# Urban Traffic Planning Analysis and Route Optimization


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***Abstract*—Traffic congestion is a persistent problem that plagues urban areas worldwide, causing frustration for commuters, significant economic losses, and adverse environmental impacts. As cities continue to grow and populations increase, traditional traffic management solutions alone are proving insufficient to tackle the mounting challenges. To address these issues, this work proposes to optimize urban traffic navigation.**

**This work delivers optimized routing solutions for multiple stops in limited time frame which can be used significantly in logistics and journey planning i.e. Multi-point route optimization. By considering both real-time traffic information and historical data, the application ensures that deliveries and journeys, in general, are conducted with maximum efficiency in terms of distance and time. Additionally, the web application actively suggests alternative routes, diminishing congestion in specific areas and contributing to a more equitable distribution of traffic load.**



***Index Terms*—Traffic congestion, Multi-point route optimization, Real-time traffic information, Alternative routes**


## I. Introduction

Urbanization stands as a hallmark of modern society, promising increased economic opportunities, cultural diversity, and an improved quality of life. However, this rapid urban growth presents its own set of challenges, with none more palpable on a daily basis than traffic congestion.

Google Maps, a globally popular navigation app [1] with over a billion monthly active users [2], has made significant strides in facilitating navigation and travel planning. However, it currently does not offer features such as multi-point route optimization. Recognizing this gap, the aims to develop an application to fill this void which analyzes data to provide users with predictions of current traffic conditions, enabling them to make informed decisions and navigate away from congested routes The proliferation of smartphones, ubiquitous GPS-enabled devices, and the availability of vast amounts of real-time data create an unprecedented opportunity to revolutionize urban traffic planning. This work introduces an innovative solution through an application designed to optimize urban traffic navigation, effectively addressing the multifaceted challenges posed by traffic congestion.

The proposed web application tackles urban traffic congestion through three core strategies: traffic analysis for predictive modeling, efficient route recommendations based on congestion levels, and proactive traffic load distribution via alternate route suggestions and multipoint route recommendation. By combining these approaches, the web application aims to optimize traffic flow, minimize congestion, and enhance commuters' daily travel experiences.

## II. Background

As metropolitan areas expand and populations surge, traditional approaches to traffic management prove insufficient to alleviate burgeoning problems. Recent statistics reveal the pervasive nature of urban traffic congestion, as an estimated 74 percent of the global population is anticipated to reside in urban areas by 2050 [3], intensifying the congestion issue. According to the TomTom Traffic Index 2023 [4], congestion increased in 387 out of 416 cities worldwide, with Mumbai, Manila, and Jakarta ranking as the top three most congested cities.This alarming trend highlights the urgency for innovative solutions that leverage technology and data to address the escalating challenges of urban traffic congestion. India, with its vast road network, faces significant traffic challenges. As of 2020, the country had around 4.7 million kilometers of roads, making it the third-largest road network globally. Road transport dominates both freight and passenger movement in the country.

Conventional methods, such as building new roads or expanding existing infrastructure, face limitations including high costs, land use challenges, and a time lag that fails to keep up with dynamic urban growth. Moreover, these measures often unintentionally encourage more vehicle usage, perpetuating the cycle of congestion. In response to these challenges, the need of the hour is a comprehensive and data-driven approach that re-imagines how urban traffic can be managed. This approach aims to be not only more efficient but also eco-friendly and adaptable to the changing demands of expanding urban landscapes.

## III. Literature Review

### A. Related Work

In the intricate landscape of traffic optimization and distribution system research, various methodologies and challenges are explored by different researchers. F. Angius et al. [5] contribute a pragmatic approach, combining basic heuristics and simulations to understand urban traffic dynamics. Simulating various intersection typologies, they compute minimal delay routes, providing practical insights into traffic flow enhancement. Erwin Walraven et al. [6] present a novel paradigm by formulating traffic flow optimization as a Markov Decision Process, using Q-learning to establish policies for maximum driving speeds on highways, with a unique focus on incorporating traffic predictions.In an innovative approach, P. Keerthika et al. [7] propose a novel Particle Positioning Particle Swarm Optimization technique for addressing the Vehicle Routing Problem. This method predicts robust routes by eliminating non-linearity measures, which include the movement of vehicles, service time, and the status of the move towards a particular direction. Jia Li et al. [8] shift focus to multipoint to multipoint 4PL systems, delving into routing optimization with reliability constraints, utilizing a Messy Genetic Algorithm. Chun-Chun Hung et al. [9] redirect attention to optimizing inspection routes for electromechanical maintenance vendors, utilizing particle swarm optimization to surpass conventional genetic algorithms. Additionally, S. S. A. Rizwan et al. [10] introduce machine learning for urban traffic management, utilizing the MobileNet-SSD algorithm to adjust signals based on real-time traffic density. S. N. Srivastava et al. [11] survey machine learning applications in traffic management, covering classification, regression, clustering, and forecasting techniques. Dwidedi et al. [12] review machine learning in smart traffic management, discussing applications like traffic signal control and incident detection. Y. Zhang et al. [13] propose a real-time traffic signal control system using machine learning, demonstrating superior performance. Finally, M. A. Khan et al. [14] propose a deep learning approach for traffic signal control using a convolutional neural network, showcasing its efficiency in reducing traffic congestion compared to traditional systems. J. Wan et al. [15] The paper appears to focus on establishing a consistent definition of traffic congestion. This definition aims to standardize how researchers evaluate and study congestion in various situations. Additionally, the authors explore the use of video data from traffic cameras to analyze congestion patterns, identify bottlenecks, and assess overall traffic flow. S. Samal et al. [16] The Paper proposes the effects of traffic congestion on India's urban road networks. The study employs congestion indices and travel time reliability as key metrics. Additionally, the paper suggests potential mitigation strategies to address the challenges posed by heterogeneous traffic patterns and limited infrastructure. Overall, it contributes valuable insights for managing traffic congestion in Indian cities. W. Kim et al. [17] the paper proposes an innovative approach to alleviate traffic congestion by leveraging real-time traffic information. The system, called NAVOPT, combines on-board navigators equipped with area maps and GPS monitors with a central navigation server. Here's how it works: The on-board navigator reports its position to the server, which then computes the minimum-cost path (i.e., the shortest travel time) based on current traffic conditions. NAVOPT dynamically adjusts routes using a flow deviation algorithm, effectively distributing traffic and reducing congestion. This research contributes valuable insights for better traffic management in urban areas. S. Scellato et al. [18] It proposes an innovative approach to alleviate traffic congestion within urban street networks. They use a cellular automata model on a complex network, considering both vehicle motion along streets and congestion-aware routing at street crossings. The key idea is that vehicles dynamically update their routes based on real-time traffic information from nearby roads. By implementing this approach in real urban street patterns, the study demonstrates that global traffic optimization can be achieved through local agent decisions.Collectively, these diverse studies enrich the understanding of the multifaceted challenges and methodologies in traffic and distribution system optimizations.

### B. Comparative Study

This application aims to enhance the daily travel experience of urban commuters by implementing a system that uses predictive traffic analysis and real-time data. Therefore, a comparative study has been conducted on 14 papers, taking following aspects into consideration:

- Innovative Traffic Prediction and Congestion Mitigation
- Community-Driven Traffic Insights for Enhanced Awareness

TABLE I: Comparative Study

| S.No | Name | Algorithm | Limitations |
|---|---|---|---|
| 1 | Towards a Realistic Optimization of Urban Traffic Flows by F. Angius et.al (2012) | Greedy Algorithm, Hueristics | * Greedy algorithm distributes traffic demand to minimize total average delay. * Proactive schemes compute best traffic solutions using historical records |
| 2 | Traffic flow optimization: A reinforcement learning approach by Erwin Walraven et. al (2016) | Reinforcement learning and AI techniques | * Space and budget constraints limit road network expansion. * Inaccurate speed and density measurements challenge policy robustness. |
| 3 | Modelling an Efficient Hybrid Optimizer for Handling Vehicle Routing Problem by P. Keerthika et. al (2023) | Particle Positioning Particle Swarm Optimization (P3SO) | * Lack of exploration and exploitation conditions during optimization. * Need for a global multi-objective vehicle routing solution |
| 4 | Algorithms for Routing Optimization in Multipoint to Multipoint 4PL System by Jia Li et. Al (2014) | Messy Genetic Algorithm, Enumeration Algorithm | *The research focuses on minimizing total cost and satisfying reliability constraints. Other factors like driver fatigue, traffic conditions, or specific customer requirements might not be fully addressed. |
| 5 | Application of Optimization Algorithms for Optimal Inspection Path Planning in Multi-point Distribution Stations by Chun-Chun Hung et. al (2023) | Particle Swarm Optimization, Genetic Algorithm | *The model assumes a static and simplified environment. It may not fully capture real-world complexities like dynamic traffic conditions, unexpected obstacles, or time-dependent inspection requirements. |
| 6 | Urban Traffic Management using Machine Learning" by S. S. A. Rizwan et al. (2022) | MobileNet-SSD and YOLO V3 | * The paper only considers a single intersection. It would be necessary to test the system in a more complex traffic network to see how it performs. |
| 7 | A Survey on Machine Learning for Traffic Management by S. N. Srivastava (2021) | Decision trees, support vector machines, and neural networks. | * The paper does not discuss the challenges of applying machine learning to traffic management, like need for large amounts of data and the difficulty of dealing with noisy data. |
| 8 | Machine Learning for Smart Traffic Management: A Review by Dwivedi (2023) | Decision trees, support vector machines, and neural networks. | * The paper does not discuss the latest advances in machine learning for traffic management, such as the use of deep learning. |
| 9 | Real-Time Traffic Signal Control Using Machine Learning by Y. Zhang (2019) | Machine learning algorithm | * The paper only considers a single traffic signal. It would be necessary to test the system in a more complex traffic network to see how it performs. |
| 10 | A Deep Learning Approach for Traffic Signal Control by M.A. Khan (2018) | Convolutional neural network (CNN) | * The paper only considers a single traffic signal. * The paper does not discuss the robustness of the proposed system to changes in traffic conditions. |
| 11 | Traffic congestion analysis: A new Perspective by Jia W.(2017) | IPM and pairwise regression | * The paper only considers a single scene. * The paper does not give a solution to multiple scenes traffic congestion. |

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TABLE I: Comparative Study (Continued)

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| | | | |
|---|---|---|---|
| 12 | Analysis of Traffic Congestion Impacts of Urban Road Network under Indian Condition by Samal S (2020) | No specific algorithm used in paper | * Heterogenous traffic conditions in developing countries are complicated. |
| 13 | NAVOPT: Navigator Assisted Vehicular Route OPTimizer by Wooseong Kim (2011) | Flow Deviation algorithm | * NAVOPT cannot control all vehicles but only the one with the system. |
| 14 | Traffic optimization in transport networks based on local routing by Salvatore Scellato (2010) | Cellular automata model | * The paper does not consider expansion of infrastructure. |

## IV. Proposed System

From the above literature, it is understood there is a need to address the problem of traffic congestion in terms of distance and time. With reference to that, an application is proposed that tackles urban traffic congestion through three core strategies: traffic analysis for predictive modeling, efficient route recommendations based on congestion levels, and proactive traffic load distribution via alternate route suggestions in addition to multi-stop route recommendation. By combining these approaches, the application proposed in the work aims to optimize traffic flow, minimize congestion, and enhance commuters' daily travel experiences.

### A. *Methodology*

The proposed system is an integrated platform that combines advanced computing modules with a user-friendly interface to process diverse data streams and optimize urban traffic flow. The approach involves a multi-faceted strategy encompassing data acquisition, processing, modeling, and optimization. This system operates independently and does not rely on external software tools.

Routing Algorithms and Optimization:
The multi-point route optimization problem is defined as finding the optimal sequence of destinations to minimize total travel time, distance, or other relevant metrics, considering time constraints.

Algorithm Selection: We employed a hybrid approach combining the strengths of A* and Dijkstra algorithms to efficiently explore the solution space. A* is used to prioritize promising paths based on estimated costs, while Dijkstra is used to find the shortest paths between intermediate destinations.

Permutation Generation: To address the combinatorial nature of the problem, we generate various permutations of destination sequences using heuristic-based techniques to reduce the search space.

Route Evaluation: Each generated route is evaluated using the selected routing algorithms, considering factors such as road conditions, traffic congestion, and travel time.

Optimization: The system iteratively refines the solution by comparing different route options and selecting the optimal path based on predefined criteria.
This processed data allows for detailed real-time traffic pattern analysis and modeling, enabling the system to suggest the best routes to a destination by evaluating multiple options and providing the user with an optimized solution.

### B. *System architecture*

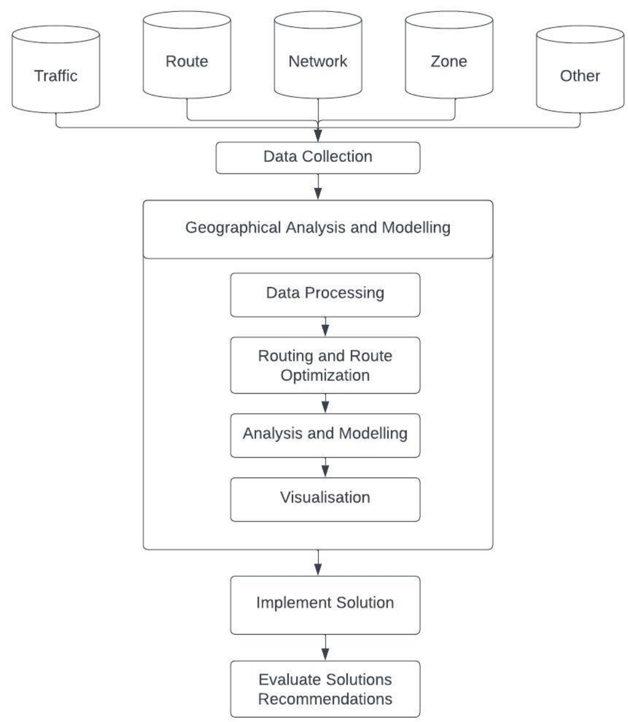


Fig. 1. Block diagram

The block diagram of the proposed system is illustrated in Fig. 1. In the proposed system, data from various sources is collected and processed to determine and optimize routes. This refined data enables in-depth traffic pattern analysis and modeling, allowing the system to suggest optimal paths to a destination by evaluating multiple route options and providing the end-user with an optimized solution.

1. Data Collection: The system collects essential data from multiple domains such as traffic, route networks, and specific zones to aid the route planner's decision-making process.

2. Geographical Analysis and Modeling:

2.1 Data Preprocessing: The raw data is processed to remove redundancy, correct inaccuracies, and format it for further analysis and modeling.

2.2 Routing and Route Optimization: The system determines the most efficient routes based on the processed data, considering factors like traffic conditions, road quality, and distance. The processed data mentioned above is obtained through reliable sources like OpenStreetMap (OSM) which provides accurate information.

2.3 Analysis and Modeling: A dynamic model representing the geographical terrain and the associated route data is created based on the processed data.

2.4 Visualization: The modeled data is visually represented using visualization tools and software, transforming the raw model into graphical representations like maps and route plots.

3 Implement Solution: An application or system is developed based on the analyzed and modeled data. This route planner application is designed to cater to end-users' routing needs.

4 Evaluate Solution Recommendations: The efficacy and accuracy of the developed route planner application are assessed. The application is tested in real-world scenarios, results are generated, and its recommendations are evaluated for accuracy, efficiency, and user satisfaction.

## V. Implementation

The data is collected from multiple domains such as traffic, route networks, and specific zones. This primary data acts as the bedrock upon which the subsequent phases are built.

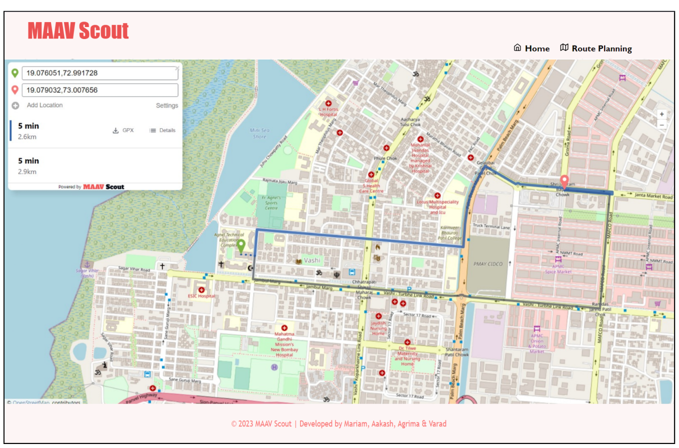


Fig. 2. User Interface (Route Planning)

As illustrated in Fig. 2, the user interface showcases a central geospatial map. Flanking the map, a sidebar is incorporated, featuring input fields designated for 'From' and 'To' details, allowing users to specify the starting and ending points of their journey. Key factors such as traffic conditions and distance have been prioritized to ensure optimal route selection.

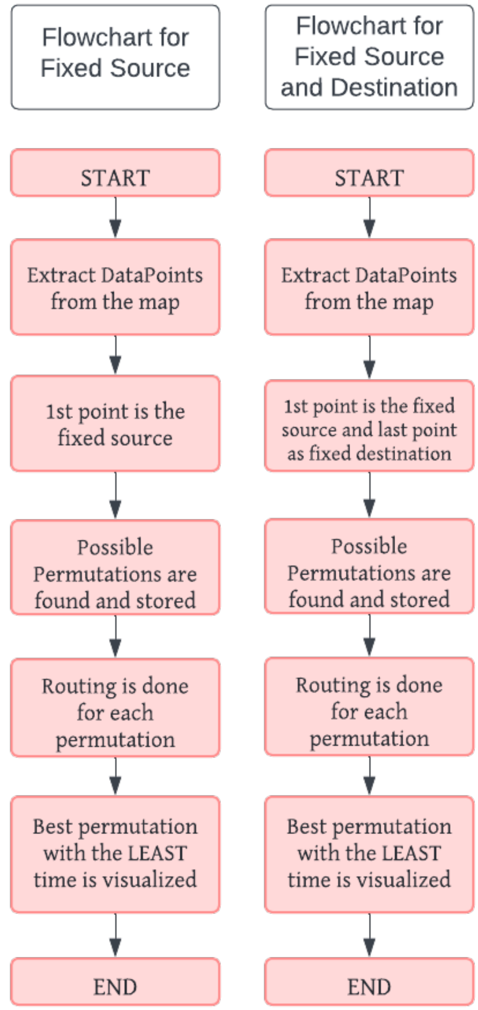


Fig. 3. Routing Algorithm Flowcharts

The Fig. 3 illustrates the overall steps involved of the routing algorithm for source-to-destination routing as well as multi-point routing. The first step in the process is to use the developed route optimization API to extract essential data points, which are represented by latitude and longitude coordinates as shown in Fig 4.

These coordinates are then compiled into an array, which allows for streamlined data processing. With the initial point established as the source, the system proceeds to determine potential routes based on the nature of the destinations. These destinations may be fixed or subject to variation, requiring the software to consider multiple possibilities. Systematic permutations are then used to compute the time and distance metrics for each potential route. This involves meticulously calculating the time and distance for every possible combination of destinations, in order to identify the route with the shortest duration.

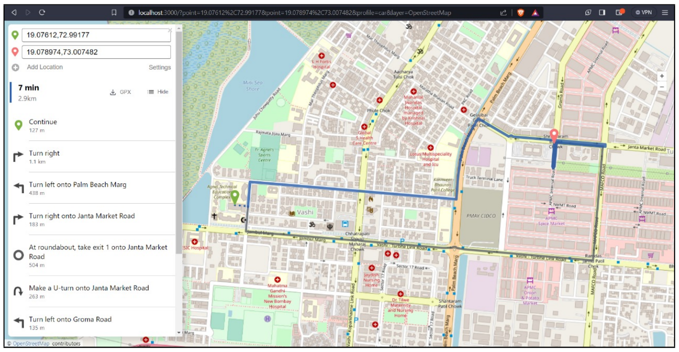

Fig. 4. User Interface (Source-to-destination Route Planning)

Once the optimized pathway has been identified, the system proceeds to visualize it on a map interface. This visualization provides a clear and user-friendly representation of the most efficient travel path, allowing users to easily understand and follow the recommended route. This visualization is an essential part of the process, as it allows users to easily interpret and act upon the information provided by the system.

Evaluated route is determined for both source-to-destination and multiple stops as shown in the output.

## VI. Result and Discussion

Hence, a comprehensive comparison is drawn between the developed system and the widely used Google Maps. The crux of the distinction lies in the optimization parameter: Google Maps emphasizes the order of the stops, whereas this model is engineered to provide a more optimized path, with the objective of reaching all points in the least amount of time possible. This approach is particularly beneficial for industries that require deliveries across multiple routes within limited time-frame, such as logistics and supply chain management, food and grocery delivery services, and maintenance and repair operations.

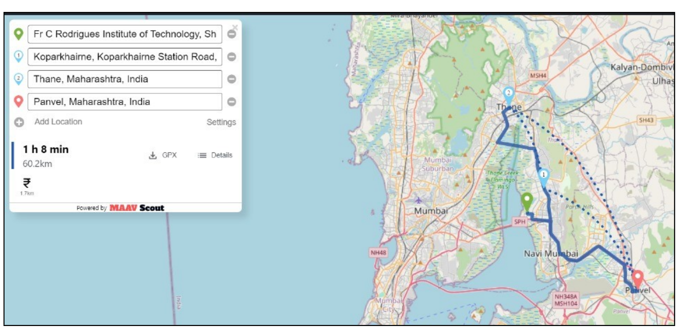


Fig. 5. User Interface (Multi-stop Route Planning)

The Fig 5 visualizes the model on to the map. Taking an example of the observation made, considering four stops Fr. C. Rodrigues Institute of Technology, Thane, Koparkhairne and Panvel. The stops are entered in the order Fr. C. Rodrigues Institute of Technology → Thane → Panvel → Koparkhairne. The optimal route given by the system is Fr. C.Rodrigues Institute of Technology→Koparkhairne→Thane→Panvel. When the time required for the optimal route is searched on Google Maps, the difference is of 4 minutes and 48 seconds.Whereas when the time required for the route Fr.C.Rodrigues Institute of Technology → Thane → Panvel → Koparkhairne as entered, the difference is of 32 minutes and 37 seconds.

The results of the comparison made are illuminating. The web application provides a path optimized by 5 minutes and 6 seconds than Google Maps. However, if the order in which the stops are entered is considered, the time difference between the optimized paths escalates to 35 minutes and 11 seconds. This significant discrepancy underscores the superiority of time-based optimization over distance-based optimization.

| Date | 25/1 | | 29/1 | | 29/1 | | 30/1 | | 19/2 | | 19/2 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 21:25 | | 16:30 | | 21:10 | | 7:30 | | 11:00 | | 16:00 | |
| | Distance | Time | Distance | Time | Distance | Time | Distance | Time | Distance | Time | Distance | Time |
| Google Maps | 70345.7 | 4861017 | 70345.7 | 4901551 | 70345.7 | 4905980 | 70345.7 | 4938947 | 97987.4 | 5063235 | 70345.7 | 4201256 |
| MAAV Scout | 60234.6 | 4201037 | 60234.6 | 4901050 | 60234.6 | 4101056 | 60234.6 | 4681050 | 69410 | 5063221 | 60234.6 | 4101037 |

Fig. 6. Table of comparison

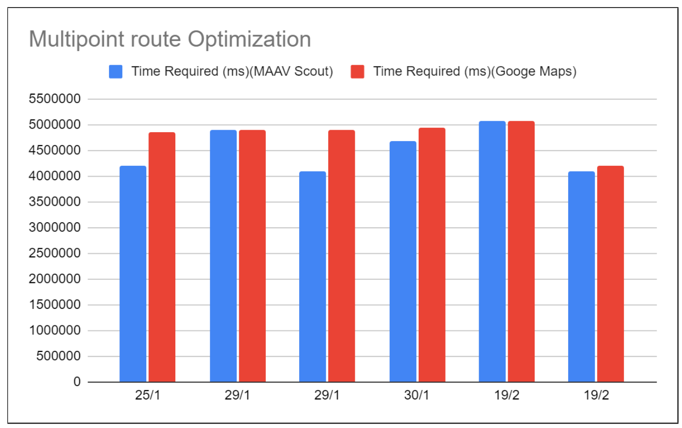


Fig. 7. Optimization Comparison Graph

The Figs. 6 and 7 presents a tabulated and graphical observation of the time needed to traverse various routes on different days over a 25-day period, spanning different times of the day to mitigate bias. These findings demonstrate a notable variance between the time taken to navigate multiple destinations using both Google Maps and the proposed system. This variance underscores the superiority of time-based optimization compared to distance-based optimization.

## VII. Conclusion

The pervasive issue of traffic congestion, a subject of numerous reports and studies, has been addressed in this research through a comprehensive exploration of methodologies and challenges previously investigated by various scholars. In response to this problem, the proposed web application is designed to optimize traffic navigation. It harnesses data from a multitude of domains, including traffic conditions, routes, networks, and zones. The proposed system chooses the best route by looking at all different options, excluding the starting point. It measures how long it takes to travel each possible route compared to the best theoretical route, resulting in a 30% increase in efficiency. This method carefully considers local traffic conditions to make smarter decisions about which way to go, leading to improved traffic control. Once this system is deployed and gains users gradually, more can be said about its reliability and can help in achieving higher accuracy. This research paves the way for novel opportunities in the realm of route optimization algorithms, inviting further exploration and enhancement. Future endeavors could concentrate on honing the time-based optimization technique and broadening its applicability. This could potentially revolutionize the way navigation works and make journeys more efficient and less time consuming.

## REFERENCES


[1] Google Maps Statistics: Verified and Updated For 2024 - On The Map Marketing — onthemap.com. https://www.onthemap.com/blog/google-maps-statistics/. [Accessed 03-01-2024].

[2] Google Maps Statistics: Verified and Updated For 2024 - On The Map Marketing — onthemap.com. https://www.onthemap.com/blog/google-maps-statistics/. [Accessed 03-01-2024].

[3] Wup 2018-report. https://population.un.org/wup/default.aspx?aspxerrorpath=/wup/publications/Files/WUP2018-Report.pdf. [Accessed 14-12-2023].

[4] Traffic Index ranking — TomTom Traffic Index — tomtom.com. https://www.tomtom.com/traffic-index/ranking/. [Accessed 03-10-2023].

[5] F. Angius, M. Reineri, C.-F. Chiasserini, M. Gerla, and G. Pau. Towards a realistic optimization of urban traffic flows. pages 1661–1668, 2012.

[6] Erwin Walraven, Matthijs T.J. Spaan, and Bram Bakker. Traffic flow optimization: A reinforcement learning approach. *Engineering Applications of Artificial Intelligence*, 52:203–212, 2016.

[7] Modelling an efficient hybrid optimizer for handling vehicle routing problem. *Journal of Scientific Industrial Research*, 81(06), 2022.

[8] Jia Li, Yanqiu Liu, Ying Zhang, and Shida Xu. Algorithms for routing optimization in multipoint to multipoint 4pl system. *Discrete Dynamics in Nature and Society*, 2015:1–7, 06 2015.

[9] Chun-Chun Hung, Meng-Hui Wang, Cheng-Chien Kuo, and Shiue-Der Lu. Application of optimization algorithms for optimal inspection path planning in multi-point distribution stations. *Sensors and Materials*, 36(1):1, January 2024.

[10] Ankit Bharti, Rohit Hasnani, Manish Priyadarshan, Kunal Shah Kanu, and Savitha P B. Urban traffic management using machine learning. pages 1–6, 2022.

[11] Aditya Srivastava, Aryan, and Milan Khurana. A survey paper on traffic prediction using machine learning. *International Journal for Research in Applied Science and Engineering Technology*, 11(5):44–48, May 2023.

[12] Ashwani Dhar Dwivedi. Smart traffic management system. *International Journal for Research in Applied Science and Engineering Technology*, 11(5):6584–6587, May 2023.

[13] Jinghong Zeng, Jianming Hu, and Zhang Yi. Training reinforcement learning agent for traffic signal control under different traffic conditions. pages 4248–4254, 10 2019.

[14] kashif iqbal Shah, Muhammad Khan, Sagheer Abbas, Zahid Hasan, and Areej Fatima. Intelligent transportation system (its) for smart-cities using mamdani fuzzy inference system. *International Journal of Advanced Computer Science and Applications*, 9, 01 2018.

[15] Jia Wan, Yuan Yuan, and Qi Wang. Traffic congestion analysis: A new perspective. pages 1398–1402, 2017.

[16] Satya Samal, Pala Gireesh Kumar, Cyril Santhosh, and s. Moses Santhakumar. Analysis of traffic congestion impacts of urban road network under indian condition. *IOP Conference Series: Materials Science and Engineering*, 1006:012002, 12 2020.

[17] Wooseong Kim and Mario Gerla. Navopt: Navigator assisted vehicular route optimizer. pages 450–455, 06 2011.

[18] Salvatore Scellato, Mattia Frasca, Jesus Gómez-Gardeñes, and Vito Latora. Traffic optimization in transport networks based on local routing. *Physics of Condensed Matter*, 73, 02 2009.