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Investigating the Implications of Transit-Oriented Land Use Development for a Potential Node in an Urban Metro for Sustainability

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ABSTRACT

Urbanization is intrinsically connected to economic progress. India's rapid economic and population growth has increased its carbon footprint and traffic congestion. A long-term strategy is essential to preserve the balance and alleviate the issues arising from the expansion. Integrating land use and transportation planning has been acknowledged as a means to achieve sustainable urban development worldwide. Transit Oriented Development (TOD) is one such strategy. TOD is a planning and design strategy for promoting urban development by clustering jobs, housing, services, and amenities around public transport stations. This strategy can help achieve sustainable communities and improve the quality of life. This research paper assessed the land use characteristics of an urban fringe area in Trivandrum city and completed a land suitability analysis using GIS software tools. A potential node for re-development was identified by looking at various traffic, demographic, and land use parameters. Detailed TOD recommendations for the area surrounding the transit node were proposed based on its development potential.

INTRODUCTION

Man's activities on land are referred to as land usage. The land pattern of a place is the result of natural and socioeconomic forces, as well as man's use of them over time and space. Due to massive agricultural and demographic pressures, land is becoming increasingly scarce. As a result, information on land use is critical for selecting, planning, and implementing land use plans to fulfill rising demands for fundamental human requirements and well-being. Transportation planners and engineers must improve the quality of transportation facilities for all citizens.

Transit Oriented Development (TOD) creates vibrant, sustainable communities worldwide (Cervero et al. 2004). It is a powerful strategy for developing compact, high-density, walkable communities around public transport stations. This reduces the heavy reliance on private modes of transportation for mobility needs. Eboli analyzed the quality of transit service from the passengers' perspective (Eboli & Mazzulla 2011). The quality of public transit services can be improved using shared autonomous vehicles. They can provide inexpensive mobility-on-demand services and facilitate dynamic ride-sharing (Krueger et al. 2016, Vakayil et al. 2017, Yap et al. 2016). A simulation analysis evaluated TOD's land development impacts across all Chinese cities expected to have metro systems by 2020. Results show that China's second and third-class cities will have more potential for TOD implementation than the first-class cities in the next five years (Xu et al. 2017). Many studies have provided strong evidence of residents' support for the characteristics of transit-oriented development (TOD) neighborhoods.

For over two decades, planners have urged changing from mobility-centered to accessibility-focused land use and transportation planning. The ease with which any land use activity can be reached from a given place utilizing a specific transportation system is known as accessibility (Burns & Golob 1976). In planning, accessibility is seen as a reliable, clear, and communicated metric (Bertolini et al. 2005, Hansen 1959). An elasticity-based metric of accessibility that can enable project-level evaluation of land-development projects as an accessibility-based alternative to traffic-impact analysis was proposed by Levine (Levine et al. 2017). TOD improves access by offering many transportation linkages and dense, mixed-use, cycling, and pedestrian-friendly land use around transit stations (Calthorpe et al. 2014, Curtis et al. 2009). How TOD components are related to the accessibility of metro station areas at the one-hour travel time catchment level was studied in Beijing (Guowei et al. 2019). TOD is a prominent accessibility-focused planning method that is gradually gaining popularity. Identifying and measuring specific TOD components related to accessibility in station areas is also studied (Shiliang et al. 2020). The advantages of TOD include increased transit ridership, reduced roadway expansions due to decreased private vehicle usage, and increased mobility choices, including walking and cycling (Handy 2002, Papa & Bertolini 2015, Yeung et al. 2015). Construction and other commercial products are expensive due to the excessive cost of transportation from natural sources (Alex et al. 2022a). This results in reduced household transportation costs, improved access to shopping, services, and the ability to live, work and shop within the same neighborhood. According to Cervero, people and places matter, not transportation (Cervero 1997).

One of the first assumptions in the research is that TOD is a strategy for sustainable development. According to Newman and Kenworthy, sustainable development is any development with social, economic, and environmental benefits. The TOD communities are also designed to promote non-motorized transport and use transit to travel larger distances. TOD aims to increase the accessibility to work and other activities so that people have more choices and can benefit economically. Sustainable urban mobility plays an important part in the competition, as several topic areas are directly or indirectly linked to transport (sustainable urban mobility, air quality, noise, climate mitigation, energy performance). European Green Capital Award (EGCA) rewards environmentally friendly cities through a competitive application, evaluation, and ranking (Müller & Reutter 2020).

In Curitiba and Bogota, TOD has been implemented successfully. In Curitiba, a transit-first policy is aggressively pursued by focusing development along the transit axes. The success element of Bogota focuses on pedestrians and bicycles as an access mode to the BRT. But in Bogota, changes were not made to the cityscape, unlike Curitiba. Thus Bogota focuses on access to the BRT, and Curitiba focuses on accessibility. Both projects are land use and transport integration, which promote public transit use. Thus in principle, they are both TOD (Rajakumari 2008, Straatemeier & Bertolini 2020, Alex et al. 2016). Most land use theories considered the transportation system as having a definite effect on the location of activities. Transport and land use largely remained in separate compartments, and the transport variables that go into the land use model were restricted to the concept of ‘distance to the center (Wegener 2020).

This research paper aims to apply the TOD concepts and guidelines for the overall development of a transit node in Trivandrum city. The guidelines must be effectively considered within the transport planning process (Turnheim et al. 2020, Alex et al. 2022b). One of the first assumptions in the research is that TOD is a strategy for sustainable development. According to Newman and Kenworthy, sustainable development is any development with social, economic, and environmental benefits. The TOD communities are also designed to promote non-motorized transport and use transit to travel larger distances. TOD aims to increase the accessibility to work and other activities so that people have more choices and can benefit economically.

This research paper aims to apply the TOD concepts and guidelines for the overall development of a transit node. The guidelines must be effectively considered within the transport planning process.

NEED FOR TOD IN TRIVANDRUM CITY

Demographic Aspects

Kerala State covers barely 1% of India’s total land area but has 3% of the country’s population. The population density of the state is 859 persons/km2 (3x the national average). The population density of Trivandrum City is 4,454/km2 (3x that of Trivandrum District). The Trivandrum Metropolitan Area (TMA) comprises Trivandrum City and its satellite towns.

Land Use

Urbanization has resulted in significant changes in land use. The urbanization trend is more in urban fringe areas adjoining the corporation area. Parks and open spaces occupy only 7.8% of the city area.

Economy

The first IT Park-Technopark was established in 1991 and situated at Kazhakuttom. Technopark spans over 300 acres and has a 4 million square feet built-up area. Since the formation of Technopark, the city has seen significant expansion and growth. Additional jobs are getting created, and this is bringing in migrant workers into the city, thereby increasing the need for infrastructure development as well as the construction of roads and buildings.

Growth of Automobiles

The population of Trivandrum district only grew by 2% in 10 years (from 32.34 lakhs in 2001 to 33.01 lakhs in 2011). This trend is not expected to change much, even during the 2021 census (awaited). Meanwhile, vehicle registrations in the Trivandrum district have grown by an average of 11% yearly. This disproportionate increase in private vehicles puts an enormous strain on the roads, results in accidents and traffic congestion, and necessitates a renewed focus on

Table 1: The percentage share of trips for different transport modes.

Year	2021		2031		2041	
Mode Share	Trips	% share	Trips	% share	Trips	% share
Two wheeler	32195	28%	35954	27%	36976	24%
Car	16933	15%	23469	17%	29567	19%
Three wheeler	11006	9%	15307	11%	23527	15%
Public Transport System	55939	48%	60772	45%	66947	43%
Total	116073	100%	135502	100%	157017	100%

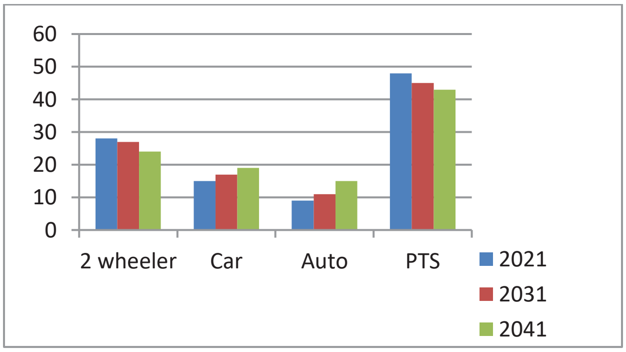

Fig. 1: Chart showing the decadal growth of automobiles.

public transport systems. The TOD areas will be served by high-quality public transit systems, thereby encouraging more people to use the public transportation systems, causing a reduction in private car use. The percentage share of trips for all modes of transport is projected until the horizon year 2041, as shown in Table 1. The data is indicated as a bar chart in Fig. 1.

MATERIALS AND METHODS

Research Area Identification

The different criteria considered for research area identification include:

1. Connectivity– National Highway (NH 66) passing through the settlements, and proximity to International Airport and railway stations
2. Residential and Commercial development projects
3. Employment Opportunities in the area
4. Land Value considerations
5. Urbanization trends

Connectivity

Traffic volume and passenger volume data were analyzed along the NH corridor. It was found that the traffic volume was relatively high in the transit nodes along the corridor.

Residential and Commercial Development Projects

More than 20 real estate projects in and around Kazhakuttom are present. Major players are Heera, SFS, Skyline, Confident, and Oceanus. One of the largest shopping malls (Lulu mall) is in close proximity.

Employment Opportunities in the Area

Kazhakuttom is developing into a major self-contained and prominent township. The increase in employment opportunities will significantly increase traffic volume from the rest of the city. Housing demand increases due to migration owing to an increase in employment.

Land Value Considerations

Owing to an increase in employment, the housing demand increases. People tend to migrate and settle close to their place of employment. This results in an increase in land value.

Urbanization Trend

The Urbanization trend is more in the fringe areas surrounding Trivandrum Corporation, along the NH Corridor and Railway line. The Census data indicate that the population growth rate pattern is the highest along the traffic corridor. These adjacent fringe areas are estimated to attain an urban state in the next 10yrs.

Settlements Selected for the Research

Based on the various criteria adopted, the following five

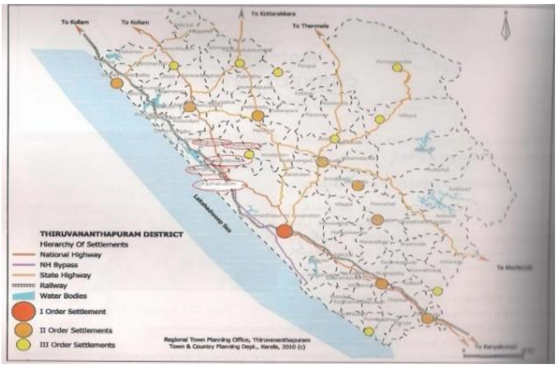

Fig. 2: Location of research zones.

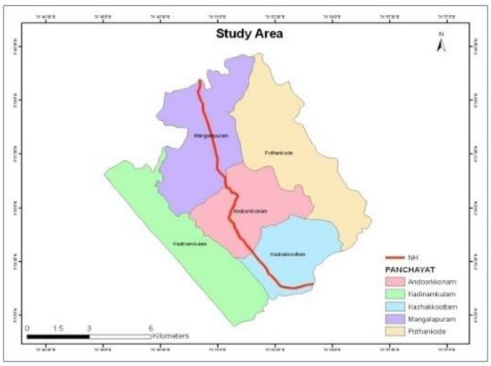

Fig. 3: Delineation of zones in the research area.

settlements were selected for land use and traffic analysis (Fig. 2 and 3). Andoorkonam, Kadinamkulam, Kazhakuttom, Mangalapuram and Pothencode.

Data Collection

Started the data collection exercise with a land use map of the research area. Various land use categories were identified and delineated as agricultural, built-up, mixed built-up, wastelands, water bodies, etc. The purpose of the trip, mode of travel, and socioeconomic characteristics of the trip maker were all identified in the travel survey. These are the elements that make up a location's travel characteristics. Travel characteristics are significant resources that provide vital information on people's travel behavior across time and throughout the population.

Primary surveys with questionnaires were employed to obtain data on the area's demographic and socioeconomic parameters. A sample size of nearly 0.2% of the research area population is considered for the survey. Data was collected from 250 households and was grouped into three categories. i.e., Data from the household, personal data, and travel data. Data were analysed using category analysis by classifying households based on the size of households, their income, and vehicle ownership.

RESULTS AND DISCUSSION

This section used Arc GIS software to analyze the five zones' land use and suitability analysis. The weighted Overlay technique is adopted to find the land suitable for development. For the identified zones, the daily trip generation is calculated using TransCAD software. This exercise intends to identify the zone with the maximum number of daily trips. A transit node in that identified zone will be selected for transit-oriented land use development.

Land Use Analysis

The collected land use map was imported into ArcGIS (Version 9.3), and by selecting different attributes, the area of different land uses was calculated. The distribution of land in the zones calculated from ArcGIS is shown in Table 2.

The data analysis shows that more than 50% of the area in all the zones is agricultural. Forest areas constitute only 1%. By considering the total area, the percentage-wise distribution of various land use types is given in Fig. 4.

Categories of Land

The land is categorized based on land use characteristics as follows:

Table 2: The percentage of land use distribution in the research zones.

Type of Land use	Andoorkonam		Kadinamkulam		Kazhakuttom		Mangalapuram		Pothencode	
	sq.km	%	sq.km	%	sq.km	%	sq.km	%	sq.km	%
Residential	0.42	3.0	0.88	5.0	1.75	9.0	0.87	4.0	1.04	5.0
Water Body	0.14	1.0	2.12	12.0	0.19	1.0	0.43	2.0	0.21	1.0
Waste Land	0.28	2.0	1.77	10.0	0.39	2.0	0.22	1.0	0.42	2.0
Forest	0.0		0.0		0.0		0.0		0.21	1.0
Agricultural	8.93	64.0	9.02	51.0	12.85	66.0	17.76	82.0	17.10	82.0
Mixed Built up	4.19	30.0	3.89	22.0	4.28	22.0	2.38	11.0	1.88	9.0
TOTAL	13.96	100	17.68	100	19.47	100	21.66	100	20.85	100

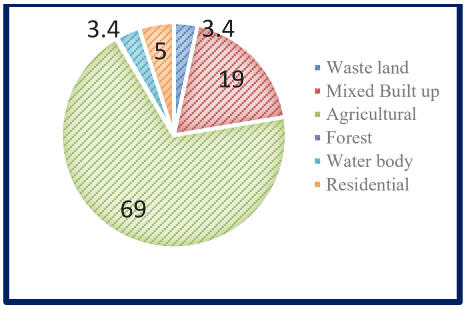

Fig. 4: Land use distribution of research area.

Built-up Land: Built-up land is defined as a habitable area that has been established as a result of non-agricultural use and includes buildings, transportation networks, and communication utilities, as well as vegetation, water bodies, and unoccupied areas.

Agricultural Land: The area is predominantly agricultural. The principal crops grown are coconut, paddy, rubber, cashew, and garden crops like bananas. The percentage of the agricultural area is 69%.

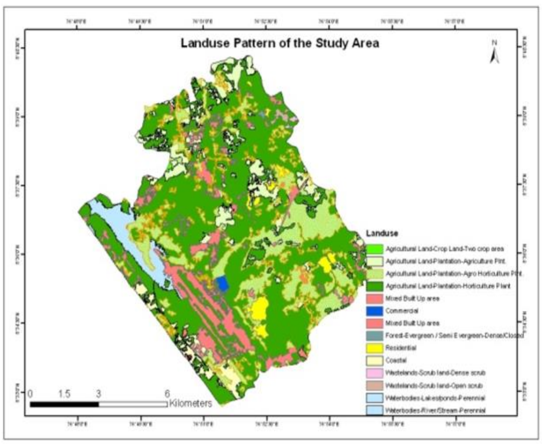

Fig. 5: Land use pattern of the research area.

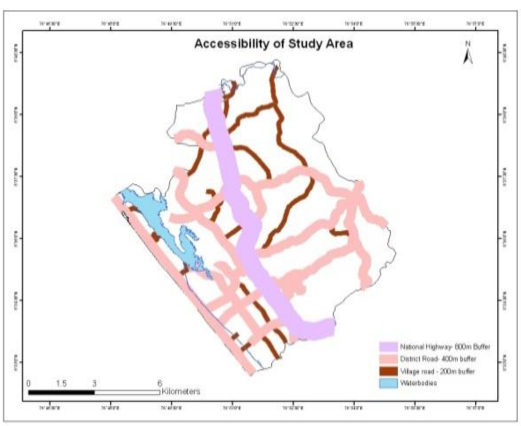

Fig. 6: Accessibility of the research area.

Waste Lands: They are degraded lands that, with reasonable effort, can be restored to vegetative cover and are now underutilized and deteriorating, either owing to poor management or natural reasons. About 3.4% of the total area is a wasteland.

Water Bodies: Water bodies are any significant accumulation of water by natural or artificial means. This constitutes 3.4% of the total area.

Land Suitability Analysis

Land suitability analysis aims to determine future land use patterns by looking at the specific requirements, preferences, or predictors of a particular activity. Changes in transportation affect the location of land investment, which affects the demand for travel to and from an area. Urban transport has a high impact on land value. Over time, transportation networks and the spatial patterns of land use they serve influence each other. Different land uses different trip generation characteristics. Fig. 5 shows the different land use patterns in the research area.

The existing road network map was used as the base map for preparing the land value layer and accessibility layer. Buffers were drawn at suitable intervals to zone the map to different levels of accessibility. Buffers were created 80m for NH, 40m for district roads, and 20m for village roads. The accessibility of the research area is shown in Fig. 6.

The land value variations in the area were also found (Fig. 7). It was observed that the land surrounding the national highway has high land value.

The slope details of the region in the area were analyzed. Gentle slope (0-5 percent), moderately sloping (5-15

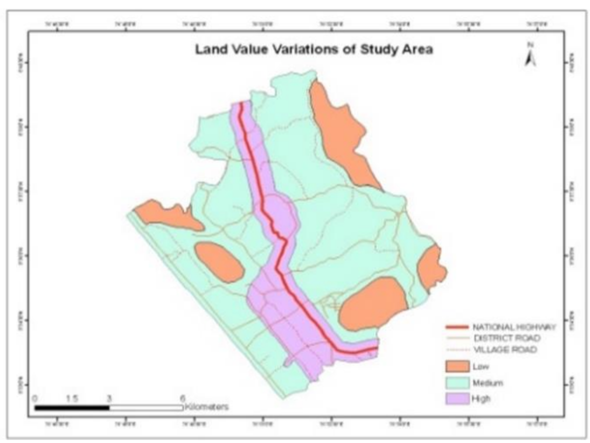

Fig. 7: Land Value variations in the research area.

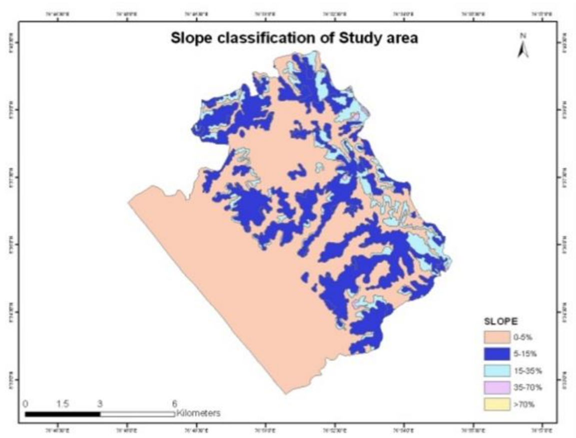

Fig. 8: Slope classification in the research area.

percent), strongly sloping (15-35 percent), moderate to steep slope (35-70 percent), and steep slope (>70 percent) were used to classify the slope (Fig. 8).

Weighted Overlay for Land Suitability Analysis

The weighted overlay is a technique for creating an integrated analysis by applying a single measurement scale of values to various and dissimilar inputs. This data is stored in many raster layers with varying value scales. It evaluates the relative influence of input rasters in a decision-making process. Within a single raster layer, values were prioritized. For example, 1 represents slopes of 0 to 5 degrees, and 2 represents 5 to 10 degrees. Steps for running overlay analysis are given in Table 3.

The overlay of the coverages was done so that the attributes of both coverages were present in the final output. The land value, slope condition, and accessibility maps were overlaid to get the composite map. This can be used as a reference for the proposed activities in the area. The results were assigned four suitability classes such as high, moderate, low, and restricted. The map showing the suitability of land parcels for development is displayed (Fig. 9).

Table 3: Weighted overlay method procedure.

Steps	Procedure I	Procedure II
1	Selecting an evaluation scale	Raster's Reclassified (1 most suitable and 5 least)
2	Adding Raster's	Raster added to weighted overlay table
3	Set scale values	The value assigned based on which land use is more suitable (Ex. Forest=Restricted)
4	Assign weights to input raster's	Assign influence percentage based on its importance
5	Execute the weighted overlay model	Cell value of each raster by influence percentage

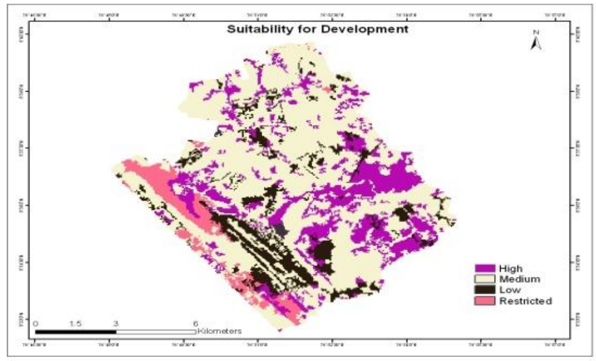

Fig. 9: Land suitable for development.

Table 4: Area of different classes of suitability.

Suitability Class	Area in Sq.km
Restricted	6.35
Highly suitable	20.43
Medium	58.55
Least	14.67

Nearly 20 Sq.km of the area is highly suitable for any development. About 7% of the total area comes under the restricted category. And more than half of the total area is moderately suitable for development, as shown in Table 4.

Estimation of Trip Generation and Transit Node Identification

For each identified zone, the daily number of trips generated is computed.

This is achieved as follows:

1. Do a Category Analysis using the zonal characteristics data points (e.g., number of persons in the household, income per household, number of vehicles) as inputs.
2. Zones and the road network are digitized in ArcGIS and imported into TransCAD.
3. Generate a Trip Rate table using TransCAD software. The Trip Rate table illustrates the number of trips by household and income for various vehicle ownership levels (Table 5).
4. Calculation of the daily trips produced for each zone.

Steps for Creating a Trip Rate Table

1. A table containing disaggregate data was opened
2. 'Planning'-Planning Utilities'-'Build Cross Classifi-

cation Table' was chosen to display the Build Cross Classification Table dialogue box

3. The classification variables selected:
   a) Number of persons per household
   b) Income per household
   c) Number of vehicles per household
4. The classification variables were given ranges, and Cross Classification table was prepared.

Steps for Analysis

The first step for the analysis was activating the zone layer and opening the trip rate table in that layer. The generation of trips in each zone was calculated by category analysis.

The zonal characteristics were calculated for the year 2022 (Table 6). The income growth was derived from the previous data on per capita income. The increase in the income rate of the people is found to be 8.76%. The number of employed persons per household and vehicle ownership had an increasing trend.

By giving the zonal characteristics as input, the trips produced daily for the year 2022 were calculated (Table 7). The bar chart showing the trip generation is shown in Fig. 10.

The highest number of trips generated was in Kazhakuttom.

TOD Design for the Transit Node

The research shows that the trip generation of Kazhakuttom is highest when compared with the other zones. A transit

Table 5: Trip rate table.

Vehicle Ownership = 0					
Income (Rs)	Household Size				
	<=2	3	4	5	>5
<10000	1.05	1.1	2.08	2.07	2.6
10000-20000	1.12	1.38	2.12	2.55	2.65
20000-30000	1.4	1.4	2.47	2.6	2.78
>30000	1.75	1.88	2.6	3.2	3.55
Vehicle Ownership = 1					
Income (Rs)	Household Size				
	<=2	3	4	5	>5
<10000	1.36	1.3	2.38	2.47	2.8
10000-20000	1.5	1.6	2.5	2.65	2.85
20000-30000	1.7	1.8	2.7	2.9	2.98
>30000	1.99	2.1	3.1	3.6	3.75
Vehicle Ownership = 2					
Income (Rs)	Household Size				
	<=2	3	4	5	>5
<10000	1.66	1.6	2.68	2.77	3.1
10000-20000	1.8	1.9	2.8	2.95	3.15
20000-30000	2.0	2.1	3.0	3.2	3.28
>30000	2.29	2.4	3.4	3.9	4.05

Table 6: Zonal Characteristics for 2022.

Zone	Name of the settlement	Number of Households	Number of employed persons/HH	Income/HH	Number of vehicles owned/HH
1	Kadinamkulam	16441	2.6	41331	0.83
2	Mangalapuram	13744	2.8	43645	0.98
3	Kazhakuttom	14935	2.6	59989	3.66
4	Andoorkonam	9989	2.8	55213	1.64
5	Pothencode	10674	2.4	45957	1.39

Table 7: Daily trips generated for 2022.

Zone	Name of Settlement	Number of trips produced
1	Andoorkonam	168659
2	Kadinamkulam	230652
3	Kazhakuttom	250754
4	Mangalapuram	177209
5	Pothencode	135657

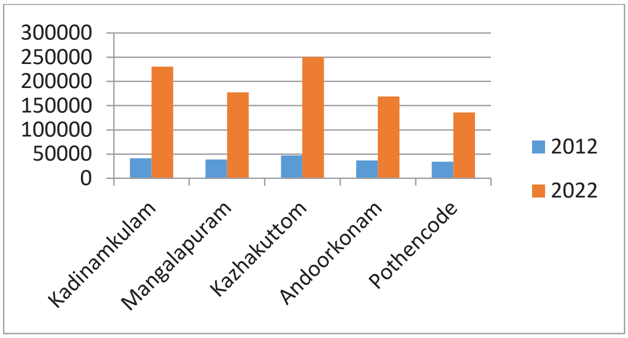

Fig. 10: Chart showing Trip Generation.

station for the proposed MRTS in Kazhakuttom was identified as a node for Transit Oriented Development based on its development potential (Fig. 11).

General TOD Guidelines

The TOD Guidelines provide a framework for anticipating transit and land use integration around the transit stops. They act as a catalyst for infrastructure investments, private development, formulation of public policies and regulations, and encourage transit-oriented development by:

1. Promoting city transportation infrastructure investment, concentrating higher density residential, retail, and job expansion near transit centers
2. Major trip generators (office buildings, commercial malls, schools, and entertainment venues) should be located near public transportation
3. Promoting a station-specific land use mix to provide people accessibility for their work, life, and mobility needs
4. Fostering the development of high-quality projects
5. Providing facilities that allow passengers to shift between modes of transportation in a timely, safe, and convenient manner
6. Create a system that connects destinations that is pedestrian and bicycle friendly, direct, safe, and convenient, and caters to all modes of transportation
7. Planning for the development of a beautiful, green city

Design of TOD for Transit Node

Based on the development potential of the node, the TOD design was formulated considering the key TOD components (Fig. 12).

Hectic zone – Zone of high-intensity conflict (First 100m from the transit stop): The first zone is 100m from the transit stop. There would be heavy traffic flow and pedestrian movements. A subway, two bus bays, and bicycle parking spaces were proposed. Bus bays are provided at least 15m from either side of the transit stop. Segregated bicycle lanes could ease smoother traffic flow and minimize conflicts. Continuous footpaths (1.5 m) on either side of the carriageway are proposed. Shopping facilities were provided close to parking areas. Existing shops can be developed into shopping complexes, malls, etc.

The key benefit of this zone is that it minimizes vehicular and pedestrian conflicts. Subways and bus bays improve the traffic flow by reducing congestion along the main road. It ensures safe and smooth connections for pedestrians and cyclists.

Fig. 11: Transit Node and Buffer Zones (A bird’s Eye View).

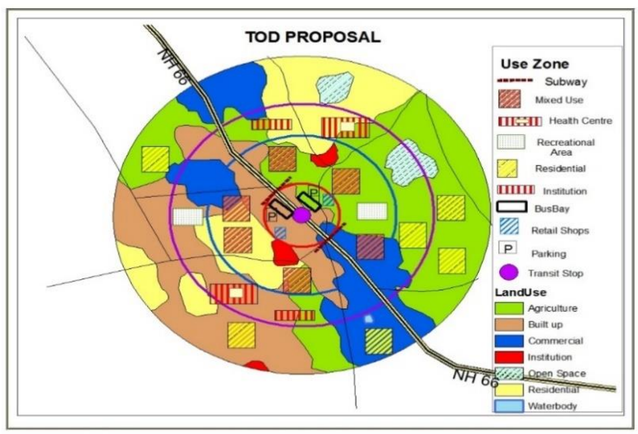

Fig. 12: TOD Design for Transit Node.

Mixed use zone (250m from the transit stop): Mixed uses are provided in the second zone, i.e., 250m from the transit stop. These include high-intensity uses like residential, retail, employment centers, institutions, etc. In addition to these uses, recreational areas and multilevel parking structures are also provided.

The benefits include high residential density with supporting activities, enabling residents to access various services and amenities. It also encourages people to walk instead of taking a car. Furthermore, it enables the formation of a close-knit neighborhood and a sense of community.

Public/semi-public zone (350m from the transit stop): In the third zone, medical and institutional activities are proposed, and provision for open spaces and recreational facilities are considered. There are many advantages, such as the best access for residents to all facilities and the availability of public services in the area.

Residential zone (500m from the transit stop): Plotted housing options are provided in this tranquil zone. This becomes the primary residential area. The advantages are people with a higher income can enjoy the benefits of open spaces and larger homes/villas. Also, the residents are protected from traffic noise and other negative effects. Public spaces for recreation, such as parks and playgrounds, are also proposed.

Preliminary Study

The exponential increase in private vehicles has many ill effects on Trivandrum city. To reduce these issues, some long-term strategy has to be looked into. Considering the growth potential of the city, it was found that transit-oriented development plans are ideal. Various criteria were considered, and the area suitable for TOD was delineated (Fig. 3). Demographic and socio-economic data were collected by conducting household surveys using questionnaires. Around 250 households were selected for the survey.

Land Use/Land Suitability Analysis

Various Land use categories like built-up areas, agricultural areas, residential areas, etc., were identified from the land use map by importing it into GIS software. The next step was to determine the percentage-wise area distribution of these land categories (Table 2). It was inferred that more than 50% of the area in all the zones was used for agricultural purposes (Fig. 4). Land use pattern of the five zones was generated using ArcGIS software (Fig. 5). Road network map was overlaid into the land use map and the accessibility of the zones were found out. Similarly, the land value variations, as well as the slope classifications, were noted. The weighted Overlay technique was adopted to find the land suitable for development (Fig. 9). The result showed that around 20 sq. km of the area is suitable for any development.

Estimation of Trip Generation

The number of daily trips generated in each of the five zones was calculated using TransCAD software. A transit node for TOD was identified in the Kazhakuttom zone, where the number of daily trips was maximum.

TOD Design for the Transit Node

A transit stop along the National Highway (NH 66) in Kazhakuttom was selected as the potential node for TOD. The area surrounding the node was chosen for TOD design. The area was divided into concentric circles, i.e., the first 100m was considered a high-intensity conflict zone. Next zone would be 250m from the node, the third zone 350m, and the last zone 500m. The TOD plans for each zone were overlaid on the land use map with the help of GIS software (Fig. 12). The plans were given according to the standard TOD guidelines mentioned earlier.

Environmental Benefits

With the help of the above TOD design, optimum land use allocation can be achieved, thereby maximizing the public transit ridership. The high residential density close to the transit stop increases the ridership on public transportation systems. This reduces the number of people driving single-occupancy vehicles, decreasing air pollution and fuel conservation, thereby reducing the region's carbon footprint. The travel time can also be reduced considerably due to decreased traffic congestion.

CONCLUSION

The transportation challenges developing countries face, especially emerging economies, are manifold. Rapid population explosion, lack of infrastructure, and significant growth in the number of vehicles imply that radical approaches are needed in transportation planning. Transit Oriented Land use Development provides solutions to solve these issues. Benefits include improved safety, accessibility, convenience, and comfort in using public transport services and reducing carbon footprint.

The above research looked at five key settlements in Trivandrum city with growth potential from land use, traffic characteristics, and demographic perspective. The findings helped identify a transit node. The research shows that the trip generation of Kazhakuttom is highest when compared with the other zones. A transit station for the proposed MRTS was identified as a node for Transit Oriented Development based on its development potential. A detailed Transit Oriented

Development design adhering to the key TOD components and guidelines was formulated for the region surrounding the transit node.

The scope of this research was limited to providing the TOD design for one identified node. The same approach can be extended to other transit nodes along the corridor for holistic, integrated land use and traffic planning for the urban metro (Trivandrum).

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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