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A QGIS-BASED APPROACH FOR DEVELOPING A NON-MOTORISED TRANSPORTATION SYSTEM IN AN URBAN REGION

MOMIN HAMMAD*, FAUWAZ PARKAR, TEHSIN KAZI

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Abstract

Urban traffic congestion has intensified in recent years, underscoring the need for sustainable and efficient transportation alternatives. Non-motorised transportation (NMT) presents a practical, affordable, and environmentally friendly option, particularly for low-income communities and student populations. However, its adoption remains limited due to inadequate infrastructure, unclear route connectivity, and insufficient public awareness of NMT regulations. This study develops a data-driven NMT planning framework to address these challenges by designing a comprehensive bicycle network using QGIS, Google Earth Pro, and OpenStreetMap. The proposed system integrates both docked and dockless bike-sharing models to enhance accessibility and operational flexibility. Class II bicycle lanes—painted on-road corridors—are recommended as the primary infrastructure due to their cost-effectiveness and ease of implementation in dense urban environments. Spatial analysis and route mapping support the feasibility of this network, ensuring improved connectivity to existing public transportation hubs. The implementation of the proposed plan is expected to reduce travel barriers, promote intermodal mobility, and enhance overall urban livability. By providing a flexible and analytically grounded approach, this study contributes to sustainable urban mobility planning and highlights the potential of NMT to mitigate congestion while encouraging eco-friendly mobility behavior in rapidly growing cities.

Keywords: Non-motorised transportation; Urban mobility planning; Bike-sharing systems; Class II bike lanes; Sustainable transport strategies.

1. INTRODUCTION

The increased urbanization and population growth in India's semi-urban areas, e.g., the outskirts of Navi Mumbai, have resulted in critical urban mobility and transport challenges [1]. The growth has resulted in an increased flow of vehicles, leading to heavy traffic congestion, increased pollution, and increased dependency on fossil fuels [2]. In this regard, the creation of sustainable, human-oriented transport systems is now no longer a choice but a requirement for the creation of livable and efficient urban spaces [3]. In direct response to these challenges, the creation of Non-Motorized Transportation (NMT) systems—pedestrian walkways, cycling tracks, and other types of active mobility—has become a vital part of sustainable urban development[4]. NMT provides a low-cost, environmentally friendly, and health-enhancing alternative with tremendous potential to mitigate emissions, enhance road safety, and make cities more inclusive [5]. In the case of India, however, NMT infrastructure languishes under systemic neglect. Transport policies have traditionally been car-focused, putting the interests of vehicles ahead of people [6-8]. Consequently, public areas adjacent to roads are contested grounds, with pedestrians' and cyclists' interests competing against parked cars and shop activities, often pushing them onto dangerous main carriageways [9-10]. The impetus for creating a non-motorized transport (NMT) system in the semi-urban area of Panvel, Navi Mumbai, arises from the area's growing stature as an emerging urban center and the imperative need to solve its mobility issues [11-12]. Panvel and Khandeshwar are a critical transit route for commuters coming to and from Mumbai and other surrounding areas [13-14]. A large number of such commuters consists of students traveling on a daily basis from railway stations to the various colleges and schools in the area. These students typically encounter challenges due to the absence o exclusive walking and cycling infrastructure, congested roads, and heavy dependence on motorized transport for short trips [15-16] In addition, Panvel is also undergoing rapid urbanization with the proposed Navi Mumbai International Airport (NMIA) and increasing residential and commercial complexes [17-18]. This development is projected to lead to a sharp spike in population density and travel demands, threatening to overload the current transportation system. Alongside educational institutions, Panvel also has public parks, markets, and other facilities that draw both residents and tourists alike, further adding to the necessity of efficient and sustainable local transport systems [19-20]

This study is concerned with the creation of an NMT system for the semi-urban area of Khandeshwar, Navi

Department of Civil Engineering, Anjuman-I-Islam's Kalsekar Technical Campus, Panvel, Navi Mumbai, Maharashtra, India
*Corresponding author email- mominhammad5153@gmail.com

Mumbai. The area is strategically located near the Khandeshwar local railway station as well as the soon-to-be-developed Navi Mumbai International Airport and thus is an ideal representative of an emerging transit-oriented center. It now does not have the specialized infrastructure to accommodate convenient and safe walking and cycling, compelling a coercive transition towards motorization even for short-distance trips. The overall aim of this project is to create a detailed, context-relevant NMT plan for the Khandeshwar area. This requires a thorough analysis of the current infrastructure, gap identification, and analysis of the local population's mobility needs and patterns, including "captive users" with no alternative.

2. RESEARCH METHODOLOGY

The primary purpose of this research is to check out the rules and guidelines for non-motorized transport. This research is stick with the Panvel-Khandeshwar area since it's a good spot. Next, gather info by looking around and asking people (especially students and commuters) about what's missing in terms of walkways and bike paths. The subsequent phase involves primary data collection, utilizing field observations and user surveys (specifically targeting captive users such as students and commuters) to identify existing deficiencies in pedestrian and cycling infrastructure. This analysis will inform the development of a conceptual NMT system plan, including the determination of optimal route alignments and design specifications. Following the design, a detailed data analysis phase will be undertaken, involving GIS-based mapping and statistical validation to assess the feasibility and efficacy of the proposed network. The economic viability will be established through a Social Benefit-Cost Analysis (S-BCA), which will quantify the project's costs against its tangible social, environmental, and health-related benefits. The research concludes with the presentation of the results, a final conclusion, recommendations for future scope, and a comprehensive list of references.

Policy and Framework (IRC Design Principles: 2011-2015)

Review existing institutional support, legislative and regulatory framework (India's Ministry of Urban Development To gauge the city's preparedness to put NMT first in terms of institutional support, plans, policies, investment, and implementation Develop a checklist of transportation institutions and their mandates. Evaluate them on their willingness and experience in assisting NMT initiatives Check existing policies, plans, and review them in light of NMT principle Some of the plans and policies to be checked: State Urban Development and Transport Policy [15][16][17][18][19][20][21][22]

Site Selection

For this study of non-motorized transport, Khandeshwar and Panvel railway stations in Navi Mumbai have been selected as focal research locations. They are important nodes in a fast-growing semi-urban cityscape. Both stations experience a high amount of mixed pedestrian traffic consisting of a large student base from well-known nearby institutions (like AIKTC, MGM, and Pillai College) and numerous commuting professionals destined for Mumbai. In addition, the strategic value of these locations is compounded by their nearness to upcoming growth drivers, primarily the Navi Mumbai International Airport and the new headquarters of the Panvel Municipal Corporation. This combination of existing high usage and future development potential positions them as ideal case studies for the demand and integration of non-motorized transport solutions.

Field Observation

Field observations at major transport points, mostly the Khandeshwar and Panvel railway station complexes, were made during peak morning and evening hours to get a sense of the prevailing mobility patterns. The observations are strongly supportive of the quantitative data gathered in the Origin-Destination survey. A key characteristic of the region is the huge, time-critical stream of commuters. It was seen that a large number of students and working professionals leave the railway stations and proceed to find transport for the remaining part of their journey forthwith. This places a high burden on last-mile connectivity. The main mode of transport serving this demand is the auto-rickshaw. Long, frequently uncoordinated queues of rickshaws and their passengers were a frequent sight, and this resulted in local traffic congestion and bottlenecks around the station exits. This heavy use of motorized transport, even for fairly short distances to local destinations such as AIKTC, Pillai College, and other local commercial areas, is a major conclusion. Most importantly, the current infrastructure is not capable of addressing this requirement in a sustainable manner. There is an obvious lack of special infrastructure for Non-Motorized Transport (NMT). Some places have footpath but they are not properly maintained and some places don’t have footpath at , and thus pedestrians must walk on the main carriageway. Special and secure bicycle lanes do not exist. This compels the full commuter burden onto motorized modes, adding congestion, emissions, and costs for users. Analysis of these short-distance journeys (less than 5 km) is a straightforward opportunity. The existing, inefficient system can be considerably enhanced by adding secure, dedicated NMT facilities since the travel distances are very suitable for walking and cycling. The existing ambiance, however, makes them unsafe and inconvenient, leaving commuters with no alternative but to adopt rickshaws.

Origin and Destination Survey

Survey of Traffic Volume. There are two main types of traffic volume surveys: intersection volume and midblock volume. Traffic volume counts are usually recorded over 16 hours (6 AM to 10 PM) to capture all peak hours in order to calculate the peak hour factor. Only rickshaw passengers are eligible to complete this origin and destination survey

.

Table 1 Origin and destination data only for rickshaw riders

Origin	Destination	Trip Purpose	Weekday Trips (Avg)	Sat Trips	Sun Trips
Khandeshwar Station	AIKTC College	Student	2,960	1,480	15
Khandeshwar Station	Khanda colony	Professional	26,250	21,000	2,625
Khandeshwar Station	Various locations		2,916	3,499	4,374
Khandeshwar Station	Other Colleges	Student	2,516	1,258	33
Khandeshwar Station	NMIA Airport	Airport Travel	800	880	960
Khandeshwar Station	New Panvel Municipal Corp.	Official/Visitor	600(app)	0	0
Panvel (General)	Pillai College	Student	740	370	0
Panvel Railway Station	NMIA Airport	Airport Travel	338(app)	372	406
Panvel Railway Station	New Panvel Municipal Corp.	Official/Visitor	226(approx.)	0	0
T. trips			37,346	28,859	8,413

3. RESULTS AND DISCUSSION

Create A Hypothetical Route of a Non-Motorized Transportation System

Non-Motorized Vehicles (NMV) include cycles, tri-cycles, cycle rickshaws, pushcarts, and any other form of mobility that is powered by humans. These users are also called 'captive cyclists'(Non Motorised Transport Planning and Design Guideline, 2014). NMV plays an important andunique role in efficient transport systems. It is the most affordable mode of transport for groups of all ages and income groups covering diverse accessibility needs. Urban local bodies should create city-wide NMV network plans based on need assessment, to ensure that the roads and streets are safe for cycling [23].

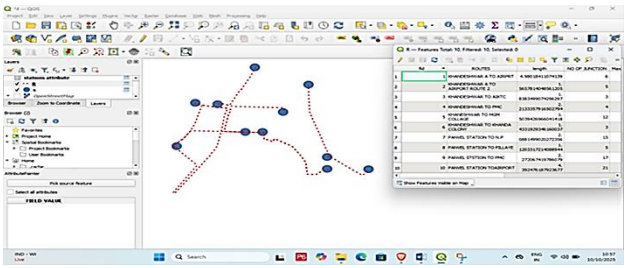


Figure 1 Stations and route length. Source: QGIS

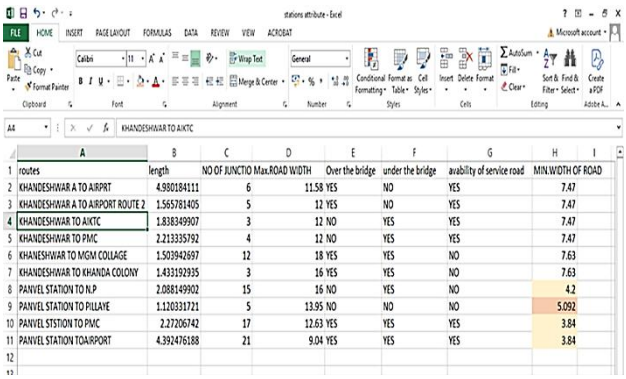
Figure 2 Open Street Map in QGIS source: Author's documentation 2025

Quantitative Data Analysis

To identify potential cycling routes, a connectivity analysis was conducted using the QGIS platform. The project area and suggested station locations were displayed using the OpenStreetMap (OSM) plug-in, and the attribute table contained the X and Y coordinates for each station. Although there is space available, it is severely constrained, according to a suitability analysis of the finalized routes. As a result, the most practical choice was a Class 2 cycle path, for which a pile-based cycling system is the best option [24].

Table 2 longitude and latitude of stations. Source QGIS

No.	x	y	STATION NAME
1	73.093	19.007	KHANDESHWAR STATION A
2	73.098	19.006	KHANDESHWAR STATION B
3	73.105	19.016	MGM COLLAGE
4	73.110	19.004	KHANDA COLONY
5	73.119	18.990	PANVEL STATION A
6	73.119	18.993	PANVEL STATION B
7	73.115	19.011	NEW PANVEL D. MART
8	73.127	18.990	PILLAYE COLLAGE
9	73.106	19.000	PMC
10	73.103	19.000	AIKTC
11	73.090	18.996	AIRPORT



routes	length	NO OF JUNCTIO	Max.ROAD WIDTH	Over the bridge	under the bridge	avability of service road	MIN.WIDTH OF ROAD
KHANDESHWAR A TO AIRPRT	4.980184111	6	11.58	YES	NO	YES	7.47
KHANDESHWAR A TO AIRPORT ROUTE 2	1.565781405	5	12	YES	NO	YES	7.47
KHANDESHWAR TO AIKTC	1.838349907	3	12	NO	YES	YES	7.47
KHANDESHWAR TO PMC	2.213335792	4	12	NO	YES	YES	7.47
KHANESHWAR TO MGM COLLAGE	1.503942697	12	18	YES	YES	NO	7.63
KHANDESHWAR TO KHANDA COLONY	1.433192935	3	16	YES	YES	NO	7.63
PANVEL STATION TO N.P	2.088149902	15	16	NO	YES	NO	4.2
PANVEL STATION TO PILLAYE	1.120331721	5	13.95	NO	NO	NO	5.092
PANVEL STSTION TO PMC	2.27206742	17	12.63	YES	YES	YES	3.84
PANVEL STATION TOAIRPORT	4.392476188	21	9.04	YES	YES	YES	3.84

Figure 3 Attribute table Source: Authors' Documentation

Types of Public Bicycle Sharing Systems (PBS)

Public Bicycle Sharing Systems Public bicycle sharing systems can be described as high-quality, bicycle-based public transit systems used on a shared, short-term basis, and typically combining with public transport for last-mile connection services. Designs are infrastructure-dependent and can usually be divided into:

i. Station-Based Dock-Based Systems: Cycles are dispatched, and retrieved to fixed, dedicated/universal docks with designated stations in a city. Examples of such an implementation model include one based on Public-Private Partnerships (PPP) or publicly owned, privately operated systems. User identification and tracking are typically done using smart cards or mobile apps.

ii. Free-Floating (Dock-less) Systems: Bicycles are not docked and can be locked and left at parking locations, commonly, but not exclusively, within a geofenced area operated commonly with a

mobile app and GPS tracking. Despite the model commonly being based upon an organization of private providers with city government licenses.

iii. Bicycle Rental (different from Sharing): Sometimes bicycle rental can be said to be an early type of PBS but mostly they are characterized by not being the actual PBS, in the sense that they mostly require the cyclist to pick up a bike, and bring it back to the same location, normally for longer-term rental, or a way trip (one place). Actual PBS, is simply an experience of the way one trip to another destination from any of the many stations

Modal Shift Percentages (Potential Users of the System)

Not all riders will switch to bicycles. We think, because of reports in literature and case studies that you're very likely to find a research study from a similar city in India, which showed that students were the earliest and more frequent adopters of a newly introduced bike system. So, student will be assigned the highest modal share of 20 percent to define the percentage of the total riders who might switch to bikes. Presumably, a percentage of riders from your survey would be willing to use the bike system based on their trip purpose [25].

Table 3 Table no 3. Modal Shift Program

Trip Purpose	Assumed Modal Shift	Rationale
Student	20%	High potential. Short-to-medium distances, cost-sensitive users.
Professional	10%	Medium potential. Good for last-mile connectivity from the station.
Official/ Visitor	15%	Good for short, official trips (e.g., station to Municipal Corp.).
Airport Travel	5%	Low potential due to luggage, but useful for staff or single-bag travellers.
Other	10%	Conservative average for various trip types.

The above reports to be important because they utilize information mutual transferred from any of by way of organizations, like the Institute for Transportation and Development Policy (ITDP), the World Bank, or academic journals, on possible modal shifts accomplished elsewhere in their literature surveys, and it is reasonable to assume that your bike system might see similar shifts based on trip types.

Peak Hour Demand Calculation

A bike system must handle the morning rush hour. We assume 20% of all daily bicycle trips will happen during the single busiest hour (e.g., 8:30 AM to 9:30 AM).

Example Calculation (Khandeshwar Station): Professional trips to Khanda Colony: 26,250 (total trips) × 10% (modal shift) = 2,625 bikes Trips/day. Morning peak hour trips from Khandeshwar: (2,625 / 2) × 20% (peak hour factor) ≈ 263 bikes departing in one hour. This process was repeated for all routes originating from each station.

Table 4 Required number of cycles and dock

Station	Suggested Number of Bicycles	Required Docks	Key Role
Khandeshwar Station	400 - 450	600+	Mega Hub (Origin)
Khanda Colony	50 - 60	400	Destination (AM), Origin (PM)
AIKTC College	25 - 30	100	Destination (AM), Origin (PM)
MGM College	20 - 25	80	Destination (AM), Origin (PM)
Pillai College	25 - 30	50	Destination (AM), Origin (PM)
Panvel Railway Station	20 - 25	40	Minor Hub (Origin)
Panvel Municipal Corp.	10 - 15	30	Destination
NMIA Airport	10 - 15	30	Destination
Buffer/Maintenance Fleet	50 - 60	-	System-wide
TOTAL FLEET	650 Bicycles		

This paper gives a complete proposal for a sustainable bicycle-sharing system along the Khandeshwar-Panvel road of Navi Mumbai, which will help solve last-mile connectivity issues. Our field traffic survey revealed high dependence on auto-rickshaws by students and working professionals and quantified a daily requirement of 37,346 trips, which justifies the need for an alternate mobility option. Utilizing QGIS in geospatial analysis, we planned a 25 km theoretical route between 8 strategic locations at major hubs such as Khandeshwar Station, different colleges, and the NMIA airport. The plan practically includes segments of mixed-traffic lanes where dedicated Class 2 bicycle lanes were not practically viable due to spatial limitations.

4. CONCLUSIONS AND FUTURE SCOPE

Our research indicates that implementing a bicycle-sharing system in Khandeshwar-Panvel is an extremely intelligent and pragmatic solution. It will address the problem of daily travel for individuals who have to travel from the station to college, office, or residence. We discovered that more than 37,000 individuals pass through the corridor each day, with rickshaw only and other passengers are other approving there is a vast, existing market for this service. We have designed a full plan with 8 stations along a 25 km route connecting all the key locations.

Moving forward, this research presents some very promising directions for future research and development. The first thing to do immediately is to convert this study of feasibility into a proper Detailed Project Report (DPR) using comprehensive engineering surveys to facilitate tendering and raising funds under the suggested PPP model. Outside of implementation, the network must be extended to other major nodes in Navi Mumbai such as Kharghar, Belapur, and Seawoods to form an integrated mobility plan that interfaces seamlessly with the train, bus, and the new Metro through a single payment system. For improved accessibility by users and coverage, a follow-up study might consider evaluating the advantages of adding electric bicycles (e-bikes) to the fleet so that it is simpler to travel across flyovers. Operationally, the real-time data from the intelligent system would be utilized to create AI models for dynamic rebalancing and

predictive maintenance, increasing efficiency. Lastly, once the project is up and running, a comprehensive socio-economic impact survey must be performed to evaluate its success based on analysing carbon emission cuts, commuter savings, and public health improvements.

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