AI and ML-Based Optimization of MultiModal Transportation*

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***Abstract*—**

The fastest path must be found in order to reduce travel time and expense for effective multimodal transportation in urban settings. In order to optimise transportation routes, this study presents optimal AI and ML-based methods ,putting speed from the source to the destination at highest priority. Various modes of transportation such as walking, taxis, biking, buses, autorickshaws, and metro are taken into account by our algorithm. The optimisation criteria that offer a comprehensive solution for users looking for the fastest travel include cost, traffic conditions, road quality, and distance. The suggested approach would be effective in reducing trip time significantly, so as to present a promising development in the field of optimised multimodal transportation.

***Index Terms*—multilmodel,transportation routes**

I. Introduction

The demand for creative ways to figure out the fastest route for multimodal transportation is growing as urban transportation networks change. Prioritising speed becomes critical as cities expand and traffic becomes more congested. In order to tackle this problem, this study suggests an optimisation strategy based on AI and ML that is aimed at figuring out the quickest route from source to destination. By taking into account variables like distance, road quality, traffic conditions, and cost, our paper seeks to streamline transportation routes that include walking, taxis, bikes, buses, autorickshaws, and metro. The research holds importance since it has the potential to greatly improve multimodal transportation's speed and effi- ciency, hence aiding in the creation of more intelligent and efficient urban transportation networks.

A. Objective

- Develop and evaluate an AI/ML-based framework for finding the fastest route for multimodal transportation in urban areas.
- Minimize travel time for users of multimodal transporta- tion by optimizing routes that consider various modes (walking, taxi, bike, bus, auto rickshaw, metro) within Bengaluru
- Contribute to the development of intelligent and efficient urban transportation networks by significantly reducing trip times through optimized multimodal route planning.

II. Problem Statement

The effectiveness of multimodal transport in modern urban environments is contingent upon the identification of optimal routes that not only minimize trip time but also reduce expenses. Current challenges within transportation networks include prolonged travel durations, suboptimal route planning, and escalating commuter expenditures. Traditional approaches struggle to seamlessly integrate diverse transportation modes and lack the adaptability to respond to dynamic factors such as traffic patterns and evolving consumer preferences.

To address these challenges, this study proposes an in- novative approach leveraging Artificial Intelligence (AI) and Machine Learning (ML) to optimize multimodal transporta- tion routes, emphasizing the reduction of trip durations. The primary concern revolves around the absence of a comprehen- sive and flexible optimization framework capable of making informed decisions about the most efficient combination of routes and transportation modes. Our goal is to bridge this gap by prioritizing speed when determining routes between two locations.

The algorithm presented in this paper encompasses various modes of transportation, including walking, taxis, biking, buses, autorickshaws, and metro. Optimization variables en- compass distance, road quality, traffic conditions, and cost, allowing users to access a thorough and dynamic framework for route planning. This system aims to enhance user experi- ence by addressing the pressing issues of extended travel times and escalating costs associated with multimodal transportation in urban environments.

III. Methodology

The main focus of the paper is in an approach for a pathfinding technique for multimodal transport. The pathfind- ing technique used works with the same principles as that of the A* algorithm. It finds an optimal or close-to-optimal path within an undirected graph using significantly less time as compared to classical Brute force methods like Depth-First-Search(DFS) or Breadth-First-Search(BFS).

In the A* algorithm, the distance between one node and the destination node is measured by 2 separate measures. The first measure is the actual distance form the source node to the current node. The second measure is a heuristic measure to estimate distance. Heuristic distance is computationally light to perform and gives an approximate but generally inaccurate distance between the current node and destination node. The algorithm for A* in reference is as follows:

1) Load the Graph with edge weights, starting node and destination node. G(n) has exact distance of nth node to staring node. G(starting node)=0
2) Load the heuristic function or heuristic distance of all nodes such that heuristic distance of nth node can be retrieved when calling function H(n). F will store the approximated path cost where F=G(n)+H(n)
3) Create a stack PATHS
4) push starting node into PATHS with parent as null
5) While complete path is not found:

- current node=pop(PATHS)
- For the neighbour nodes of Currentnode

a) If neighbour is destination then Completed path found
b) G(neighbour)=G(currentnode)+ weight of edge(currentnode, neighbour) in graph
c) Find F=G(neighbour)+H(neighbour)

- push the neighbour node with into PATHS in descending order of F with parent as current node

In the technique we intend to use, we take a similar approach, but with some differences :

- Heuristic function, H(n), as Euclidean distance between two geographic coordinates
- Multiple graphs for each mode of transport:
  – Metro
  – Driving
    ∗ Traffic route
    ∗ Waiting in a region time in case of taxi, auto, etc
- Heuristic distance for metro is considered as heuristic distance of station closest to destination + time taken to reach that station from current station
- Every node regardless of mode of transport will have coordinate information
- Every time neighbours are calculated in A* algorithm for traffic nodes, the closest metro station by Euclidean distance and bus terminals within a radius of 200m of the current node are also taken as neighbours.
- If current node is a metro station, then a direct path to the metro station with least heuristic distance is found. Due to the topology of Metro in Bangalore, to travel from one metro station to another, trains need not be switched or switched only

A. Metro Analysis

Metro systems, also known as rapid transit or subways, have become a vital component of urban transportation in major cities worldwide. They offer a fast, efficient, and often more environmentally friendly alternative to traditional modes of transportation like cars and buses. Analyzing metro systems involves a comprehensive assessment of various aspects to understand their effectiveness, impact, and potential for im- provement. Key areas on Metro Analysis:

- **Network Structure:** This involves examining the layout of the metro lines, number of stations, connectivity across different parts of the city, and potential gaps in the network.
- **Ridership Patterns:** Analyzing ridership data helps un- derstand who uses the metro, travel frequency, peak hours, and origin-destination patterns. This information is crucial for optimizing schedules and capacity allocation.
- **Travel Efficiency:**Evaluating travel times, transfer points, frequency of trains, and overall network efficiency in reducing congestion is essential.[2]

So,Here we are analyzing our **Namma Metro trains Of Bengaluru**

1) Brief Introduction on Bengaluru Metro: Bengaluru Metro, sometimes called Namma Metro (meaning Our Metro in Kannada), is a rapid transport network that serves Ben- galuru, India. With an operational length of 73.75 kilometers, it is the second-longest metro network in operation in India, trailing only Delhi Metro.When it was first opened, it was South India's first underground metro system Namma Metro features a combination of elevated, at-grade, and subterranean stops. As of October 2023, Namma Metro had 66 operating metro stations, consisting of 57 elevated stations, 8 under- ground stations, and 1 at-grade station. The tracks used by the system are standard gauge.The organization responsible for developing, running, and growing the Namma Metro network is Bengaluru Metro Rail Corporation Limited (BMRCL), a joint venture between the Indian government and the state government of Karnataka. Every day, from 5:00 to 24:00, services are offered, with headways ranging from five to fifteen minutes.There are now two lines in use in the metro: the purple line and the green line.The green line travels 30 km from Nagasandra to Silk Institute with 29 stations, while the purple line travels 42.17 km from Challaghatta to Whitefield with 37 stations overall.

- **Green Line:**Green Line of Namma Metro was built along with the Purple Line during the first phase of construction of the metro rail system for the city of Bengaluru, Karnataka, India. The 30.5 km (19.0 mi) line connects Nagasandra in the northwest to Silk Institute in the south. The line connects the industrial centers of Peenya and Yeshwanthpur in the north with the cen- tral hub of Majestic and the southern residential areas of Bangalore (Basavanagudi, Jayanagar, Banshankari , Thalaghattapura, Kanakapura Road etc.). Green Line is mostly elevated, with 26 elevated and 3 underground stations. The Line passes through Majestic station which is an interchange station between Green and Purple Lines. Trains initially operated on the Green Line from 6 am to 11 pm. This was extended from 5AM to 11PM from 1 December 2015. The frequency along the line was 15 minutes between 5AM and 8AM and 8PM and 11PM, and 10 minutes between 8AM and 8PM.[40] Trains halt for 30 seconds at each station.[41] The 24.2 km journey is usually covered in about 42 minutes. Each six-coach train has a capacity of 2,004 passengers -

- **Purple Line:**The Namma Metro train system in Bengaluru, Karnataka, India, includes the Purple Line. The line stretches across 37 stations across 43.49 km (27.02 mi) as of 2023, from Challaghatta in the southwest to Whitefield (Kadugodi) in the east.[2] With 31 elevated stations, 5 underground stations, and 1 at-grade station, the Purple Line is primarily elevated. The line goes through a number of the city's most popular activity hubs, such as Majestic station, which serves as an in- terchange for the Purple and Green Lines, Whitefield, Krishnarajapura, MG Road, and Vidhana Soudha. The first underground metro stretch in South India was the Purple Line's Phase I. The Purple Line currently has 37 stations. Cut-and-cover construction was used to build every underground station.The majority of subterranean stations have dimensions of 300 meters by 25 meters. Majestic's interchange station is significantly bigger. Ev- ery day, the metro service is available from 5 am to 12 am. A Purple Line train takes 82 minutes to complete from start to finish.[68] In order to accommodate the increasing volume of passengers during morning peak hour, Purple Line trains started operating every four minutes on November 7, 2016.[69] Later on, this timing was changed because the trains were not running at their fullest capacity. A new weekday schedule was implemented by the BMRC on February 27, 2017. The line's headway was adjusted to 4 minutes between 08:30 and 09:10, 7 minutes
between 07:00 and 08:30 and 09:10
and 10:40, 8 minutes between 16:00 and 20:40, and 15 minutes during all other periods.On rare occasions, metro services have run into 2200 hours. On festival days or during an international cricket match played in Bangalore, services are typically extended.

2) Metro visualization:

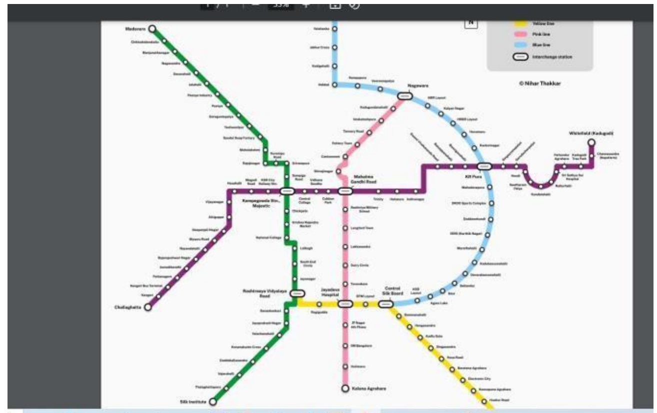


Fig.1. Purple and green line page

The above image indicates that that there is green line and purple line . The 30.5 km (19.0 mi) line connects Nagasandra in the northwest to Silk Institute in the south. The line connects the industrial centers of Peenya and Yeshwanthpur in the north with the central hub of Majestic and the southern residential areas of Bangalore (Basavanagudi, Jayanagar, Banshankari , Thalaghattapura, Kanakapura Road etc.). Purple line stretches across 37 stations across 43.49 km (27.02 mi) as of 2023, from Challaghatta in the southwest to Whitefield (Kadugodi) in the east.

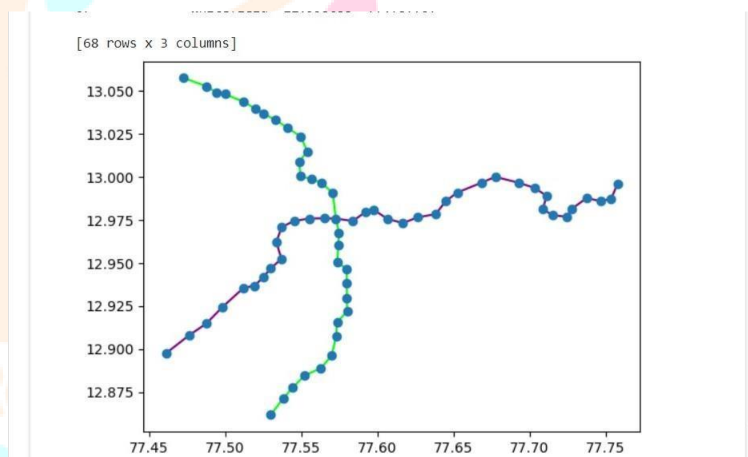


Fig.2. Data Visualization showing latitude vs longitude plot

- we can calculate the distance between any two stations using their latitude and longitude coordinates.
- we can identify which stations are closest to a particular point of interest.

Taking an example of Majestic Metro Station, we can see the amount of time it takes to travel from Majestic Metro To every other station. The amount of time taken is indicated by the color of the path. A blue hue would mean shorter time and a red hue indicated longer travel time. The Red Marker indicates Majestic Metro Station's location

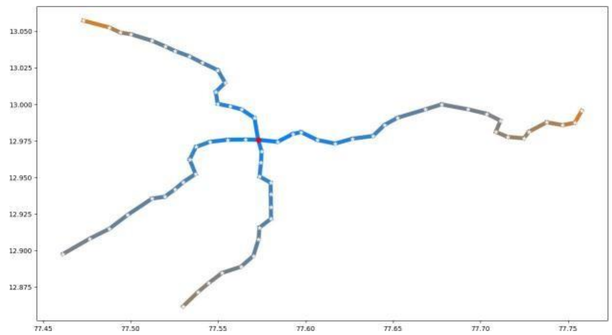


Fig.3. Time required to travel from Majestic Metro Station to all other Stations

Taking starting station as JP Nagar Metro Station instead, We can see that that the stations closer to JP on the Metro lines are faster to reach and shows that duration of travel between stations does not confirm to Euclidean distance. Here, The Red Marker in Fig 4 indicates the location of JP Nagar Metro Station

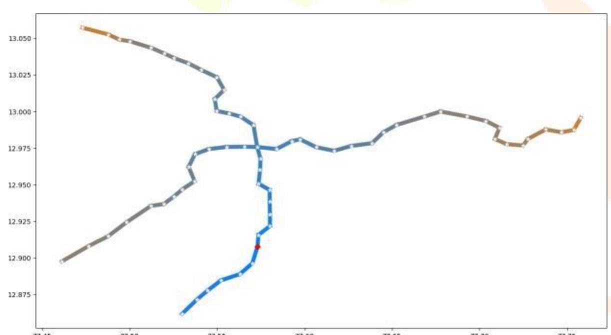


Fig.4. Time required to travel from Majestic Metro Station to all other Stations

Due to the simple structure of Namma Metro, it is very fast to compute distance using the brute force method, Depth-First-Search(DFS).

IV. Shortest Path Optimization of BMTC Bus Routes

The Bangalore Metropolitan Transport Corporation (BMTC) operates an extensive network of bus routes serving the urban and suburban areas of Bangalore, India. To optimize the efficiency of this multi-modal transportation system, AI and ML-based techniques are being increasingly employed. In this section, we focus on the optimization of bus routes through the determination of shortest paths.

Dataset and Sources Our analysis utilizes publicly available datasets provided by BMTC and other open data platforms. The primary dataset is sourced from BMTC's official GitHub repository, which contains detailed information about bus routes, stops, schedules, and other relevant parameters. Ad- ditionally, we reference the Open City Data platform, which offers insights into bus stops and routes mapped by ward within Bangalore.

Description of Shortest Path Optimization Shortest path optimization is a crucial aspect of bus route planning aimed at minimizing travel time, distance, and operational costs while maximizing service coverage and efficiency. AI and ML-based techniques play a pivotal role in analyzing large-scale trans- portation datasets to derive optimal route configurations.[3]

By leveraging graph-based algorithms such as Dijkstra's al- gorithm or A* search algorithm, the shortest path between any two bus stops within the BMTC network can be determined efficiently. These algorithms consider various factors including road network topology, traffic conditions, bus stop densities, and passenger demand patterns.

- **Graph Representation:** The BMTC bus network is represented as a weighted graph, where nodes correspond to bus stops and edges represent the roads connecting these stops. The weights on edges denote factors such as travel time, distance, or a combination of both.
- **Data Preprocessing:**Raw data from the BMTC dataset is processed to extract relevant information such as stop coordinates, route schedules, and historical travel data. This preprocessing step ensures that the input data is suitable for optimization algorithms.
- **Route Planning:**Given a source and destination bus stop, the optimization algorithm computes the shortest path using graph traversal techniques. This path is determined based on minimizing a predefined cost function, which may incorporate factors like distance, traffic congestion, and service frequency.
- **Dynamic Updates:**To adapt to real-time changes in traf- fic conditions and passenger demand, the optimization process can be dynamically updated using streaming data sources. This allows for continuous refinement of bus routes to optimize efficiency and service quality.

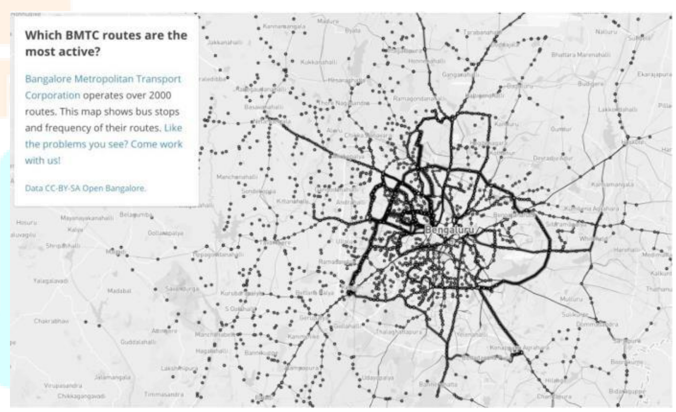


Fig.5. BMTC Bus Stop Frequency

This map depicts a visualization of Bengaluru Metropolitan Transport Corporation (BMTC) bus stop frequency. Thicker lines represent routes with more frequent service. The map covers a large portion of the city, including areas like

Kanpamangala, Kengeri, and Jalahalli. Notably, areas in the south appear to have a higher frequency of buses compared to those in the north. The text at the bottom indicates the data is licensed under CC-BY-SA by Open Bangalore. The route with the most frequent service appears to be the one that runs along the eastern edge of the map, labelled with NAL-BRK [possibly NAL refers to Nallurahalli and BRK to Brooke Road].

Longest Route

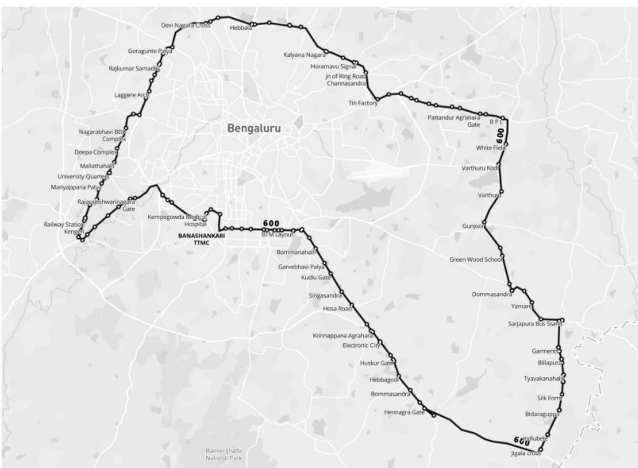


Fig.6. BMTC Bus Longest Route

This map shows the longest route (Route 600) on the BMTC bus network in Bengaluru, India. The route stretches 117 kilometers and covers over 130 bus stops. It traverses the city from Kengere in the southwest to Electronic City and Bommasandra in the southeast.The route winds its way through various areas of Bengaluru, including Rajarajeshwarinagara, Silk Board Junction, and Hosa Road. The map also includes landmarks like the Kempegowda International Airport and the Bannerghatta National Park.The route winds its way through various areas of Bengaluru, including Rajarajeshwarinagara, Silk Board Junction, and Hosa Road. The map also includes landmarks like the Kempegowda International Airport and the Bannerghatta National Park.

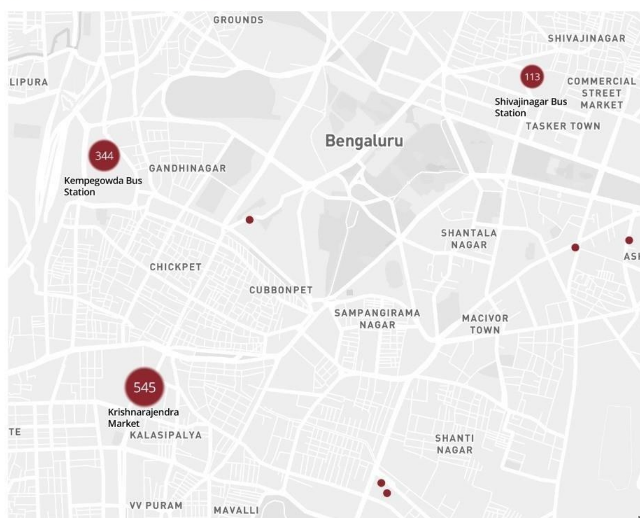
Most frequent trips

Fig.7. BMTC Most frequent rips

The image depicts a map fragment of Bengaluru, India, showcasing a portion of the BMTC bus network. The area extends from Yeshwanthpura in the north to Attibele in the south. It includes several bus stops, including Peenya 2nd stage, Kempegowda Bus Station, and Kengeri TTMC. The text labels, though not entirely visible, seem to indicate route numbers or distances between stops.

While this image provides a glimpse into Bengaluru's bus network, it's recommended to consult the BMTC website or app for comprehensive and up-to-date route information, as well as real-time bus locations and schedules.

Where do most buses start from?



Most routes start from Krishnarajendra Market as opposed the notion that is Kempegowda Bus Station.

Fig.8. Section of BMTC bus network

This map excerpt from Bengaluru, India, displays a section of the BMTC bus network. It centers around Shivajinagar Bus Station and covers areas like Cubbonpet, Kalasipalya, and Shantinagar. The map highlights bus routes with color-coded lines, but the specific route numbers are not discernible. While this image offers a general idea of bus routes in this part of

Bengaluru, it's advisable to refer to the BMTC website or app for detailed route information, including stop locations and real-time bus positions.

Fig.9 Section of BMTC bus network-Koramangala

This map excerpt from Bengaluru, India, showcases a portion of the BMTC bus network in the Koramangala area. It displays major roads and landmarks like IIMB, Agara Junction, and Koramangala Forum. The map indicates bus routes with color-coded lines, but route numbers are not entirely visible. While this image provides a general idea of bus routes in Koramangala, it's recommended to consult the BMTC website or app for comprehensive route information, including stop locations and real-time bus locations.

Fig.10. Section of BMTC bus network-Koramangala

This map excerpt from Bengaluru, India, depicts a section of the BMTC bus network in the Marathahalli area. Key locations like KIADB Road, Marathahalli Bridge, and Marathahalli Outer Ring Road are visible. The map showcases bus routes with color-coded lines, but route numbers are difficult to discern. While this image provides a general idea of bus routes in Marathahalli, it's advisable to refer to the BMTC website or app for comprehensive route information, including stop locations and real-time bus locations

A. Conclusion of BMTC Bus Analysis

- Optimizing Bengaluru's BMTC bus network is imperative for creating a more efficient and user-friendly public transportation system. The complexity of the network, as evidenced by the analysis of BMTC route maps (referencing the uploaded images), underscores the need for real-time data integration and AI/ML-powered route optimization. AI/ML models offer the capability to sug- gest personalized multimodal travel plans that consider real-time traffic conditions, passenger volume, and user preferences. However, responsible implementation must address concerns regarding data quality, privacy, and accessibility for all.
- In conclusion, AI/ML presents significant promise for optimizing Bengaluru's BMTC network, thereby paving the way for a more efficient, user-centric, and equitable multimodal transportation system. Future research could explore integrating AI/ML with real-time traffic prediction models for even more dynamic route optimization. Additionally, the investigation of reinforcement learning algorithms could provide further benefits in adapting to unforeseen changes in traffic conditions. Once proven successful in Bengaluru, this approach could be scaled and replicated in other cities with complex public trans- portation networks, albeit with necessary adjustments to accommodate local infrastructure and travel patterns.
- The successful implementation of AI/ML-based route optimization in Bengaluru's BMTC network not only promises improved efficiency and user experience but also contributes to a more sustainable urban environment. This includes benefits such as reduced congestion, shorter travel times, improved air quality, and potentially increased ridership, ultimately fostering a more vibrant and livable city.

V. Traffic Analysis:Traffic Flow

The methodical study of patterns, behaviors, and trends in transportation networks, with a primary focus on road networks but also encompassing air and sea transportation, is known as traffic analysis. It entails gathering, analyzing, and using data to comprehend many facets of traffic flow, such as volume, speed, density, and congestion. Traffic analysts can find bottlenecks, optimize routes, and raise the general level of safety and efficiency in transportation networks by studying this data.[1]

The application of intelligent transportation systems (ITS) to improve mobility and lessen environmental effects depends heavily on traffic analysis. Since the introduction of cutting- edge technologies like GPS, sensors, and machine learning algorithms, traffic analysis has developed further, providing ever-more-advanced insights and strategies for handling the intricate dynamics of modern transportation systems

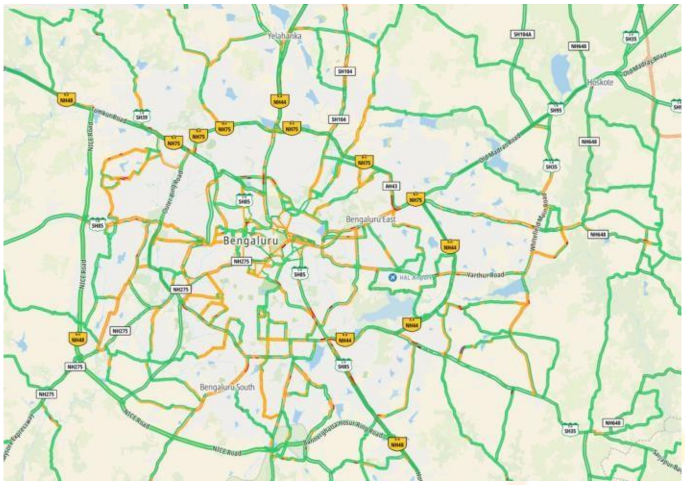


Fig.11. Traffic Flow in Bangalore

The Figure 11 [**?**] shows traffic congestion within Bangalore. The lines signify roads of importance. The colors represent different conditions of traffic

- Green: No Congestion
- Orange: Moderate Congestion
- Red: Heavy Congestion

The roads of importance refer to the inter city Road, Ring Roads and Highways. Based on the congestion of the roads, the heuristic distance is incremented if a zone of congestion exists somewhere on a straight line between the node and destination. This is done to discourage choosing a congested road during path finding

VI. Effective Routing Methods for Pedestrians, Cyclists, and Rental Cabs

Urban transport systems that are efficient and allow for the movement of people in many ways—including bicycles, pedestrians, and rental cars—are essential to the sustainability and operation of cities. In order to maximise these modes' effectiveness, safety, and environmental impact, routing is essential. This paper explores the use of the A* algorithm, which is well-known for its effectiveness in pathfinding, in the routing of pedestrians, cyclists, and rental cars. The A* algorithm effectively determines the shortest path between nodes in a network by taking into account both the expected cost to achieve the objective and the cost of reaching a node from the start. Whereas A* takes traffic congestion and bike lane availability into account for bikers, it gives pedestrians priority when it comes to considerations like pavement availability and shortest trip route. Similar to this, A* reduces trip time in rental car routing by accounting for passenger demand and traffic conditions. A* routing has the advantages of quicker travel times, more safety, and less environmental impact. But there are issues that need to be resolved, like algorithm complexity and real-time updates. All things considered, the A* algorithm provides a strong means of maximising urban mobility, encouraging effectiveness, sustainability, and inclusivity in urban transportation networks.

A. Introduction

- The modern world is characterised by urbanisation, as more and more people choose to live and work in cities. Cities are facing more and more difficulties in properly managing their transit systems as their population grows. In the past, automobile traffic has been given priority in transportation planning, which has resulted in traffic jams, pollution, and safety risks. But the emergence of environmentally friendly forms of travel like cycling, walking, and shared mobility services has forced a change to more effective and inclusive routing techniques.
- The adoption of multimodal transport systems that meet the many needs of urban commuters is a result of the search for efficient urban mobility solutions. The optimi- sation of routing techniques for rental cars, bicycles, and pedestrians—all essential parts of the urban transportation ecosystem—is at the heart of this project. Conventional methods frequently fail to meet the particular needs of each mode, highlighting the need for creative alternatives that can strike a balance between effectiveness, security, and environmental sustainability.
- In this context, the A* algorithm emerges as a promising tool for optimizing routing methods across various trans- portation modes. Renowned for its efficiency and effec- tiveness in pathfinding, the A* algorithm offers a princi- pled approach to navigating complex urban environments. By leveraging heuristic functions to guide the search for optimal routes, A* facilitates informed decision-making, enabling pedestrians, cyclists, and rental cabs to navigate cities with greater ease and efficiency.

B. Application of A* in Routing Methods

1) **Pedestrain Routing** By taking into account variables like sidewalk availability, pedestrian crossings, and shortest trip distance, A* can optimise pedestrian routes. Pedestrian-specific factors, like avoiding high-traffic ar- eas, uneven terrain, and steep inclines, can be incor- porated into heuristic functions. Real-time updates on pedestrian traffic flow and impediments can be added to dynamically modify route recommendations.

2) **Cyclic Routing** Using variables like traffic conges- tion, road grade, and the availability of bike lanes, the A* algorithm can determine the best cycling routes.

- Considering elements like designated bike lanes and accessibility to bike-sharing stations, heuristic functions may give preference to bike-friendly routes. • Adaptive routing is made possible by the integration of GPS data and real-time traffic updates, which help prevent accidents, road closures, and traffic jams.

3) **Rental Cab Routing** • By minimising journey time and taking into account variables like traffic, passenger demand, and driver availability, the A* algorithm opti- mises rental car routes. • Effective pick-up and drop-

off sites may be given priority by heuristic functions, cutting down on passenger wait times and maximising fleet utilisation.
• Proactive route planning and resource allocation are made possible by the integration of predic- tive analytics, which can forecast future demand trends.

This research highlights the A* algorithm's potential to com- pletely transform urban mobility by examining its use in rental car, bicycle, and pedestrian routing. In order to shed light on how cities might use cutting-edge algorithms to tackle urgent transport issues, this paper will explain the fundamentals of the A* algorithm and look at its useful applications for routing techniques. Urban areas may set the stage for a future that is more resilient, equitable, and sustainable by thoroughly analysing A* routing.
Several different algorithms can be used to optimise routing in rental car services in addition to the A* algorithm. Here are a few noteworthy instances:

1) **Dijkstra's Algorithm:** Another well-liked method for locating the shortest path in a graph is Dijkstra's al- gorithm. It investigates every route that could lead from the source node to every other node and chooses the one with the least amount of total expense. Because it lacks a heuristic component, it can be less effective than A* for bigger graphs even if it assures finding the shortest path.
2) **Bidirectional Search:** In bidirectional search, pathways from the source and destination nodes are simultane- ously explored and met in the middle. By taking advan- tage of the problem's intrinsic symmetry, this method can drastically cut down on search time, especially for big graphs. To guarantee that both searches converge well, bidirectional search calls for close coordination.
3) **Contraction Hierarchies:** This preprocessing method reduces the size of the graph, which expedites short- est path calculations. It simplifies the network while maintaining the shortest paths by locating "important" nodes and shrinking less significant ones. Significant performance gains can be achieved with this method, especially in networks like road networks that have a hierarchical structure.
4) **Ant Colony Optimization (ACO):** ACO is a meta- heuristic inspired by the foraging behavior of ants. It involves simulating the pheromone trail deposition and evaporation process to find optimal paths in a graph. ACO can be particularly effective in dynamic routing scenarios where the optimal path may change over time, as it adapts to changing conditions based on local search heuristics.
5) **Reinforcement Learning:** Using this machine learning technique, an agent gains decision-making skills through interactions with its surroundings. When it comes to routing, reinforcement learning algorithms are capable of acquiring the best policies for route selection based on past data and input from the surroundings. RL is a good fit for real-time routing optimisation because of its flexibility in complicated and dynamic contexts.
6) **Genetic Algorithms (GA):** Genetic algorithms are algo- rithms for optimisation that draw inspiration from natu- ral selection and genetics. Through selection, crossover, and mutation procedures, they evolve a population of potential solutions iteratively. By modelling potential routes as chromosomes and evolving them to find nearly optimal solutions, GA can be used to solve routing challenges. Even though GA can be costly to compute, it is an efficient way to search across big solution spaces and identify excellent answers.

Rental car businesses can customise their routing techniques to meet certain needs, like real-time responsiveness, scala- bility, and conditional adaptability, by utilising these various algorithms. Additionally, combining these algorithms or using hybrid approaches can improve the efficacy and efficiency of routing even more, giving taxi businesses a full arsenal for maximising urban transportation.

1) **Pedestrain Routing:** Pedestrians are an important part of the urban commuter population, and their convenience and safety are of utmost importance. Good pedestrian routing takes into account a number of factors, such as:

- Footpath Infrastructure: For safe and effective pedestrian mobility, well-maintained pavements, pedestrian crossings and pedestrian-only zones are necessary.
- Accessibility: Wheelchair users should have priority when designing routes, thus ramps, lifts and other facilities should be provided.
- Wayfinding Systems: Pedestrians can be helped to navigate urban areas more effectively with the help of clear signage, maps, and smartphone applica- tions.
- Safety Measures: Pedestrian safety is enhanced by traffic calming techniques including speed bumps and traffic lights.

2) Furthermore, pedestrian routing can be further im- proved by using walkability-focused urban design prin- ciples, such as mixed land use and pedestrian-friendly streetscapes.
3) **Cyclic Routing:** Cycling presents a sustainable and ef- ficient mode of urban transportation, offering numerous health and environmental benefits. Effective routing for cyclists involves:

a) **Bike Lanes and Paths:** Cycling routes that are safe and effective for cyclists and kept apart from motorised traffic include designated bike lanes and off-road cycling trails.[4]
b) **Bike-Sharing Systems:** This encourages riding as a practical form of transportation and makes it easier to access bicycles.
c) **Cyclist-Friendly Infrastructure:** Features like bike racks, repair stations, and safe parking spaces promote riding and help cyclists on their travels.

d) **Traffic calming Measures:** On shared roads, lower speed restrictions and traffic slowing measures improve bicycle comfort and safety. An urban environment that is more bike-friendly can also be created by enacting laws that are friendly to bicycles and encouraging cycling culture through lobbying and educational programmes.

4) **Rental Cab Routing:**In addition to ride-hailing services and shared mobility platforms, rental cars have revo- lutionised urban transportation by providing practical substitutes for private vehicle ownership. In order to route rental cars effectively, one must:

- **Dynamic Routing Algorithms:** To maximise route choices and reduce trip times, sophisticated al- gorithms examine real-time traffic data, passenger demand, and driver availability.
- **Integration with Public Transit:** Passengers can combine rental car trips with other forms of trans- portation thanks to seamless interaction with public transportation networks, offering all-encompassing mobility solutions.
- **Environmental Considerations:** Giving electric and low-emission cars priority lessens their negative effects on the environment and advances the cause of sustainable mobility.
- **Safety protocols:** To guarantee passenger safety and confidence in rental car services, strict safety measures are implemented. These include driver screening, vehicle inspections, and emergency re- sponse systems.

C.Benifits and Challenges

- **Benifits:**

1) **Improved Travel Time:*** algorithm effectively de- termines the best routes, resulting in shorter travel times for bicycles, walkers, and users of rental taxis.
2) **Enhanced Safety:**The A* route encourages safer travels for all passengers by avoiding congested regions and dangerous situations.
3) **Environmental Impact:**Fuel consumption and emissions are reduced by optimised routing, which helps maintain a sustainable environment.

- **Challenges:**

1) **Real-Time Updates:** Accurate route optimisation requires the incorporation of real-time data on traffic conditions, road closures, and incidents.
2) **Algorithm Complexity:** To strike a balance be- tween accuracy and efficiency, heuristic function fine-tuning and algorithm parameter optimisation need careful thought.
3) **Accessibility:** Planning thorough routes and build- ing infrastructure are necessary to ensure accessi- bility for people with impairments, which is still a concern.

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VII. References

[1] J. Gui and Q. Wu, "Taxi efficiency measurements based on motorcade- sharing model: evidence from gps-equipped taxi data in sanya," *Journal of Advanced Transportation*, vol. 2018, pp. 1–10, 2018.

[2] R. Xu, F. Wang, and F. Zhou, "Metro train operation plan analysis based on station travel time reliability," *Journal of Advanced Transportation*, vol. 2021, pp. 1–13, 2021.

[3] H. Zhang, S. Zhao, Y. Cao, H. Liu, S. Liang *et al.*, "Real-time integrated limited-stop and short-turning bus control with stochastic travel time," *Journal of Advanced Transportation*, vol. 2017, 2017.

[4] Y. Guo, J. Zhou, Y. Wu, J. Chen *et al.*, "Evaluation of factors affecting e- bike involved crash and e-bike license plate use in china using a bivariate probit model," *Journal of advanced transportation*, vol. 2017, 2017.