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BUS ROUTE MAPPING AND EVALUATION USING GIS- A CASE STUDY OF GOODWILL GROUP OF SCHOOLS, OBAAGUN, OSUN STATE, NIGERIA

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ABSTRACT

This study deals with transportation inefficiencies in a rural school by applying a Geographic Information System (GIS) to examine the bus network of Goodwill Group of Schools in Obaagun, Nigeria. Primary data, comprising route coordinates based on GPS, together with feedback on student satisfaction, were gathered with a view to creating a geodatabase. The methodology involved spatial analysis techniques, specifically Nearest Neighbor Analysis (NNA) to assess bus stop distribution and a weighted overlay suitability analysis to identify optimal locations for new stops. Results revealed significant operational challenges, including persistent late arrivals (failing to meet the 7:45 am schedule) and bus overcrowding. The NNA confirmed that in the spatial arrangement of existing stops, a clustered pattern exists contributing to inefficiency in the routes. Accordingly, based on the suitability analysis, 15 new bus stops were proposed for an optimized network. Student feedback collected through the survey (dissatisfaction being 35.8%) pointed at key deterrents such as bus conditions and stop locations. The study concluded that a GIS-based approach is, in essence, a data-driven framework for the enhancement of school transport logistics, hence improving service delivery, punctuality of students, and academic success as a whole.

Keywords: Geospatial framework, School transportation, Geodatabase, Transportation Management, Student Satisfaction.

INTRODUCTION

The efficiency of a school bus system remains one of the critical determinants for educational quality, directly affecting students' hourly schedules, safety issues, and their very well-being. Around the world, it seems that there are considerable logistical and operational challenges for school transportation systems in payment route optimization, scheduling, and guaranteeing student safety (Newton & Thomas, 1969; Guo *et al*., 2006). In developing countries, especially Nigeria, these universal challenges are given additional local characteristics. Such characteristics include poor road infrastructure and the lack of connectivity in rural areas (Nkom, 2016; Olorunfemi, 2020). The consequence is often a system characterized by inefficient routing, extended travel times, and overcrowded buses, all of which disrupt academic routines and negatively affect student performance (Olorunfemi, 2020).

The School Bus Routing Problem (SBRP) has been an important issue in operations research since its formal inception. The literature highlights that with seminal work (Guo *et al*., 2006), a two-step procedure was suggested for solving this type of problem, with special regard being given to bus capacity and riding time. This groundwork has been built upon by more recent investigations that proposed more sophisticated algorithmic solutions, for example, Shafahi *et al*., (2018), who suggested a matching-based heuristic algorithm that optimized bus routes by matching students with their nearest stops in an efficient manner. Apart from just reducing travel time and cost, this approach proved superior to conventional methods and so is more fit for real-world transportation planning in dense areas (Sciortino *et al*., 2021; Sciortino *et al*., 2022).

The late 1990s and early 2000s saw the widespread adoption of Geographic Information Systems (GIS), marking a crucial development in this area. GIS-based methods have become essential due to the provision of a technology to integrate and analyze many different data sets giving information on spatial phenomena with a road network, student residencies, and traffic conditions as a few examples. Such details help in understanding great routing schemes, visualization of travel times, and performing spatial optimizations on other parameters of system usability (Spasovic

et al., 2001; Le *et al.*, 2020). The use of GIS beyond routing is quite well established in school planning. In one such study, (Ojiako *et al.*, 2018) used GIS in the formulation of geospatial databases for educational facilities in Nigeria, emphasizing the importance of accurate spatial data for efficient resource management-an assumption on which this study is based. The practical benefits of GIS have been further demonstrated by (Dragan *et al.*, 2011; Alistair *et al.*, 2015), who successfully used GIS to reduce travel time, enhance safety, and improve transport accessibility in various case studies.

Going further from logistics' efficiency, an essential question to ask is how transportation systems can influence student satisfaction. Lincoln & Widyastuti, (2020); Karabulut & Dogan, (2021), in their framework of separate studies, examined student satisfaction with school bus services in Indonesia and Turkey, respectively. Both studies confirmed average satisfaction levels and emphasized that punctuality, comfort, and driver behavior stand paramount in influencing student perception. The findings were at pains to convey the aching need for user input on evaluations of transportation.

While existing literature has extensively explored school bus routing problems and transportation planning using GIS, other studies have dealt with student satisfaction. This leaves a void in research that integrates GIS-based optimization with the holistic evaluation of student satisfaction within the more specific rural African setting. Previous works have treated these two elements as separate from each other and simultaneously left a void in understanding how transportation systems consider this holistic aspect. This study intends to fill this void by rigorously evaluating the school bus transportation system in the context of Goodwill Group of Schools, Obaagun, Nigeria, using GIS. Preliminary evaluations have, in fact, pinpointed systemic inefficiencies pertaining to bus overcrowding, stops that are poorly located, and frequent late arrival of buses that interfere with class time. Therefore, this project primarily seeks to conduct the systematic analysis of the bus routes and stops through GIS. This will be accomplished by first mapping out the existing transportation network and chartering the assessment of its efficiency and lastly, evaluating the student satisfaction with the system. Theoretically, the research results should generate guiding principles that could be practically implemented to improve school transportation services in similar areas. The research area is spatially located at Obaagun, a town in Ifelodun Local Government Area of Osun State, Nigeria, an area with infrastructure characterized by poor roads that act as bottlenecks during periods of traffic or logistical movement. For the study purposes, a "school bus stop" shall be considered an actual stop where students are picked up or dropped off, the opposite of those used by the general public.

MATERIALS AND METHODS

The methodology for this study was designed to systematically map and evaluate the bus routes of the Goodwill Group of Schools using a Geographic Information System (GIS) framework, while also assessing student satisfaction. The research process comprised four key phases: data acquisition, geodatabase creation and modeling, GIS analysis, and student satisfaction assessment, as illustrated in the methodology process in Figure 1.

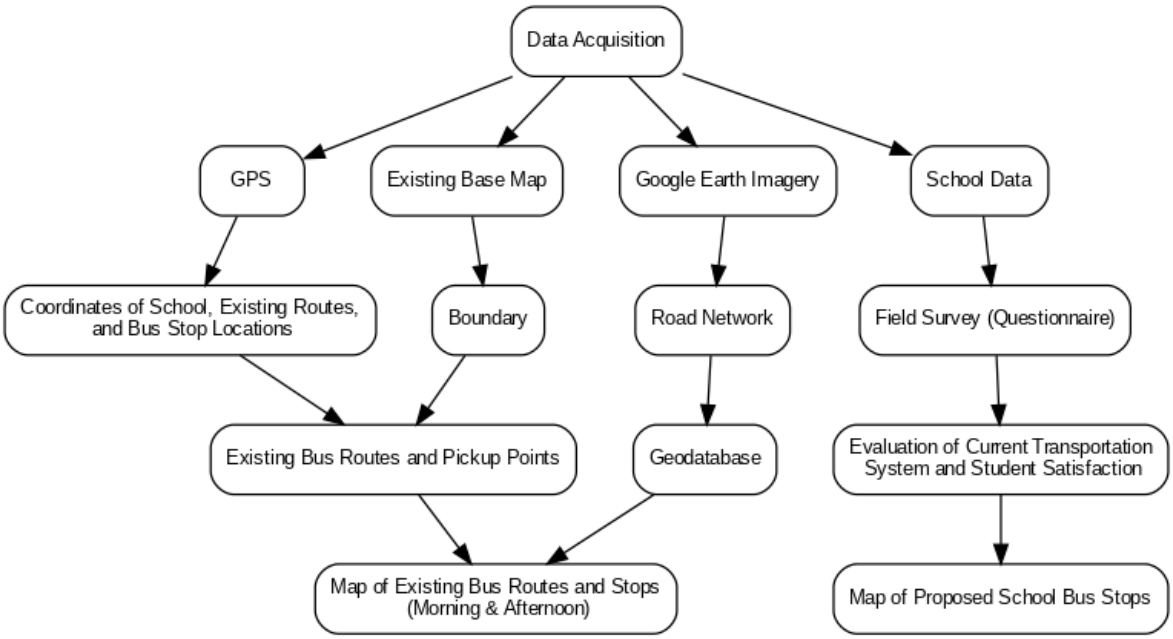

Figure 1: Methodology

Study Area

The research was undertaken in Obaagun, a town within Ifelodun Local Government Area of Osun State, Nigeria. In fact, it is located northeast to Osogbo, the state capital, at a distance of approximately 12 km. The LGA of Ifelodun spans an area of about 114 km² and had an estimated population of 96,748 based on the 2006 national census [15, 16]. While such demographic data for Obaagun is nonexistent, LGA-wide figures thus create some contextual background.

The area is basically rural agrarian; meanwhile, roads are either pavements or unpaved, mostly devoid of good infrastructure such as sidewalks or drainage. So, this constitutes a logistical challenge for school bus transportation. The study focuses on the Goodwill Group of Schools, with students who commute into school from various parts of Obaagun and environs. Hence, this setting would be very appropriate in the application of GIS techniques for optimizing bus route taking into consideration student satisfaction. The Map for the study area is shown in Figure 2.

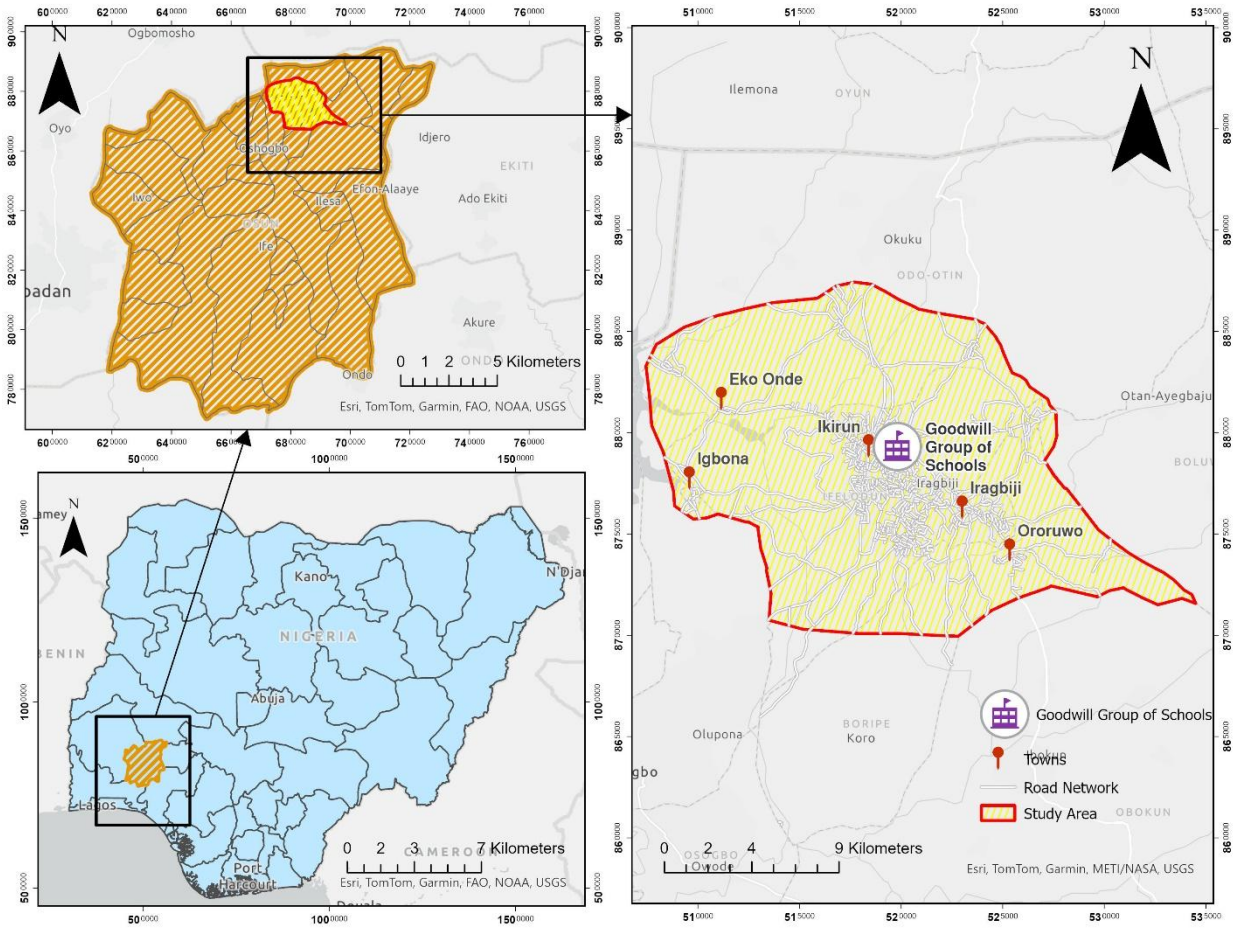

Figure 2: Map of Study Area

Data Acquisition

In this study, data collection employed primary and secondary sources. The primary data on the geographical coordinates of the existing bus routes and stops were collected through fieldwork using a handheld GPS receiver. In addition, there was a field survey aimed at collecting student attribute data, with interviews given to students and school managers about the present transportation system. Moreover, the students were asked to fill out a questionnaire relating to their satisfaction with the bus service. Secondary data included Google Earth images, satellite imagery retrieved from the USGS website, and other relevant literature from a variety of online sources. For a detailed description of the nature of data, their type, their source, and relevance, see Table 1.

Table 1: Data Requirements and Sources

S/N	Name	Source	Relevance
1	Google Earth Imagery	Google Earth Pro	For digitizing road networks and geolocating school buildings.
2	School Data	Goodwill Group of Schools, Obaagun	Basic information on the current transportation system.
3	GPS Coordinates	Field Survey (Handheld GPS)	For obtaining the precise coordinates of existing bus routes and stops.
4	Satellite Imagery	USGS website https://earthexplorer.usgs.gov/	For land use/land cover classification to identify suitable land for new bus stops.
5	SRTM Data	USGS website https://earthexplorer.usgs.gov/	For generating a Digital Elevation Model (DEM) to determine slope and elevation.
6	Student Attribute Data	Field Survey Bookings	For creating the geodatabase.
7	Student Satisfaction Assessment	Field Survey (Questionnaire)	For evaluating the level of student satisfaction with the bus service.

A geodatabase with high integrity was created to serve as the central repository for all spatial and non-spatial data as is customary in any GIS project. Three levels of database design were involved: conceptual, logical, and physical.

Conceptual Modeling: A conceptual model based on an Entity-Relationship framework defined the relationship between the key entities: School, Students, Roads, Bus, Bus Stops and Route. The School entity was designated as the central component that connects all other entities since no transportation management system may exist without it. The relationships among these entities and their attributes are illustrated in Figure 3.

Logical and Physical Modeling: The logical data model was translated into an executable database schema. This involved defining specific field names and attributes for each entity. For example, the STUDENTS entity contained fields for STU_Id (primary key), STU_Name, STU_Age, and BusStp_Id (foreign key). Table 2 details the entities and their corresponding attributes. The physical database design was executed in ArcGIS 10.7.1, where the spatial and non-spatial data were organized into feature classes and tables.

Table 2: Entity and Attribute Representation

S/N	Entity	Attributes
1	Students	Id, name, age, location (X,Y), bus stop
2	Roads	Id, name, streets, location, route
3	Bus	Id, number
4	Bus stops	Id, location, description
5	Route	Id, name, roads, bus stop, bus
6	School	Id, name, location, contact

The relationships between entities were defined using primary and foreign keys, where a one-to-many (1:M) relationship was identified between a school and its various entities (e.g., a single school has multiple students). The E-R diagram (Figure 3) visually represents these connections.

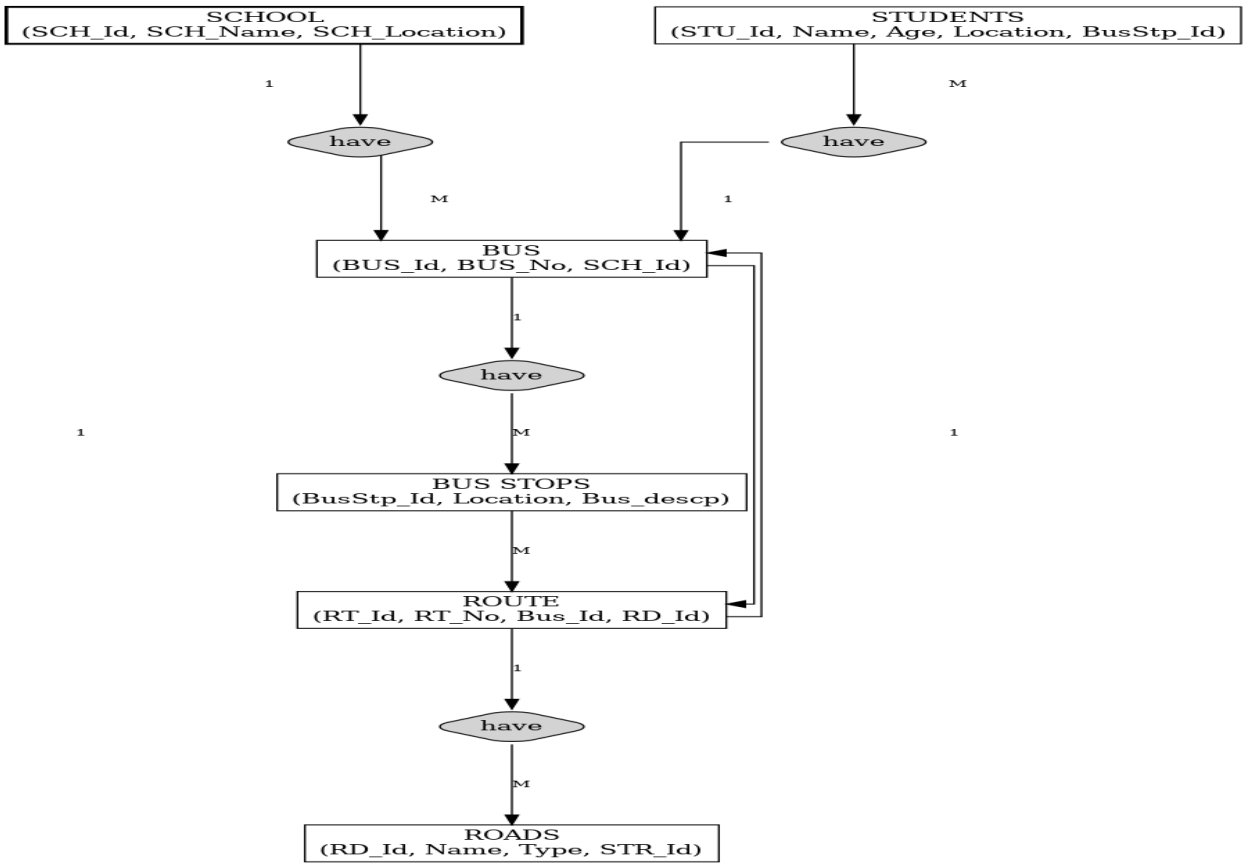

Figure 3: The E-R diagram

Student Satisfaction Assessment

A questionnaire-based study was conducted to find out how satisfied the users were. This survey was both systematic and purposive in sampling. It wanted to reach out to direct recipients at the secondary school level because it felt these students would be qualified to make a nuanced judgment of the transport service. The population for this study was divided into two: those that make use of the school buses and those that do not. A sample size of 96 students were taken for those who do not use the school transportation system, with 16 randomly selected students from each class. A sample size of 100 students was chosen for those who currently use the system, with 25 students per bus divided by the number of buses.

A total of 100 questionnaires were printed for bus users among whom 75 questionnaires were distributed and 57 received back, indicating a response rate of 76%. For non-bus users, 96 questionnaires were printed; all were distributed and 95 received back, yielding a response rate of 98%. Such sampling technique allowed for the comparative study of student perceptions. The questionnaires consisted of closed-ended questions pertaining to certain service attributes such as punctuality, comfort, and safety. Statistical software was used to analyze data for determining the overall level of student satisfaction. Table 3 shows the responses rates.

Table 3: Rate of Response from the Sample Size

S/N	Purpose of Questionnaire	Number of Printed Questionnaires	Number of Distributed Questionnaires	Number of Retrieved Questionnaires	Percentage of Response
1	For students who utilize the school bus	100	75	57	76%
2	For students who do not utilize the school bus	96	96	95	98%

With this sampling method, it was possible to carry out a comparative analysis of students' perceptions. The questionnaire had closed-ended questions to collect data on the key aspects of the service, punctuality, comfort, and safety. The analysis of the data was done through a statistical software to ascertain the overall satisfaction rating from the students.

RESULTS AND DISCUSSION

This section presents the results of the GIS-based evaluation of the bus route, the assessment of student satisfaction, and the subsequent suitability analysis of locations for new bus stops. The results are discussed with regard to the aim of the study and literature.

1. Mapping and Evaluation of Existing Bus Routes and Stops

The study revealed that the school operates with four vehicles that serve a total of about 137 pick-up and drop-off points scattered around Obaagun. Sixty pick-up points are used for pick-up in the mornings, while 77 drop-off points are used for drop-offs along the ways in the afternoon. The four buses exhibited significant operational disparities, with three vehicles designed for a maximum capacity of 27 passengers often conveying up to 40 students, leading to overcrowding. The existing routes and stops are shown in Figure 4. The spatial distribution of these stops, analyzed using the Nearest Neighbor Analysis (NNA) tool, revealed a clustered pattern (NNA Ratio: [0.71, $p < 0.01$), indicating that bus stops are

concentrated in specific areas rather than being randomly distributed. This clustering likely contributes to the circuitous and lengthy routes.

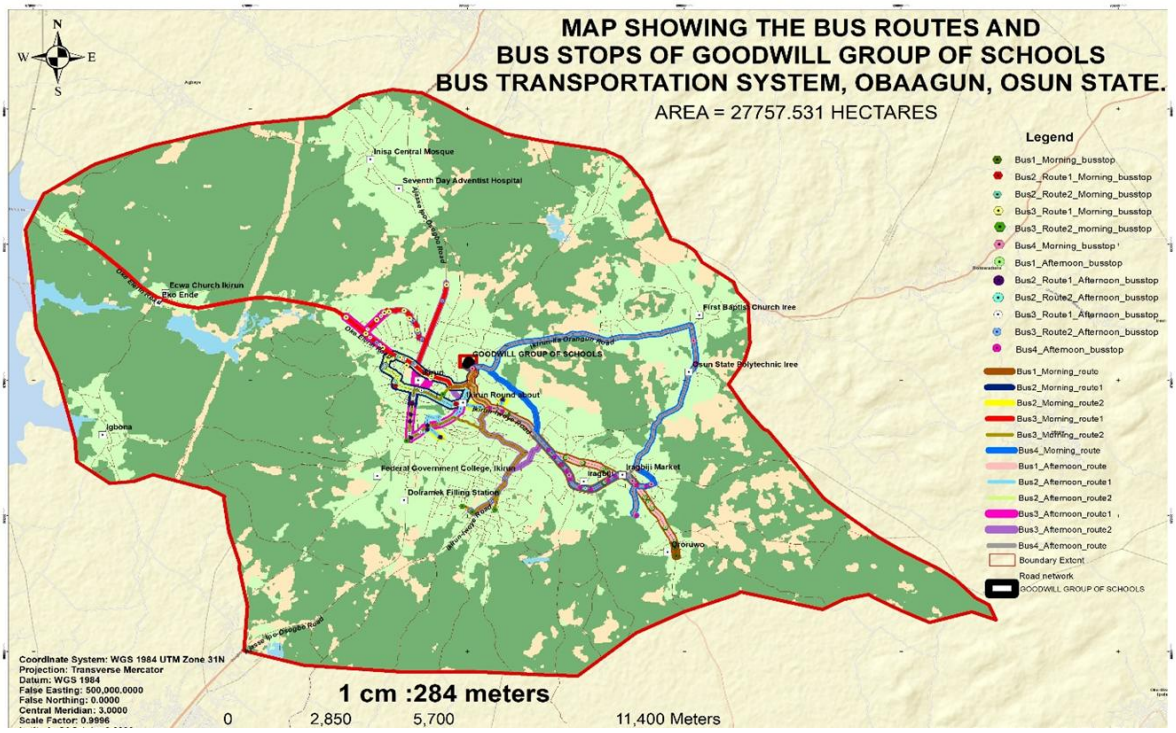

Figure 4: Map showing the existing bus routes and bus stops of the Goodwill Group of Schools.

The operational details for each bus are summarized in Table 4 for the morning trips and Table 5 for the afternoon trips.

Table 4: Arrival and Departure time for the morning bus rides

Date	Bus Number	Route	Departure Time from School	Arrival Time at School	Duration Of Bus Ride	Total Distance Travelled (Km)	No of bus stops
07/02/2023	BUS 1		06: 31am	07: 52am	1 h, 16 min, 37 s	20.446	16
08/02/2023	BUS 2	ROUTE 1	07: 04am	07: 41am	36 min, 25 s	8.62	6
		ROUTE 2	07: 45am	08: 13am	29 min	8.54	3
09/02/2023	BUS 3	ROUTE 1	06: 24am	07: 18am	54 min	15.12	14
		ROUTE 2	07: 22am	08: 15am	52 min, 30 s	18.56	7
10/02/2023	BUS 4		06: 16am	07: 50am	1 h, 32 min, 59 s	21.844	14

Table 5: Arrival and Departure time for the afternoon bus rides

Date	Bus Number	Route	Departure Time from School	Arrival Time at School	Duration Of Bus Ride	Distance Travelled (Km)	No of bus stops
07/02/2023	BUS 1		04: 30 pm	05: 21 pm	51 min	17.61	16
08/02/2023	BUS 2	ROUTE 1	04: 11 pm	04: 53 pm	39 min, 30 s	11.32	9
		ROUTE 2	04: 56 pm	05: 24 pm	28 min	7.74	5
09/02/2023	BUS 3	ROUTE 1	04: 11 pm	05: 09 pm	58 min	15.20	17
		ROUTE 2	05: 13 pm	06: 10 pm	57 min	24.96	14
10/02/2023	BUS 4		01: 07 pm	02: 15m	1 h, 8 min.	22.01	16

2. Route Efficiency and Geodatabase Functionality

The law of the school gives grounds for the arrival of students by or before 7:45 am. However, the study revealed a huge issue with non-punctuality that ran throughout the whole transportation system. Excepting the first trip of Bus Three, all other morning bus trips were late relative to their scheduled time. This then corroborated the preliminary observation: that the bus system very rarely achieves the objective of arriving students in time. In fact, the geodatabase created in this work acted as a catalyst in the analysis, where spatial and non-spatial data were able to be organized and queried. The populated attribute tables and the results of selected queries are presented in Figures 5–10, demonstrating the database's functionality to retrieve specific information. For example, the query on student data (Figures 5 and 6) indicated that there were five students picked up at the bus stop with ID "002_2BS1," while the one on bus stop (Figures 7 and 8) indicated that there are 21 stops associated with "BUS_003." This is important in the efficient management of routes and represents one key output of the GIS methodology.

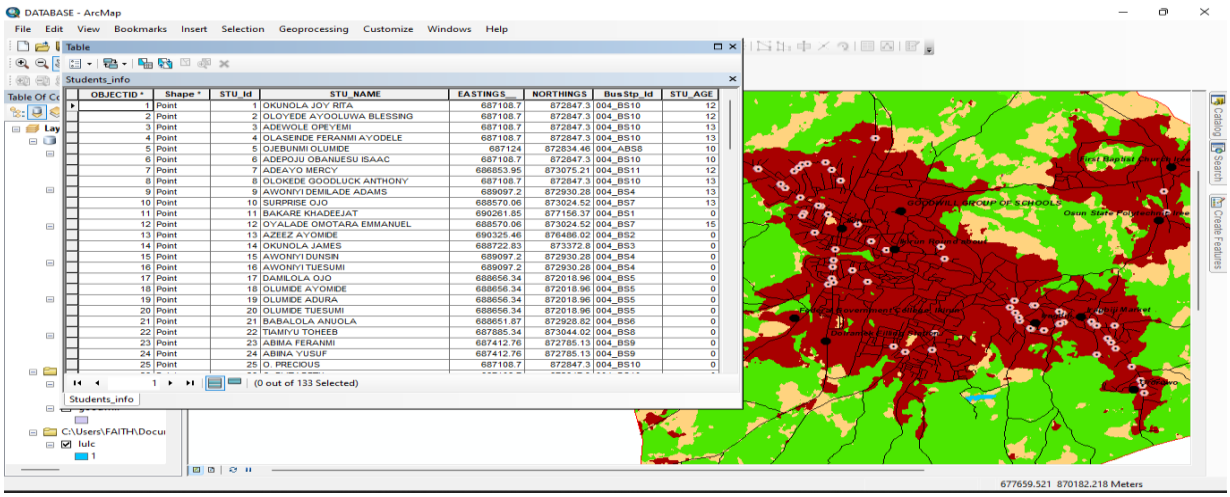

Figure 5: Student entity data contained in the database.

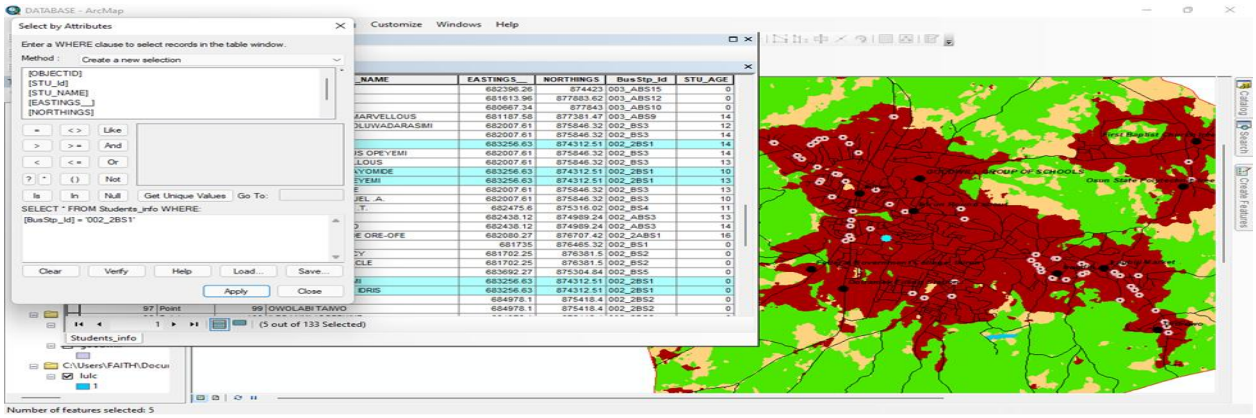

Figure 6: Query on student entity data and bus stop as contained in the database.

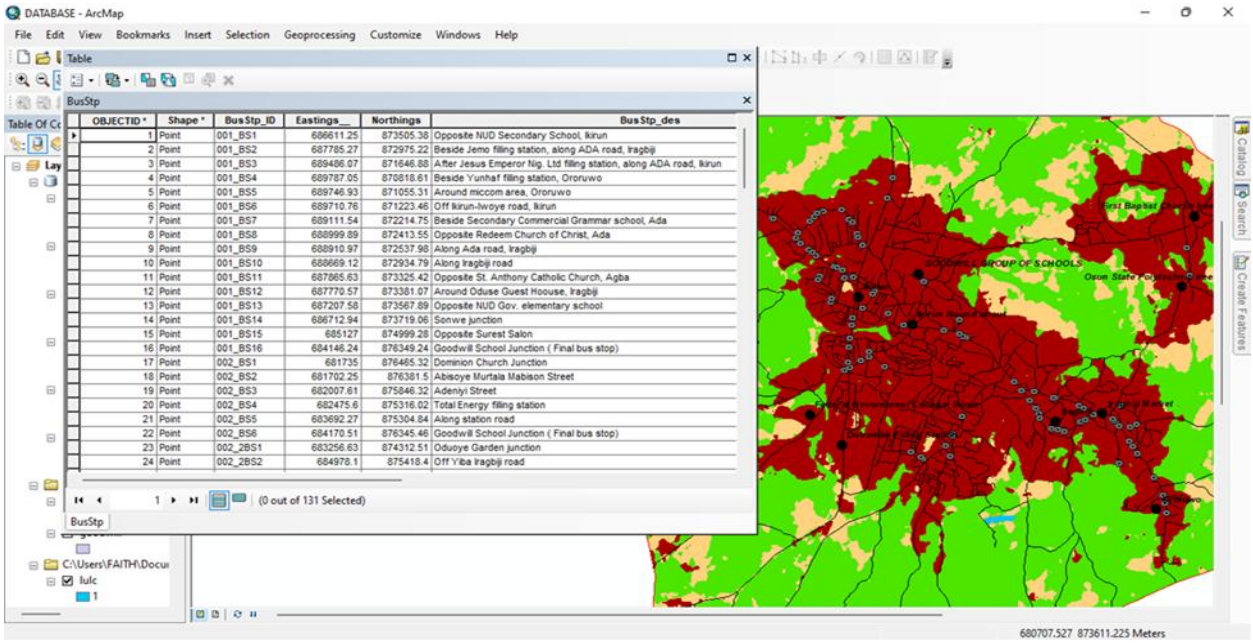

Figure 7: Bus stop entity data contained in the database.

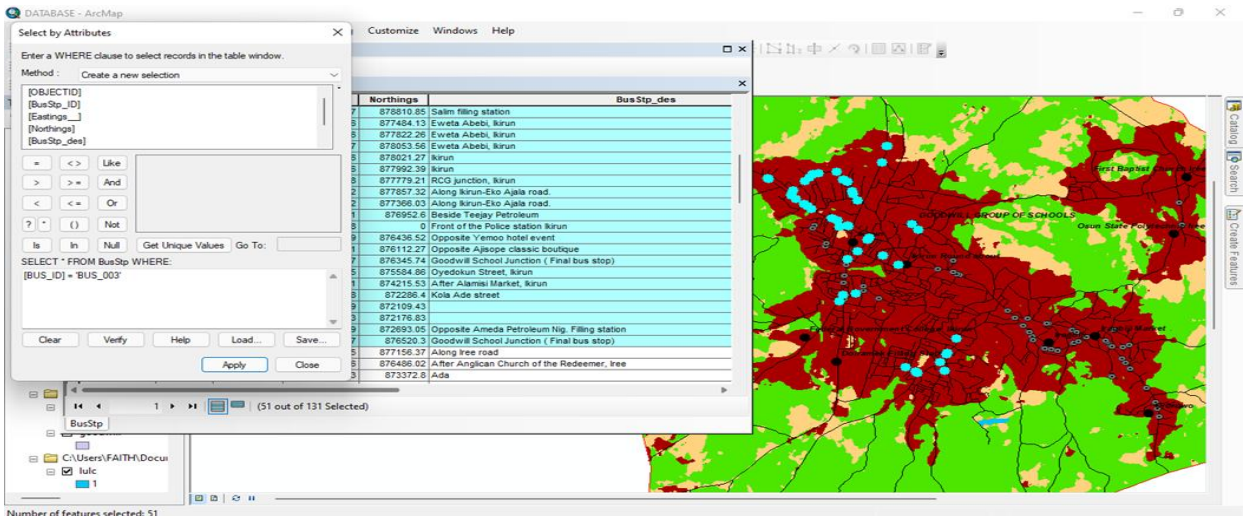

Figure 8: Query on bus stop where Bus ID-003 as contained in the database.

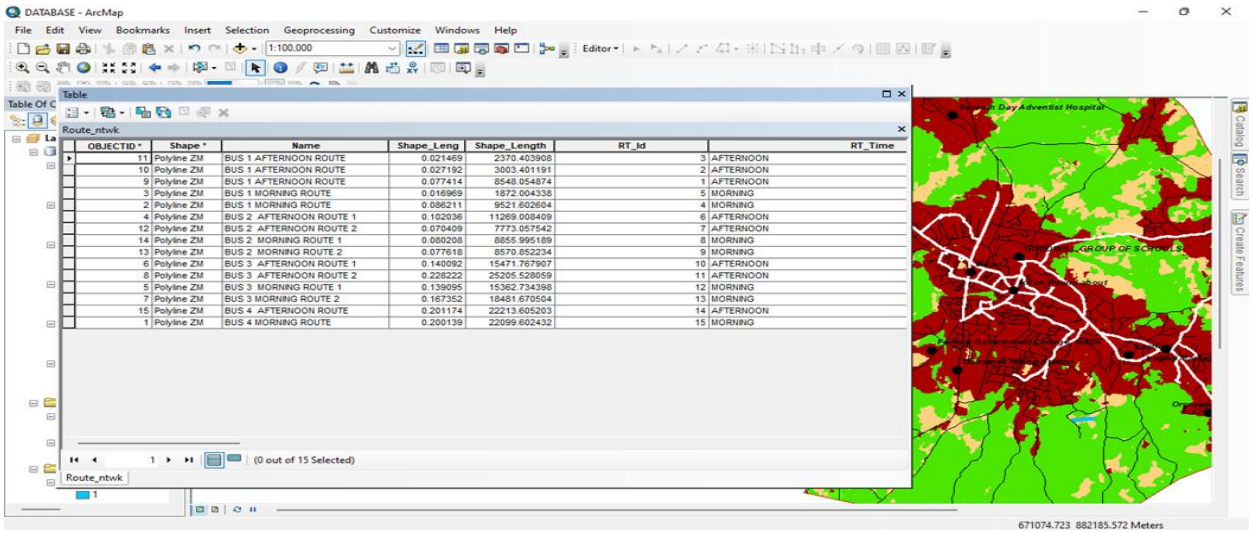

Figure 9: Route entity data contained in the database.

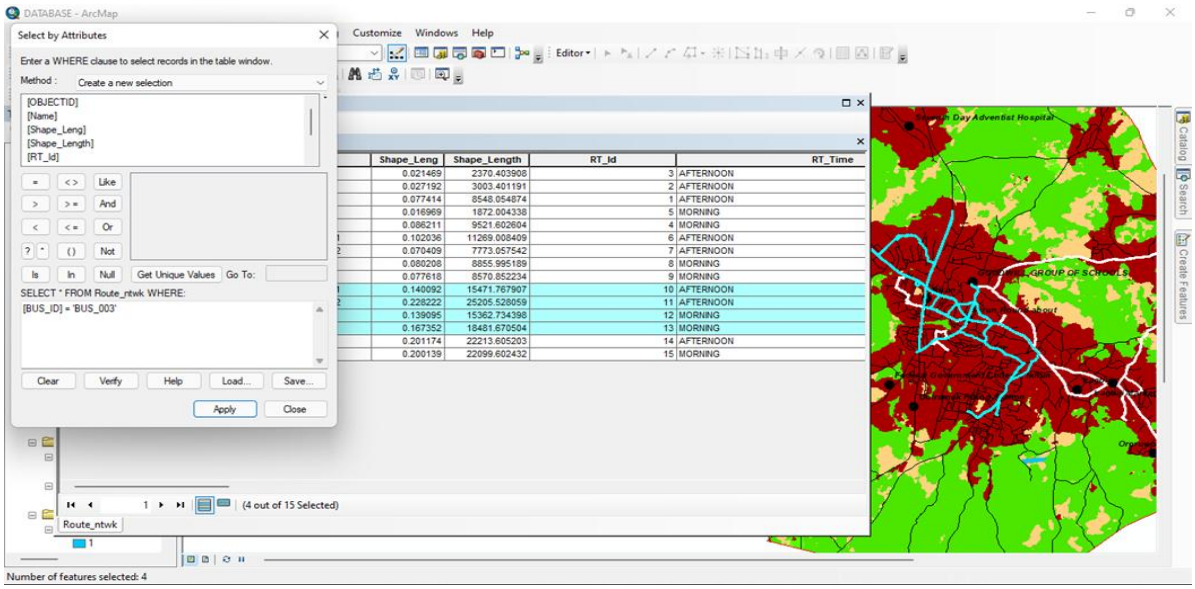

Figure 10: Query on route entity data contained in the database.

3. Suitability Analysis for Proposed Bus Stops

In order to address long travel times and poor service, a suitability analysis was run to identify new bus stop locations. Such analysis underwent reclassification and weighted overlay methods on six primary criteria: land use/land cover map, student location data, road network map, slope data, elevation data, and bus stop location data. Each of these layers was resampled to the same cell size with classes reclassified from "Not Suitable" (1) to "Most Suitable" (7). The criterion was then assigned equal weights of 17% in the overlay analysis. The final suitability map (Figure 11) shows areas with huge student concentrations, near road networks, and favorable topographical conditions. Based on this analysis, 15 new bus stops were proposed to optimize the routes. The coordinates and descriptions of these stops are provided in Table 6, and their locations are shown in Figure 12. Figure 13 shows the combined map of both the existing and proposed bus stops.

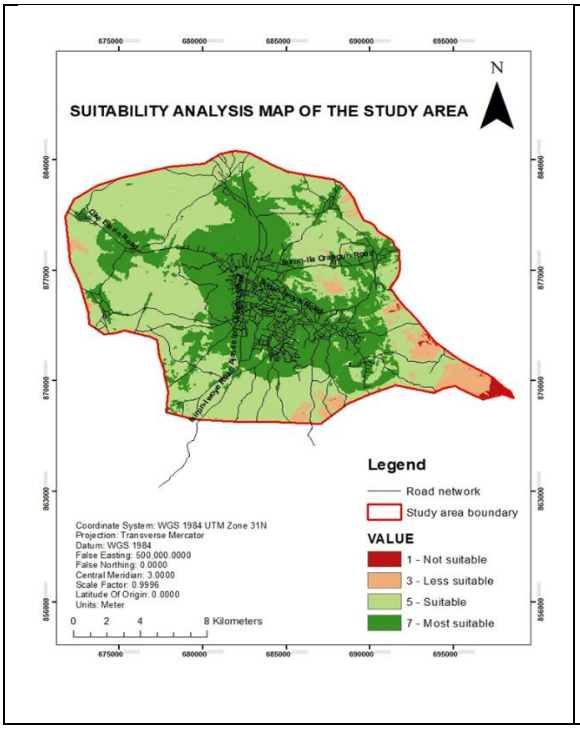

Figure 11: Suitability analysis map of the study area.

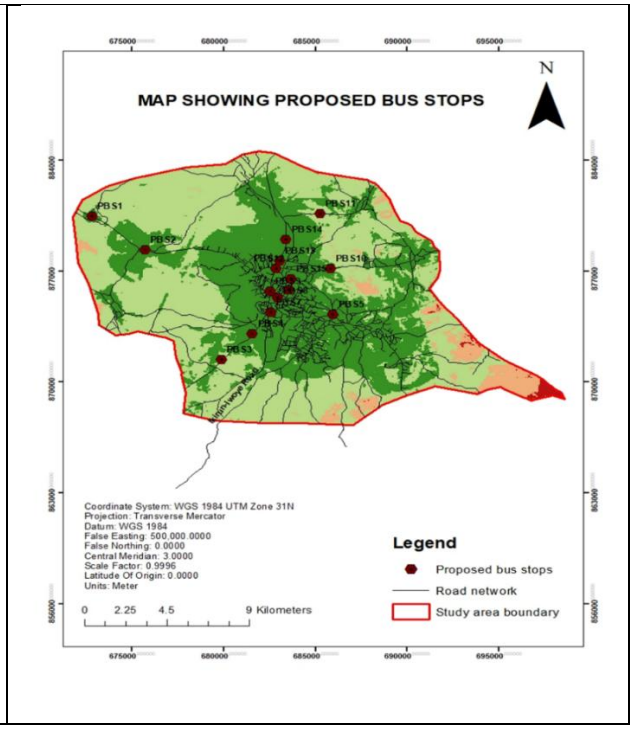

Figure 12: Map showing proposed bus stops.

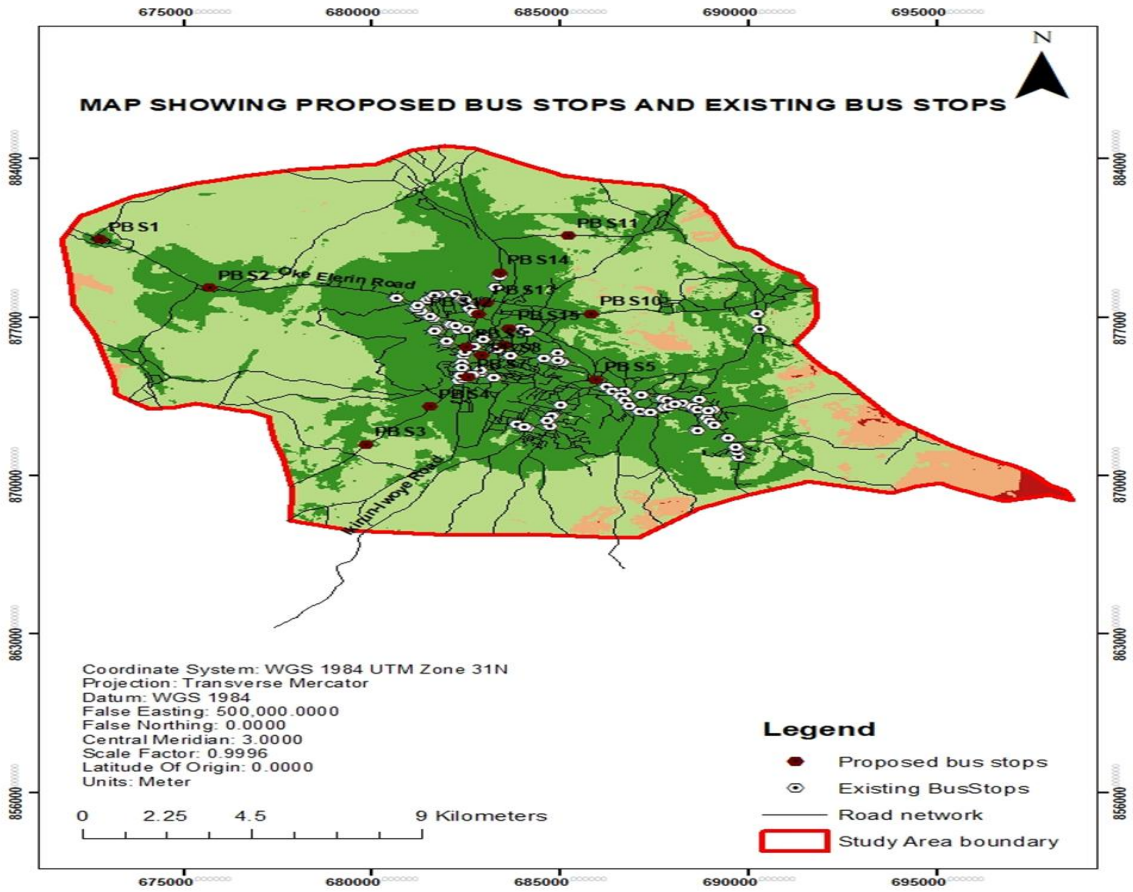

Figure 13: Map showing the existing and the proposed bus stops.

Table 6: Coordinates and description of the proposed bus stops

S/N	ID	Bus stop description	Eastings (m)	Northings (m)
1	PBS1	After Ore Central Mosque, Ore	672815.100	880450.800
2	PBS2	Before Court Hall Ogbomosho Rd, Ikirun	675723.200	878324.300
3	PBS3	Around Aromokola area, Ikirun	679892.100	871399.900
4	PBS4	Federal Gov. College junction, Ikirun	681577.900	873059.400
5	PBS5	Opposite Iragbiji central mosque	685984.600	874261.900
6	PBS6	After Total Energy, Abbebi Area, Ikirun	683563.100	875802.300
7	PBS7	Opposite Alamisi Market, Ikirun	682582.800	874383.100
8	PBS8	Opposite Olori Hotel, Ikirun	682938.300	875340.600
9	PBS9	After Emaayo General Nig Ltd	682529.300	875721.800
10	PBS10	Opposite Blesso Hotel, Obaagun	685859.000	877164.500
11	PBS11	Along Iba road, quarry area, Obaagun	685263.300	880621.800
12	PBS12	After Afi Suuru Petroleum, Ikirun	682865.900	877147.700
13	PBS13	Opposite Mascot Oil, Ikirun	683057.200	877659.000
14	PBS14	After testing Ground area, Ikirun	683412.400	878981.800
15	PBS15	Victoria Guest House, Ikirun	683688.000	876513.000

4. Student Satisfaction Assessment

The student satisfaction survey revealed a mixed but insightful picture of the transportation system.

Students Who Did Not Use the Bus: Among the 95 respondents who did not use the school bus, the primary reasons were lack of comfort, bus stops being too far from home, poor bus condition, and the bus's late arrival at school, as detailed in Table 7. These findings confirm that the existing system's deficiencies directly deter a significant portion of the student body. The discomfort and poor condition of the buses are major factors, as is the inadequacy of the bus stop network.

Table 7: Results for the selected criteria that restrict the use of school bus transportation by some students

S/N	Parameters	No of responses
1	I usually attend preschool activities in the morning before the bus's arrival at the school.	24
2	I attend an after-school activity after the bus's departure from the school	10
3	Bus pick-ups in the mornings are too early.	13
4	Bus pick-ups in the mornings are too late for me.	32
5	Bus drop-offs in the afternoon are too early for me.	7
6	Bus drop-offs in the afternoon are too late for me.	33
7	The bus ride schedule to school is too long for me.	10
8	The bus ride schedule home is too long for me.	9
9	The bus's arrival at school is too late for me.	36
10	The bus's arrival at school is too early for me.	7
11	The school bus stops are too far from my house.	45
12	I always go late to the bus stop.	11
13	My parents often drive me to school.	33
14	I prefer to trek down to school.	11
15	I prefer to take a bike to school.	43
16	The condition of the bus is too poor for me.	40

17	I usually get a free ride to school.	13
18	My parents cannot afford the bus fare.	18
19	I do not feel safe taking the school bus.	19
20	I am not comfortable using the school bus.	53
21	No available bus stop	1

Students Who Used the Bus: While the survey of student passengers revealed that 64.1% were satisfied with the service (13.2% "Very satisfied," 50.9% "Just satisfied"), a huge percentage of 35.8% were not satisfied. A high percentage of 88.2% had positive interactions with the drivers, and all testified to their safety in the hands of the drivers, but 72.2% said they had at least one negative experience with the service. This indicates that the dissatisfaction arises from systemic inadequacies such as overcrowding, punctuality, and condition of the buses rather than the drivers. The safety of students being questioned by 8.2% is ridiculous and requires an urgent consideration.

CONCLUSION

This study successfully demonstrated that a Geographic Information System (GIS) is a very efficient tool in the evaluation of a school bus transportation system and the formulation of solutions for improvement. Using geospatial techniques, the research performed a thorough study of the existing bus routes at the Goodwill Group of Schools, revealing gross inefficiencies at the systemic level, including irregular punctuality, poor route planning, and overcrowding of buses. The findings of the study directly established that, as the preliminary assessment had predicted, operational inefficiencies in the existing system, particularly in the timely arrival of buses, adversely affect the academic experiences of students.

The geodatabase developed in this study was an enabling tool in integrating spatial and non-spatial data to achieve core objectives in the research. The design and functionality of this database enabled the school management to carry out targeted queries to gain insights into student-route assignments and bus stop distributions-from a purely descriptive to an analytical viewpoint of transportation management. Also, the suitability analysis of GIS helped to identify 15 new optimal bus stop locations. Those proposed stops serve as a practical solution to very long travel times and poor route coverage, thus providing a strategic opportunity to foster improvement in the system's effectiveness and student satisfaction.

The survey's results reiterated the above views, with some students unsatisfied with service, and they cited not driver faults but systemic shortcomings, from vehicle condition to insufficient comfort to location of the bus stops. Such a holistic approach combining a GIS-based route analysis with a direct user-interface, feedback assessment represents a key contribution to the literature and offers a replicable framework for school districts in similar contexts. Ultimately, this study has furnished the Goodwill Group of Schools with a data-driven transportation blueprint that could aim for better student punctuality, student safety, and student well-being.

LIMITATION OF STUDY

While this study effectively utilized GIS to evaluate and propose improvements for the school's transportation system, it is important to acknowledge the limitations inherent to the study area. The poor road networks and generally underdeveloped infrastructure within rural Obaagun, Nigeria, posed a significant constraint on the potential for route optimization. Although the GIS-based suitability analysis successfully identified more efficient locations for new bus stops, the physical limitations of the road conditions and a lack of alternative road networks meant that a complete overhaul of the routes was not feasible. This highlights a critical downside of implementing such systems in rural areas where the solutions provided by advanced geospatial tools are ultimately bounded by real-world physical infrastructure.

CONFLICT OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Finally, we extend appreciation to every staff member and student of the Goodwill Group of Schools for their warm welcome and hospitality during our visit; we hope the results of this project will improve their transportation system.

AUTHORS' CONTRIBUTIONS

This research was collectively carried out by all the authors: C. O. Oluwadare: Conceptualization, Methodology, Review and Editing of Prepared Manuscript. Supervision. A. I. Abidoye: Conceptualization, Data analysis and manuscript preparation, Review and Editing of Prepared Manuscript. E. F. Ataman: Conceptualization, Methodology, Investigation, Writing-Original Draft, Project administration. A. O. Abiri: Review and Editing of Prepared Manuscript. O. E. Onimhawo: Data analysis and manuscript preparation, Resources.

Institutional Review Board Statement: Not applicable to this research

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Data Availability Statement: The data used for this research will be available on request

Conflicts of Interest: The authors declare no conflicts of interest.

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