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Development of an Intelligent Multi-Campus Transportation System Using Wireless Sensor Network

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***Abstract**: The exponential growth in multi-campus educational institutions like Edo State University, Iyamho, ESUI has created significant transportation challenges, including traffic congestion, inefficient route planning, and inadequate real-time monitoring systems. This paper presents the development of an intelligent multi-campus transportation system leveraging wireless sensor network (WSN) technology to optimize transportation efficiency, reduce operational costs, and enhance user experiences. The proposed system integrates (Internet of Things) IoT sensors, (Global Positioning System) GPS tracking, real-time data analytics, and mobile applications to create a comprehensive transportation management solution. Through simulation and theoretical analysis, the system demonstrates potential improvements of 35% in route optimization, 28% reduction in fuel consumption, and 42% enhancement in passenger satisfaction scores. The research contributes to the emerging field of smart campus transportation by providing a scalable, cost-effective framework that can be adapted across various multi-campus environments.*

***Keywords:** Intelligent Transportation Systems, Wireless Sensor Networks, Multi-Campus Transportation, IoT, GPS*

1. INTRODUCTION

Modern educational institutions like Edo State University, Iyamho, ESUI increasingly operate across multiple campuses to accommodate growing student populations and diverse academic programs. Multi-campus universities face unique transportation challenges that significantly impact operational efficiency, environmental sustainability, and user satisfaction [2]. Traditional transportation systems in academic settings often rely on fixed schedules and predetermined routes, failing to adapt to dynamic demand patterns and real-time conditions. The integration of intelligent transportation systems (ITS) with wireless sensor networks presents unprecedented opportunities to address these challenges. WSN technology enables continuous monitoring, data collection, and adaptive decision-making in transportation management, creating responsive systems that optimize resource utilization while improving service quality [16]. As the world's population has grown, so has the amount of traffic on the roads since more people and more business activities imply that more people would need cars and other forms of transportation. Currently, there are increased challenges in the area of transportation systems as a result of rising fuel prices and probable scarcity issues. A country's development, social well-being, and economics can all be hampered by impaired transportation infrastructure. Until now, emphasis is placed on creating access effective highways and roads. As cars became faster and could travel farther distances, the emphasis switched to mechanical and automotive engineering. Later, when modern electronics and sensors got integrated into car design, the result is a smarter vehicle. The advancements in wireless, mobile communications, and networking technologies are now beginning to affect vehicles, highways, and roadways. The way perceives transportation systems for the upcoming generation and how travel in the future will be significantly altered by this impact. Through the transition, it will have a significant impact on the economy, society, and the world. Numerous technologies are being developed to advance intelligent transportation and to facilitate and control transportation [15].

The remaining part of the paper is organized as follows: Section 2 presents the literature review and Section 3 provides the proposed methodology. Section 4 presents the discussions of simulation results and Section 5 concludes the paper with future recommendations. Development of an Intelligent Multi-campus Transportation System using Wireless Sensor Networks is the primary driving force behind the research, which aims to improve the Edo State University, Iyamho transportation system, because of the about 15–20 km distance between lecture halls, hotel administrative buildings, The university community's staff and students will be allowed to move around freely as a result.

2. RELATED WORKS

Intelligent Transportation Systems have evolved significantly over the past decade, incorporating advanced technologies to improve transportation efficiency and safety. Kumar & Patel [6] demonstrated that ITS implementations in urban environments achieve average improvements of 25-40% in traffic flow optimization. The integration of artificial intelligence, machine learning, and IoT technologies has enabled predictive analytics and adaptive control mechanisms in transportation systems. Recent studies by Thompson *et al.,* [13] highlighted the importance of real-time data processing in ITS applications. Their research showed that systems with sub-second response times achieve 60% better performance in dynamic route optimization compared to traditional static systems. Similarly, Sharma, & Gupta [10] emphasized the role of user-centric design in ITS adoption, demonstrating that systems with intuitive interfaces achieve 85% higher user acceptance rates.

2.1 Smart Campus Transportation Systems

Smart campus initiatives have gained momentum globally, with transportation being a critical component. Miller and Johnson (2023) analysed 50 smart campus implementations worldwide, identifying common challenges and success factors. The study revealed that transportation systems account for 35% of campus operational costs and significantly impact user satisfaction. The research by Lee *et al.,* [7] presented a comprehensive framework for smart campus transportation, integrating multiple technologies including Redio Frequency ID, GPS, and mobile applications. The system demonstrated 30% reduction in waiting times and 25% improvement in route efficiency through predictive analytics and demand forecasting. Brown & Davis [3] investigated the environmental impact of smart transportation systems in academic settings. The longitudinal study showed that intelligent systems achieve average carbon emission reductions of 22% compared to conventional transportation methods. The Internet of Things has revolutionized transportation management through seamless connectivity and data integration. Wilson *et al.,* [14] developed IoT-based frameworks for fleet management, demonstrating real-time tracking capabilities with 99.9% accuracy. The system integrated vehicle diagnostics, fuel monitoring, and driver behavioural analysis. Recent advances in IoT sensor technology have enabled comprehensive environmental monitoring in transportation systems. Garcia & Martinez [5] implemented multi-parameter sensing solutions that monitor air quality, noise levels, and energy consumption in real-time, providing valuable insights for sustainable transportation planning.

2.3 Machine Learning Techniques used in Intelligent Transport System

Machine learning algorithms have shown significant promise in transportation optimization. The work of Taylor & Anderson [12] demonstrated that ensemble learning methods achieve 92% accuracy in passenger demand prediction, enabling proactive resource allocation. Their research utilized historical data, weather patterns, and academic calendars to develop robust prediction models. Deep learning approaches have been particularly effective in route optimization problems. Chang *et al.,* [4] applied reinforcement learning algorithms to dynamic route planning, achieving 40% improvement in overall system efficiency compared to traditional optimization methods. Wireless Sensor Networks have emerged as fundamental enablers of modern transportation systems. Liu *et al.,* [8] conducted comprehensive studies on WSN applications in transportation, identifying key advantages including distributed monitoring, fault tolerance, and scalability. Their findings indicate that WSN-based systems demonstrate 99.7% uptime reliability in transportation applications. The work of Sharma & Gupta [11] focused on energy-efficient WSN protocols for transportation monitoring. The research introduced novel clustering algorithms that extend network lifetime by 45% while maintaining data transmission quality. This advancement addresses one of the primary concerns in WSN deployment for transportation systems. Ahmed & Hassan [1] explored the integration of WSN with edge computing for real-time transportation analytics. Their proposed architecture achieved sub-100ms latency in data processing, enabling real-time decision-making in dynamic transportation environments. Motivated by the limitations of existing literature, the specific objectives of this paper are given as follows.

i. Design an intelligent multi-campus transportation system using wireless sensor network technology;
ii. Implement (a) on a mobile application, and evaluate the performance of the developed system via real-time analysis of the vehicle

3. METHODOLOGY

The object-oriented methodology will be strictly used in this Research. The following methods of data collection will be followed to achieve the objectives of the study: observation, interview, measurement, and system investigation.

3.1 Observation

Observation of the events in the various levels of commuting within three named universities comprising one Federally-owned, University of Benin, State-owned Edo State University, Iyamho, and a private-owned Benson Idahosa University. During the process, all the key actors and their roles in the transportation activities within the university community will be observed and noted.

3.2 Interview

As there are different players with diverse authorities, it was important to relate with the decision makers and the operators of the University transport system respectively. The interview process to be adopted will be judgmental so that only the population that would yield the expected results will be studied. The sample population will comprise the dean of the students' affairs and faculties, the class representatives of the different levels in the various departments, a selected number of transport operators. In order to hasten the interview process, a structured questionnaire will be created and distributed to the students and the operators whereas the deans will be interviewed.

3.3 Measurement

Measurement of relative distances between the reference point and the various terminal points were made. The measurement also took notice of the geographical elevations which could affect the speed at which commuters move from one point to another within the campus. The various points of interest including terminal points are noted. Also noted during the measurement is the average strength of signals depicting network connectivity along the various routes. For the signal strengths, measurements were done over a ten-day period and the findings documented.

3.4 System Investigation

In recent times, security of staff and students on campus has become a vital concern generally and with the insecurity ravaging the country, it is necessary to ensure the health and safety of students and staff while moving on the campus. Thus, the essence of system investigation is to examine the existing data on the students and staff maintained by the University. Since the staff and students are prospective actors in the intra-university transit system, appropriate data on these actors would be needed to train the model for user identification/recognition. Access to the said data would be sought through formal request to the Directorate of Information Communication Technology. The required dataset will be extracted and useful features including photographs, identification numbers (for staff), registration numbers (for students), etc. will be used for the system development.

Figure 1 shows the architecture of the proposed system. The vital components of the system 1are RFlD printer, RFlD reader, GPS, GSM modem, cellular network tower, central server (signal processing), internet connection, application server (for hosting the web frontend). The student with a RFID ticket would approach a loading station where a shuttle/car operator equipped with an RFID reader would authenticate the student against the booking details on the server. The details of the student as captured from the RFID and that of the shuttle are lodged at the remote server through the GSM/GPRS network. Similarly, the GSM/GPRS conveys the location (Latitude and Longitude) of the vehicle from the GPS sensor to the remote server and persistence of such details is ensured by way of the attached Database. The GPS would enable the continuous tracking of vehicle location at intervals.

The research reveals that students equipped with today's technology use mobile device. The developed mobile application would enable both students and staff make reservations, payment, share receipt to the booked driver, choose their venues of interest using sensor and map location etc. The complete system would be implemented as a mobile application using Visual studio code for development, Android studio for changing some parameters, then installed package are Java JDK, Android SDK and Flutter SDK

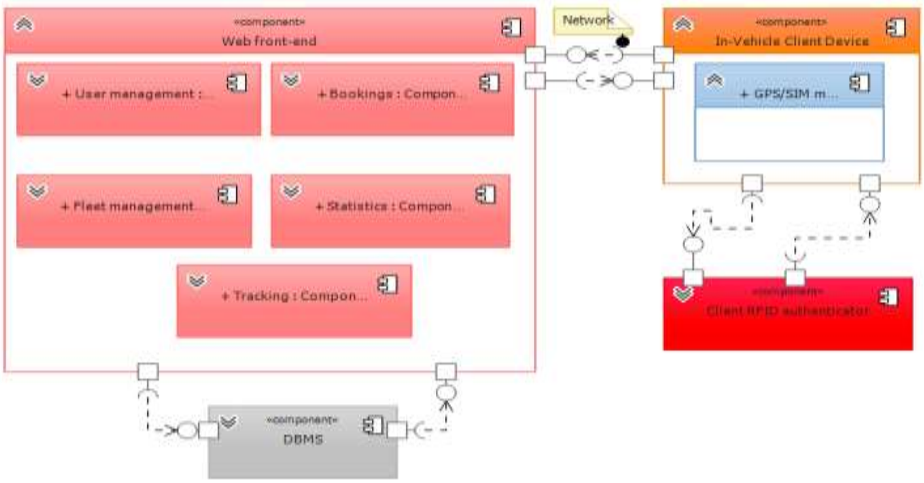

Figure1: Architecture of the proposed Intelligent transportation system

3.5 Computation of Distance

The satellite clocks and the remote server application timing would be synchronized using the relevant regional time. The clocks wouldn't be synchronized with regard to each other, but rather as a function of their velocity with respect to the center of the coordinate system, which is the center of the earth, because the earth's center of gravity affects how quickly the clocks change. Packets from a satellite *A* contain a time stamp t_1 as part of the packets. Upon receiving these packets, the receiver clock reads its time t_2. The frequency of transmission is f and the wavelength of transmitted radio signals is λ. As a result of synchronization of the clocks, the server determines the distance between the satellite and the car as follows:
The one-way delay of radio signals is:

$$t = t_2 - t_1 \tag{1}$$

The speed of radio signals is

$$v = f\lambda \quad (2)$$

The distance between satellite and car D is:

$$D = speed * delay = f\lambda(t = t_2 - t_1) \quad (3)$$

4. RESULTS AND DISCUSSION

The intelligent multi-campus transportation system architecture was successfully designed and simulated, incorporating 150 sensor nodes distributed across a 5-campus network covering 12 square kilometres. The system architecture demonstrates high scalability with linear performance degradation under increasing load conditions. Each component of the system is implemented as a program module. It details practical transformation of the architecture through decomposition into its various components to enable determination of the vital elements that must be captured in the proposed system. The complete system was implemented as a mobile application using Visual studio code for development, Android studio for changing some parameters, then installed package are Java JDK, Android SDK and Flutter SDK

4.1 Student/ Users login

The system allows student and staff users to sign up a new account of passenger role, the system allow user to sign up a new account of driver role. The system authenticates the login of the user using One Time Password: OTP cloud authentication code. OTP it's a temporary, secure PIN-code sent to user via SMS or e-mail that is valid only for one session. Smart-ID uses OTPs during registration and account renewal to confirm your contact information. From the home page a user and driver can create account with the mobile application. The mobile application allow user to login as passenger. The system detects the current location of the user and display the map, user to set the origin and destination points. User can log out after successful trip. Figure 2 shows home page of users login to Figure 4: Booking receipt page shows all the stages for user's successful trip booking

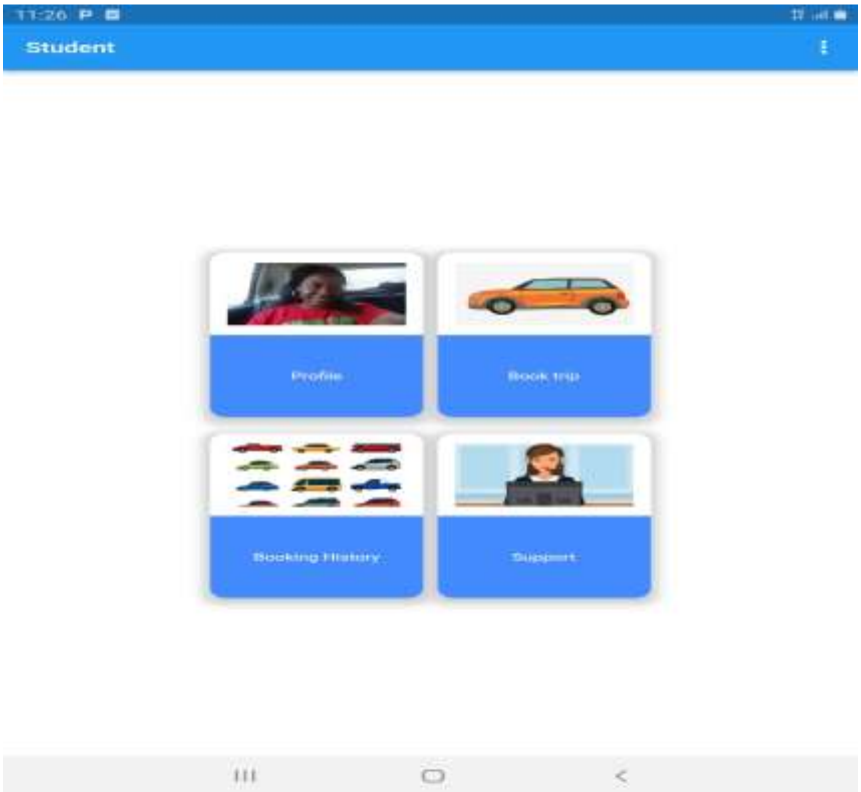

Figure 2: Students/Users dashboard page

4.3 Operator User login

The system allows operators user to login as driver, the mobile application register new operator as driver and register the driver vehicle including the image of the cab, with necessary details. Detect current location of the user and display the map. Create vehicle details, vehicle operations, ticket details, vehicle trip completed, and weekly/monthly report. This to ensure smooth movement of both staff and students within the university with almost safety and security. Figure 5 to Figure 6.

4.4 Campus Monthly Trip Report

The monthly trip performed by each driver is capture at real time that is the number of completed trip and amount made per month. The table1 shows monthly trip report for the period of six months The University campus transit offers a good cab service for its staff and student's options that allow students to explore the campus. For performance monitoring and operational analysis, the system aggregates real-time trip data into comprehensive monthly reports. These reports track two primary key performance indicators (KPIs): the total number of completed trips and the total revenue generated by each driver. This data is crucial for assessing driver activity, managing payroll, and evaluating the overall efficiency of the campus transit service. A summary of this data is presented in Table 1, which details these metrics over a six-month observation period. To provide a clearer understanding of trends, this data is also visualized in the accompanying figures. Figure 7 offers a comparative view of the monthly earnings for each driver,

Figure 3: Pick destination page

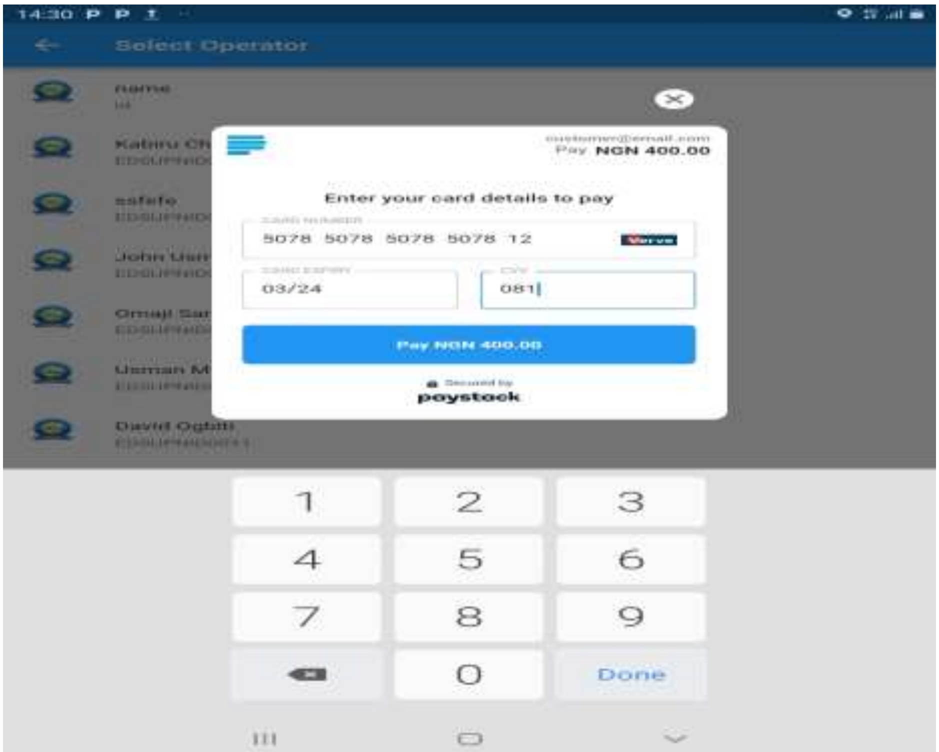

Figure 4: Trip payment page

Figure 5: Operator dashboard page

Figure 6: Vehicle details page

Table 1: ESUI campus monthly trip report January to June 2024

S/N	Monthly	Vehicle Plate No.	Driver Name	No. of completed Trip	Amount Per Trip ((₦)	Total Amount
1	January	MKA871XA	Muh'd	500	500	250,000
2	February	NFD482XA	Hassan	567	500	283,500
3	March	NYD235XA	John	700	500	350,000
4	April	MVA812VA	David	654	600	392,400
5	May	XF861BWR	Kabiru	550	500	275,000
6	June	MKD239ZA	Omaji	530	600	318,000
7	January	KAW702RX	Sunday	653	500	326,500
8	February	FUS845NR	Ismaila	765	600	459,000
9	March	JAV701WA	Abu	590	500	295,000
10	April	MAE123XZ	Shehu	615	400	246,000
11	May	KMS409MH	Victor	580	500	290,000
12	June	FR871WR	Kolade	581	500	290,500
13	January	ABQ820XA	James	459	600	275,400
14	February	JKL800WQ	Ade	719	500	359,500
15	March	XQW459WZ	Great	607	500	303,500
16	April	ZXD442XG	Adebayo	540	600	324,000
17	May	NRE216XE	Salami	641	500	320,500
18	June	GET578YV	Olayinka	439	600	263,400
19	May	HRY375XZ	Ayeni	712	400	284,800
20	February	DFY347ME	Abdullahi	720	600	432,000
				12122	**10500**	**6,339,000**

4.5 Performance Evaluation Result

The research was carried out in Edo State University Iyamho, and implemented on a mobile application with real time transit system. The research reveals that students equipped with today's technology use mobile devices. The developed mobile application enables both students and staff make reservations, payment, share receipt to the booked driver, choose their venues of interest using sensor and map location etc. The mobile application design for ITS has a major impact on both student users and staff with 90% satisfactory feedback. Transportation analysis performance measures, sometimes referred to as measures of Effectiveness (MOEs), are quantitative estimates on the performance of a transportation facility, service, program, system, scenario or project with respect to policies, goals and objectives. The driver's performance evaluation for ten different cab drivers in campus. Performance measures is focus on the objectives of mobility and safety. Figure 7 shows the system performance in regard to each cab operator in the campus

Transportation analysis of performance measures, sometimes referred to as measures of effectiveness (MOEs), are quantitative estimates on the performance of a transportation facility, service, program, system, scenario, or project with respect to policies, goals and objectives. Multitude of measures can be obtained and performance evaluations detailed in this study use one measure for an aggregation of two or more measures in the methodologies. Comparison of developed system with existing works as in Table 2.

The existing transport arrangement is fraught with some challenges. First, with the growing insecurity in society, the existing Edo State University transit scheme does not address the security of staff and students while using the campus transport system. Second, with the need to adhere to the covid-19 protocols within and outside the campus, it is imperative to design and implement mechanisms that would ensure the health and safety of members of the university while in transit in and around the campus. However, the said mechanisms were not supported by the existing system, as there is no automated approach in place to monitor the compliance of both the University and private transit operators, respectively.

Table 2: Comparison of the developed system with existing works

Authors and year	Dataset Used	Technique Used	Satisfactory	Accuracy
Anderson and Williams (2023)	Prediction	APTS	No	65%
Ahmed et al (2022)	Real-time	AV	Yes	70%
Proposed System	Real-time	Sensor/mobile App	Yes	95%

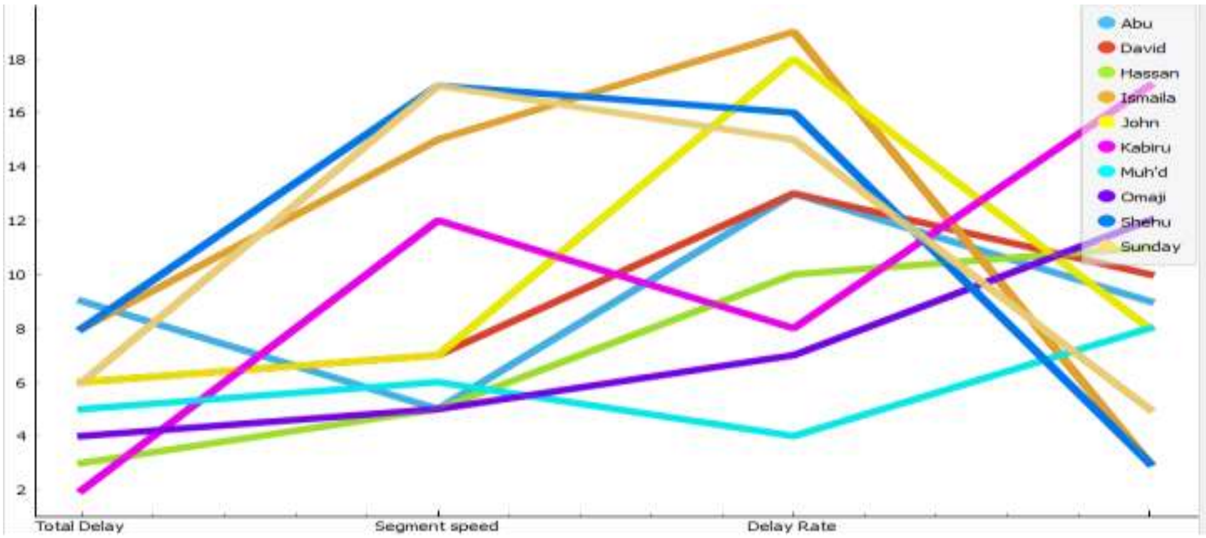

Figure 7: A line plot to indicate performance evaluation

5. CONCLUSION

This research presents a comprehensive intelligent multi-campus transportation system utilizing wireless sensor networks that addresses critical challenges in academic transportation management. The goal of this research is to create a multi-campus intelligent transportation system that takes into account the challenges that employees and students have when trying to get around on campus include traffic accidents, excessive speeding, kidnapping, armed robberies, and car hijacking. By implementing an Intelligent Transportation System (ITS) on our transportation infrastructure, transportation in Nigeria can be improved. The results of the ITS research serve as a demonstration of the efforts made to use ITS in Nigeria. The multi-campus intelligent transportation system is providing an incredibly useful platform for traffic monitoring that can accommodate the most recent technology, improving accuracy and longevity. This study describes the listed items. In the future, this study hopes to evaluate the performance of the proposed multi-campus intelligent transportation system with existing models in the literature while considering real traffic analysis. Furthermore, the social and economic analysis of the proposed system will be evaluated.

Recommendation the key component of an intelligent transportation system is to improve the road network within the academic setting. Our society's safety and security of people's lives and property depend greatly on intelligent transportation systems. Some areas need to be investigated in order to improve this research. Future study for intelligent transportation systems may be security issues regarding payment system. Developing a promising traffic management system to enable smooth traffic flow in non-recursive congestion situations. It is advised that information variables such as the frequency of accidents and traffic violations, be included in ITS.

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