ATINER's Conference Paper Proceedings Series
TRA2023-0301
Athens, 29 September 2023

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ATINER's Conference Paper Proceedings Series
TRA2023-0301
Athens, 29 September 2023
ISSN: 2529-167X

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ABSTRACT

Throughout the last twenty years, the environmental debate was deeply marked by the concept of sustainable development. More recently, with the mounting concern over the extent of the earth's climate change, new paradigms have been emerging and rapidly moving from the academia to the political arena. Among these, the low-carbon cities paradigm is standing out as a serious and coherent attempt to introduce in the global environmental debate a more pragmatic approach, based on measurable targets. Low-carbon cities emphasize, in the first instance, the importance of our cities and metropolitan areas as key producers of carbon dioxide in an increasingly urban world. Non-motorized transport (NMT) has gained a lot of importance over the past few decades since it is a mode of transportation that is safe, comfortable, and sustainable in terms of cost and energy use and is a healthy alternative to the fast lives of people these days. Hence it is an upcoming need of the hour but is always underrated due to the unavailability of proper and safe infrastructure which includes footpaths, bicycle tracks, and comfortability for pedestrians and cyclists. Nevertheless, to achieve efficient NMT usage, there should be a well-planned strategy to lessen the usage of private vehicles and provide an efficient development plan to make cities NMT-friendly. However, most of the cities in India have undergone urban sprawl i.e., low-density development in a linear growth manner, and hence providing fully walkable cities is greatly challenged for the urban planners/city administrators. Smart Growth Principles, such as compact development and Transit Oriented Development along with efficient feeder systems are required to bring about high-density-mixed land-use development. It encourages mixed-use development with a diversity of housing alternatives, that are compact and transit-oriented so that it can promote walkability and cyclability. Keeping the aforesaid knowledge in mind, the authors have chosen Kochi city as the study region for further detailed investigation. In this research study, authors have attempted to explore the current state of non-motorized transport networks in the study region, by mapping the accessibility to NMT infrastructure employing ArcGIS. Finally, based on the findings, the study concludes design strategies through principles *of Transit Oriented Development (TOD) which can pave the way to building a compact city and navigating towards achieving Low-Carbon Development in Kochi city.*

Keywords: *Urbanization; Nonmotorized transport; Smart Growth; Compact city; TOD; Low Carbon Development*

Introduction

Transportation that is not powered by a motor is often referred to as non-motorized transportation. Typically, it involves cycling and walking. Over the past few decades, NMT has grown in significance because it is a generally safe, comfortable, and cost- and energy-efficient alternative to today's fast-paced lifestyles. It also minimizes pollution. To live sustainably, non-motorized is essential.

Despite the benefits mentioned above, non-motorized transport modes are consistently undervalued because there is a lack of NMT infrastructure due to encroachment on walkways, poor or non-existent walkway conditions, or a lack of walkways altogether, all of which discourage people from walking. A proper NMT infrastructure should have bike lanes and continuous, appropriate walkways that are both comfortable and safe for both cyclists and pedestrians to utilize. Therefore, a well-planned strategy to reduce the use of private vehicles and offer an effective development plan making cities NMT friendly should be in place to achieve efficient NMT usage.

Figure 1. *Metro Transit Line*

Source: Google Earth

People are becoming more dependent on practical transportation options in this rapidly developing economy, which has led to a significant rise in the number of private vehicles on the road and a drop in the usage of public transportation, including buses and metros. The comfort and convenience of traveling in one's own space, along with the element of privacy, safety, and cleanliness that is often absent in the public transportation system, makes private automobiles a preferred choice for transit around the city.

Kerala's district of Ernakulam is where the City of Kochi is located. The Government of India has ranked Kochi as a Tier II city. In the State of Kerala, it is the metropolitan area with the highest population. The Cochin Municipal

Corporation is the civic authority in charge of running the city. For many years, Kochi—also known as the "Queen of the Arabian Sea"—was the hub of the Indian spice trade. Cochin Stock Exchange, the Southern Naval Command of the Indian Navy, and state offices are located in Kerala's commercial center. The transportation system in Kochi is well-connected in all available ways. The city of Kochi has Kerala's second-highest population density 6340 people per Km2.

Figure 2. *Broken Footpath in Study Area*

The city has disregarded the needs of bicycles and pedestrians. Kochi's inadequate or nonexistent pedestrian infrastructure reflects poor city design and a lack of consideration for persons who prefer to stroll. The lives of pedestrians are a living nightmare due to poorly constructed sidewalks, broken slabs covering drains, uneven surfaces, moving or parked cars in pedestrian areas, invasion by vendors and hawkers, and rubbish lying about. Despite Kochi Metro Rail Ltd.'s (KMRL) efforts to build walkways along the metro line and other specific regions, there hasn't been a significant attempt to build thoughtfully-planned walkways in the city.

Pedestrians and cyclists have been neglected by the city. The non-motorized transport mode share for the city was 15%, with walking trips accounting for 12%, while cycling trips accounted for the remaining 3%. Although 15% of the roads have footpaths on both sides, there is a lack of infrastructure for cycling, despite the establishment of a public bicycle-sharing system by KMRL. The Non-

Motorized transport facilities have a Level of Service D, as per the Comprehensive Mobility Plan

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The Cochin Smart Mission Limited (CSML) is constructing temporary cycle lanes throughout the smart roadways to promote cycling in Kochi. According to a statement from CSML, the bike lanes are intended to promote cycling as a safe, healthy means of transportation. Six city arterial roads will now have the designation of smart roads thanks to a decision made by the agency.

Aim & Objective of the Research

The objectives of this research are:

1. To analyze and understand the user characteristics of existing mass transit stations and their influential zones in the study region.
2. To assess the mobility patterns and understand the existing scenario of accessibility level in the public transport system.
3. To determine the connectivity Index of the network and to explore factors that decide the functions of NMT modes to develop the Walkability Index (WI) and Bikeability Index (BI)
4. To evolve the model and to recommend strategies & guidelines to enhance last-mile connectivity and promote low-carbon development in the study region

Literature Review

Various journals & articles were referred to for understanding the necessary parameters that are important to provide a qualitative and quantitative assessment of the infrastructural facilities that are available in the city.

Table 1. *Literature Review 1*

Title of Article	The Walkability Of Transit-Oriented Development (TOD): A Case Study Of Bangkok Metropolitan, Thailand
Objective) of the Article	• provide a system or framework to help planners enhance the walking environment of TOD planning and suggestions for enhancing walkability to boost connection and encourage ridership
Data used in the article	sidewalk width, walking condition, planter strip, trees, block connection, flow, and network, curbing, street width, density, garage, distance from home to the street, surveillance to the street, minimum hours of significant activity, level of mixed-use
Summary	• As evidenced by the efforts of governments and corporate operators, notably in transport projects, urban connectivity challenges become significant in this region and call for proactive measures. • There is a strong correlation between commuters' transit use, walkability behavior, and socioeconomic status, all of which are related to their level of satisfaction with walkability.
Conclusion	• The survey found that while some important elements, such as increased street width and greater connectivity, are at a high level, satisfaction with physical changes is moderate to high. • The features of responders who were born within 500 meters of the station required a lot of upkeep of a decent physical environment to go to the station.

Source: (P. Iamtrakul, 2021)

Table 2. *Literature Review 2*

Title of Article	Developing A Bikeability Index In The Context Of Transit-Oriented Development (TOD)
Objective) of the Article	• To develop a bike-ability index (BI) in the TOD zone and hence analyze the different spatial scales of TOD
Data used in the article	The maximum speed of motorized vehicles, Traffic disruption, Intersection density, Bicycle lanes density, Cycling Route Directness, Pavement quality, Street lighting quality, Bicycle lanes along natural environment, Slope percentage of bicycle lanes, Quality of bicycle parking condition at the train station
Summary	• In urban areas, traffic and intersections are more frequent, making it difficult for cyclists and pedestrians to access a train station. Therefore, traffic conditions are worse in urban stations, whereas suburban stations have slightly better connectivity. • Suburban areas located near water canals or built-up cycling networks are ranked higher than urban areas with more built-up space in terms of cycling and pedestrian environment.
Conclusion	• The developed bike-ability index offers a comprehensive perspective on the determinants of cycling behavior as a feeder mode to transit, thus providing valuable insights for policymakers interested in enhancing indicators associated with infrastructure provision and promoting non-motorized transport policies in the context of transit-oriented development.

Source: (Developing a bikeability index , July 2017)

Table 3. *Literature Review 3*

Title of Article	**Estimating use of non-motorized infrastructure: Models of bicycle and pedestrian traffic in Minneapolis, MN**
Objective) of the Article	• This research paper presents a summary of cyclist and pedestrian counts in Minneapolis city. • The study develops scaling factors that can be used to estimate 12-hour daily counts from hourly counts of non-motorized traffic. • The paper also presents two models, i.e., ordinary least squares and negative binomial regressions, for estimating non-motorized traffic in the city. • The validity of each model is confirmed through a comparison with bicycle and pedestrian counts, and the resulting estimates of non-motorized traffic are reported for every street in Minneapolis
Data used in the article	The variables considered in this study include counts of bicycles and pedestrians, weather conditions, socio-demographic characteristics of the neighborhood, characteristics of the built environment, and road features such as the presence of a bus line or type of bicycle facility.
Summary	• The research methodology included compiling data on non-motorized traffic, creating independent variables, analyzing descriptive statistics, establishing scaling factors, and constructing regression models for cycling and pedestrian traffic. The study focused on collecting traffic data for bicycles and pedestrians in Minneapolis, MN, and developing statistical models to estimate non-motorized traffic for roads and sidewalks where counts were not conducted
Conclusion	• Taking into account the aforementioned factors, there was a gradual rise in bicycle traffic over time, which was found to be more prominent on roads with dedicated bicycle facilities compared to those without, and reached its peak on off-street facilities. This observation was made in the context of the research study.

Source: (Steve Hankey, 15 September 2012)

The aim of the study published in the Journal of Urban Design, Volume 23, by SMona Jabbari, Fernando Fonseca, and Rui Ramos (Oporto, 2018), was to create a tool to evaluate the pedestrian network's walkability and connectivity in Oporto. The study utilized a GIS-based integrated approach that incorporated multi-criteria and space syntax analysis to assess the pedestrian network. The multi-criteria analysis included four criteria and nine sub-criteria that majorly impact walkability, while space syntax was used to measure street connectivity. According to the findings of the study, green spaces are linked to higher walkable scores and create more appealing walking environments that have a positive impact on microclimatic conditions. The study also indicates that improving public transportation coverage, particularly by installing intelligent transportation systems at bus stops, is vital in decreasing car dependency. In conclusion, the study highlights that green spaces are a significant factor in creating appealing and walkable environments, and that enhancing public transportation coverage is crucial to reducing car dependency. GIS-based integrated approaches, such as multi-criteria and space syntax analysis, provide a useful tool for assessing pedestrian networks. The indicators and factors used in the study include land use, public transportation accessibility, urban function, green spaces, climatic conditions, and intelligent transportation system facilities.

The study titled "Integrating Bicycle Network Analysis in Urban Design: Improving bikeability in Trondheim by combining space syntax and GIS methods using the Place Syntax tool" by Bendik Manum and Tobias Nordstrom (Bendik Manum, 2013) presented at the Ninth International Space Syntax Symposium in Seoul in 2013 aimed to improve bikeability in Trondheim by integrating bicycle network analysis into urban design using space syntax and GIS methods. The study's primary objective was to compute bikeability and compare the results with real bicycle routes to provide design guidelines that would minimize carbon emissions. To achieve this, the researchers used space syntax-based methods for analyzing the bikeability of street networks and compared the results with actual people's bicycle routes. The Place Syntax tool, developed at the Royal Technical University in Stockholm, Sweden, was used to combine space syntax analysis and GIS. The tool combines space syntax concepts for modeling urban space with GIS-based descriptions of attractions/destinations, resulting in a combined accessibility analysis.

The study concluded that urban planning and urban form can play a significant role in increasing bicycling and identified several issues related to urban form and people's daily travel modes. One of these issues is the accessibility properties of the bicycle route network, which includes all streets, lanes, and paths where cycling is possible, allowed, and relatively safe. The study provided guidelines for urban design and evaluated their effectiveness. The factors identified in the study, including safety, bicycle lane width, connectivity, and traffic, are relevant for understanding bicycle friendliness and computing the Bikeability Index of the street network. Overall, the study highlights the importance of integrating bicycle network analysis into urban design to promote sustainable transportation and reduce carbon emissions.

In 2016, Jay Shah and Bhargav Adhvaryu (Jay Shah, 2016) conducted a study that was published in the Journal of Public Transportation. The study aimed to assess the levels of accessibility of public transportation and highlight its significance in urban planning. The researchers utilized a methodology that was originally developed by the London Borough of Hammersmith and Fulham, which was later adopted by Transport for London (TfL), and customized it to fit the city of Ahmedabad, India. To generate a visual representation of Public Transport Accessibility Levels (PTAL), the researchers employed a GIS mapping tool that factored in various variables such as average walking speed and time, distances to public transport stops, and peak-hour route frequencies of different modes of public transport. The study concluded that PTAL maps could be beneficial to urban planning authorities in integrating land-use zoning with public transport accessibility, prioritizing public transportation and its corresponding investments, formulating parking policies, and creating transit-oriented zoning regulations. The variables considered in computing the accessibility level of PT, such as average walking speed and time, distances to public transport stops, and peak-hour route frequencies of different modes of public transport, are pertinent and can be utilized in similar studies.

In the context of low-carbon development (Subash Dhar, August 2013), interventions can be made on both the demand and supply sides to reduce transport emissions. Demand-side interventions aim to reduce the number of trips taken, increase the modal share of non-motorized transport, and shift demand from private vehicles to public transport. This can be achieved by creating an urban form that integrates non-motorized and public transport, thereby making public transport more accessible. However, to effectively manage the demand for passenger transport, it is essential to build and maintain high-quality infrastructure for non-motorized transport and provide reliable public transport. A framework for low-carbon development should take into account urban form, non-motorized transport, public transport, and technology, and should evaluate the impact of alternative strategies on mobility, safety, and the local environment, as well as more aggregate indicators such as $CO2$ and energy use. While it is difficult to find a single model that can estimate all of these indicators, various documents can be studied to understand the current condition of infrastructure facilities for pedestrians and cyclists.

Materials and Methods

The tool used for the various analysis done in the paper is ArcGIS. The Public Transport Accessibility Level was computed statistically and the PTAL values were mapped in GIS using Fishnet Analysis. Walkability Indexing and Bikeability Indexing were done using the Weighted Overlay Tool in ArcGIS.

The study was conducted around the TOD buffer zone around selected metro stations which were primarily selected using the metro ridership data obtained, Landuse around the metro stations, and considering the metro access trip mode share.

A buffer zone of 1.5km was then plotted around the selected metro stations and then the Walkability& Bikeability Indices were calculated. To understand the level of accessibility to Public Transport the PTAL levels were calculated and mapped.

Analysis & Results

Public Transport Accessibility Level-PTAL Analysis

Public Transport Accessibility Levels (PTAL) are based on average walking distances, times, speeds, and the peak-hour frequency of various public transport modes. The technique used to conduct an accessibility analysis of public transport is as follows:

1. The first step involves defining Points of Interest (POI) and Service Access Points (SAP), which refer to public transport stops such as bus stops or metro stations.
2. Next, the walk access time from each POI to SAP is calculated based on the actual road network distance and a walking speed of 4.8 km/h. The

maximum walk times for bus and metro rail are 8 and 12 minutes, respectively.

3. Valid routes are identified at each SAP and the average waiting time (AWT) is calculated, which is the sum of half of the hourly frequency of services and a reliability factor K.
4. The minimum total access time (TAT) is then calculated for each valid route at each SAP, which is the sum of the walk access time and AWT.
5. TAT is then converted into the equivalent Doorstep Frequency (EDF) by dividing 30 by TAT.
6. The Accessibility Index (AI) is obtained for each POI, assigning a weighting factor of 1.0 to the route with the highest frequency and 0.5 to all other routes.
7. Finally, the AIs obtained for each POI are allocated to eight bands of Public Transport Accessibility Level (PTAL), resulting in a mapped PTAL.

Figure 3. *PTAL Mapping Edappally*

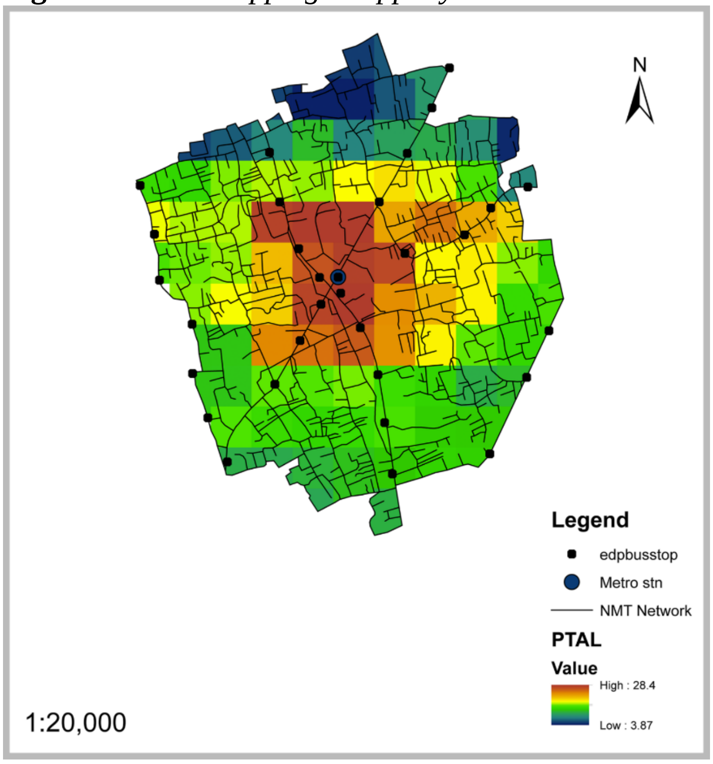
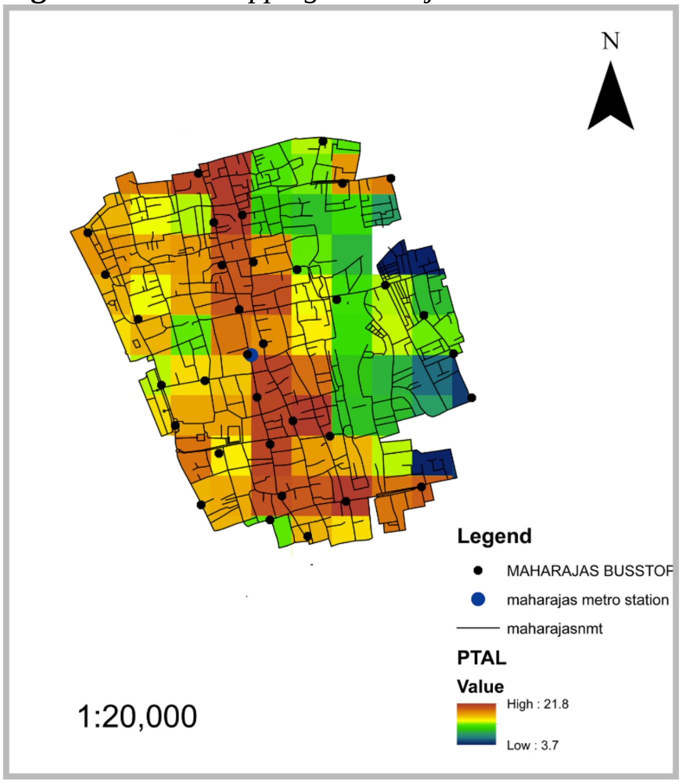


Figure 4. *PTAL Mapping Maharajas*



Walkability Index and Bikeability Index Analysis

Walkability and Bikeability Indices were calculated using Weighted Overlay in ArcGIS. The analysis was done in the following manner.

1. Many criteria are considered to determine the walkability concerns around the metro station.
2. The weights for these criteria are then assigned, and each component is given a weight based on the user's preferences.
3. The weighted index for each stretch is then determined. utilizing ArcGIS's Weighted Overlay tool to map the relevant components.
4. The DepthMapX software was used for Space Syntax Analysis to examine street connectedness.
5. Equal weights are given to the street connectivity and walkability criteria once values have been normalized.
6. The maps are overlaid to produce the final Walkability Index and Bikeability Index, which are superimposed.

Space Syntax was used to examine the network's Connectivity Index. The term "connectivity" describes how physically connected and spatially configured various spaces or locations are to one another within a constructed environment. High connectivity and prominent location make spaces more visible and accessible, which may make them more appealing to people. Lower values in blue suggest regions that are more dispersed and challenging to travel, while higher values in red indicate areas that are more interconnected and simpler to go through.

A network is used to visualize the spatial arrangement of a built environment, with the spaces serving as the nodes and the connections between them as the edges. It is easy to determine which spaces are most connected to one another, which spaces are most central to the network, and which spaces are most isolated or peripheral by examining the attributes of this network.

The Walkability index and Bikeability index were determined and examined for a 1500-meter buffer zone surrounding the chosen metro stations. For the analysis, several factors that affect walkability were taken into account, including the presence of infrastructure, safety, comfort, green spaces, climatic conditions, the material of the footpath, drainage conditions, and land use Similar parameters, such as traffic volume, bike lane width, and bicycle parking spaces, were taken into account for the bike-ability analysis. Then, to calculate the Index, the Weighted Overlay Method was used.

Figure 5. *Walkability Index Mapping around Edappally Metro station*

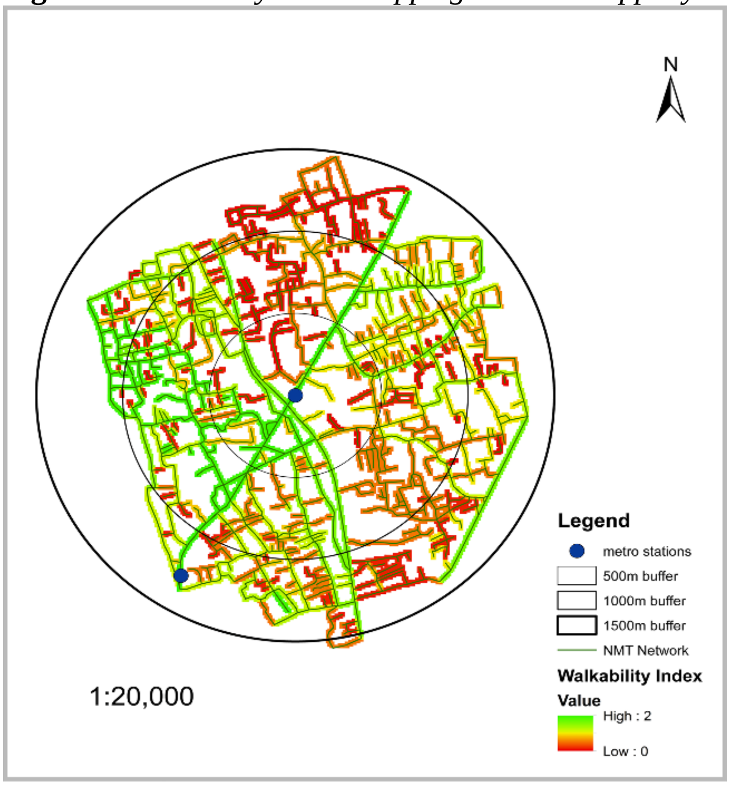


Figure 6. *Bike-ability Index Mapping around Edappally Metro Station*

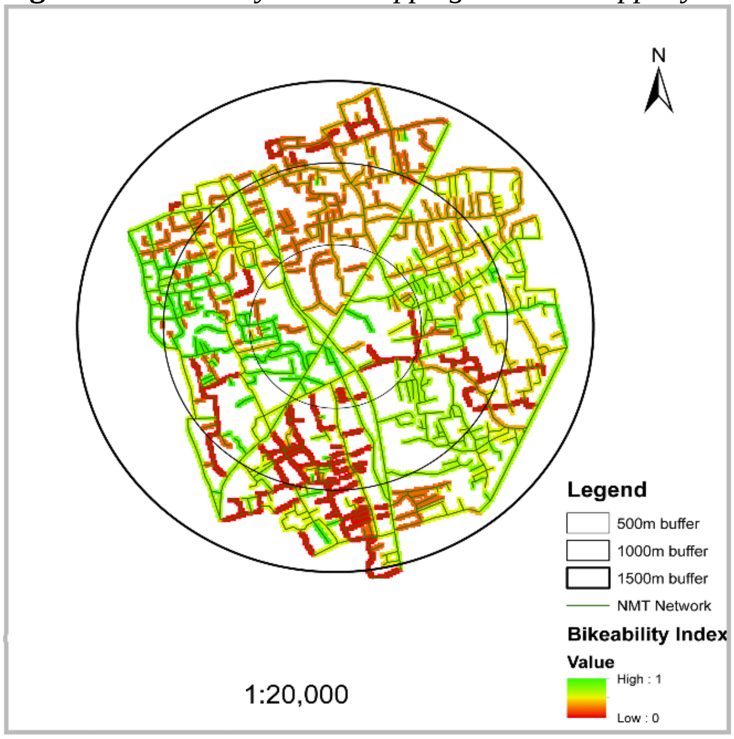


Figure 7. *Walkability Index Mapping around Maharajas Metro Station*

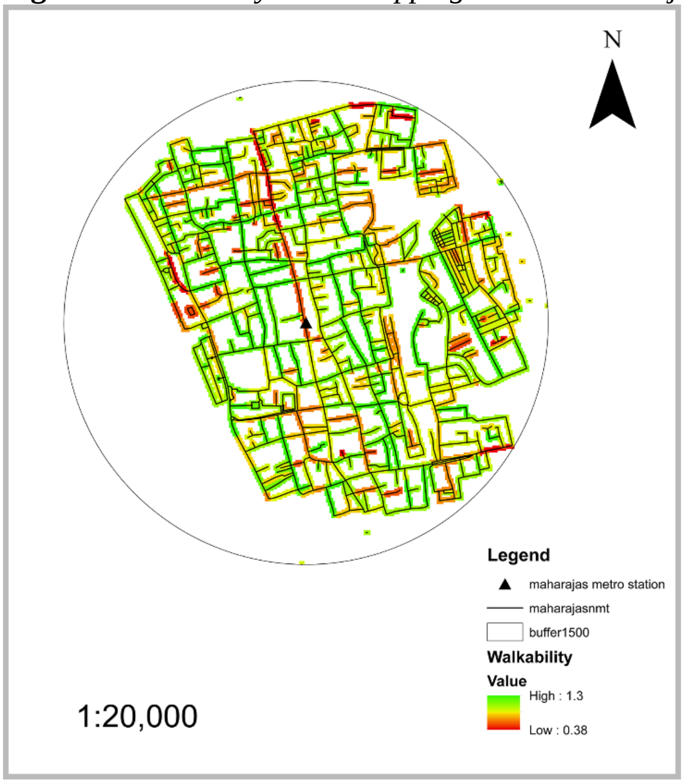
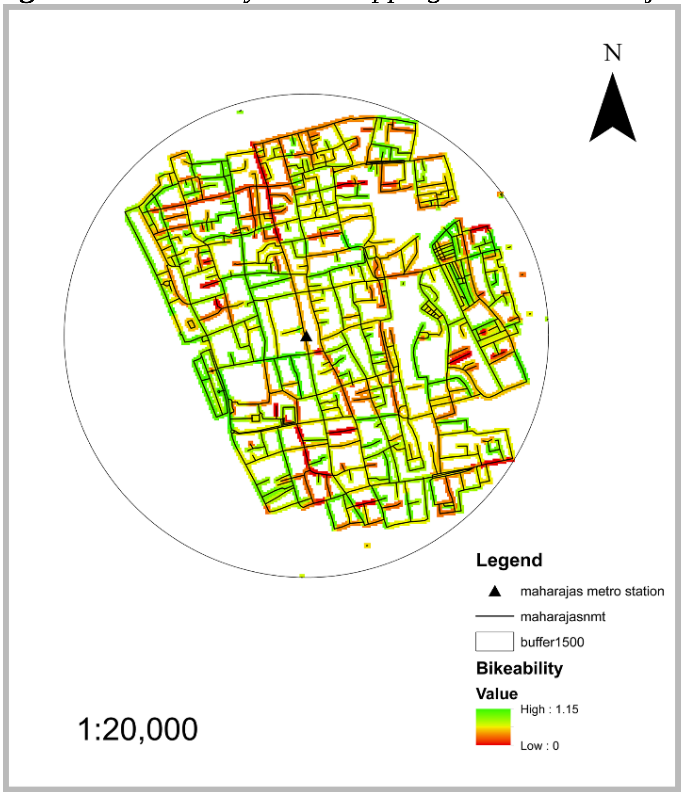


Figure 8. *Bike-abilityIndex mapping around Maharajas Metro Station*



Cycle Routing

Network Analyst in ArcGIS provides a set of tools for performing network analysis on transportation networks. With the ArcGIS Network Analyst extension, users can effectively tackle various network-related issues. These may include determining the most efficient route across a city, locating the nearest emergency facility or vehicle, identifying the service area around a particular location, optimizing fleet management to fulfil a set of orders, or selecting the most appropriate facilities to operate or shut down.

This analysis was done primarily for Maharajas metro station because there is an existing cycle lane in the study area and the buffer zone is a prime CBD area in the region.

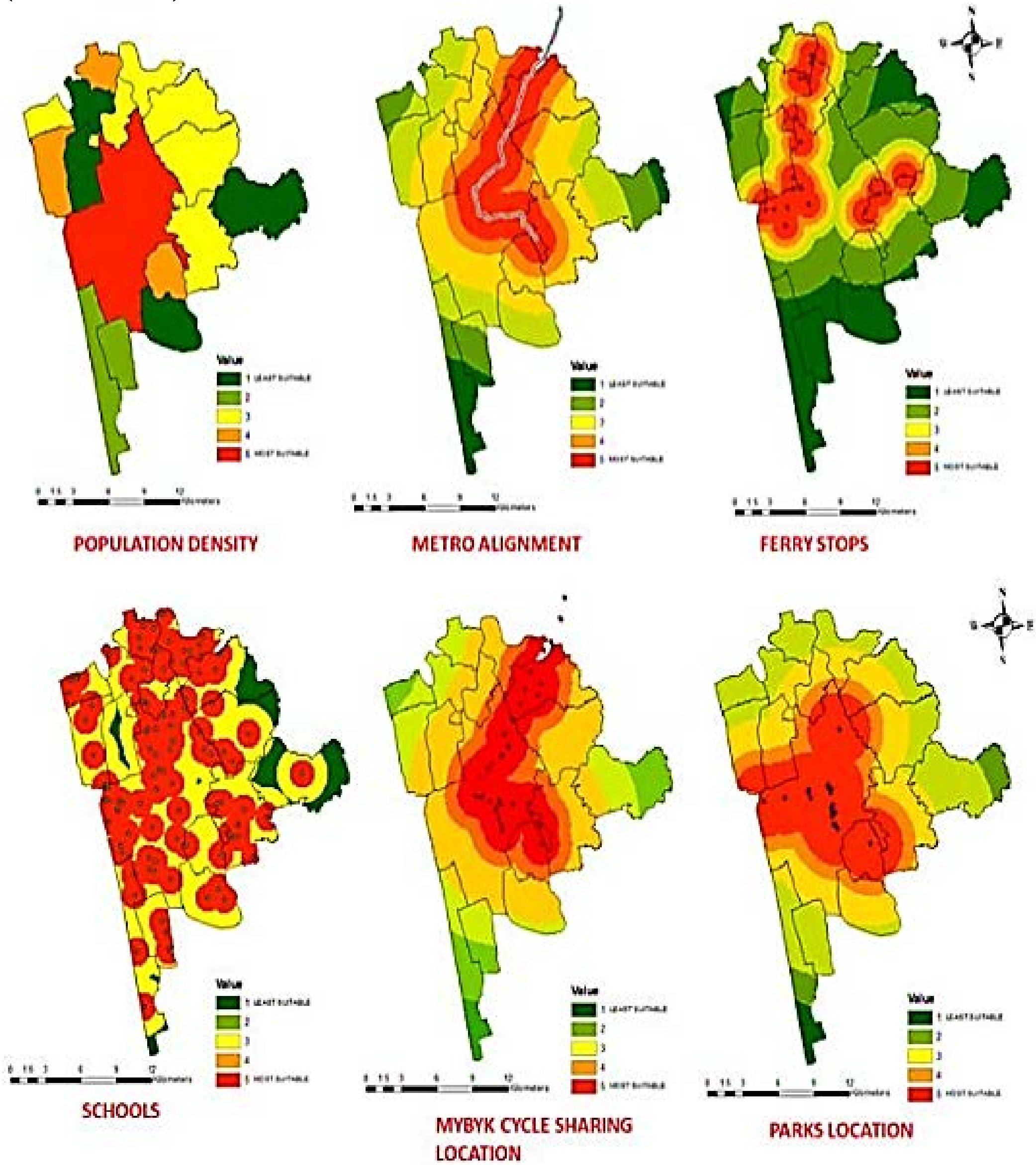
The shortest route method provides an optimal path from location A to location B (either quickest or shortest) along lines within a network. This was done to understand the most cyclable route in the network and hence find out the shortest paths which can be taken by pedestrians and cyclists alike. Major activity areas were connected to the metro station as shown.

Figure 9. *Cycle Routing around Maharajas Metro Station*

Some Theoretical Studies conducted on Walkability and Bike ability

A recent study (Soltanian, 2022) for the Kochi City Region considered various determinants for bicycle planning the demand-based determinants include Land use and Population while the supply-based determinants include transportation networks, locations of transit hubs, schools, recreational areas, existing cycling infrastructure, etc. To identify the most suitable areas to build bicycle routes, the study carried out an overlay analysis using city-scaled thematic maps in GIS. The overlay map identifies the most suitable areas by summing the highest level of suitability of each data for bicycle routes across the city.

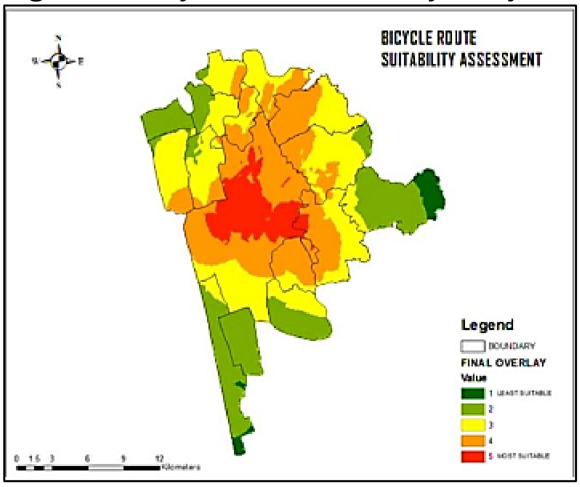
Figure 10. *Bicycle Suitability Analysis due to Various Factors* (Placeholder1)



Source: (Soltanian, 2022)

The classification labelled as 1-5 scale value and 1 denoting "Least suitable area" and 5 denoting "Most suitable area" for cycling was taken and hence the most suitable area for cycling routes was mapped.

Figure 11. *Bicycle Route Suitability Analysis*



Source: (Soltanian, 2022)

As a part of a study conducted by (K. R., M. A., Raveendran, Philip, & Roy, 2017) in which Vytila Junction was taken as a part of the study because of its rising importance as a multi-modal hub and has a very high traffic and pedestrian volume count, the pedestrian level of safety was evaluated. The study analyzed the performance of the roadway using PV2 analysis and the pedestrian level of service as per IRC 103-1988 for this junction was found which showed that the stretch is not safe for pedestrians

Table 4. *Road Inventory Data*

1	*Name of the road*	*NH - 47 KUNDANOOR*	*NH - 47 PALARIVATTOM*	*S-A ROAD (ERNAKULAM)*	*VYTILLA – THRIPUNITURA ROAD*
2	*Type of the road*	*PWD*	*PWD*	*PWD*	*PWD*
3	*Width of the road*	*8.5 m*	*8.5m*	*7m*	*7m*
4	*Median*	*1.2m*	*1.2m*	*1m*	*1m*
5	*Footpath*	*1.5m*	*1.5m*	*1.5m*	*1.5m*
6	*Shoulder*	*1m*	*1m*	*1m*	*1m*
7	*Conditions of the footpath*	*Poor, unauthorized encroachments.*	*Very poor, interruption to flow.*	*Obstructions are present, not well conditioned.*	*Absence of hand rail, poor.*
8	*Bus stops: Left*	*0*	*1*	*1*	*1*
	Right	*1*	*0*	*1*	*0*
9	*Remarks*	*Heavy pedestrian and traffic flow.*	*Heavy pedestrian and traffic flow.*	*High vehicular flow and moderately high pedestrian flow*	*Moderately high vehicle and pedestrian flow*

Source: (K. R., M. A., Raveendran, Philip, & Roy, 2017)

Table 5. *Pedestrian LOS*

MONDAY	V_{15}	E m	Q p/min/m	LOS	SPEED m/min	SPACE m^2/p	LOS
NH 47(Kundanoor stretch)							
Morning	599	1.5	26.62	D	60	2.25	C
Evening	748	1.5	33.24	E	60	1.8	D
NH 47(Palarivattom stretch)							
Morning	704	1.5	31.28	E	60	1.91	C
Evening	779	1.5	34.62	E	60	1.73	D
S-A Road							
Morning	364	1.5	16.17	C	60	3.71	B
Evening	413	1.5	18.35	C	60	3.26	C
Vytilla-Petta Road							
Morning	348	1.5	15.46	C	60	3.88	B
Evening	418	1.5	18.57	C	60	3.23	C

Source: (K. R., M. A., Raveendran, Philip, & Roy, 2017)

Discussion

The analysis mapping shows that the Bike-ability of the selected buffer zones is low. This can be mainly attributed to the absence of proper infrastructure in the study area even though there is a Public Bicycle Sharing system in place. The traffic volume and traffic speed along the major roads deter people from cycling. Walkability was found to be considered good on major arterial roads but it was found weaker on the local roads. This can be attributed to the absence of shaded walkways and the climatic conditions. Also. there are no provisions in the collector and local roads due to Right of Way restrictions.

The Public Transport Accessibility Analysis that was mapped showed high accessibility values which indicates that the buffer zone has good connectivity to the nearby bus stops and the frequency of services to these bus stops is also good. The timely schedule of buses operated in the city makes the PT service dependable.

The cycle routing around Maharajas Metro Station showed that in cases where RoW is less restricting the vehicular movement can help facilitate pedestrian and bicyclists' friendly spaces.

Conclusion

From the above, it can be deduced that there is an urgent requirement to establish secure infrastructure for non-motorized transportation. In order to cater to this need, arterial and sub-arterial roads that have adequate right of way should have walkways and bicycle lanes on both sides of the street. Additionally, suitable street-scaping should be implemented to guarantee a comfortable and stress-free experience for both pedestrians and cyclists. If the road lacks enough space to construct bicycle lanes, then at a minimum, walkways must be constructed.

The study by (K. R., M. A., Raveendran, Philip, & Roy, 2017) concluded that there is a need to increase the road infrastructure with necessary steps to protect pedestrians in the area.

To ensure the implementation of universal design principles, it is recommended to consider measures such as the installation of tactile paving with guiding or warning tiles, as well as detectable warning strips at transitions between pedestrian, vehicular, or shared areas such as curb ramps.

Pedestrian ramps serve as a means of enhancing accessibility to sidewalks for individuals who use wheelchairs or other personal mobility devices, as well as those who are pushing strollers, carts, or carrying heavy luggage. It is essential to provide appropriate signage for individuals who are hearing impaired, by the relevant guidelines. Pedestrian crossings should also be accompanied by intelligent transportation systems (ITS), such as automated pedestrian signals and surveillance cameras. Additionally, incorporating grade differences in pedestrian crossings along the road can help to slow down high-speed traffic and promote safe pedestrian crossing.

To ensure safety from crime, it is crucial to install appropriate lighting that facilitates proper visibility, especially in areas that are dark or at night. Pedestrian-scale lighting, typically consisting of lamps that are less than 25 feet high, can enhance comfort and safety around stops, such as pedestrian crossings or bus stops.

The design of ground floor building frontages, particularly those near pedestrian pathways, is directly linked to urban safety. Appropriate lighting and seamless interaction between the street and private spaces can encourage a steady flow of people, thereby making pedestrians feel safer and more secure on sidewalks.

In addition, it is important to ensure proper drainage facilities to prevent waterlogging of sidewalks during the monsoon season. Sidewalks should have a cross slope to facilitate drainage, directing rainwater towards drains and collection points. Rainwater management techniques, such as bioretention in rain gardens, tree planting along sidewalks, and the use of porous paving, can help to reduce surface runoff.

Furthermore, it is recommended to remove existing on-street parking and provide off-street parking spaces to avoid parked vehicles obstructing pedestrian traffic.

Furthermore, Cochin Smart Mission Limited (CSML) is constructing cycle lanes all over the smart roads in Kochi to promote cycling. With the assistance of the German development organization GIZ, the cycle lanes are being constructed on these routes as part of the "India Cycles 4 Change Challenge." A project of the Smart Cities Mission, Ministry of Housing and Urban Affairs, Government of India, Kochi is one of the 107 cities that have signed up for the India Cycles4Change Challenge. Since the Covid 19 outbreak, cycles have remained in great demand in the city. More people are eager to start cycling to keep in shape despite the lack of available bicycles. There is also a Non-Motorized Transport Master Plan for the city of Kochi being prepared by the UMTC.

Acknowledgement

Our thanks to "The Transport Engineering Unit of ATINER organizing the 9th Annual International Conference on Transportation" for allowing us to modify templates they had developed.

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