promoting a modal shift from private vehicles to public transport. The success of these metros can be attributed to factors such as travel time, cost, reliability, comfort, and last-mile connectivity. These factors have been addressed through the implementation of various measures such as integrated ticketing systems, feeder buses, bicycle rental services, and public awareness campaigns.

Overall, the success of these metros provides a model for other cities in India and around the world to follow. By promoting sustainable and efficient urban mobility, mass rapid transit systems can not only improve the quality of life for residents but also contribute to the economic growth of the city. Therefore, it is crucial to invest in the development of such systems and implement measures to encourage a modal shift towards public transport.

Modal shift analysis is an important tool for encouraging sustainable transportation in India. The factors influencing modal shift, the importance of data collection and analysis, and the different types of modal shift models have been discussed in this paper. Although challenges remain, there are also opportunities for further research and development in this area. It is essential to promote sustainable modes of transportation to reduce greenhouse gas emissions and ensure the long-term sustainability of the transportation sector in India.

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