

Sustainable Civil Infrastructures

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Bharath Haridas Aithal
Swati Maitra
Ankhi Banerjee *Editors*

Infrastructure and Built Environment for Sustainable and Resilient Societies

Proceedings of IBSR 2023



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Sustainable Civil Infrastructures

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Preface

As the world continues to urbanize and build new infrastructure, it is essential to ensure that the benefits of such investments are equitable and sustainable. To this end, the Annual Conference on “Infrastructure and Built Environment: Towards Sustainable and Resilient Societies (IBSR 2023)” was conducted by the Ranbir and Chitra Gupta School of Infrastructure Design and Management, IIT Kharagpur, in February 2023. This book presents the select proceedings from the conference, which was an agglomeration of bright minds from industry, government, and academia, who shared their experiences and brainstormed solutions for the future.

The conference’s thematic areas included multimodal urban transport, sustainable transport infrastructure development, smart inclusive habitat, and spatial informatics in urban planning. A total of 44 research papers were presented by researchers from 14 prestigious higher education institutes in the country. The conference participants were also exposed to eminent keynote speakers, who delivered talks on wide-ranging topics that included hospitality infrastructure, safe design, urban mobility, infrastructure finance, and conservation of cultural heritage. The conference organizers are thankful to all the agencies who supported and sponsored the conference.

This book serves as a valuable reference for students, researchers, and professionals interested in urban travel behavior, transport infrastructure, spatial data analytics, urban planning, and habitat systems.

Kharagpur, India

Arkopal Kishore Goswami
Bharath Haridas Aithal
Swati Maitra
Ankhi Banerjee

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Dr. Ankhi Banerjee is currently working as an Assistant Professor at Ranbir & Chitra Gupta School of Infrastructure Design and Management, Indian Institute of Technology, Kharagpur. Her research interests include Housing Affordability, Livability and Urban Infrastructure, Urban Design, Urban Morphology and Sustainable Tourism. Dr. Banerjee has published research findings through publications in reputed peer reviewed journals, International and national conferences, and book chapters. Dr. Banerjee has been closely associated with several projects based on Smart Urban Regeneration, Development of Index as a measure of Happiness in new Town, Kolkata and Improvement of Corridor based Traffic Mobility and has also collaborated with researchers from UK and US. She was Principal Investigator of a research project which aimed at developing an Integrated Housing and Transportation Model under the Scheme for Promotion of Academic and Research Collaboration (SPARC). Dr. Ankhi Banerjee has completed her graduation in Architecture and post-graduation in Urban Design from Jadavpur University. Dr. Banerjee has previously taught in the Department of Planning and Architecture, National Institute of Technology, Rourkela.

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Part I
Multimodal Urban Transport

Chapter 1

Transportation Hub as an Urban Magnet: A Case of Nagpur Metro



Mrunalini Joshi and Manmohan Kapshe

Abstract Public transportation networks have the potential to act as urban magnets, catalyzing growth and development inside cities. The paper investigates the Nagpur Metro in India and how it is drawing travelers, real estate investment, and urban renewal initiatives. First, an overview of how transportation hubs act as magnets that boost, employment opportunities, trade, and property values is given. The impact of the Nagpur Metro on connectivity, local economy, ecology, and real estate in Nagpur is then examined. Forecasts of metro ridership demonstrate the system's capacity to entice residents as well as visitors. Studies of two metro stations in Nagpur show clear effects on land value and land use, with property values rising by up to 50% as a result of the metro's construction. Additionally, the metro is reducing the city's traffic jams and pollutants from vehicles. The study analyzes these advantages as well as legislative considerations to ensure equitable transportation improvements. The Nagpur Metro serves as a concrete example of how strategic transportation investments can spur development. The paper adds a ground-level analysis of the growth and changes that can be directly linked to a metro system acting as an urban magnet.

1.1 Introduction

A city's development of its neighborhoods is a complicated process that is impacted by a number of variables, such as population expansion, economic development, and governmental regulations. The accessibility and caliber of public transportation are two important factors that may have a big influence on how a place develops. The rise of transit-oriented development is an illustration of the relationship between public transportation and the development of a community (TODs). A railway station or bus terminal are the most common examples of the kind of public transit hubs that are the

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center of a mixed-use development known as TODs. People find these developments attractive as they offer walkable and complete neighborhood (Ewing et al. 2014).

Additionally, transit hubs can help foster local economic growth. They can aid in luring new investment and promoting economic growth by offering a convenient location for businesses and people. For instance, studies have shown that transit hubs may enhance property prices and boost the performance of enterprises based in these regions (Ewing et al. 2014).

1.1.1 Urban Magnets

Due to its potential to promote neighborhood growth and renewal, the idea of the urban magnet has attracted a lot of interest in the field of urban development. The term ‘urban magnet’ describes the focal point or attraction that spurs growth in a city or neighborhood. A few examples of this include industrial projects, highways, airports, and other forms of transportation infrastructure along with institute of higher learning (Adeniran & Joseph, 2018). A flourishing commercial area or a thriving arts community are examples of intangible urban magnets. In either situation, the urban magnet acts as a catalyst for growth by luring people, capital, and resources to a certain location.

The impact of urban magnets in the area can be conceptualized into physical, social, cultural, and economic changes (Adeniran & Joseph, 2018). One research discovered that the existence of urban magnets might result in improved real estate values and regional economic growth (Lee & Kim, 2010). Part of this might be attributed to the fact that these attractions enhance foot traffic and the demand for regional products and services. In addition to increasing the neighborhood’s appeal, urban magnets can act as catalysts for the construction of new facilities and infrastructure. All this growth and development caused by urban magnet formulates into changed land use of the area.

1.1.2 Urban Magnets Throughout History

Towns have formed throughout history around some anchor point, which were the urban magnets of that era; in ancient times, cities were frequently established around a supply of water. Later towns, such as those in Mesopotamia and Egypt, were erected around a great temple complex that functioned as the focus of religious and commercial activity. In medieval European towns, the center of the city was frequently built around a fortified central palace or castle.

The industrial revolution in the nineteenth century resulted in the creation of new types of urbanization, with the Central Business District becoming an urban magnet, focusing on commercial sectors. In recent years, there has been another paradigm shift in which transportation nodes have emerged as urban magnets.

1.2 Need for the Study

It is historically evident that establishment of metro rail station or similar infrastructure is followed by catalyzed growth in the area bringing in increased activities along with changes in neighborhood quality which highly impacts the demand in the area and therefore the real estate of the same.

Several goals that the study will assist to achieve are listed below.

- The study will help to understand why and how such precincts impact the area and to what extent, which can serve as the base for determining the standards and other substantial studies.
- The demands for such areas can be outlined based on the understanding of the study.
- This can lead to controlled growth and development along with redevelopment in the area.
- This in turn can help catalyze or inhibit the growth as may be the case to unify the urban fabric.

1.3 Aim

To examine how the Nagpur Mass Rapid Transit System (NMRTS) is acting as an urban magnet and catalyzing development in the city.

1.4 Objectives

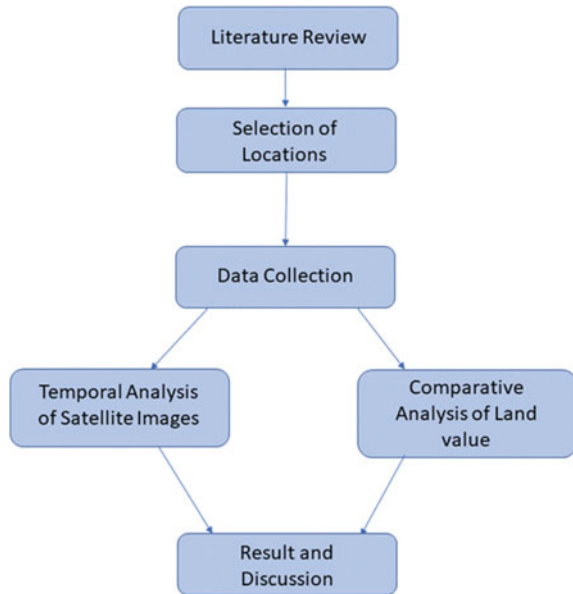
The objectives of the study are as follows:

- To apply understanding of urban magnet theory to metro station.
- To understand various physical, economic, and socio-cultural impacts associated with the construction of metro stations in the area.
- To study the impact of NMRTS as an urban magnet.

1.5 Methodology

The study included temporal analysis of satellite images taken before and after the introduction of NMRTS to assess the impact of the same. The satellite imagery utilized in this study was acquired from Landsat 7 for the year 2011 and from Sentinel-2A and Sentinel-2B for the year 2022. The imagery was obtained through the Google Earth platform. In addition, a comparative analysis of the land values at four different locations in Nagpur was done. The first location, Jaiprakash Nagar, was in the CBD

Fig. 1.1 Methodology of the study



area with a metro station. The second location, Telangkhedi, did not have metro connectivity and, consequently, did not have any metro station. The third location, Khapri, was on the outskirts of the city with a metro station, and the fourth location, Sonegoan, was outside the influence zone of a metro station but still in close vicinity. The following Fig. 1.1 summarizes the methodology followed in the study.

1.6 Transportation as an Urban Magnet

As crucial links in a city's transportation network and as centers of social and economic activity, transportation hubs have long been acknowledged as significant accelerators for urban growth. The purpose of this section is to examine how transportation hubs contribute to urban expansion and how they might promote the redevelopment of neighboring areas.

Transportation hubs may serve as 'regional anchors' and 'catalysts for economic growth', according to one *research* (Hagerty, 2008). Due to their accessibility and connectedness, these hubs can draw companies and inhabitants to the neighborhood. Airports in particular have been found to have a significant influence on a region's economic growth since they may draw tourists and act as a hub for international trade (Fujita, 1991).

Another research discovered that transportation hubs can also serve as 'job magnets', luring people from nearby communities (Cervero & Murakami, 2010). Particularly for lower income individuals who do not have dependable transportation,

these centers offer quick access to job options (Seo & Nam, 2019). Additionally, the growth of transportation hubs may result in the opening of new employment opportunities in the neighborhood, such as those related to the building and maintenance of transportation infrastructure as well as skill-intensive businesses (Du & Zheng, 2020).

Transport hubs may also operate as commercial and recreational hotspots and draw a wide variety of establishments. According to a case study of the Barcelona Sants Train Station, the neighborhood's general livability was improved by the station's reconstruction which resulted in the development of a mixed-use district featuring office, retail, and residential space (Pujol & Rieradevall, 2015).

The capacity to spur real estate development is another element that adds to the growth potential of transportation hubs. The existence of a transportation hub may boost local real estate values and spur demand for homes and office space (Lina et al. 2022). According to one study, having a transportation hub nearby is associated with higher real estate prices and more vibrant local economies (Kim et al. 2010).

The transportation hub has the ability to act as a social hub as well, promoting a sense of neighborhood and kinship (Yin et al. 2021). The transportation hub provides environmental advantages in addition to economic and social ones (Xiao et al. 2020).

However, the advantages of transportation hubs as urban magnets are not always equally dispersed (Glaeser & Gyourko, 2002). therefore there is a need for better policy making so as to put rules in place to make sure that the advantages of transportation hubs are dispersed more fairly in order to allay these worries.

1.7 Impact of Metro Station on Neighborhood

There are several noticeable changes that are seen in a neighborhood after the construction of a metro station. As a result, these modifications have a significant impact on the local real estate market, with values of residential property rising not just as a result of better accessibility but also as a result of the neighborhood's general transformation after the construction of the metro station. Some of the common changes observed are as discussed below.

1.7.1 Physical Changes

Urban land-use changes in the area are influenced by metro development, as well as land development and redevelopment. An early research conducted in Sapporo, Japan, in the 1990s found that the growth of built-up regions was a direct outcome of metro expansion. After the metro's construction, there has been a rise in the commercial land use along the metro corridor, an increase in the sports and leisure land use close to the metro systems, and a noticeable development in the number of places with parks (Jothimani & Yamamura, 1995).

The establishment of metro networks promotes population increase, residential growth, and commercial growth surrounding metro stations. In regions of Madrid, Spain, where the metro extension has had an impact, there has been noticeably more active urbanization and residential construction than in other comparable areas where the metro has had no impact. New suburbs that rose quickly with the metro expansion showed stronger residential development and population increase than the city center and satellite towns. As distance from the station increased, population density decreased around new metro stations in satellite towns and outer metropolitan districts, notably in the new urban area developments generated by new metro stations (Calvo et al. 2013).

The building of new metro lines in Singapore has led to an increasing density of upper-class and upper-middle-class housing near metro stations. Housing developers added a greater number of smaller housing units in the station area as a result of the market's needs and the Master Plan's restrictions on the quantity and concentration of residential development. This is due to the fact that people from upper-class and upper-middle-class backgrounds may afford private residences (Zhu & Diao, 2016).

The changes in activity and built environment vary with the location of a metro station in the city. For example, new metro stations built in London's suburbs over the nineteenth and twentieth centuries resulted in a rise in suburban population, and higher population densities prompted more metro constructions. In contrast, the greater accessibility that the metro gave in central London resulted in commercial expansion and the corresponding population decline (Levinson, 2007). Similarly, according to research conducted in Seoul on how the metro system affects people and their urban activities, only commercial activities—as opposed to residential, entertainment, and work—are intimately associated with the metro network. Residents left the urban core area and moved to the suburbs as a result of the commercial suburbanization process that separated residential activities from business operations in the urban core region (Lee et al. 2021).

1.7.2 Economic Changes

Although there may be regional differences in how metro construction impacts land and property values and prices, the research that is now accessible largely supports the idea that metro has a positive effect as measured by property price. Citizens may opt to live in metro station precincts to have greater access to the metro, hence metro accessibility influences where residents choose to live (Lina et al. 2022).

The direct transportation cost reductions is added to the value of the home in most cases (Bajic, 1983). When public transit systems are in operation, home placement decisions for the majority of socio-economic strata were affected positively by subway accessibility. Despite the fact that high-income households sacrifice easier access to public transit for a more appealing area, middle-income and low-income households actively sought convenience and the greenness of station surroundings (Seo & Nam, 2019).

With hikes of 7 to 14% for previously owned homes within 1600 m in Wuhan, China, new metro stations have dramatically pushed up housing prices. Similarly in Singapore, a 1.6% increase in property prices is found within 400 m, while in Hangzhou, China, a 2.3% increase in property prices is noted within 1000 m, a 15% increase in residential apartment prices within 400 m, and 11% within 800 m, and homes in Daegu, Korea, had an increase of 96.3 USD per square meter if they are within 500 m (Lina et al. 2022). Along with these cases, there are various other studies around the world that support the notion that there is a clear rise in property prices due to improved accessibility provided by metro stations.

Wider economic benefits of metro growth include altered job densities, which have an impact on the labor market's productivity and efficiency. A study on Beijing subway revealed the number of new skill-intensive businesses grew by 0.44% with a 1% increase in the metro network's accessibility to agglomerations; similarly, the number of skill-intensive businesses increased by 0.74% with a 1% increase in the metro network's accessibility to cheap rental housing (Du & Zheng, 2020). Similar research in Brazil indicated increased labor productivity and mobility, with improvements of 32% in the city of So Paulo, 11% in neighboring municipalities, 12% in the State of So Paulo, and 45% in the rest of the nation (Haddad et al. 2015).

1.7.3 Socio-Cultural Changes

People use public transit as a mode of mobility when they don't have access to private, motorized vehicles. When transportation networks are improved, such as by providing high-quality metro services, significant societal benefits may follow (Fouracre et al. 2003).

According to research on Gwangju, Korea, transportation equity continued to improve as a result of the metro extension. Those who used public transit did not gain from the first linear metro line. However, it seems that while a second circular metro line was operating, travel by women and young people was considerably and favorably influenced by the expanded transit availability (Song et al. 2018). In another study of Delhi metro, it was found that women typically had good and empowering experiences traveling the metro since they felt relatively secure there because of safety precautions taken by the metro system (Gopala & Shin, 2019).

There are several studies which talk about the impact of metro on physical health. According to research on the impact of subways on air pollution, increasing the mileage of subways will lower the amount of pollution. Different air pollutants are affected differently by the construction of subways. Development of the subway system can lower the concentrations of PM_{2.5} and PM₁₀ (Xiao et al. 2020). Along with this, in a study conducted in Chengdu, China, survey respondents reported an average body mass index (BMI) increase of 1.0 kg/m² over a ten-year period. However, those who lived less than 400 m from the nearest metro station experienced a BMI increase that was significantly lower (by 0.545 kg/m²) than those who lived farther away (Xiao et al. 2021).

Life satisfaction and metro transportation had been linked. Metro transportation in Xi'an, China, was favorably correlated with life satisfaction through links to quality transit service, walkability, accessibility, and travel pleasure. In comparison to developed countries, metro development has a greater impact on improving welfare in developing country cities (Yin et al. 2021).

Contrary to above-mentioned positive socio-cultural effect, there are studies that suggest in certain cases negative impacts on the same. For instance, research suggests that locals were dissatisfied with the metro stations in the region due to rising traffic, noise pollution, lack of mobility safety, as well as a rise in the presence of non-locals and a lack of social security (Abbaszadegan et al. 2011).

1.8 Nagpur Metro as Urban Magnet

The Nagpur Metro, commonly referred to as the Nagpur Mass Rapid Transit System (NMRTS), is a rapid transit system that serves the city of Nagpur in the Indian state of Maharashtra. Nagpur Metro was sanctioned for implementation in 2014, with Phase-I covering 38.2 km in two corridors (Nagpur Metro Rail Corporation Limited, 2016). In order to draw people and companies to the city, the metro system has been created to function as an urban magnet. The project got inaugurated in 2019, amid COVID-19 which led to delay in overall functionality (Nagpur Metro Rail Corporation Limited, 2019).

Connectivity is one of Nagpur Metro's key benefits. People may easily travel to various sections of the city because of the metro system's connections to important portions of the city, including the airport, railway station, and bus station. In turn, this has increased the number of tourists coming to Nagpur, which has benefited the local economy. The Nagpur Metro Rail Corporation (NMRCL) conducted research that found that the metro system is anticipated to bring in around 5 million visitors annually, generating an estimated INR 15,000 crore in economic benefits (Nagpur Metro Rail Corporation Limited, 2017) (Fig. 1.2).

The real estate industry in the city has benefited from the Nagpur Metro as well. Property in locations with good metro connections is in higher demand as a result of the metro system. Due to this, property values have risen and new residential and commercial developments have been created in these locations, increasing their property values. The Nagpur Metro has increased property prices in locations like Sitabuldi, Kamptee, and Hingna, claims a report by the Confederation of Real Estate Developers' Associations of India (CREDAI) (Confederation of Real Estate Developers' Associations of India, 2018).

The ecosystem of the city has benefited from the Nagpur Metro as well. The metro system has caused a decline in the number of vehicles on the road, which has decreased air pollution. The Nagpur Metro is anticipated to lower the city's carbon emissions by around 50,000 metric tonnes annually, according to a research (Promoting Sustainable Low-carbon Mobility in Nagpur, n.d.).

According to a Nagpur Municipal Corporation report, the average land value in the region has grown by almost 20% in the last five years (Nagpur Municipal Corporation, 2019). The change in land usage is another notable modification in Jaiprakash Nagar Nagpur. Figure 1.3 shows significant increase in built-up area after construction of metro station. It also shows improvement in the road network along with increase in green cover, which can be directly linked to introduction of metro station in the area.



Fig. 1.3 Jaiprakash Nagar area before (2011) and after (2022) the construction of metro station (Source Google earth)

1.8.2 Real Estate Scenario Near Jaiprakash Nagar Metro Station

Near Jaiprakash Nagar Metro Station, the real estate market is steadily expanding. The neighborhood's expansion overall and closeness to the metro station have caused property values to rise. There are several commercial and residential projects now under construction in the neighborhood, providing buyers and investors with a range of choices. Since it provides quick access to services like retail malls, public transit, and other amenities, the neighborhood is well-liked by young professionals and families. To understand the real estate scenario, Ready Reckoner Rate/Circle Rate are taken as an indicator for land value in the area.

Figure 1.4a demonstrates how the start of metro station construction marked the first increase in the Ready Reckoner Rate/Circle Rate. Despite the fact that the COVID-19 pandemic prevented the opening of the metro station from having an influence on the real estate market at the time, the rates have been rising since 2021. The fact that this pattern does not duplicate when it is compared to the trend in the Telangkhedi region in Fig. 4b, where there is no metro station nearby, further supports the positive impact of the metro station as an urban magnet for Jaiprakash Nagar.

In Nagpur, India, the building of the Khapri Metro Station has resulted in a major shift in land value and land usage, according to research done by the Nagpur Municipal Corporation in 2019. The region had a poor land value and was mostly utilized for agricultural before the metro station was built. However, since the metro station was built, the area's property prices have significantly increased, and its land use has shifted toward commercial and residential.

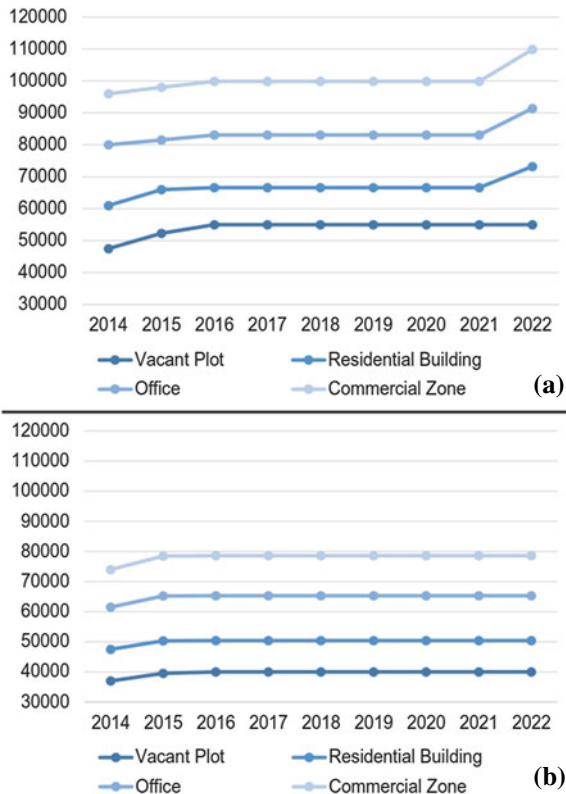
According to the report, since the building of the Khapri Metro Station, the average land value in the neighborhood has grown by more than 50%. This may be ascribed to the metro station's improved accessibility and convenience, which makes the region more desirable for residential and commercial development (Nagpur Municipal Corporation, 2019).

Figure 1.5 shows drastic changes in land cover of Khapri area after introduction of metro station. There is a high increase in built-up area and road network connectivity. Along with this, land-use change from agriculture to residential and commercial can also be observed.

1.8.3 Real Estate Scenario Near Khapri Metro Station

The present real estate market in Nagpur is highly promising near the Khapri Metro Station. In recent years, there have been a lot of residential and business construction projects in the region. The nearby metro station, which offers quick access to the city center and other key places, has fueled the demand for accommodation in the

Fig. 1.4 Ready reckoner rates (in Rupees/Sq.m.) near Jaiprakash nagar metro station (a) and in Telangkhedi (b) (Source Government of Maharashtra)



neighborhood. To meet the requirements of the middle-class population, several developers are now constructing affordable housing complexes in the neighborhood.

Figure 1.6a, similar to Jaiprakash Nagar Metro Station area, demonstrates how the start of metro station construction marked the first increase in the Ready Reckoner Rate/Circle Rate in residential section. Despite the fact that the COVID-19 pandemic prevented the opening of the metro station from having an influence on the real estate market at the time, the rates have been rising since 2021. Figure 1.6b illustrates the trend of Sonegaon region, which is further from the station, and shows how the influence of metro station as an urban magnet on the area lessens with distance.

1.9 Impact of Metro Station in Other Cities

Cases from India as well as other countries shows positive impact of metro station on nearby area in terms of development and real estate. For instance, research on the effects of Central London’s Cross-rail on residential property values (Knight Frank consultancy, 2013), an analysis of the effects of Dallas Area Rapid Transit