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Application of Intelligent Transportation Systems (ITS) for Mitigating Traffic Congestion in Nigeria's Road Transportation Industry

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ABSTRACT

In Nigeria's cities, traffic congestion has grown to be a significant problem that slows down mobility, lowers productivity, and interferes with millions of commuters' daily lives. In order to alleviate these congestion issues and enhance the overall effectiveness of the road transportation network, this study investigates the potential applications of Intelligent Transportation Systems (ITS). Examining important ITS solutions like dynamic lane management, adaptive traffic signal control, real-time traffic monitoring, and electronic toll collection—all of which can be tailored to Nigeria's particular traffic conditions—it draws on examples from around the world. The study examines traffic patterns, pinpoints the primary causes of congestion, and suggests workable solutions for implementing ITS for improved traffic management using data from Lagos, Abuja, and Port Harcourt. The findings showsthat ITS can greatly enhance traffic flow, shorten travel times, and promote more environmentally friendly urban mobility. The study highlights that in order to make Nigerian cities safer, more effective, and more livable, intelligent, technology-driven systems must be implemented.

Keywords: Intelligent Transportation Systems (ITS), Traffic Congestion, Adaptive Traffic Control, Real-Time Traffic Monitoring, Urban Mobility

1. INTRODUCTION

An Intelligent Transportation System (ITS) is a state-of-the-art technology created to provide creative solutions for managing traffic and different forms of transportation. It assists users in staying informed, making safer choices, and making more intelligent and efficient use of transportation networks (Mahmood et al., 2022). ITS seeks to enhance traffic control, safety, and environmental sustainability, among other facets of transportation, by utilising these cutting-edge technologies (Ejem, 2018). In order to improve the effectiveness, security, and sustainability of road transportation networks, Intelligent Transportation Systems (ITS) have become essential innovations (Elassy et al., 2024). In order to maximise traffic flow, lessen congestion, and enhance overall transportation management, ITS offers real-time data and facilitates decision-making processes (Pompigna& Mauro, 2022). In addition to being a technological advancement, the implementation of ITS is a calculated move to solve the complex problems that contemporary transport systems face, especially in developing nations like Nigeria (Booysen, 2013).

Because it makes it easier to move people and goods over long distances, road transport is an essential part of Nigeria's economy. Traffic congestion, poor infrastructure, high accident rates, and ineffective traffic enforcement systems are just a few of the problems plaguing this industry (Elassy et al., 2024). To improve operational effectiveness and safety, these issues call for the application of creative solutions. ITS provide promising answers to these persistent issues by combining multiple technologies, including sensors, communication networks, and data analytics (Pompigna& Mauro, 2022). Nigeria's economy depends heavily on road transport, but traffic congestion is still one of its main obstacles. Millions of drivers lose valuable time, fuel, and productivity every day as they sit in traffic, and the number of accidents and inefficiencies keeps increasing. Though their use in Nigeria is still quite limited, Intelligent Transportation Systems (ITS) offer promising tools to help ease this burden. This study looks at the main barriers to their adoption, examines how ITS can be used to address traffic congestion, and offers workable solutions for their successful integration into Nigeria's road networks.With an emphasis on practical solutions, the study seeks to offer insights and suggestions that stakeholders, transportation authorities, and policymakers can utilise to improve road safety, traffic flow, and the development of a more effective and sustainable transportation system for Nigerian cities.

2.OVERVIEW

Intelligent Transportation System (ITS) integration has become more and more crucial given the road transportation sector's vital role in Nigeria's economy and the serious problems caused by ongoing traffic congestion. The purpose of this study is to examine how ITS might be used to alleviate traffic congestion, assess the present barriers to their uptake, and suggest workable ways to successfully integrate ITS in Nigeria's road transport sector.

In order to help policymakers, stakeholders, and practitioners use ITS to improve traffic flow, increase road safety, and advance the sustainability of Nigeria's urban transport systems, this research focusses on congestion mitigation.

Intelligent Transportation Systems (ITS) bring together advanced technologies designed to make transportation safer, more efficient, and more sustainable. Shaheen and Finson (2013) explain that tools such as wireless, electronic, and automated systems not only improve safety and travel decisions but also contribute to energy efficiency as a secondary benefit. More recently, artificial intelligence (AI) and machine learning (ML) have become central to ITS. As Bharadiya (2023) notes, these technologies play a crucial role in dynamic routing, congestion management, and intelligent traffic control, making transportation systems more adaptable to the fast-changing needs of modern cities. In developing regions, Vanderschuren and McKune (2011) show how ITS has grown from simple traffic controllers into complex systems that save lives, improve productivity, and raise quality of life through the use of information and communication technology (ICT).

Different components of ITS demonstrate their potential in easing congestion. Advanced Traffic Management Systems (ATMS), for example, use real-time data to optimize traffic signals and handle incidents more effectively (García et al., 2021), while Advanced Travel Information Systems (ATIS) provide travelers with accurate updates and smarter route options (Huang et al., 2021). On the vehicle side, Advanced Vehicle Control Systems (AVCS) reduce human error through features like adaptive cruise control and collision avoidance (Yang et al., 2022). Public transport has also benefited, with Advanced Public Transportation Systems (APTS) improving service reliability and encouraging more people to use buses and trains (Chen et al., 2021). In rural areas, Advanced Rural Transportation Systems (ARTS) have helped expand access to essential services and improve mobility (Smith et al., 2022).

Yet, despite these promising developments, Nigeria still faces a major gap: the application of ITS to tackle its persistent traffic congestion. Most studies on ITS are centered on developed countries, leaving little guidance for Nigeria’s unique urban realities—daily gridlock, overstretched infrastructure, and high accident rates. To close this gap, this research will focus on congestion-specific ITS solutions that are tailored to Nigerian cities, showing how they can be implemented effectively and sustainably. Doing so would not only ease traffic but also improve road safety and create a more reliable and efficient transport system (Shaheen&Finson, 2013; Vanderschuren&McKune, 2011; García et al., 2021; Huang et al., 2021; Chen et al., 2021; Yang et al., 2022; Smith et al., 2022; Bharadiya, 2023).

3. Methods

This study examines the potential of Intelligent Transportation Systems (ITS) to address traffic congestion by reviewing global best practices, analyzing the unique congestion challenges within Nigeria’s road transportation system, and proposing practical solutions for integrating ITS technologies in ways that are tailored to Nigeria’s urban realities.

3.1 Investigating the Potential Applications of Intelligent Transportation Systems (ITS).

Intelligent Transportation Systems (ITS) address traffic congestion through various innovative applications. Real-time traffic monitoring and management utilize sensors, cameras, and data analytics to detect congestion and adjust traffic signals dynamically, improving traffic flow. Adaptive traffic signals adjust their timings based on current conditions, which helps optimize vehicle flow through intersections and reduces delays.

Dynamic traffic information systems provide drivers with real-time updates on traffic conditions, road closures, and incidents through variable message signs, mobile apps, and in-car navigation systems, enabling better route choices and avoiding congested areas. Congestion pricing involves charging fees for using specific roads or areas during peak times, aiming to reduce demand and alleviate traffic congestion during high-demand periods.

Intelligent traffic control systems integrate various ITS components to manage traffic across extensive networks, coordinating traffic signal control, ramp metering, and incident management to enhance overall network performance. Automated incident detection and management use sensors and cameras to identify incidents and alert traffic management centers promptly, reducing the impact on traffic flow. Traveler information systems deliver real-time updates on traffic conditions and travel times through websites, apps, and roadside displays, helping travelers plan their routes more effectively and avoid congested areas.

3.2 Analyzing the current challenges being faced in the road transportation industry due to the absence of intelligent transportation

In Nigeria, particularly in major cities like Lagos and Abuja, traffic congestion presents a significant challenge. Lagos, one of Africa's most populous cities with over 20 million residents, suffers from inadequate road infrastructure and a high volume of vehicles (National Population Commission, 2021). This situation leads to severe traffic jams, costing commuters an average of 2.21 hours per day, which impacts productivity and incurs substantial financial costs (Faminu, 2021).

The social consequences of this congestion include increased stress, physical discomfort, and emotional fatigue, affecting the overall well-being of residents. The lack of Intelligent Transportation Systems (ITS) has worsened these issues, leading to severe economic and social consequences.

3.2.1 Traffic Congestion in some parts of Lagos

Road intersections form a major component of urban roads and are generally prone to traffic congestion. Traffic wardens and parking problems are the greatest causes of traffic congestion/delays at road intersections these major cities. Lagos, one of the major cities, known for its sprawling population and economic importance, struggles with traffic management. Figure 3.1 depicts the flow of traffic in specific areas in a part of Lagos mainlandon Thursday 12th September 2024 by 5pm, using color-coded data to indicate levels of congestion on roads and highways.

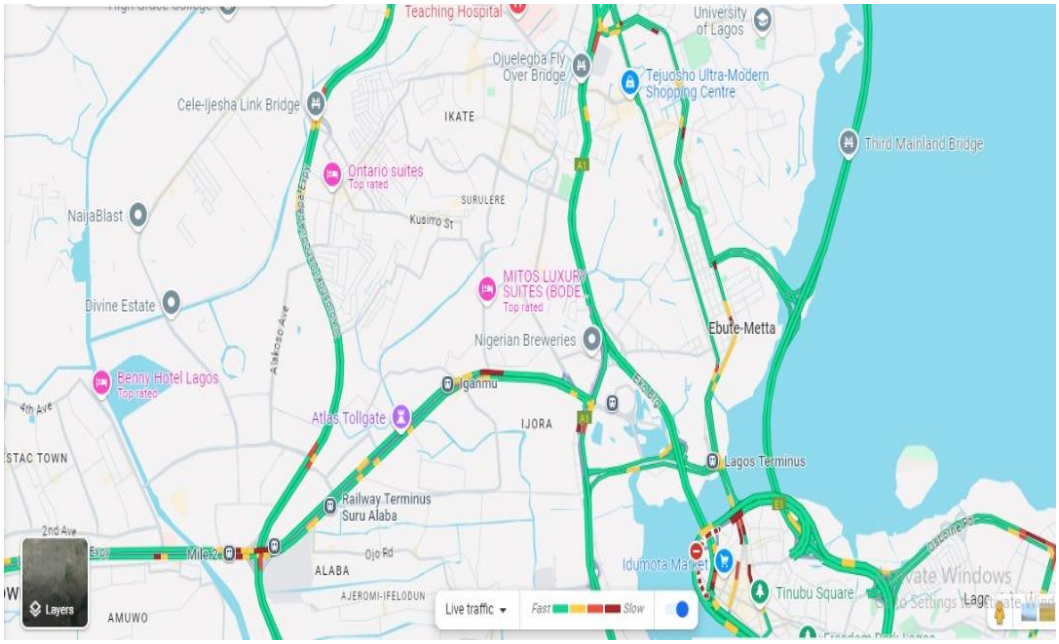

Figure 3.1 Traffic Congestion in Some parts of Lagos State (Google live traffic, 2024)

The map shows live traffic conditions with various color codes such as green, yellow and red lines. Green lines represent areas of fast-moving traffic, while yellow and red lines show moderate to heavy congestion.

Table 3.1 provides an overview of traffic congestion levels at various key locations in Lagos as indicated in the map in figure 3.1.

Table 3.1: Traffic Congestion Levels by Location in some parts of Lagos State on 12th December, 2024 by 5PM.

Location	**Traffic Congestion Level (%)**
Ontario Suites	30% (Light Traffic)
Nigerian Breweries (Iganmu)	70% (Moderate to Heavy Traffic)
Cele-Ijesha Link Bridge	50% (Moderate Traffic)
Atlas Tollgate	90% (Heavy Traffic)
Iganmu	80% (Moderate to Heavy Traffic)
Lagos Terminus	60% (Moderate Traffic)
University of Lagos	10% (Free Flow)
Third Mainland Bridge	20% (Light Traffic)
Ebute-Metta	30% (Light Traffic)
Mile 2	80% (Moderate to Heavy Traffic)
Tejuosho Ultra-Modern Shopping Centre	40% (Moderate Traffic)
Benny Hotel Lagos	10% (Free Flow)
SuruAlaba	70% (Moderate to Heavy Traffic)

The congestion percentages reflect the severity of traffic in each area, ranging from free-flowing conditions to heavy congestion. This variation highlights the diverse traffic patterns experienced across the city, with some areas showing minimal traffic disruption while others face significant delays.

At 10% congestion, such as at the University of Lagos and Benny Hotel Lagos, traffic flows smoothly with no significant delays. These locations represent areas where vehicles can move without hindrance. Locations with 20% to 40% congestion, such as the Third Mainland Bridge and Tejuosho Ultra-Modern Shopping Centre, experience light to moderate traffic. While vehicles may slow down slightly, they are still able to maintain a steady flow.

Areas like Cele-Ijesha Link Bridge and Lagos Terminus, with congestion levels between 50% and 60%, experience moderate traffic. Here, cars may move slower, but traffic remains manageable without major delays. As congestion levels rise to 70%, at places like Nigerian Breweries (Iganmu) and SuruAlaba, traffic becomes more severe, with frequent slowdowns and longer waiting times.

The highest levels of congestion, at 80% and above, occur in locations such as Mile 2, Iganmu, and Atlas Tollgate. These areas face heavy traffic, where cars move slowly and can sometimes come to a halt, leading to significant delays and extended travel times. In particular, Atlas Tollgate, with 90% congestion, represents one of the most affected areas, with severe traffic jams.

Causes of Traffic Congestion in some parts of Lagos

Traffic congestion in Lagos is driven by several factors, primarily centered around the city's commercial, industrial, and transportation activities. Commercial hubs such as Mile 2 and SuruAlaba experience frequent congestion due to the high number of traders, customers, and commercial vehicles attracted to the markets and businesses in these areas. Industrial zones, like the area around Nigerian Breweries (Iganmu), see moderate to heavy traffic as large trucks and delivery vehicles move goods in and out of the industrial complexes. Additionally, locations such as the Atlas Tollgate experience significant delays due to the presence of toll collection points, which act as bottlenecks, slowing down the flow of vehicles, especially during peak periods.

Key transportation corridors like the Cele-Ijesha Link Bridge and Third Mainland Bridge also play a role in the city's traffic dynamics. These bridges connect densely populated areas, and the sheer volume of daily commuters leads to moderate to heavy traffic, particularly during rush hours. The combination of high commuter volumes, industrial transport, and frequent bottlenecks at tollgates and bridges contributes to the overall traffic situation in Lagos.

3.2.2 Traffic Congestion in some parts of Abuja

Abuja, like Lagos, faces significant traffic congestion, especially at road intersections. Several factors contribute to this issue, including the presence of traffic wardens, illegal parking, and the lack of sufficient traffic signals. These problems are exacerbated during peak hours when a high volume of vehicles is concentrated around business districts and residential areas. Specifically, mixed land use in these regions leads to conflicts in traffic flow, causing significant delays. Illegal parking near offices, particularly during rush hours, is one of the primary culprits, and these challenges affect travel time and economic activities in the city.

Figure 3.2 highlights central areas of Abuja, including the Central Business District, parts of Wuse, and Asokoro. These areas, known for housing numerous government offices, businesses, and residential zones, experience varying levels of traffic congestion. The figure uses color-coded data to represent traffic flow and congestion levels on major roads and highways in these key parts of the city as of Thursday, 12th September 2024, at 5:00 PM.

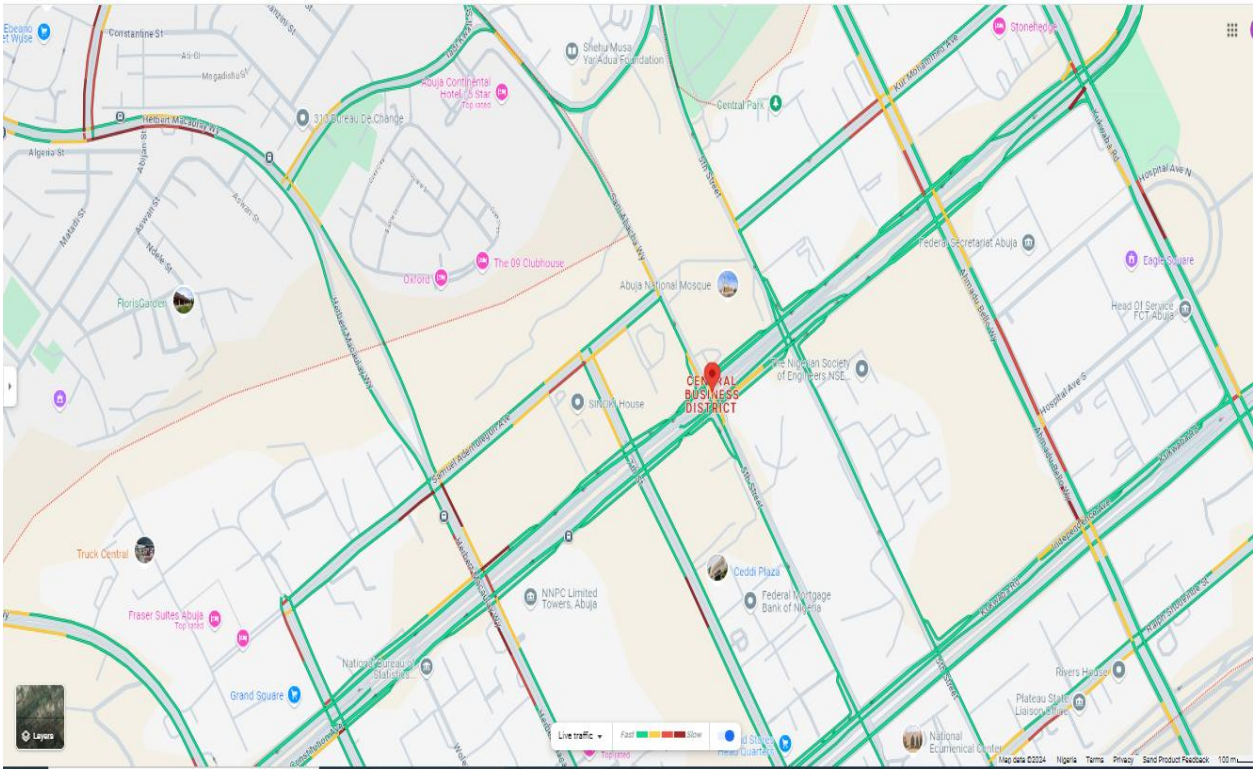

Figure 3.2 Traffic Congestion in Some parts of Abuja (Google live traffic, 2024)

Table 3.2 presents a summary of traffic congestion levels at several major locations in Abuja, as depicted in the map shown in Figure 3.2.

Table 3.2: Traffic Congestion Levels by Location in some parts of Abuja on 12th December, 2024 by 5PM.

Location	**Traffic Congestion Level (%)**
Central Business District (CBD)	90% (Heavy Traffic)
Herbert Macaulay Way	60% (Moderate Traffic)
National Ecumenical Centre	70% (Moderate to Heavy Traffic)
Wuse Zone 5	40% (Moderate Traffic)
Eagle Square	50% (Moderate Traffic)
Federal Secretariat	80% (Moderate to Heavy Traffic)
NNPC Towers	70% (Moderate to Heavy Traffic)
Asokoro (Yakubu Gowon Crescent)	30% (Light Traffic)
Abuja National Mosque	60% (Moderate Traffic)
Shehu Shagari Way	70% (Moderate to Heavy Traffic)
Ahmadu Bello Way	80% (Moderate to Heavy Traffic)
Grand Square	40% (Moderate Traffic)
Fraser Suites Abuja	30% (Light Traffic)
Federal Mortgage Bank of Nigeria	50% (Moderate Traffic)
CBN Headquarters	90% (Heavy Traffic)
Ceddi Plaza	60% (Moderate Traffic)
Nigerian Society of Engineers	50% (Moderate Traffic)

Location	**Traffic Congestion Level (%)**
The 09 Clubhouse (Maitama)	40% (Moderate Traffic)
Yakubu Gowon Crescent (Asokoro)	30% (Light Traffic)
Muhammadu Buhari Way	60% (Moderate Traffic)
Nile University of Nigeria	40% (Moderate Traffic)
Truck Central	50% (Moderate Traffic)
Central Park	30% (Light Traffic)
Head of Service (FC Abuja)	60% (Moderate Traffic)
National Pension Commission	50% (Moderate Traffic)

Congestion percentages range from light to heavy traffic, with some areas experiencing free-flowing movement, while others face significant delays. This variation reflects the diverse traffic conditions in the city, which are influenced by the location's importance and the volume of vehicles passing through.

In areas like the Central Business District (CBD) and the Central Bank of Nigeria (CBN) Headquarters, traffic congestion reaches 90%, indicating heavy traffic where vehicles move very slowly or come to a standstill. Similarly, Ahmadu Bello Way and the Federal Secretariat experience high congestion levels of 80%, showing severe traffic conditions and longer delays.

Moderate traffic, around 60%-70%, is prevalent in locations like Herbert Macaulay Way, the National Ecumenical Centre, and Shehu Shagari Way, where traffic is moving but slows down at certain points. Wuse Zone 5 and Grand Square show moderate congestion levels of 40%, allowing vehicles to move at a relatively steady pace, though some delays are expected.

In contrast, locations such as Asokoro (Yakubu Gowon Crescent) and Central Park experience lighter traffic, with congestion levels around 30%. These areas generally see smoother traffic flow with minimal delays, providing a more comfortable driving experience.

Heavy traffic in Abuja is primarily concentrated in business hubs and key government offices, whereas residential and less busy areas tend to have lighter traffic.

Causes of Traffic Congestion in some parts of Abuja

In Abuja, the capital city's traffic congestion is closely tied to the concentration of government offices, business centers, and the daily influx of employees and visitors. The Central Business District (CBD) and Federal Secretariat are home to many government agencies, which results in high levels of vehicular movement during work hours. These areas are also major destinations for visitors, increasing the traffic burden, particularly in the mornings and late afternoons when employees commute to and from work.

Key roads like Ahmadu Bello Way and Shehu Shagari Way serve as essential transportation links for commuters, government officials, and businesspeople. These roads see a constant flow of traffic as they connect critical areas of the city. Congestion is further exacerbated by the presence of important landmarks such as the CBN Headquarters and NNPC Towers, which attract a significant number of employees and visitors daily. Furthermore, commercial areas and public service centers, such as the National Pension Commission and Eagle Square, also add to the traffic levels as people frequent these places for various purposes.

3.2.3 Traffic Congestion in some parts of Port Harcourt

Port Harcourt, a city recognized for its industrial importance and large population, often experiences significant traffic congestion, particularly at major intersections. The roads are commonly jammed due to a high volume of vehicles, parking difficulties, and the involvement of traffic wardens in controlling traffic. These issues, especially during peak times, lead to considerable delays. Figure 3.3 presents the traffic map of Port Harcourt on Thursday, 12th September 2024, at 5 PM, highlighting significant congestion patterns across various locations. The map, utilizing a color-coded system, depicts different levels of traffic congestion on roads and highways.

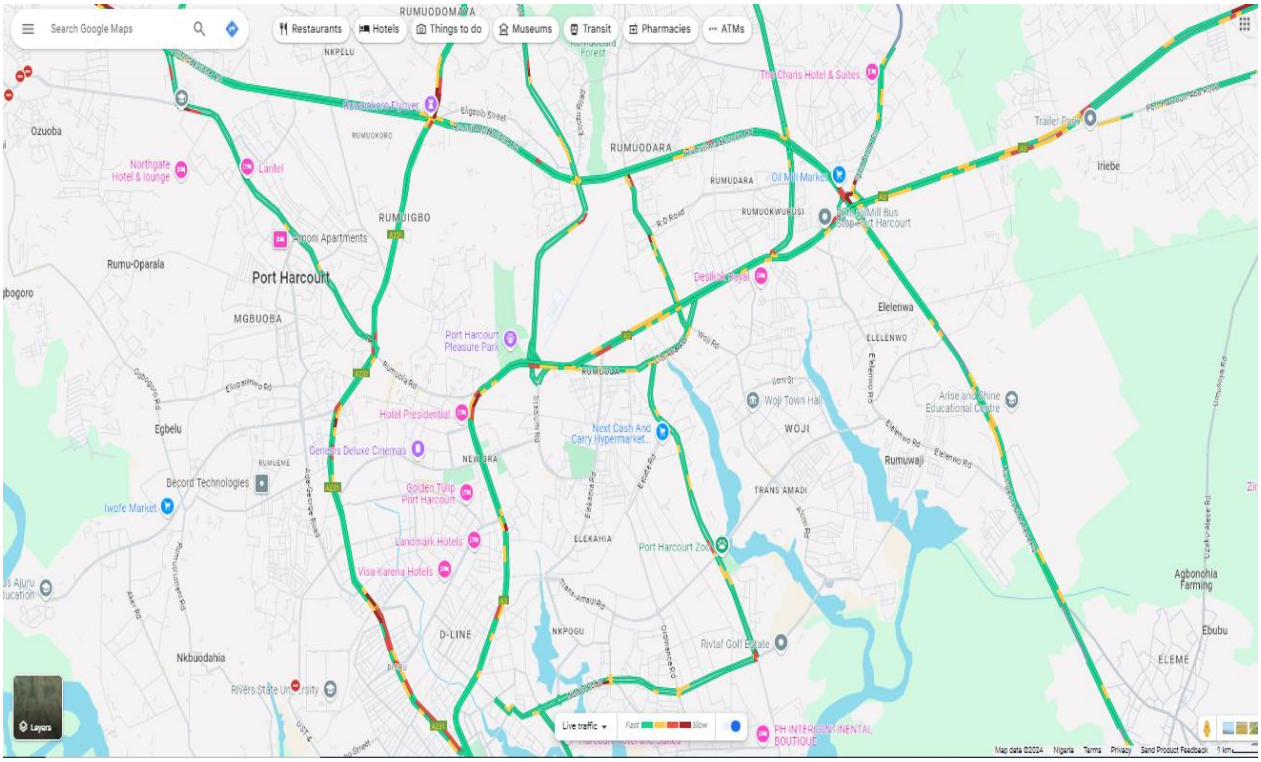

Figure 3.3 Traffic Congestion in Some parts of Port Harcourt (Google live traffic, 2024)

Table 3.3 provides a summary of traffic congestion levels at key locations in Port Harcourt, based on the information illustrated in the map displayed in Figure 3.3.

Table 3.3: Traffic Congestion Levels by Location in some parts of Port-Harcourt on 12th December, 2024 by 5PM.

Location	**Traffic Congestion Level (%)**
Rumuokoro Roundabout	80% (Moderate to Heavy Traffic)
Elelenwo Junction	70% (Moderate to Heavy Traffic)
GRA Phase 2	40% (Moderate Traffic)
Aba Road (Rumuola Junction)	90% (Heavy Traffic)
Oil Mill Market	50% (Moderate Traffic)
Trans Amadi Industrial Area	60% (Moderate Traffic)
Mile 1 Diobu	70% (Moderate to Heavy Traffic)
Old GRA (Government House Area)	30% (Light Traffic)
Eleme Junction	80% (Moderate to Heavy Traffic)
Choba Bridge	40% (Moderate Traffic)
Rumuigbo Junction	50% (Moderate Traffic)
Slaughter (Trans-Woji Road)	70% (Moderate to Heavy Traffic)
Woji Estate	20% (Light Traffic)

Congestion percentages in the table below range from light to heavy traffic, reflecting the diverse traffic conditions in different areas. Some locations experience significant delays, while others allow for smoother movement. These variations are influenced by the importance of the location, road capacity, and the volume of vehicles.

At heavily congested areas like Aba Road (Rumuola Junction) and Rumuokoro Roundabout, traffic congestion reaches 90% and 80%, respectively, indicating severe delays with vehicles either moving very slowly or coming to a complete stop. Similar conditions are seen at Eleme Junction, where congestion is 80%, reflecting long delays.

Locations like Elelenwo Junction and Mile 1 Diobu experience moderate to heavy congestion, with levels around 70%. These areas still allow some vehicle movement, but traffic is slow and prone to delays, especially during peak hours. Trans Amadi Industrial Area and Slaughter (Trans-Woji Road) show moderate congestion levels of around 60%-70%, where traffic flows, but bottlenecks are common at critical points.

Areas like GRA Phase 2 and Choba Bridge show moderate traffic congestion at 40%, where vehicles can move more steadily, though minor delays are expected. Oil Mill Market and Rumuigbo Junction show similar conditions at 50%, indicating moderate delays.

In contrast, lighter traffic is observed in places like Old GRA (Government House Area) and Woji Estate, with congestion levels of 30% and 20%, respectively. These areas experience smoother traffic flow, allowing for a relatively easy driving experience with minimal delays.

Causes of Traffic Congestion in some parts of Port-Harcourt

In Port Harcourt, traffic congestion is primarily influenced by the city's road infrastructure and the importance of certain junctions and commercial zones. Major intersections like Rumuokoro Roundabout and Elelenwo Junction experience moderate to heavy traffic as they are vital junctions where multiple roads converge. These intersections are critical for accessing different parts of the city, and as a result, they often face heavy traffic, especially during peak travel hours.

Commercial areas like Mile 1 Diobu and Trans Amadi also contribute significantly to traffic congestion. These areas are known for their busy markets and industrial zones, which attract a large volume of both pedestrians and vehicles, particularly trucks transporting goods. The movement of people and goods in these areas often leads to bottlenecks and slow-moving traffic. Furthermore, major roads like Aba Road (Rumuola Junction) are prone to heavy congestion as they serve as primary routes for commuters traveling between different parts of the city.

3.3 Addressing Traffic Congestion through Intelligent Transportation Systems (ITS) Integration

The integration of Intelligent Transportation Systems (ITS) in Lagos, Abuja, and Port Harcourt is essential to addressing the unique traffic challenges these cities face. Each city’s congestion is driven by distinct factors such as commercial activities, industrial transport, and inadequate road infrastructure. ITS can enhance traffic management, improve safety, and optimize the overall efficiency of transportation in these urban centers. Below are practical and viable solutions for integrating ITS into the road transportation industry in Lagos, Abuja, and Port Harcourt.

3.3.1 Adaptive Traffic Signal Control Systems

Adaptive Traffic Signal Control Systems (ATCS) are a vital component of Intelligent Transportation Systems (ITS), designed to enhance urban traffic management and reduce congestion. These advanced systems utilize real-time data collected from various sources, such as sensors, cameras, and vehicle-to-infrastructure communication, to adjust traffic signal timings dynamically based on current traffic conditions.

By integrating ATCS within the broader framework of ITS, cities can effectively address the unique challenges of urban transportation. ATCS gathers and analyzes information about vehicle volume, speed, and waiting times at intersections. This data-driven approach allows the system to adapt signal timings in real-time, optimizing traffic flow and improving overall efficiency.

One of the primary benefits of ATCS as part of an ITS framework is its capability to alleviate congestion. Unlike traditional traffic signal systems that rely on fixed schedules, ATCS responds to fluctuating traffic volumes throughout the day. This flexibility is particularly beneficial during peak hours, special events, or unexpected traffic disruptions caused by accidents or roadwork. Furthermore, ATCS enhances road safety by reducing the likelihood of accidents at intersections through better control of traffic signals and minimizing instances of speeding through yellow lights.

ATCS also facilitates the integration of multiple intersections, creating a coordinated network that optimizes urban transportation efficiency. For instance, if traffic is heavy in one direction, the system can allocate more green time to that flow, easing bottlenecks and minimizing the number of stops and starts for drivers.

3.3.2 Electronic Toll Collection Systems

Electronic Toll Collection (ETC) systems are a key element of Intelligent Transportation Systems (ITS) that streamline the toll collection process by allowing vehicles to pass through toll plazas without stopping. These systems use technologies such as Radio Frequency Identification (RFID), transponders, or automatic number plate recognition to electronically deduct toll fees from prepaid accounts or charge them to a user's account.

Within the ITS framework, ETC systems enhance traffic flow by eliminating the need for vehicles to queue at toll booths, significantly reducing delays and congestion on highways and bridges. These systems improve efficiency and reduce fuel consumption, as vehicles maintain consistent speeds through toll plazas, minimizing stop-and-go driving.

ETC systems also contribute to environmental benefits by reducing the amount of vehicle idling at toll booths, leading to lower emissions. Additionally, they offer the convenience of cashless transactions and improved financial accountability for toll operators.

Instances where ETC systems are highly effective include highways with high traffic volumes, urban expressways, and busy bridge crossings where toll collection is necessary. By integrating ETC systems into the ITS infrastructure, cities and highway operators can improve traffic flow, enhance efficiency, and reduce congestion at toll plazas.

3.3.3 Dynamic Lane Management

Dynamic Lane Management (DLM) is another critical ITS component that optimizes road capacity by adjusting lane usage based on real-time traffic conditions. This system allows lanes to be designated for different purposes, such as high-occupancy vehicles (HOV), reversible lanes, or even opening additional lanes during peak hours. DLM uses electronic signage, sensors, and cameras to monitor traffic conditions and communicate changes to drivers.

As part of an ITS strategy, DLM can significantly improve traffic flow, especially during times of high congestion. By reallocating lane usage dynamically, the system helps alleviate bottlenecks and improves road efficiency without the need for costly infrastructure expansions. For example, during rush hours, DLM may open extra lanes in one direction to accommodate increased traffic flow, while reversing lanes during off-peak times to maintain optimal traffic distribution.

DLM also improves safety by actively managing lane usage in response to accidents, road closures, or other incidents. It can automatically close lanes to guide traffic around a blockage, reducing the risk of further collisions.

Applications of DLM can be found in congested urban areas, highways, and roads leading to large event venues, where traffic conditions fluctuate throughout the day. By integrating DLM into ITS, cities can better manage lane capacity and improve overall traffic flow.

3.3.4 Public Transportation Priority Systems

Public Transportation Priority Systems (PTPS) are an integral part of ITS, designed to give buses, trams, and other public transport vehicles priority at intersections and along dedicated routes. These systems use traffic signal preemption or priority technology, allowing public transit vehicles to extend green lights or shorten red lights to minimize delays and improve service reliability.

As a key ITS solution, PTPS enhances the efficiency of public transportation by reducing travel time and increasing the attractiveness of mass transit options. PTPS is especially beneficial in densely populated urban areas where public transportation plays a vital role in reducing traffic congestion. The system helps ensure that public transport vehicles are not held up by regular traffic, encouraging more commuters to switch from private vehicles to public transit, further reducing traffic on the roads.

PTPS also contributes to environmental benefits by improving the speed and reliability of public transportation, reducing the number of cars on the road, and lowering emissions.

PTPS can be applied at major intersections in cities where public transport vehicles frequently experience delays due to congestion. By prioritizing public transportation as part of ITS, cities can promote efficient, sustainable mobility, making public transit more appealing to residents while easing overall traffic burden.

4. RESULTS AND DISCUSSION

The findings underscore the critical bottlenecks and patterns in traffic flow, which serve as a foundation for identifying potential interventions through the integration of Intelligent Transportation Systems (ITS). This analysis aims to clarify the relationship between congestion and the challenges encountered in emergency response within urban areas. The implementation of ITS in Nigeria's road transportation sector has the potential to substantially alleviate traffic congestion, enhance safety, and improve overall urban mobility. Data from major cities such as Lagos, Abuja, and Port Harcourt illustrate that the introduction of ITS could lead to significant improvements in traffic conditions, thereby facilitating smoother transportation and more efficient emergency response strategies.

In figure 4.1, the congestion percentages in the chart illustrate varying levels of traffic density across different intersections in Lagos, ranging from minimal disruption to high traffic intensity. Locations with lower congestion percentages indicate smoother traffic flow, while higher percentages correspond to more severe traffic delays.

Figure 4.1: Rate of Congestion at Intersections in Lagos

As shown in table 3.1, the congestion levels vary significantly. In Lagos, which is characterized by high congestion rates at critical intersections such as Atlas Tollgate (90%) and Mile 2 (80%), the implementation of adaptive traffic signal control systems could optimize traffic flow by adjusting signal timings based on real-time data. Such systems would minimize delays and reduce vehicle idling, particularly in busy commercial zones like Iganmu, where congestion reaches 70%. Furthermore, integrating electronic toll collection (ETC) at congested toll points would alleviate bottlenecks and enhance the overall efficiency of major arterial roads, such as Cele-Ijesha Link Bridge (50%).

Figure 4.2 presents the rate of congestion at various intersections in Abuja, illustrating the varying levels of traffic density across the city. The chart categorizes congestion percentages from light to heavy, reflecting the impact of location and vehicle volume on traffic flow.

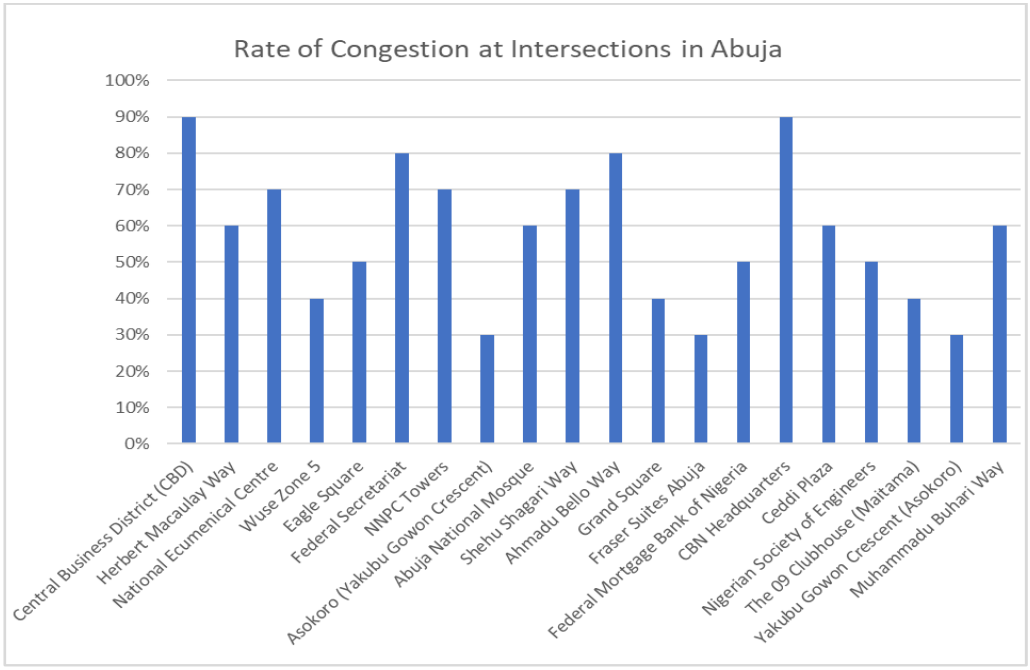

Figure 4.2: Rate of Congestion at Intersections in Abuja

In Abuja, the impact of ITS would be similarly profound. With areas such as the Central Business District and CBN Headquarters experiencing severe congestion levels of 90% as shown in Table 3.2, adaptive signal control and dynamic lane management could drastically improve traffic conditions during peak hours. This would facilitate smoother vehicle movement along heavily trafficked routes like Ahmadu Bello Way (80%) and Wuse Zone 5 (40%).

Figure 4.3 presents the rate of congestion at various intersections in Port Harcourt, demonstrating the differing levels of traffic density across the city. As indicated in Table 3.3, congestion levels range from moderate to heavy, influenced by the volume of vehicles and specific locations.

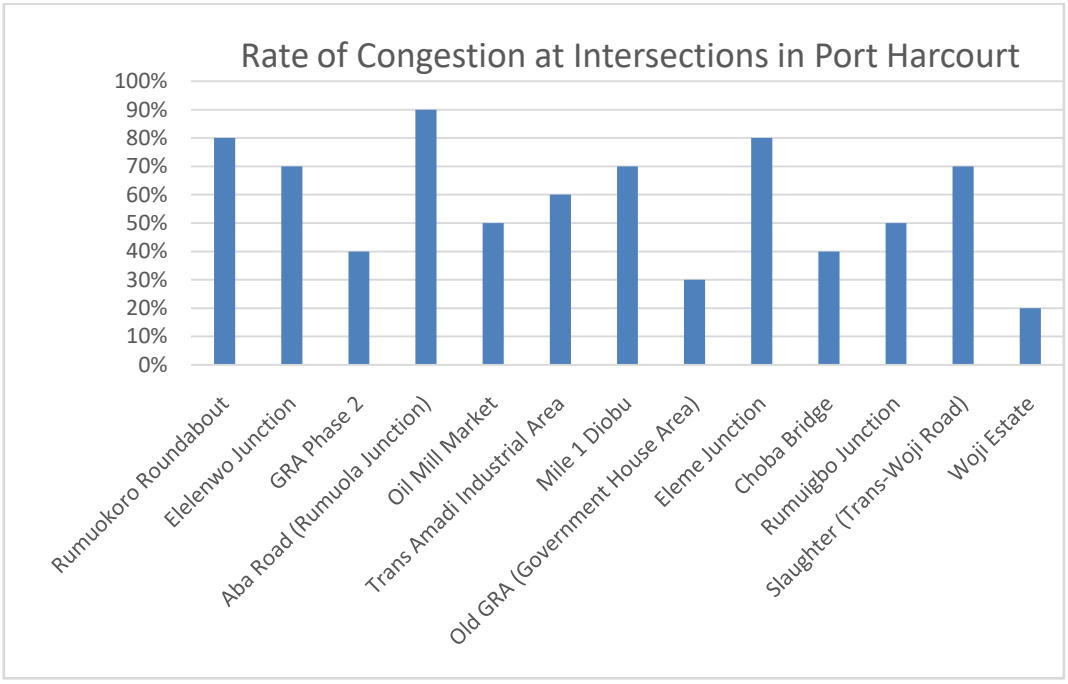

Figure 4.3: Rate of Congestion at Intersections in Port Harcourt

Port Harcourt's major intersections, including Rumuokoro Roundabout (80%) and Aba Road (Rumuola Junction) (90%), would benefit from the deployment of ITS technologies as well. Enhanced traffic management systems would address the persistent congestion experienced in these areas, leading to better traffic flow and reduced delays during peak travel times.

Overall, the integration of ITS in Nigeria's transportation infrastructure will yield substantial benefits, including reduced congestion levels, improved road safety, decreased fuel consumption, and lower greenhouse gas emissions. By tailoring ITS solutions to the unique traffic patterns and challenges faced in each city, Nigeria can foster a more efficient and sustainable urban transportation network.

5. CONCLUSION

The findings from this study reveal the strong potential of Intelligent Transportation Systems (ITS) to ease traffic congestion and make Nigeria's road transportation network more efficient. Congestion continues to be one of the biggest challenges facing Nigerian cities, slowing down movement, reducing productivity, and affecting the daily lives of millions of commuters. This study shows that ITS technologies—such as adaptive traffic control, real-time traffic monitoring, and intelligent signal coordination—offer practical and effective ways to manage and reduce these traffic bottlenecks. When properly implemented, these systems can help create smoother traffic flow, shorten travel times, and make road transport more reliable. By targeting the main causes of congestion, ITS can play a transformative role in improving mobility and promoting a more sustainable and efficient transportation system across Nigeria's urban centers

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