SSRG International Journal of Civil Engineering
ISSN: 2348-8352 / https://doi.org/10.14445/23488352/IJCE-V10I4P103

Volume 10 Issue 4, 13-21, April 2023

Original Article

Study on Geometrical and Pavement Improvements for Proposed Up-Gradation of Perumthuruthy to Manarcadu Stretch in the State of Kerala

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Received: 27 February 2023 Revised: 29 March 2023 Accepted: 11 April 2023 Published: 30 April 2023

Abstract - *One of the major issues currently facing developing countries is heavy urban traffic. Growing volumes of through traffic is often attributed to traffic flow challenges. To improve traffic flow in the city centre, bypass roads or alternative routes are being investigated. These Bypass/alternate routes divert through traffic away from town centers leaving local streets to local traffic. This paper aims to explore the feasibility of such a proposed route to serve as an alternative route or bypass to ease the traffic congestion in the cities of Kottayam and Changanassery in terms of expected divertible traffic. On the basis of the engineering survey and the traffic survey of the proposed route, the necessary improvements and the up gradation to two-lane standards are also recommended.*

Keywords - *Alternate route, Traffic survey, Divertible traffic, Geometric design, Pavement composition, Cost estimate*.

1. Introduction

The provision of adequate infrastructure is a prerequisite for sustained growth of the economy, and inherent to such growth is the need to ensure the cost-effective movement of people and goods. Efficient road infrastructure is, therefore, an essential requirement for the development of any nation. Though Kerala has a good network of roads, capacity augmentation has been minimal compared to vehicle growth. Traffic plying on rural highways many a time has to pass through urban areas of various sizes with or without the purpose of halting within the urban areas. This non-halting traffic is known as through traffic, with its origin and destination lying outside the limits of urban areas. The frequent interaction of through traffic with the local traffic of the urban area, bringing down the level of operation besides both types of traffic, would also erode the traffic environment of the town. In all such cases, proper planning of bypasses/alternate route assumes great importance for providing unhindered movement to the through traffic and decongesting the towns.

An alternate route between Perumthururthy to Manarcadu and Puthupally to Kanjikuzhy is analysed to let through the traffic flow without hindrance and to ease the traffic congestion at Kottayam and Changanassery towns in the state of Kerala. Details such as Classified Traffic Volume Count (CVC), AADT (annual average daily traffic volume), ADT (Average daily traffic) Volume, Origin destination (O-D) survey and delay for the local and through traffic are collected and analysed to justify the provision of an alternate route.

The scope has also been broadened to conduct engineering and traffic surveys to help improve the alignment of the selected route to two-lane standards without acquiring much additional land and propose other improvements to improve road safety and travel time.

2. Research Methodology

For this study, a three-phase methodology is adopted. The project stretch between Perumthuruthy and Manarcadu (23.390 km) and Puthupally and Kanjikuzhy (5.105 km) has been divided into seven homogeneous sections for detailed analysis of existing traffic, road characteristics, pavement condition, and travel behaviour.

The first phase includes a thorough inventory of existing roads, traffic surveys, topography research, and soil analysis. The data from the traffic inventory and the O-D survey are analysed in the second phase, and the potential divertible traffic is estimated. On the basis of information gathered from road condition surveys and divertible traffic projections, recommendations for geometrical improvements, pavement composition, road furniture, and potential improvement costs are suggested.

3. Literature Review

In Kerala, [3] analysed the current traffic flow of the Ettumanoor-Kottayam route using transportation surveys and traffic volume. Based on the survey results, the main nine factors contributing to congestion and the condition of the area were identified. Analysis was carried out using SPSS software, and solutions were recommended based on the results. [4] also assess the present condition of the road network using traffic analysis, including speed and delay survey, traffic volume survey, and other surveys such as existing road condition survey, parking features, and pedestrian volume count. Based on this information, a suitable road development plan and improvement plans were formulated.

All studies carried out in the past indicate that proper traffic and engineering surveys and analyses need to be carried out to propose improvements [13].

Research conducted by [2] indicates a simplified model of traffic allocation to the intended bypass road. The purpose of such a model is to provide the planners with a tool for a simple, fast and inexpensive way to estimate the expected traffic volume on the planned bypass, which will help the planners to check the viability of the bypass.

[9] This study indicates that the road is designed efficiently and precisely using Civil 3D when compared to other traditional methods. When done manually, geometric design takes a lot of time, and mistakes may be very expensive. Using a total station, a survey can be finished rapidly.

4. Materials and Methods

Through the following surveys, the study aims to learn the present condition and characteristics of the project stretch.

4.1. Reconnaissance Survey

To better understand the study stretch, identify potential locations for traffic surveys, and plan the survey and related activities appropriately, a preliminary survey was conducted. The project stretch was split into 7 homogeneous sections for better analysis.

4.2. Field Inventory

Road inventory was carried out for the project stretch by traversing the entire project corridor. Based on the data collected, the existing terrain was found to be mostly rolling. The existing carriageway width ranged between intermediate to two lanes without paved shoulder. The land use is predominantly commercial and residential, with an average available right of way of 12m. The pavement and cross-drainage structures are found to be mostly in good condition.

4.3. Classified Traffic Volume Count Survey

Traffic volume counts as passenger car units (PCU) were carried out at (i) outer cordon points, (ii) mid-blocks on major links of the section and (iii) major road intersections. PCU values adopted as per IRC: 64 – 1990 are –

Table 1. PCU equivalency factor

Sl. No.	Vehicle Type	Equivalency Factor
1	Motor Cycle/Scooter	0.50
2	Passenger cars, Pick-up vans, Auto rickshaws	1.00
3	Agricultural tractor, Light commercial vehicle	1.50
4	Truck, Bus	3.00
5	Truck-trailer, Agricultural tractor-trailer	4.50
6	Cycle	0.50
7	Hand cart	3.00
8	Others	6.00

Link volume count survey was carried out at midpoints of all 7 homogeneous sections of the route for a period of 12 hours, between 8.00 AM and 8.00 PM. The observed traffic flows were converted to equivalent Passenger Car Units (PCU) by using equivalency factors.

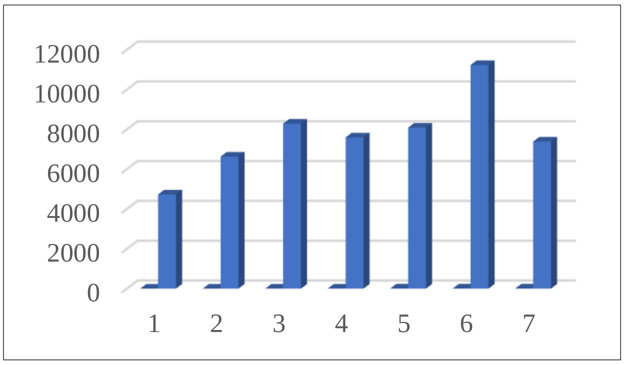

Fig. 1 Traffic volume of the links

4.4. Turning Movement Survey

This survey was carried out at seven major intersections along the proposed project stretch to understand the peak hour demands.

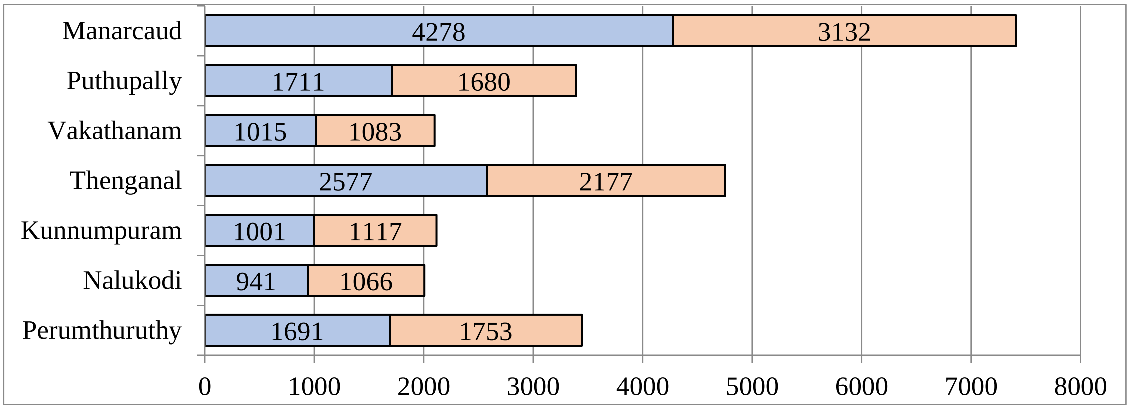

Fig. 2 Peak hour volume at major intersections

The morning peak hour was found to be varying from 8.30 AM to 12.00 Noon, and the evening peak hour from 3.15 PM to 6.00 PM for the different intersections.

4.5. Origin-Destination Surveys and Analysis

Origin–Destination (O-D) surveys were carried out through the roadside interview method at two points outside the project road, Muthoor, near Thiruvalla and Erumapetty, near Manarcadu. For a meaningful analysis of O-D survey data, the region under the immediate influence of the project road was divided into seven traffic zones; in a similar way, the outside region was divided into 18 traffic zones, which included the immediate surrounding areas, adjoining districts and neighbouring states thereby making it a total of 25 Zones which were selected for O-D survey.

The classified count of vehicles plying through the two O-D points was taken for 24 hours. Total daily traffic through these points was found to be 17113 PCU at Erumapetty and 23318 PCU at Muthoor. The car and two-wheeler sample size was found to be a 30% to 40% share out of the total distribution of vehicles at the O-D points.

The sample size of vehicles was assessed to understand the percentage of vehicles interviewed at the O-D points. The sample size of interviewed passenger vehicles varied from 2% for two-wheelers to 15% for cars, and for goods, vehicles varied from 10% for goods autorickshaws to 50% for multi-axle trucks.

Modal split analysis was conducted to understand the number of trips on different modes given the travel demand between different zones. A total of 77,116 passenger trips occurred through the O-D points in 29,688 vehicles, with 60% of passengers using a Car/Van/Jeep. For goods vehicles, a total of 4,831 goods vehicles passed through the survey points, and the quantum of goods handled by the goods vehicles was 12373 tonnes.

4.6. Topographic Survey

A topographic survey of the project corridor was performed using Global Position System (GPS) and Total Station. Control points were fixed with the help of GPS, which was followed by traversing and detailed surveying using Total Station. The survey was carried out for a width of 15m on either side of the existing centre line, and cross sections were taken at 25m intervals and a distance of 10m at curves. The data collected was processed, and AutoCAD was used to develop the existing alignment centreline and other features.

4.7. Soil Investigation

At a frequency of one sample per 2 km, subgrade soil samples from the proposed project road were acquired at 14 locations. Lab tests such as particle size analysis, the Atterberg limit, the modified proctor test, and CBR were performed on the samples.

5. Results and Discussion

The analysis of the data from the various surveys conducted are formed as inputs for assessing the viability of the project stretch to serve as an alternate route and also for developing capacity augmentation to accommodate the expected traffic volume, designing the pavement, design of intersections and other amenities to improve road safety and travel time.

5.1. O-D Survey Analysis of Passenger Vehicles

The data obtained is analysed to understand the distribution of passenger trips according to the purpose of the trip.

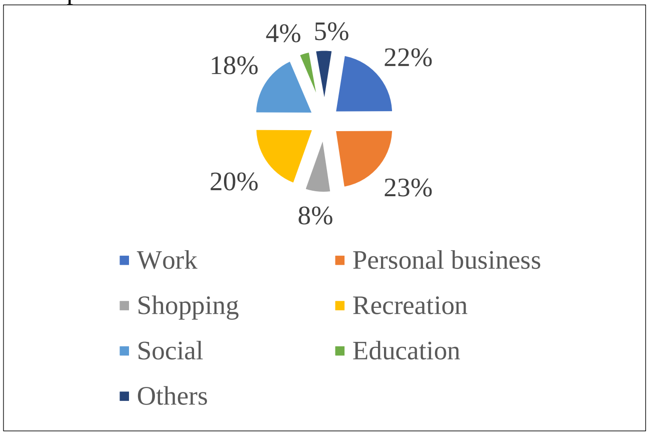

Fig. 3 Distribution of daily passenger trips according to the purpose of Trip

Of the total 77,116 passenger trips through the O-D points, an estimated 17,303 trips were work trips, followed by 17,496 personnel business trips. The occupational characteristics of passengers were ascertained from the data obtained.

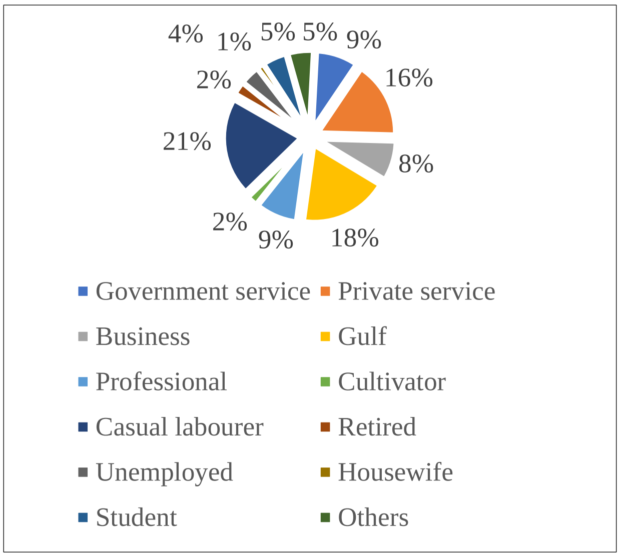

Fig. 4 Distribution of passenger trips according to occupation of trip maker

It could be seen that out of 24.6 % of the trip makers, 16 % worked in the private sector and 8.6 % in the government sector. The dependent population, like unemployed, housewife, student and retired hands, together constituted 17.5 percent of the total passengers. Based on the data, the O-D matrix for passenger vehicles, both in terms of trips and vehicles from zone to zone, was tabulated to understand the movement.

Out of 77,116 passenger trips, there were 5194 trips to the proposed stretch (Zone 1 to 7) and 7774 from these zones.

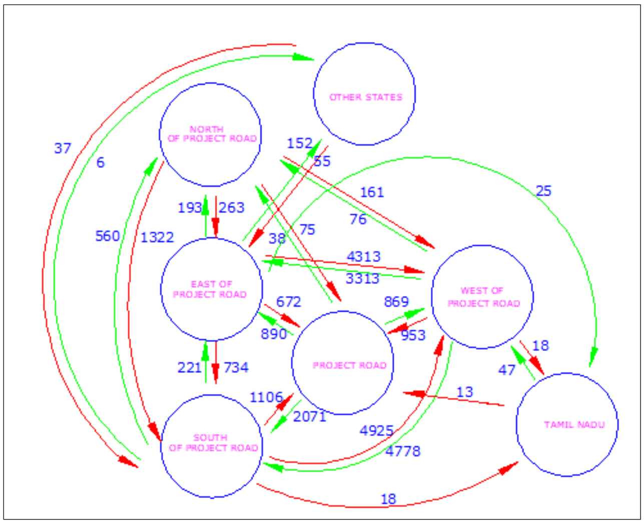

Fig. 5 Pattern of passenger movement (in trips)

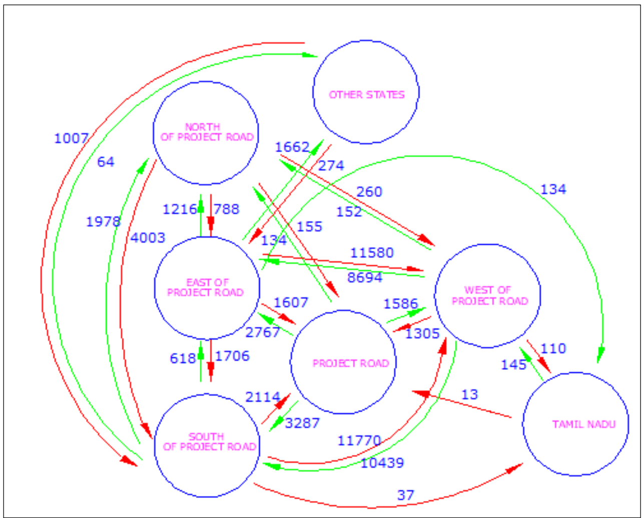

Fig. 6 Pattern of passenger movement (in vehicles)

5.2. O-D Survey Analysis of Goods Vehicles

A total of 4,831 goods vehicles passed through the survey points. The total goods volume comprised 1434 trucks (including 69 MATs), 2257 Mini trucks and 1140 goods autorickshaws. The quantum of goods handled by the goods vehicles was the tonne of 12373 tonnes. Based on the data, the O-D matrix for goods vehicles, both in terms of tonnes and distribution of vehicles from zone to zone, provides a better understanding of movements.

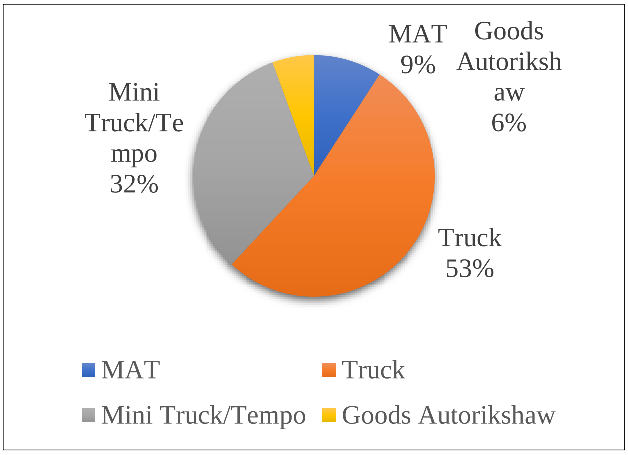

Fig. 7 Distribution of goods as per modal split

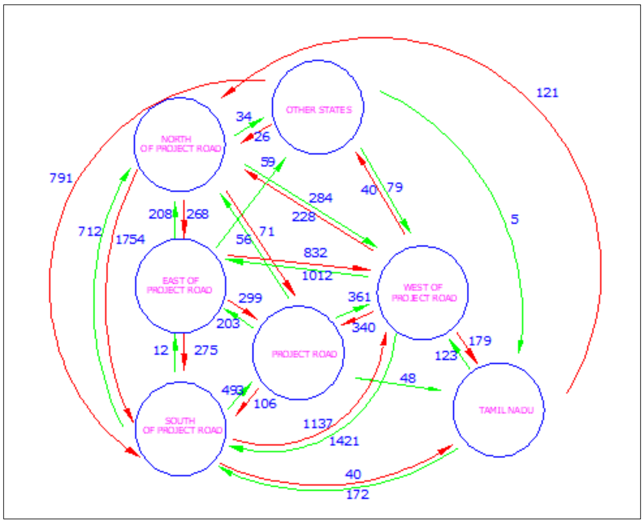

Fig. 8 Pattern of goods vehicles movement (in tonnes)

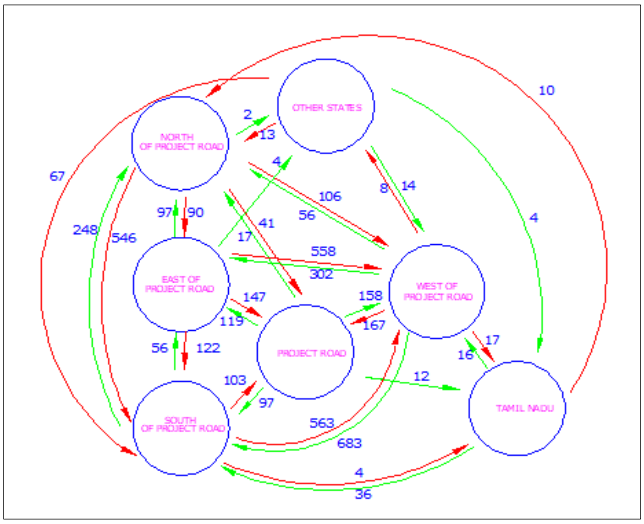

Fig. 9 Pattern of goods vehicles movement (in vehicles)

The zones within the study stretch (Zone 1 to 7) attracted 1,203 tonnes, while the total quantity of generated goods was 773 tonnes.

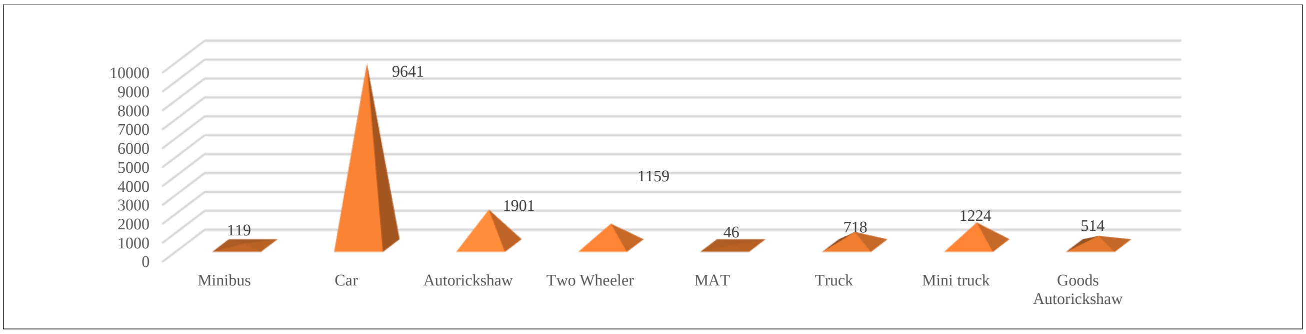

Fig. 10 Distribution of maximum likely divertible traffic

5.3. Diverted Traffic

O-D matrix shows that the entire traffic bound from/ to zones from zone 1 to 7, 10 to 13 and 15 can get diverted through the project road. Also, some portion of the traffic is bound from/ to zones 8, 14, 16 and zones 17 to 25, which is assumed to get diverted through the road. Therefore most likely traffic that may get diverted through the project road is found to be 12,820 passenger vehicles and 2501 goods vehicles amounting to a total of 17,008 PCU.

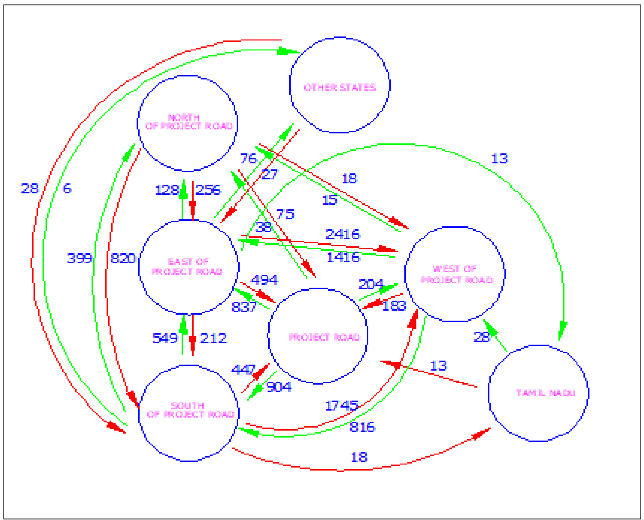

Fig. 11 Pattern of divertible passenger vehicles

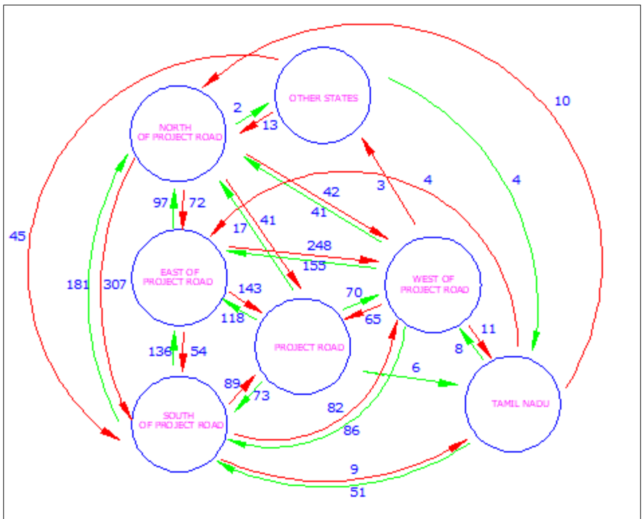

Fig. 12 Pattern of divertible goods vehicles

Table 2. Divertible commercial vehicles

Sl. No.	Vehicle Type	Likely Traffic	
		Max.	**60%**
1	Bus	414 (20% of 2072)	
2	MAT	46	28
3	Truck	718	431
4	Mini truck	1224	734
Total		2609	1607

In the absence of O-D data on buses, it is assumed that 20% of the buses (2072 obtained from the daily traffic volume at the O-D survey location) can be diverted through the project road. Also, for a realistic scenario, it can be assumed that 60% of the maximum likely traffic will use the project road. Thus the total number of commercial vehicles comes to 1607.

The fundamental principle involved is to formulate a long-term plan which will serve the community. Thus it becomes necessary to forecast the future travel pattern. Traffic projection helps evaluate the shortfall in the road network and accordingly plans the road network improvements, augmenting the facilities such as providing new roads, developing missing links, bypassing roads etc. For the present project, a growth rate of 7% has been adopted. The traffic volume for 20 years on the proposed road is projected. It is observed that the traffic volume in the project road will reach 15004 PCU by 2026, which demands a four-lane road of National Highway standards.

5.4. Volume/Capacity Ratio

Capacity utilization of the road stretch was measured by volume-to-capacity ratio (V/C Ratio). It is the ratio of the volume of traffic plying on the road stretch to the capacity of the road stretch.

The ratio of link volume count of daily vehicular traffic obtained along the 7 links is compared to the capacity of the road section as per the lane configuration. Also, the information compiled during the road inventory survey was compared with the specifications of IRC-64-1990 (Guidelines for Capacity of Roads in Rural Areas).

As seen in the table below, the V/C value for the links computed varies from 0.60 to 1.02. This necessitates the improvement of the road to cater to the purpose of a bypass.

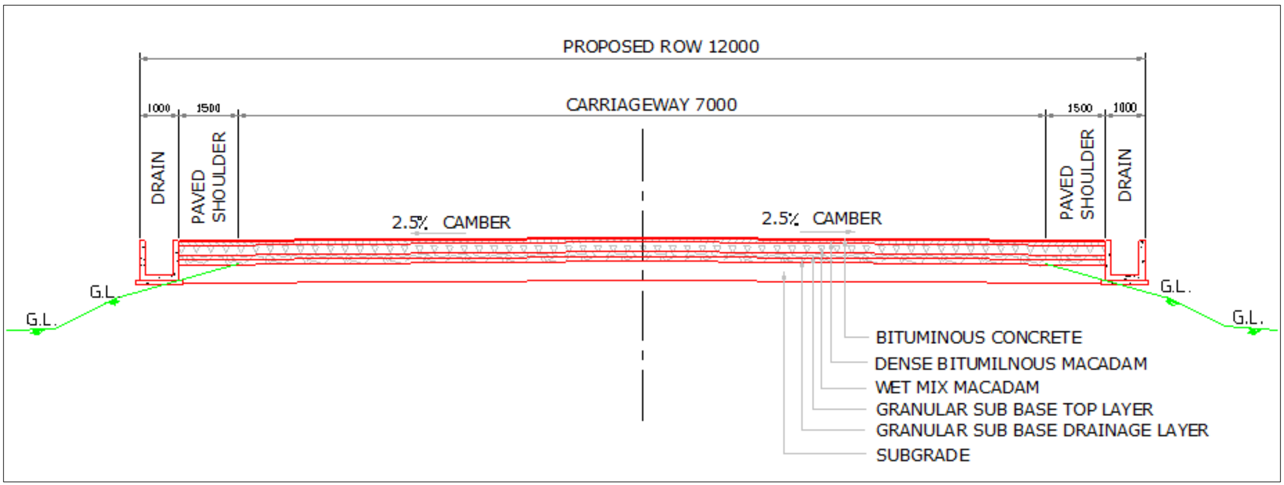

Fig. 13 Proposed cross section

Table 3. Volume-Capacity ratio of road links

Link No.	Capacity (PCU/ day)	Volume (PCU/ day)	V/C
1	5,700	4,729	0.83
2	11,000	6,627	0.60
3	11,000	8,284	0.75
4	11,000	7,593	0.69
5	11,000	8,085	0.74
6	11,000	7,385	0.67
7	11,000	11,230	1.02

5.5. *Improvement Proposal*

The project stretch passes through a highly rolling terrain. A ruling design speed of 40 kmph and a minimum design speed of 30 kmph is adopted to formulate design standards for the entire stretch. With the help of CIVIL 3D software, the centreline was harmoniously blended with the centreline of proposed bridges and other cross-drainage structures. The existing carriageway alignment was generally retained except in locations where geometric deficiencies exist.

As the land use along the project stretch is predominantly built-up and commercial, different design speeds are adopted along the project road for minimising land acquisition and demolition of residential buildings. The proposed design speed varies from 40 to 50 kmph. Vertical geometry was improved to a design speed of a minimum of 40 kmph throughout the road stretch. Existing gradients steeper than 3.33% are proposed for moderation. The approaches of bridges were proposed with a gradient of less than 3.3%, as per the provisions of IRC: SP- 73.

Based on the traffic survey analysis, the proposed standardisation of the proposed project stretch to two-lane standards and at–grade improvement to all major intersections. Only those culverts and bridges with a width of fewer than 8m are warranted for new construction/widening to cater to two-lane traffic.

Pick-up bus stops with a 3 m bus bay have been proposed on both sides of the project road. Other amenities like street lighting at built-up and bridge sections, traffic signs, road markings and road furniture like cats eye, delineators, guard stones, overhead gantry signboards, and crash barriers at bridge approaches and embankments more than 1m are proposed for enhanced traffic safety.

5.6. *Soil Investigation*

The subgrade soil sample was subjected to all necessary soil surveys, including field and laboratory tests, to identify and treat problematic ground locations, propose improvements, and finalise structural features and pavement design.

It is observed that existing soil is generally sand with varying percentages of fines. Clayey sands, silty sands, clayey, silty sands and poorly graded sands are found as subgrade soil. The Optimum Moisture Content (OMC) varies from 7 % to 19.4% across the road corridor, and the Maximum Dry Density (MDD) varies between 1.708 g/cc and 2.2 g/cc. The plasticity index values vary from 2.93% to 30.20%. The CBR values are between 8.1% to 30%.

5.7. *Pavement Design*

The pavement was designed in accordance with the method prescribed in IRC: 37-2018.

Out of the various types of vehicles encountered during traffic counts and axle load surveys, Light Commercial Vehicles (LCV's), Buses, 2-Axle Trucks, 3 Axle Trucks and Multi Axle Vehicles (MAV's) have been considered.

The following equation (1) is used to compute the design traffic Ns, in terms of the cumulative number of standard axles.

$$Ns= \frac{365\,[(1+r)n-1]}{r} \times A \times D \times F \qquad (1)$$

r - 7.0% is adopted for present traffic
n - Design life in years which is taken as 20 years
D – Lateral Distribution factor, which is taken as 0.50.
F – Vehicle Damage Factor (VDF), which is taken as 5.0.

(Equivalent number of standard axles per commercial vehicle.)
A - Number of commercial vehicles per day-
A = $P(1+r)^x$ (2)
P = Number of commercial vehicles as per the last count
x = number of years between the last count and the year of completion of construction

A = $1607(1+0.07)^1$
= 1720 cpvd

The value of A obtained is 1720 commercial vehicles per day. Using the formula cited in equation (1), Ns Cumulative number of million standard axle load is computed for a design period of 5 years, 10 years, 15 years & 20 years.

Table 4. Design traffic in terms of MSA

Sl. No.	Period	MSA
1	5 Years	9.03
2	10 Years	21.68
3	15 Years	39.44
4	20 Years	64.34

Based on the MSA obtained for different design periods and the design subgrade CBR assumed as 8%, pavement composition is estimated for different design periods.

Table 5. Purposed pavement design for the project road

Design Life	Design Sub-Grade CBR = 8%			
	Bituminous Surface		Granular Base	Granular Sub Base
	BC	DBM		
20	40 mm	115 mm	250 mm	200 mm
15	40 mm	105 mm	250 mm	200 mm
10	30 mm	90 mm	250 mm	200 mm
5	30mm	60 mm	250 mm	200 mm

As shown above, pavement composition as per IRC: 37-2018 works out to be 40 mm BC+ 105mm DBM+ 250 mm WMM+ 200 mm GSB is designed for 15 years and 40 mm BC+ 115mm DBM+ 250 mm WMM+ 200 mm GSB is designed for 20 years. It is recommended to have the design for 15 years.

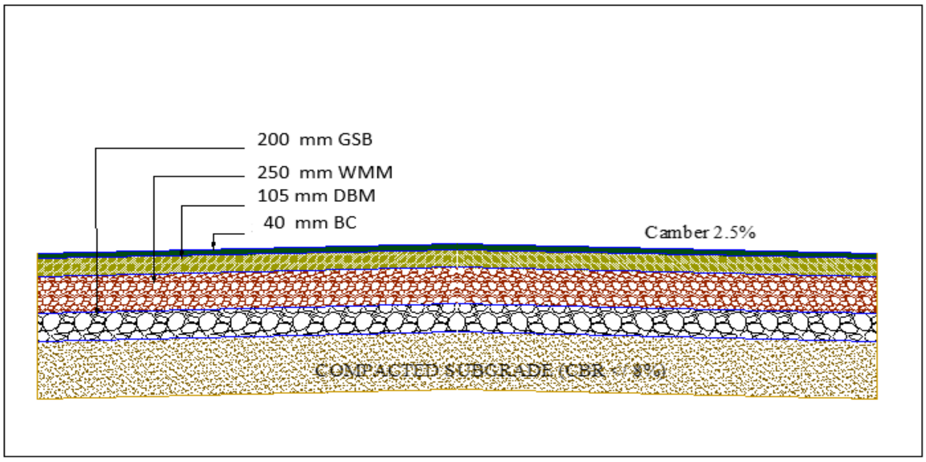

Fig. 14 Proposed pavement composition

5.8. Cost Estimate

The cost estimate has been prepared separately for the two sections of the project road. Section 1 starts from Perumthuruthy Junction and ends at Manarcadu Junction on Kottayam-Kumily Road, covering a total length of 23.440 km. Section 2 starts from Puthupally Junction and ends at Kanjikuzhy Junction, covering a length of 5.150km.

The rate analysis has been worked on based on the Delhi Schedule of rates. The basic rates for each construction item were analysed on the basis of the material study undertaken and the anticipated source distance to the site of work. For items where these rates are not available, the rates were adopted as per the prevailing Market rates.

Detailed quantities were worked out to develop the project road to two-lane standards per the proposed cross-section.

The total cost for developing the project road has been found to be Rs. 14 Crores per km with Section 1 – 6.94 Cr and Section 2 -7.38 Cr.

6. Conclusion

The following conclusions are drawn from the study:
The proposed route from Thiruvalla to Kottayam/Manaracadu via Perumthuruthy, Nalukodi, Thenganal, Vakathanam and Puthuppally can be developed as an alternate route to Changanassery and Kottayam towns

Classified traffic volume surveys were conducted along the alignment after dividing the entire length into 7 homogeneous sections.

It could be seen that the daily traffic flow along the proposed project stretch in the links varies from 4700 PCU to 11200 PCU, corresponding to a V/C value of 0.60 to 1.02.

To understand the existing quantum and pattern of traffic, Origin-Destination (O-D) surveys were carried out through the roadside interview method.

Of the total of 77,116 passenger trips through the O-D points, an estimated 17,303 trips were work trips, followed by 17,496 personnel business trips.

The traffic volume in the project road will reach 15000 PCU by 2026, which demands a four-lane road of National Highway standards.

A design speed of 40 kmph could only be proposed for the project road due to the presence of built-ups and problems related to land acquisition.

It is proposed to provide paved shoulders with 40 mm BC+ 105mm DBM+ 250 mm WMM+ 200 mm GSB, corresponding to a design load of 40 msa and 8% subgrade CBR.

Appropriate provisions for roadside furniture, road signs and markings and lighting have been made.

Concrete drains are proposed on either side of the entire length of the stretch.

The per km cost for development has been worked out to be Rs. 6.94 Crores for the Perumthuruthy-Manarcadu section and Rs. 7.38 Crores for the Puthuppalli-Kanjikuzhy section, the total cost being Rs. 14 Crores.

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