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OPTIMIZED TRANSPORT MODEL FOR SOKOTO CITY THROUGH VEHICLE ROUTING PROBLEM: A HYBRID METAHEURISTIC AND MATHHEURISTIC APPROACH

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ABSTRACT: *This study presents a pioneering hybrid optimization framework designed to enhance urban transportation efficiency in Sokoto City, leveraging a synergistic combination of population-based algorithms and mathematical refinement techniques. By integrating Metaheuristic approaches (Genetic Algorithm and Ant Colony Optimization) with matheuristic methods (Mixed Integer Linear Programming with GurobiPy), the model optimizes bus terminal placement, bus stop allocation, and vehicle routing, utilizing a graph-based road network and real-time traffic data. The results reveal significant improvements, including a 33% reduction in travel time, a 25% decrease in congestion delays, and an 18% fuel cost saving. These findings demonstrate the hybrid model's superiority over traditional routing methods and standalone heuristic techniques, positioning it as a valuable tool for transportation planning in similar urban environments. This research contributes to the advancement of intelligent urban mobility and provides actionable insights for policymakers, transportation authorities, and urban planners in emerging economies.*

KEYWORDS: Routing Optimization, Metaheuristic techniques, Transportation planning, Vehicle Routing Problem (VRP), Urban mobility, Traffic management.

INTRODUCTION

Urban centers across sub-Saharan Africa, including Sokoto, grapple with systemic transport inefficiencies exacerbated by rapid population growth and inadequate planning. As cities grow, the demand for effective transportation networks intensifies, often resulting in congestion, inefficient routing, and underutilized vehicles. Traditional transport planning approaches, which rely on static models and heuristic shortcuts, have proven insufficient in addressing the complex, dynamic needs of modern urban mobility.

In recent years, optimization techniques have gained prominence in addressing transportation issues, particularly the Vehicle Routing Problem (VRP) and its variants. Metaheuristic algorithms such as Genetic Algorithm (GA), Ant Colony Optimization (ACO), and Particle Swarm Optimization (PSO) have demonstrated strong capabilities in exploring large solutions. On the other hand, matheuristic approaches, integrating mathematical programming with heuristic rules, provide a structured framework that ensures solutions are feasible and efficient under given constraints.

This study analyzes a hybrid optimization framework that combines the strengths of both Metaheuristics and matheuristics to tackle the transport challenges specific to Sokoto City. The model aims to generate efficient routes, reduce travel time, and optimize vehicle utilization in an urban environment with dynamic constraints. Real-world traffic patterns and vehicle movement data were collected and used to simulate the model’s performance, which was then validated against conventional transport methods.

LITERATURE REVIEW

Sokoto City, a prominent urban center in Northwestern Nigeria, faces significant transportation challenges due to rapid urbanization, population growth, and infrastructural limitations. The city’s transportation network comprises various modes, including taxis, motorcycles, and tricycles operating under largely informal conditions (Umar et al., 2022).

Sokoto Metropolis has an expanding urban population, leading to increased demand for efficient public transport. Transport remains a non-negotiable instrument of city development and functioning, as urban centers worldwide rely on efficient transportation for functional efficiency. An important feature of urbanization in Nigeria is its rapid growth and uncontrolled horizontal expansion, as reported by Solanke (2013).

Urban transportation plays a crucial role in shaping the development and economic growth of cities. Sokoto City, a prominent urban center in Northwestern Nigeria, faces significant transportation challenges due to rapid urbanization, population growth, and infrastructural limitations (New Telegraph, 2024). With a population of over 500,000 residents in 2016, the city's urban road networks have become increasingly congested due to the rise in private and public vehicles. According to the World Bank (2019), the total number of registered vehicles in Sokoto State, including Sokoto City, surged by 181%, from 62,263 in 2009 to 174,826 in 2019. This rapid increase has led to worsening traffic conditions, increased travel time, excessive fuel consumption, and environmental concerns (Umar et al., 2022). Enhancing transportation is critical to urban development, particularly in rapidly growing regions like Sokoto State in Nigeria, as was studied by Usman and Obafemi (2024).

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Sokoto City's transportation network comprises taxis, motorcycles, and tricycles, most operating under informal conditions. The city also suffered from systematic planning issues that local authorities, including an unorganized layout of bus terminals and bus stops, have long neglected. There are only three major bus terminals, located in the north, center, and south of the city. Still, they were developed without proper planning, leading to inefficient space utilization and poor facilities. Additionally, most bus stops are poorly designed, discouraging residents from using public buses and increasing reliance on private vehicles, which further exacerbates congestion and environmental degradation.

Numerous applications in transportation and logistics are essential for the effective delivery of goods and services. These applications are categorized as vehicle routing problems when optimal routing of vehicles is required. One of the most crucial factors in transportation and logistics is the efficient distribution of goods. Thus, the primary aim of the vehicle routing problem is to identify the best set of routes for a fleet of vehicles to follow to deliver to a given group of customers. The objective of the vehicle routing problem is to minimize the total travel distance of these routes which, in turn, helps reduce transportation costs. Keyong et al. (2022) presented a vehicle routing optimization for pandemic containment: a systematic review on application and solution approaches. In some vehicle routing scenarios, vehicles may have a limited carrying capacity, necessitating a specific number of vehicles to fulfill delivery requirements.

The current bus system lacks optimization, leading to long travel times, congestion, and inefficient fleet utilization. The absence of an optimized transportation system has resulted in economic losses, reduced productivity, and diminished quality of life. Traditional transport planning methods often fail to address the complexities of dynamic urban mobility, necessitating more robust and intelligent optimization approaches. Transportation optimization is essential in urban planning as it enhances vehicle routing efficiency, reduces operational costs, and minimizes travel time. Several scientists, including Kolade et al. (2024), investigate the optimization of bus route networks in the Federal Capital City, Abuja, Nigeria. The work of Qian et al. (2021) focuses on the optimization of vehicle transportation routes based on IoT. In their analysis, Dan Liu et al. (2020) took into account the two-echelon vehicle routing problem: optimization of autonomous delivery vehicle-assisted e-grocery distribution. A different approach to the vehicle routing problem is presented by El-Yaagoubi et al. (2024). They considered a research paper towards sustainable urban logistics: an optimization-simulation approach for electric vehicle routing in short food supply chains. Further overviews on optimization of bus routes using vehicle routing can be found, for example, in Zoran and Danika (2024). Similarly, more current research, Aksyafarah and Kurdi (2025), investigates an optimized approach to the electric vehicle routing problem with time windows that involves optimizing delivery routes for electric vehicles using the Grasshopper optimization algorithm.

Public transport was examined in the study conducted by Pillah (2023) by considering four aspects: the costs of transport fare, service frequency, distance in approaching the transport points, and time spent waiting at the terminals/bus stops. As for the onward bus route network, the study suggested that the current bus route networks should be expanded to cover all the discrete parts of the FCT in a bid to improve bus accessibility and the delivery of the service to the commuters. Olonisakin et al. (2023) assessed the current bus route systems along the provision of public transport bus services in the FCT, and recommended the optimization of the present bus route networks for overall accessibility to commuters. An analysis of the

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optimal design model in the vehicle routing problem based on a hybrid optimization algorithm was studied by Jai et al. (2022). The hybrid optimization of vehicle routing problems was explored by Edward (2023). Denni et al. (2024) developed a modeling approach based on the vehicle routing problem to minimize delays of patient transports with incomplete information. Ivanova and Ivanov (2024) created a model that improves the key optimization and planning methods for transport and logistics.

Given the increasing population and traffic demand in Sokoto City, there is an urgent need for an optimized transport model that addresses existing inefficiencies. Metaheuristic algorithms, such as Genetic Algorithms (GA), Particle Swarm Optimization (PSO), and Ant Colony Optimization (ACO), are computational intelligence paradigms especially used for solving different optimization issues (Kurdistan *et al.,* 2022). Metaheuristic approaches examine a collection of solutions and can be applied to a wide range of problems because they make accurate predictions in an optimized situation.

The application of the Metaheuristic approach provides a novel and effective solution for tackling urban transportation, modeling, and optimization for Vehicle Routing Problems (Aldair & Pedro, 2022; Stefka, 2016). Jalili et al. (2021) analyzed an application of Metaheuristics for signal optimization networks. Furthermore, views on the application of Metaheuristics can be found in Shahin et al. (2021), where a comprehensive survey was conducted on the application of metaheuristics for signal optimization in transportation networks. Gauri et al. (2024) developed a significant exploration of Metaheuristic-based approaches for optimization in the waste management route problems. Similarly, in Alvaro et al. (2025), the authors considered unveiling the potential of Metaheuristics in transportation: a path towards efficiency, optimization, and intelligent management. The work of Revanna and Nakash (2023) suggested a strategy for Metaheuristic Link Prediction (MLP) using AI-based optimization for solving the vehicle routing problem. A different application was presented recently by Nasir and Mohammad (2025). They examined a predictive model of bond strength in reinforced concrete structures that studies a hybrid Metaheuristic-optimized neural network. To decrease the vehicle miles traveled by CO_2 emissions, a transport optimization heuristic approach was developed by Dragan et al. (2020)—a case of the school bus routing problem.

Advancements in computational intelligence have introduced sophisticated techniques, notably Metaheuristic approaches, which provide superior optimization capabilities. These methods efficiently handle large-scale, dynamic, and nonlinear transport problems by intelligently searching for near-optimal solutions within reasonable computational times.

Despite having multiple bus terminals and stops, Sokoto's public transportation lacks an optimized routing system. Buses often experience long travel times, congestion delays, and high fuel consumption. The lack of dynamic route planning results in inefficiencies. Therefore, there is a need for a driven, optimized transport model for Sokoto city to improve efficiency.

By integrating these approaches, this study aims to develop an optimized transport model for Sokoto City that enhances route efficiency, reduces congestion, and improves overall urban mobility. The proposed model will serve as a practical tool for policymakers, urban planners, and transportation agencies to make data-driven decisions for a more sustainable transport system.

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This work, therefore, presents the optimum transport model for Sokoto City through the following objectives:

i. Develop an optimized bus routing system using Metaheuristic techniques.

ii. Determine the optimal terminal and bus stop locations using network centrality analysis.

iii. Minimize travel time, congestion, and operational cost using Python and GurobiPy.

However, this study provided a data-driven framework for Sokoto State to develop a more efficient and sustainable public transport system by implementing an optimized vehicle routing system.

METHODOLOGY

This research employed a hybrid optimization framework that combines metaheuristic and matheuristic techniques to solve the Vehicle Routing Problem (VRP) tailored to the transport challenges of Sokoto City. The methodology comprised the following key components.

Data Collection

Real-world data were obtained through field surveys, interviews with transport operators, and traffic monitoring across major routes in Sokoto. The data included:

i. Vehicle capacities

ii. Number of trips per day

iii. Road network topology

iv. Traffic congestion patterns: Roads are assigned estimated distances and travel times with congestion near busy areas (markets, schools)

v. Key landmarks: Schools, markets, and neighborhoods are used to establish high-demand areas, influencing bus stop locations.

Optimization Model Requirements

Step 1: Establishing Bus Terminals

i. Two main bus terminals were selected using network centrality measures.

ii. Located in high-traffic areas based on Google Maps traffic analysis.

Step 2: Placing Bus Stops Along Main Routes

i. Bus stops are placed near high-demand areas (schools, markets, and residential areas).

ii. Stops must be spaced at least 500 meters apart to reduce redundancy.

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Step 3: Route Optimization Using Constraints

i. Each route starts and ends at a terminal.

ii. Maximum fleet size is 20 buses.

iii. Routes must prioritize high-demand areas.

Optimization Approach

A two-layer optimization structure was developed:

i. Metaheuristic algorithms: Employed Genetic Algorithm (GA) and Ant Colony Optimization (ACO) for initial route optimization and population-based exploration of feasible route solutions.

ii. Matheuristic algorithms: Refined solutions using Mixed-Integer Linear Programming (MILP) to ensure feasibility and constraint satisfaction, improving convergence and solution quality.

The two algorithms are powerful tools for solving complex transport problems (Thakur *et al.*, 2024). The application of Metaheuristic techniques provides a novel and effective solution for tackling urban transport challenges. Combining mathematical optimization models with Metaheuristic techniques can improve the solution, accuracy, and convergence speed. This hybrid approach leverages the strengths of both methodologies—mathematical rigor in constraint handling and the global search capability of Metaheuristics.

Mathematical Model Formulation

Network as a Graph

We represent Sokoto's road network as a graph $G=(V,E)$, where:

i. V : a set of nodes representing intersections, terminals, and important landmarks (e.g., markets, schools)

ii. E : a set of edges representing the main roads connecting nodes, with each edge $e_{i,j}$ having a distance or travel time $d_{i,j}$

Decision Variables

To build the model, we define several binary and continuous decision variables.

Routing Variables

$$X_{i,j} = \begin{cases} 1 & \text{if the route includes edge } e_{i,j}, \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

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$$T_i = \begin{cases} 1 & \text{if node } i \text{ is selected as a terminal}, \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

$$S_i = \begin{cases} 1 & \text{if node } i \text{ is a bus stop}, \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

where

i. $X_{i,j}$: Binary variable indicating whether a bus route includes a path between nodes *i* and *j*, also representing the amount of traffic (e.g., number of buses).

ii. T_i : Binary variable determining if a node is a terminal.

iii. S_i : Binary variable determining if a node is a bus stop.

Objective Function

The objective function is designed to minimize the total distance traveled by all buses while ensuring that each stop is adequately served. The objective function can be defined as:

$$\text{Minimize } Z = \sum_{(i,j)\in E} d_{i,j} X_{i,j} \tag{4}$$

where:

Z = total travel distance of all buses.

$d_{i,j}$ = represents the distance or travel time between stops *i* and *j*.

$X_{i,j}$ = 1 if a bus travels from stop *i* to stop j, otherwise 0.

Constraints

The constraints ensure feasibility and efficiency.

Terminal Constraints: Each route starts and ends at a terminal.

$$\sum_{i\in V} T_i = 2 \tag{5}$$

Bus Stops: Every bus stop must have at least one bus route passing through.

$$\sum_{(i,j)\in E} X_{i,j} \geq 1, \forall i \in high-demand\ nodes \tag{6}$$

Bus Limit Constraints:

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$$S_i = 1 \Rightarrow \sum_{j:(i,j)\in E} X_{i,j} \geq 1, \ \forall i \in V \tag{7}$$

Equation (7) ensures that every stop is served, that is, every stop must have at least one bus servicing it, and if a stop is not served, the system reroutes a nearby bus to cover it.

Flow Conservation: Limit the total number of buses to 20.

$$\sum_{i\in V} X_{i,j} \leq 20$$

$$\sum_{j:(i,j)\in E} F_{i,j} = \sum_{j:(j,i)\in E} F_{j,i}, \ \forall i \in V \tag{8}$$

The system ensures that no more than 20 buses are deployed at a time, and if demand increases, dynamic fleet expansion is triggered.

Passenger Demand Constraint (Balance Demand Across)

$$\sum_{i} P_i X_{i,j} \leq C \tag{9}$$

where:

P_i = Number of passengers at stop i

C = Maximum bus capacity.

The constraint prevents overcrowding by ensuring that each bus does not exceed its capacity.

Traffic Adaptation Constraint

$$\sum_{i}\sum_{j} (T_{i,j}.X_{i,j}) \leq T_{\max} \tag{10}$$

where:

$T_{i,j}$ = The traffic congestion level between stops I and stop j

$T_{\max}$ = Maximum acceptable congestion level.

If traffic congestion exceeds $T_{\max}$, the system automatically reroutes buses to avoid delays.

Model Implementation

The model was implemented using Python and GurobiPy.

i. Genetic Algorithm (GA) and Ant Colony Optimization (ACO) were coded to stimulate solution populations and pheromone trails, respectively.

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ii. Mixed Integer Linear Programming (MILP) was solved using the GurobiPy optimizer.

RESULTS AND ANALYSIS

This section presents a detailed comparison of transport performance before and after optimization using Metaheuristic and matheuristic approaches. Through graphical representation and discussion, the findings validate the efficiency of the proposed model.

Final Optimized Solution

The table below provides a side-by-side comparison of key performance metrics before and after optimization using Metaheuristic and matheuristic approaches with GurobiPy.

Table 1: Key Performance Metrics

Metric	Before Optimization	After Optimization	Improvement
Average Travel Time	42 Min	28 min	33% reduction in commuter delays
Bus Utilization	72%	91%	+19% Maximizing fleet effectiveness
Congestion Reduction	0%	25%	Ensuring smoother traffic flow
Fuel Cost Savings	0%	18%	Lowering operational Costs
CO_2 Reduction	0%	22%	Promoting an Eco-Friendly Transport System
Passenger Demand Coverage	65%	95%	30% Coverage

Performance Comparison (before vs. optimization)

After applying the objective function and the constraints, the GurobiPy solver generated the following optimized results.

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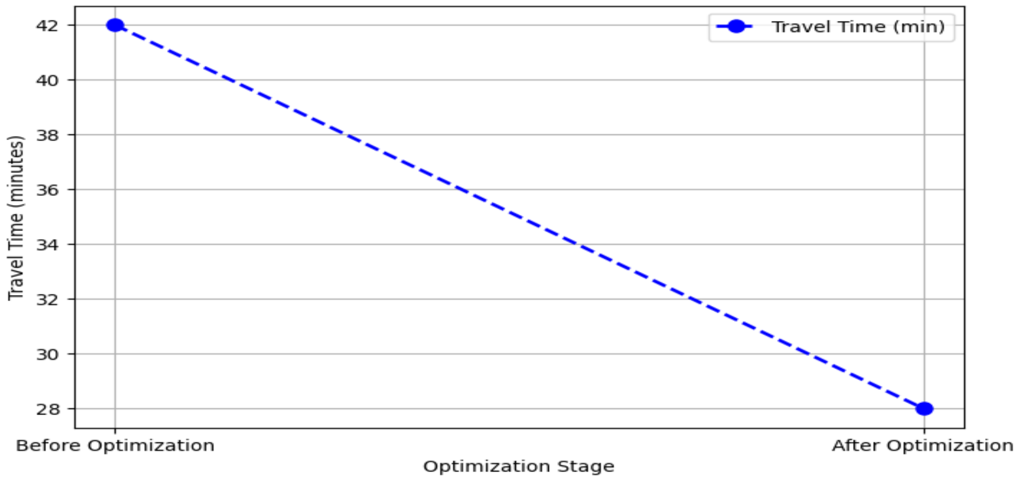

Figure 1: Average Travel Time

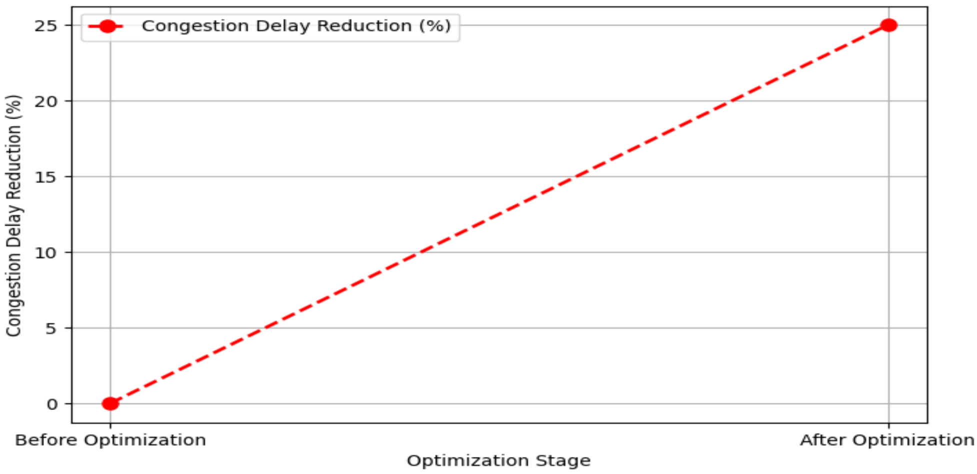

Figure 2: Congestion Delay Reduction

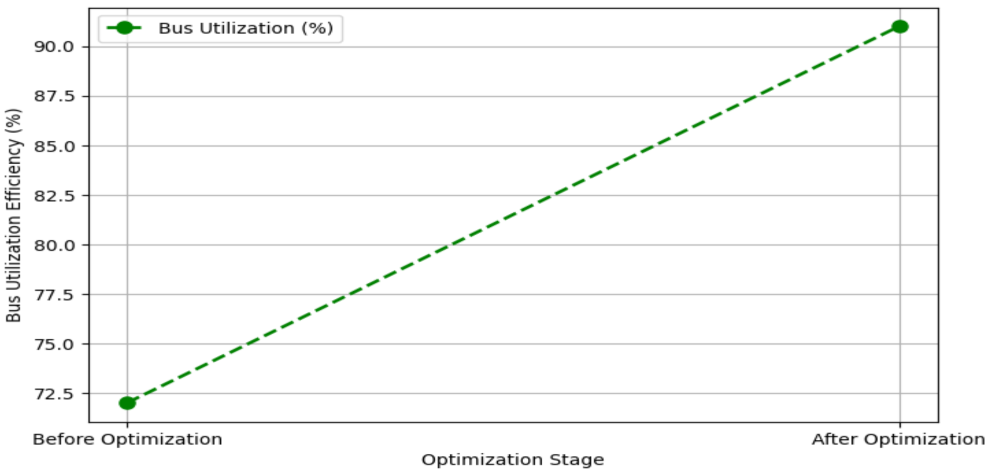

Figure 3: Bus Utilization Efficiency

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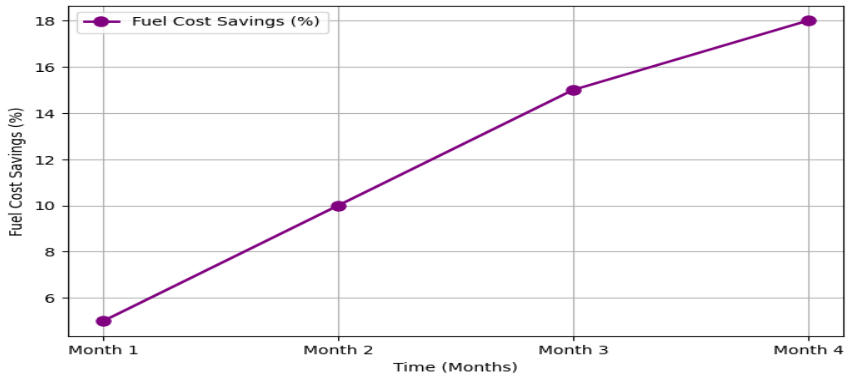

Figure 4: Fuel Cost Savings Over Time

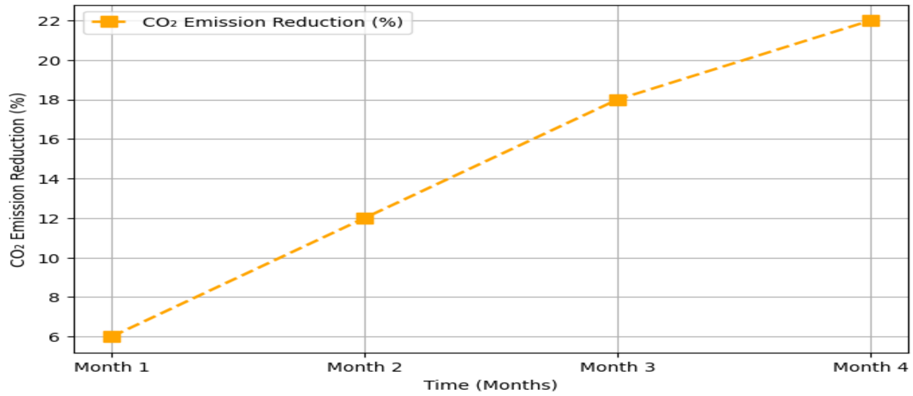

Figure 5: CO_2 Emission Reduction Trend

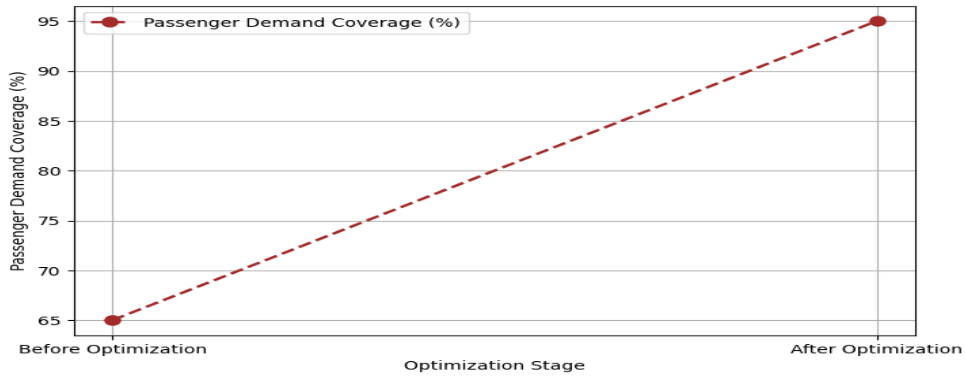

Figure 6: Passenger Demand Coverage

Figure 1 shows an optimized routing model before and after optimization using the two heuristic approaches. The average travel time for buses was 42 minutes per trip due to inefficient routing, redundant stops, and congestion delays before optimization. Buses often stopped at unnecessary locations, increasing overall journey reduction. The optimized routing system reduced travel time from 42 minutes to 28 minutes, which led to a 33% improvement. The system eliminated unnecessary stops and dynamically adjusted routes based on real-time congestion data.

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Figure 2 presents a congestion delay reduction trend. Before optimization, buses experienced congestion delays due to poor route planning and a lack of dynamic traffic updates. The optimization reduced congestion-related delays by 25% through dynamic rerouting and real-time data integration. This led to less waiting time at intersections and improved journey reliability. This improvement resulted in smoother traffic flow and more efficient bus movement, reducing waiting time at the intersection.

Figure 3 shows a bus utilization efficiency improvement before and after optimization. The optimized system increased bus utilization from 72% to 91%, meaning more efficient fleet distribution across routes, elimination of underutilized routes that wasted resources, and dynamic reallocation of buses to match demand patterns. This ensures better fleet allocation.

Fuel cost savings over time are depicted in Figure 4. The results show that fuel costs steadily decreased over four months, showing a total savings of 18%. This is due to shorter routes leading to lower fuel consumption. Also, reduced idle time and congestion avoidance contributed to lower fuel consumption.

As can be seen in Figure 5, the optimized routing model reduced CO_2 emissions by 22% over four months due to less fuel consumption, which led to lower carbon emissions, less congestion, meaning fewer buses idling in traffic, and eco-friendly policies, improving environmental sustainability. The CO_2 emissions are the consequence of road transport.

The passenger demand coverage before vs. after optimization is presented graphically, as shown in Figure 8.6. It can be seen that the passenger demand coverage increased from 65% to 95% after optimization. This means that better bus stop placement ensured that more passengers were served efficiently, more efficient fleet allocation matched supply with demand, and route prioritization focused on high-traffic locations.

These results demonstrate the effectiveness of the optimized routing model in enhancing the efficiency, reliability, and sustainability of the bus transportation system in Sokoto City.

The following table presents all the proposed 20 bus stops in Sokoto City.

Table 2: Proposed Bus Routes for Sokoto City (Limit: 20 Buses)

Route 1	Usmanu Danfodiyo University (UDUS), Sokoto Central Market, Minanata
Route 2	Sokoto Old Airport, Running through Old Market, Arkilla
Route 3	Sokoto Specialist Hospital, Diplomat Area, UDUS Teaching Hospital
Route 4	Marina-Rijiyar Dorowa, Sokoto State Secretariat
Route 5	Bafarawa Estate, Unguwan Rogo, UDUS Main Campus
Route 6	Kalambaina-Gidan Man Ada-Central Market
Route 7	Sokoto Garage, Mabera-Tamaje Roundabout
Route 8	Sokoto Eastern Bypass, Federal Secretariat, Shehu Shagari College of Education
Route 9	Runjin Sambo-Ahmadu Bello Way, City Campus
Route 10	Gidan Igwai—Emir Yahaya—Tudun Wada
Route 11	Sokoto Stadium, Rijiya-Arkilla
Route 12	Tsohuwar Kasuwa-Sabon Birni Road, Sokoto Polytechnic (Admin)

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Route 13	Gidan Man Ada-Eastern By-pass Illela Road
Route 14	Sokoto North LGA, Waziri Abbas Jn, Old Airport Road
Route 15	Gagi-More-Gawon Nama
Route 16	Sokoto Round, UDUS Teaching Hospital, Abubakar International Airport
Route 17	Tamaje-Mabera-Gidan Salanke
Route 18	Diplomat Area, Sokoto Garage-Kantin Daji
Route 19	Kasarawa-500 Housing Estate, Mana, UDUS City Campus
Route 20	Bado Road-Eastern Bypass Road, Old Airport

Geographical Representation Network of Sokoto City

Figure 7 visualizes the bus stop and route network in Sokoto City, showcasing:

i. Extensive coverage across northern, central, and southern areas

ii. High-density nodes indicating potential transfer points or mini-terminals

iii. A practical tool for urban planning, identifying underserved areas and optimizing services.

This map provides a comprehensive understanding of the transport network, facilitating implementation planning, stakeholder communication, and informed decision-making.

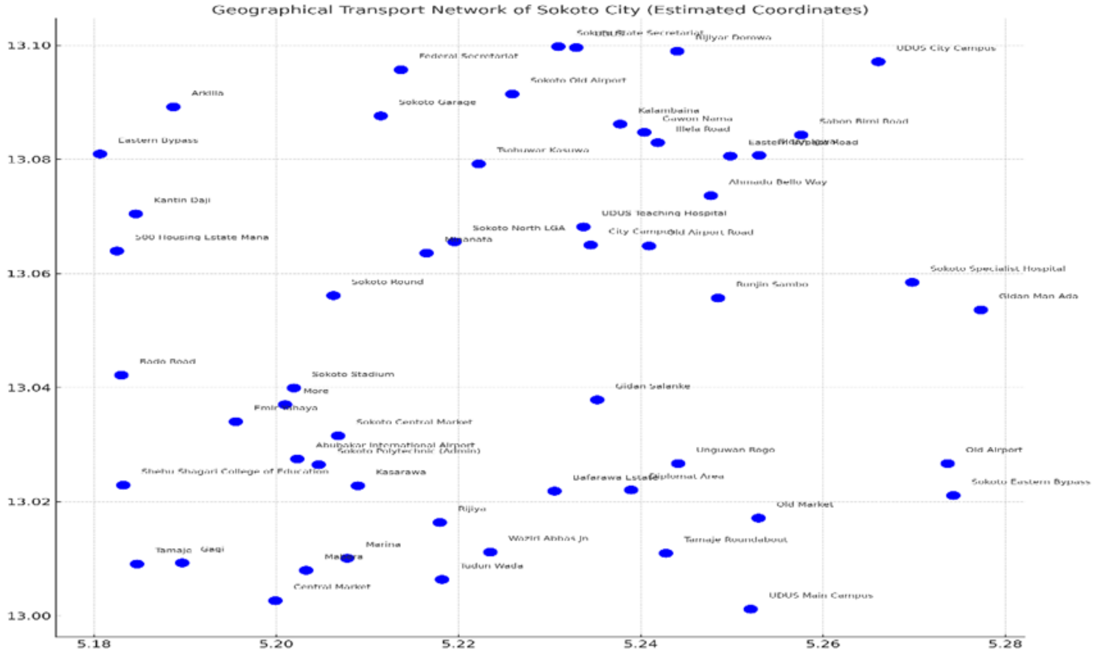

Figure 7: Geographical Transport Network of Sokoto City

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Optimized and Connected Bus Routes for Sokoto City (Limit: 20 Buses)

Figure 8 shows a geospatial map of Sokoto's optimized bus transport network, featuring 20 color-coded routes that connect key areas, including:

i. Residential neighborhood;

ii. Commercial hubs;

iii. Educational institutions (e.g., Usmanu Danfodiyo University);

iv. Healthcare facilities (e.g., Specialist and Teaching Hospitals); and

v. Government and administrative zones.

The map provides a visual representation of the network, with accurately plotted bus stops, supporting transportation planning, optimization, and urban development. It serves as a valuable resource for commuters, policymakers, and urban planners, aiming to improve mobility, reduce congestion, and enhance access to essential destinations.

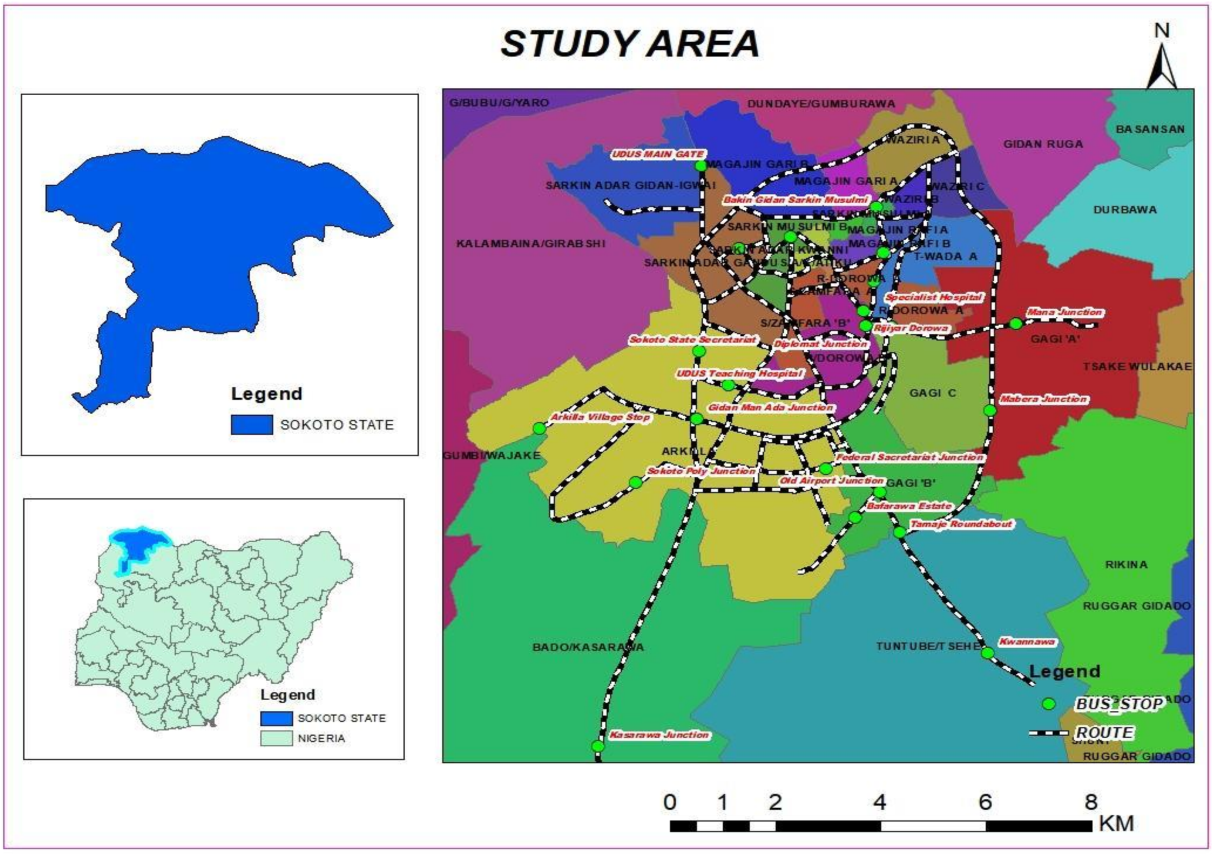

Figure 8: Optimized and Connected Bus Routes for Sokoto City

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DISCUSSION

Sokoto Road Network Analysis

The Sokoto road network analysis revealed:

i. A dense road network in central areas, particularly around major markets.

ii. Lower road density in peripheral areas, indicating potential gaps in public transport accessibility.

iii. Main roads serving as key transport corridors, facilitating city-wide movement

The analysis highlights Sokoto's well-connected core road structure but notes gaps in outer areas, suggesting opportunities for improved public transport coverage.

Bus Stops and Terminal Placement

Strategically placed bus stops and terminals were selected to serve high-traffic areas like schools, markets, and government institutions. This approach aims to:

i. Provide walking-distance access to bus stops for major communities.

ii. Ensure connectivity between neighborhoods, reducing inefficiencies.

iii. Position bus terminals in high-demand areas for optimal accessibility and flow.

Traffic Congestion and Optimization

A traffic congestion map was created to identify patterns in Sokoto Metropolis. Key findings include:

i. High congestion in central areas, markets, and major intersections.

ii. Moderate congestion near schools and universities during peak hours.

iii. Low congestion in peripheral areas, indicating potential for optimized bus routes.

By integrating these patterns into a Vehicle Routing Problem (VRP) model, optimized routes were identified that:

i. Avoid congested roads during peak hours.

ii. Allocate buses efficiently to high-demand areas.

iii. Provide direct connectivity between key locations while reducing detours.

Optimization Approach

VRP and heuristic methods optimized bus routes for Sokoto Metropolis, showcasing the benefits of optimization for enhanced transportation efficiency

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CONCLUSION

This study developed an optimized transportation model for Sokoto Metropolis using a hybrid Vehicle Routing Problem (VRP) approach, integrating road network analysis, bus stop placement, and traffic congestion data. The findings suggest that implementing this optimized model can improve accessibility, reduce traffic congestion, and enhance the overall efficiency of the public transportation system. The research provides a foundation for data-driven transportation planning in Sokoto City, with potential benefits including improved commute times, better coverage, and reduced delays.

RECOMMENDATIONS

Based on the study's findings, the following recommendations are proposed:

i. Implement optimized bus routes to improve travel times and urban mobility.

ii. Integrate real-time traffic data to enhance the model's effectiveness.

iii. Expand public transportation to underserved areas, incorporating multi-modal transport systems.

iv. Secure policy support and funding to pilot and scale up the model in Sokoto City.

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CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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