Development of an Intelligent Traffic Management System to Address Visibility Obstruction at Urban Intersections: A Case Study of Ibadan Metropolis

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ABSTRACT

Visibility obstructions at urban intersections due to larger vehicles and adverse weather conditions pose significant safety risks and exacerbate traffic congestion. Urban traffic intersections in Nigerian cities like Ibadan often experience visibility obstructions caused by large vehicles, poor road geometry, and adverse weather conditions—factors that impair driver response, increase waiting time, and contribute to congestion. This research proposes an Intelligent Traffic Management System (ITMS) using IoT and GPS technology to enhance visibility and reduce congestion at intersections, specifically in Ibadan, Nigeria. The study focuses on the Agodi Gate corridor, a critical urban intersection, where real-world observational surveys revealed frequent signal occlusions due to vehicle height disparities and limited headway. Through field data collection, VISSIM-based simulation, and mathematical modeling, the study analyzes key parameters such as headway distance, angle of view, vehicle dimensions, and driver response delay. The proposed ITMS prototype provides real-time signal status through dashboard interfaces or mobile applications and dynamically adjusts signal timing based on detected visibility conditions. Results show that visibility-related obstructions significantly impact intersection efficiency and safety. By addressing these challenges, the system enhances driver situational awareness, reduces traffic delays, and improves overall intersection performance. The developed ITMS framework is scalable and offers practical solutions for similar urban environments experiencing visibility-induced traffic challenges.

Keywords: Intelligent Traffic Management System, Visibility Obstruction, Urban Traffic Flow, IoT, GPS.

INTRODUCTION

Urban intersections face complex traffic management challenges due to vehicle congestion and visibility obstructions, especially in high-density areas like Ibadan. Past research by Akintayo (2011) highlighted critical traffic parameters—such as headway and traffic flow—that are key to mitigating congestion. However, visibility issues due to larger vehicles blocking signals remain a safety risk and a contributor to delays. This study introduces a targeted ITMS leveraging IoT and GPS for real-time management, focusing on a critical intersection at Agodi Gate.

BACKGROUND

Traffic congestion remains one of the most persistent problems plaguing modern urban areas, especially in fast-growing cities across developing countries like Nigeria. Over the years, many researchers have addressed this issue using rational approaches that involve traffic parameters such as vehicle headway, density, flow, and capacity. Akintayo (2011) emphasized the critical role that headway plays in managing urban traffic and how its modeling can help to better understand and reduce congestion, especially in cities like Ibadan. Similarly, Akintayo and Agbede (2009) demonstrated that modeling headway distribution on two-lane roads in Ibadan gave insights into traffic flow characteristics, yet these studies primarily focused on vehicular interaction without fully addressing the impacts of visibility on traffic performance. While the modeling of vehicular flow is well established in traffic engineering literature—grounded in theories such as those proposed by

Greenshields (1935) and further developed by Daganzo (1994) and Hidas (2002)—visibility obstructions on roads, particularly those caused by infrastructure, large vehicles, roadside vegetation, or weather conditions, have not been sufficiently mitigated. These obstructions significantly affect drivers' ability to respond appropriately to road signs, signals, and hazards, thereby impairing safety and flow efficiency.

The study by Salisu *et al.* (2020) particularly brought attention to the Nigerian context, where rapid urbanization and poor traffic infrastructure planning exacerbate visibility-related traffic problems. Djahel *et al.* (2015) also highlighted the communication gap between traffic signals and approaching vehicles, which contributes to inefficiencies in traffic systems, especially in developing urban areas. These findings suggest a systemic lack of attention to visibility in traffic flow modeling and real-time traffic signal control. Visibility obstructions can arise from several sources—large vehicles blocking signage (Al-Kaisy *et al.*, 2005), overgrown vegetation (Hou, Tian, and Zhang, 2017), poor road geometry (AASHTO, 2018), low lighting or adverse weather conditions (Zhou and Xie, 2017), or even inappropriate placement of signs and signals (Faghri, 2000; AAA Foundation for Traffic Safety, 2023). These obstructions not only compromise road safety but also introduce inefficiencies in adaptive traffic signal control systems. Abdel-Aty *et al.* (2019) discussed how modern adaptive signal systems attempt to incorporate real-time data, but without accounting for visibility disruptions, their effectiveness is often diminished. Research has shown that the occlusion of road signs and traffic signals by large vehicles like trucks and buses can reduce the recognition distance and reaction time of drivers. For example, Luo, Zhang, and Zhang (2014) and Mahajan and Singh (2016) found that the presence of heavy vehicles in front of a driver can significantly reduce the visual field, which leads to late recognition of signage and poor decision-making. These findings are further supported by Bramson (1971), who noted as early as the 1970s that trucks often block critical signs, yet many cities still design signage placement without considering the vertical profile of vehicles on the road.

Furthermore, advances in intelligent transportation systems (ITS) and traffic simulation models like VISSIM (Al-Dabass *et al.*, 2017; Badia *et al.*, 2006) have made it possible to simulate traffic under varying visibility conditions. Still, most implementations fail to incorporate real-world occlusion factors. The works of Agarwal and Chakroborty (2014), Pan and Xie (2014), and Saraf (2019) have all emphasized the importance of factoring in the duration and impact of sign occlusion in traffic simulations, especially when considering large-vehicle interactions. The development of computer vision and machine learning tools has improved traffic sign detection (Koutaki and Okada, 2019; Steffens and Endres, 2022), yet these systems too are not immune to the effects of environmental and vehicular occlusion. Studies by Mounce and Zhou (2000) and Chunsheng, Liu, and Chang (2016) show that occlusion remains a challenge even for automated systems, raising concerns about the readiness of these technologies for full deployment in real traffic environments. In addition, the use of fuzzy logic and artificial intelligence for real-time traffic management, as explored by Djahel *et al.* (2015) and Allan *et al.* (2017), offers promise in creating more responsive systems. However, these models must now begin to integrate visibility-related data, such as obstructions caused by road design, vehicle size, or adverse weather, into their algorithms. This is crucial in cities like those in Nigeria, where infrastructure limitations compound the problem.

Urban design guidelines and policies, such as those from the USDOT (2014) and AASHTO (2018), provide geometric standards for signage and signal placement, but their application in many African cities is limited or poorly enforced. Researchers like Adeniyi (2018) have called for a more multi-pronged approach to traffic mitigation in Nigerian cities—one that includes public education, road infrastructure design, better enforcement, and improved signal control. This research builds on these findings and aims to develop a model that explicitly integrates visibility obstructions into traffic flow analysis and signal timing systems, particularly during periods of adverse weather or in geometrically constrained urban environments. Using insights from observational studies (Zhang and Li, 2015; Zhu and Li, 2019), simulation tools (Chen, Yang, and Yu, 2010; Bologna and Gatto, 2009), and human factors research (Katila and Norros, 1998; Ma and Zhang, 2013), this study will help to fill the gap in current models that often assume ideal visibility conditions. The goal is to propose practical, localized solutions for developing cities like those in Nigeria, aligning with global best practices while addressing local realities. In summary, while much progress has been made in understanding traffic flow from a mechanical and infrastructural perspective, visibility-related issues—particularly in the Nigerian context—remain underexplored. By integrating insights from global literature and local case studies, this research intends to offer practical tools and models that not only simulate but also mitigate the impact of visibility obstructions on urban traffic performance.

Research Problem

This study addresses the issue of visibility obstruction for approaching vehicles (Va) at intersections, particularly when larger vehicles block traffic signals. On March 1, 2024, at 2:44 p.m., the researcher experienced a visibility obstruction when a truck blocked the signal while approaching Agodi Gate. Such obstructions lead to congestion, delays, and accidents, creating a need for an ITMS to enhance visibility and safety for all road users. This study aims to provide a solution to this problem using advanced technologies.

Aim and Objectives

The study's aim is to establish a rational procedure to minimize traffic signal visibility problems observed along the two-lane segment at Agodi Gate, Ibadan. The ITMS will use IoT and GPS to improve signal visibility and overall road safety.

Objectives:

1. Identify parameters contributing to traffic signal visibility blockage on selected Ibadan roads.

2. Develop models to represent and replicate these parameters.

3. Formulate strategies to enhance traffic signal visibility** and reduce obstructions at target intersections.

Justification

Addressing visibility problems at the Agodi Gate intersection is crucial to enhance safety, reduce congestion, and mitigate risks posed by obstructed signals. This research seeks to develop an ITMS that ensures safe and efficient traffic flow, potentially serving as a model for similar urban intersections. Figure 1 and 2 shows the satellite view of Oritamefa to Agodi gate Road, Sabo-Badan Road as well as of Traffic intersection at Agodi Gate, Ibadan.

Scope of the Study

1. **Geographic Scope:** Focuses on the two-lane segment leading to Agodi Gate from Orita Mefa in Ibadan, known for visibility issues due to traffic signal occlusions.

2. **Technical Scope:** The ITMS integrates IoT, GPS, and intelligent algorithms to optimize signal timing, improve traffic flow, and enhance intersection safety.

3. **Functional Scope:** Designed to provide alternative signal visibility through devices like dashboard displays or mobile apps, mitigating obstruction issues.

4. **Evaluation Scope:** Simulation studies, field trials, and assessments of intersection throughput, travel time savings, and safety improvements will evaluate the ITMS.

5. **Stakeholder Scope:** Collaboration with local traffic authorities, community members, and technology providers to ensure system effectiveness and community adoption.

Figure 1 Sattelite View of Oritamefa to Agodi gate Road, Sabo-Badan Road, Ibadan

Source: Google Maps (2024)

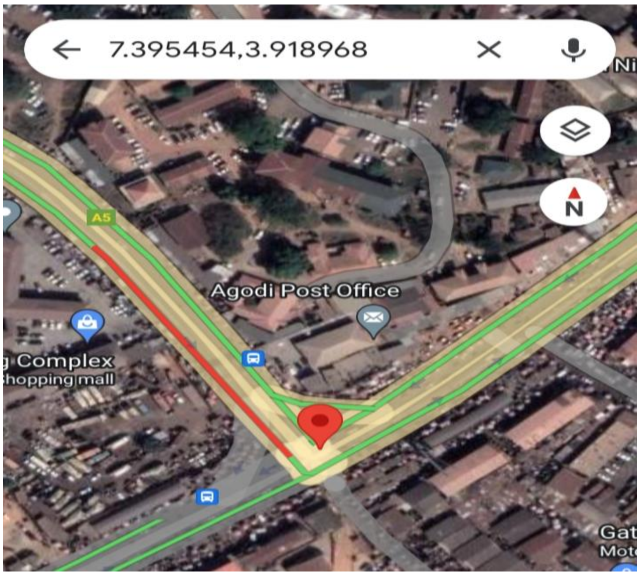

Figure 2 Satellite view of Traffic intersection at Agodi Gate, Ibadan

Source: Google Maps (2024)

Study Area

The study area for this PhD research work encompasses the bustling city of Ibadan, located in Oyo State, Nigeria. Known as one of the largest cities in Africa, Ibadan serves as a major economic and cultural hub in Nigeria, with a rapidly growing population and urban infrastructure. The city's road network plays a crucial role in facilitating transportation and connectivity within and beyond its borders. The focal point of the study is the stretch of road from Orita Mefa to Agodi Gate, a double two-way lane road that traverses through the heart of Ibadan. Designated as an A5 road, this route is integral to the city's transportation system, serving as a primary artery for vehicular movement. It connects various key destinations, including the prestigious Oyo State Governor's House and the Nigeria Television Authority (NTA), making it a vital thoroughfare for commuters and residents alike. Figure 3 shows Nigeria's road network.

At the intersection of Agodi Gate (coordinates: 7.395454, 3.918968), the study examines the challenges posed by obstructed visibility of traffic signals for approaching vehicles (Va), particularly when large trucks or vehicles block the view. This intersection is strategically positioned and experiences heavy traffic congestion, especially during peak hours, necessitating effective traffic management solutions. Similarly, the study also

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investigates the intersections at Orita Mefa (coordinates: 7.398436, 3.909088) and the Governor's House, which serve as critical junctions along the route. These intersections are equipped with traffic signals operating in the standard three-color mode (red, yellow, and green), along with timers to regulate traffic flow in multiple directions.

The road infrastructure along the study area is well-developed, featuring clearly demarcated lanes, signage, and markings to facilitate smooth vehicular movement. However, the presence of visibility challenges at certain intersections poses safety concerns and necessitates innovative solutions for effective traffic management. The research aims to conduct a comprehensive analysis of the traffic systems in Ibadan, focusing on the identified intersections and addressing the specific issue of obstructed signal visibility. By leveraging advanced technologies and innovative strategies, the study seeks to propose solutions to enhance intersection safety, optimize traffic flow, and improve overall transportation efficiency in Ibadan Metropolis. Through rigorous data collection, analysis, and experimentation, the research endeavors to contribute valuable insights and practical recommendations to address the complex challenges of urban traffic management in Ibadan and beyond.

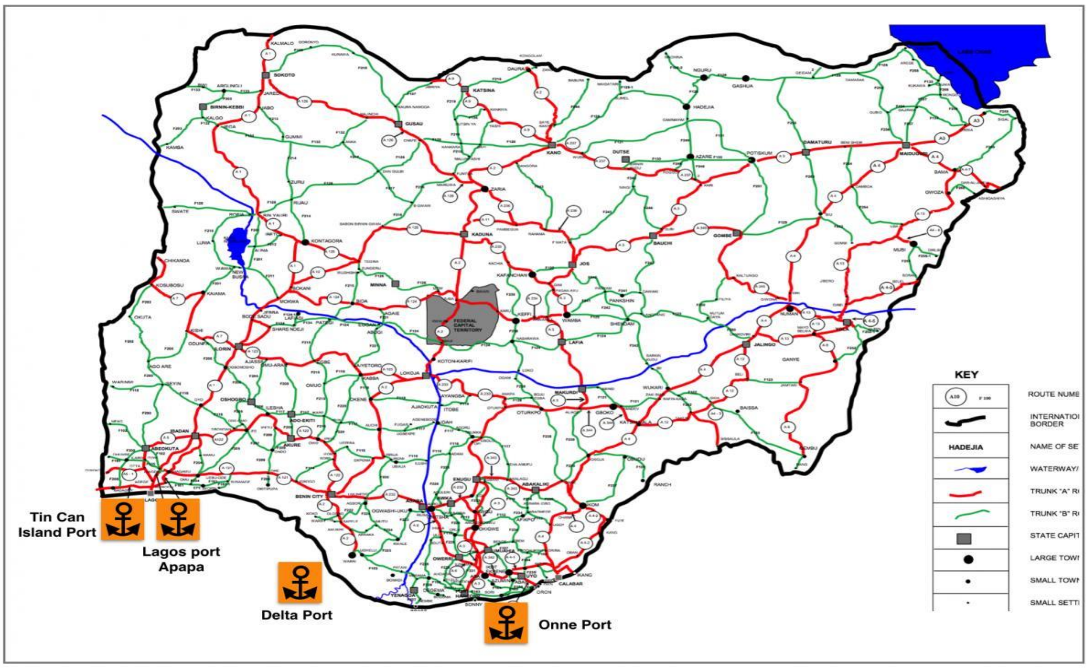

Figure 3 Nigeria’s Road Network

Source: Google

METHODOLOGY

This research employs a mixed-methods approach, combining qualitative and quantitative data collection to develop an ITMS tailored to visibility issues in Ibadan.

Step 1: Traffic Data Collection

1. Observations and Surveys: Document traffic volume, vehicle types, and visibility issues.
2. Sensor and GPS Data: Use cameras, lidar, GPS, and GNSS devices to collect data on vehicle trajectories, speeds, and traffic flow.
3. Field Measurements: Measure intersection geometry, signal timings, and visibility aspects. - Figure 4 shows how a large vehicle (e.g., a truck) obstructs a driver’s view of the traffic signal, which is one of the core issues addressed by Intelligent Traffic Management System (ITMS).

Step 2: Data Collection for Microscopic Traffic Simulation

Data on vehicle counts, speed, headway, and signal timing will be collected to create a detailed model in VISSIM, simulation software.

Step 3: Prototype Development and Simulation Analysis

1. Prototype Development: Design a prototype ITMS using relevant hardware and software components.
2. Simulation Setup: Create a VISSIM model of the intersection and simulate various traffic volumes, visibility scenarios, and weather conditions.
3. Performance Metrics: Measure travel times, throughput, and safety to assess the ITMS's effectiveness.
4. User Interface and System Refinement: Enhance the user interface based on testing and feedback to improve functionality and usability.

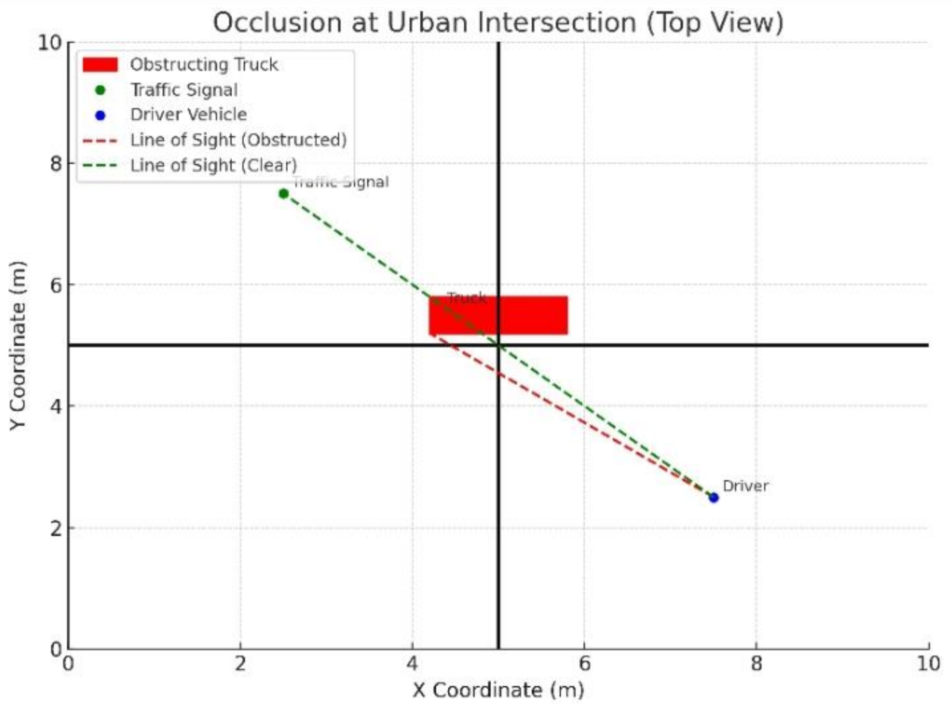

Figure 4**:** A sample diagram illustrating Occlusion Angle at Urban Intersections

Report From Reconnaissance Survey: Observed Traffic Signal Occlusion At Agodi Gate Intersection

The reconnaissance survey conducted on March 1, 2024, at 2:44 pm (an off-peak period) at Agodi Gate intersection revealed a critical visibility obstruction issue. While driving a Jeep and approaching the T-junction from Orita Mefa, the driver encountered a blocked view of the traffic signal due to a truck in front, owned by Peak Milk. The truck's height (180 cm) and dimensions (width: 148 cm, length: 340 cm) contributed to this occlusion problem, obstructing the driver's view of the signal despite adjustments in viewing angles through the inner rearview mirror and steering position. Further factors, including headway, angle of view, and lane interswitch limitations, were examined to understand the circumstances of this obstruction. Figure 5 shows the proposed system on Agodi-Gate Ibadan road and figure 6 shows how Google lens was used to search out the vehicle type, model and dimension. Figure 7 shows result of the search via Google lens proving the dimensions of the truck blocking the view. This analysis covers a thorough comparison of parameters observed during the survey, as well as a mathematical model simulating the traffic signal occlusion under various traffic conditions.

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Figure 5: The proposed system on Ibadan roads – traffic signal visibility occluded by the truck in front at Agodi-gate intersection Ibadan

Source: Field reconnaissance survey

Figure 6: Using Google Lens To Verify The Truck Dimension (Source: Google)

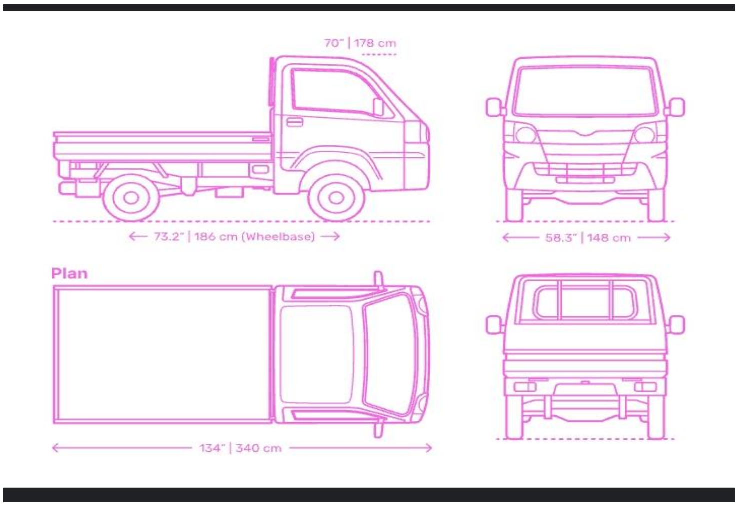

Figure 7: dimensions of the observed suzuki truck

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Observational Data and Parameters

The following parameters were observed and recorded:

1. Time and Visibility:

a. Time of Day: 2:44 pm, identified as an off-peak period for the intersection.

b. Vehicular Type of Approaching Vehicle (V_a): Jeep

c. Vehicular Type of Occluding Vehicle (V_f): Suzuki truck with dimensions of height (180 cm), width (148 cm), and length (340 cm).

2. Headway (H) and Obstruction:

a. Headway: Distance between V_a and V_f: The precise headway between the vehicles was not recorded, but it was noted that even an increase in headway may not necessarily clear the obstructed view due to the height and size of the truck.

b. Occlusion Dynamics: Visibility was blocked even with adjustments in the driver's view angles, including through the center rearview mirror aligned with the dashboard.

3. Angle of View (θ): Angle at which the driver of V_a could potentially view the signal if unoccluded

4. Signal Distance (d_s): Approximate distance between V_a and the traffic signal (observed at 30–50 meters)

5. Lane Conditions: Adjacent lane was congested, preventing lane-switching

6. Waiting Time (T_{wait}): 45 seconds due to obstruction

7. Driver's Response Delay ($T_{response}$): Unknown but hypothesized to increase due to obstruction

8. Traffic Signal Details:

a. Signal Height (h_s): Not recorded.

b. Traffic Management: No traffic warden was observed on-site to assist with visibility issues.

9. Cell Transmission Model Reference: Assesses lane-switch potential

Each of these parameters plays a role in the visibility issue. Pairwise comparisons reveal complex dependencies that contribute to visibility challenges. Lane interswitching was constrained, as the alternate lane on the carriageway was jammed. Principles of the cell transmission model suggest that lane-switching is beneficial in avoiding occlusion under ideal traffic conditions.

Pairwise Comparison Of Parameters

To understand the interactions between parameters, each significant pair is analyzed in the context of visibility obstruction.

1. Time of Day (Peak vs. Off-Peak Period Analysis) vs. Vehicle Types (V_a and V_f)

Visibility issues may be influenced by lighting conditions and vehicle positioning relative to the time of day. Although this observation was made in daylight, different lighting conditions may influence how V_a perceives signals if V_f is opaque. The relative sizes and positions of the vehicles further affect sightlines.

Peak and off-peak differences are crucial in assessing flow variations and lane-switch potential:

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VIII August 2025

a. Off-Peak (2:44 pm): Lower traffic density, theoretically allowing for alternate lane-switching under usual conditions.

b. Peak Period: Higher flow and potential obstruction increase, raising both occlusion frequency and T_{wait} due to limited maneuverability.

This analysis of traffic signal occlusion offers insights into potential adjustments in headway, lane-switch protocols, and signal positioning necessary to alleviate such incidents, especially at critical intersections like Agodi Gate.

2. Time of Day vs. Waiting Time

During off-peak periods, waiting time T_{wait} due to occlusion can vary with traffic density and vehicle position. Since this incident took place at 2:44 pm (off-peak), fewer vehicles were present on the road, theoretically allowing for easier maneuverability. However, the lane next to the obstructed vehicle was congested, limiting the possibility of lane interswitching. Peak periods could see increased waiting times and reduced sight clearance due to higher traffic volume.

3. Headway (H) vs. Signal Distance (d_s)

The visibility of the signal depends on the headway between V_a and V_f. A minimal headway reduces the likelihood of the driver of V_a observing the signal. Modeling H in relation to d_s is critical to determine the minimum safe headway that maintains visibility.

4. Signal Distance (d_s) vs. Angle of View (θ)

The signal distance and angle of view affect the visibility of the signal from within V_a. Given an obstructing vehicle V_f, a higher d_s or θ may potentially restore visibility by expanding the visual field. Calculating the critical angle at which θ restores visibility is essential.

5. Vehicle Types (Jeep and Truck) vs. Headway (d_h)

The obstructing vehicle's height (180 cm) and length (340 cm) played a significant role in the Jeep's visibility obstruction. Even with an increased headway, the visibility line would still be compromised due to the truck's height relative to the Jeep's eye level, positioned around 150 cm. The model, therefore, must account for this height disparity:

$$\text{Visibility} = \begin{cases} 0 & \text{if } H_{truck} > H_{jeep} \text{ and } d_h < d_{clearance} \\ 1 & \text{otherwise.} \end{cases}$$

6. Lane Condition vs. Interswitch Potential

The congested lane condition obstructed V_a from interswitching to the adjacent lane. The principles of the cell transmission model suggest that lane-switching becomes an unviable option if the adjacent lane is jammed; confirming that congestion severely limits alternative visibility strategies.

7. Angle of View $\Theta_{obstruct}$ vs. Signal Distance (d_s)

For an effective visibility line, the angle formed by the driver's line of sight to the traffic signal must remain within a permissible range. If the angle due to truck width W_{truck} exceeds the visibility cone, occlusion occurs:

$$\Theta_{obstruct} = \arctan \frac{W_{truck}}{d_h}$$, where visibility remains obstructed if $\Theta_{obstruct}$ is 30°

Here, $\Theta_{obstruct}$ suggests an obstruction in off-peak conditions. During peak periods, this angle is likely higher due to more vehicles occupying surrounding lanes.

8. Lane Interswitch vs. Cell Transmission Model Principles

The cell transmission model, which divides roads into cells that vehicles move through, supports lane interswitching to avoid occlusion. However, the jammed adjacent lane in this scenario prevented interswitching, reinforcing that alternative solutions (e.g., mobile app notifications of traffic signal status) may be necessary.

9. Driver Response Delay vs. Waiting Time T_{wait}

The driver's reaction time due to blocked signal visibility affects T_{wait}. Although the actual response delay is unknown, it contributes to total waiting time when visibility is obstructed.

Mathematical Model To Simulate Traffic Signal Occlusion

The following model simulates the traffic signal occlusion by incorporating the aforementioned parameters.

Variables and Definitions

1. H: Headway between V_a and V_f (meters)

2. d_s: Distance from V_a to the traffic signal (meters)

3. θ: Angle of view from the driver's perspective in V_a to the traffic signal (degrees)

4. h_s: Height of the traffic signal above the road surface (meters)

5. h_{va} and h_{vf}: Heights of vehicles V_a and V_f respectively (meters)

6. L_{occl}: Length of the occluding vehicle (meters)

7. T_{wait}: Waiting time (seconds)

8. $T_{response}$: Driver's response delay due to occlusion (seconds)

Mathematical Modeling Of The Observed Incident

To simulate the visibility occlusion, we model key parameters using simplified mathematical relationships. These equations can serve as the basis for predicting occlusion probabilities under similar conditions.

1. Headway and Signal Obstruction Correlation

Given:

- H_t (Truck height) = 180 cm,

- H_v (Average driver eye level in Jeep) is assumed around 150 cm.

For a vehicle headway d_h, the probability of occlusion P_o can be assessed based on the height disparity and distance:

$$P_o(d_h) = \begin{cases} 1 & \text{if } H_t > H_v \text{ and } d_h < 50 \text{ meters} \\ 0 & \text{otherwise.} \end{cases}$$

2. Waiting Time Due to Occlusion

Using waiting time T_{wait} and delay T_{delay}:

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VIII August 2025

$T_{delay} = T_{wait} - f(\text{visibility conditions})$

where $f(\text{visibility conditions})$ reflects driver response and view adjustments, which can further extend the wait time at the intersection.

3. Angle of Obstruction (Visibility Cone)

For a driver's visibility cone $\Theta_{obstruct}$ with obstructed view due to vehicle width (W_t):

$\Theta_{obstruct} = \arctan\left(\frac{W_t}{d_h}\right)$ where visibility remains obstructed if $\Theta_{obstruct}$ is 30^o

Model Formulation

1. Occlusion Probability Function (P_o)

P_o is defined based on the visibility angle, headway, and height differential:

$$\mathbf{P_o}(d_h, \Theta_{obstruct}) = \begin{cases} 1 & \text{if } \Theta_{obstruct} \geq 30^o \text{ or } H_{truck} > \\ 0 & \text{otherwise} \end{cases}$$

2. Waiting Time Function T_{wait}

If $P_o = 1$, the waiting time includes driver response delay T_{delay}, traffic conditions, and signal wait:

$$\mathbf{T_{wait}} = T_{signal} + T_{delay}$$

where T_{signal} represents the signal cycle time at this intersection, and T_{delay} reflects occlusion response time.

3. Headway Adjustment Model

To prevent occlusion, headway d_h must reach a threshold, $d_{clearance}$, where the visibility line clears the truck's height:

$$d_{clearance} = \frac{H_{truck} - H_{jeep}}{\tan(\Theta_{obstruct})}$$

This equation helps determine if increasing headway can reduce occlusion probability during peak and off-peak periods.

4. Headway and Signal Distance Relation

The visibility of the signal depends on the headway H. If H is less than a critical distance H_{crit}, the signal remains occluded. We define H_{crit} as follows:

$$H_{crit} = \frac{L_{occl}}{\tan(\Theta)}$$

where Θ is the critical viewing angle.

5. Angle of View Calculation

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue VIII August 2025

The angle of view Θ at which Va can view the signal depends on the vertical alignment:

$\Theta = \frac{\arctan\{h_s - h_{vf}\}}{d_s}$, where h_s is the height of the signal and h_{vf} is the height of the occluding vehicle.

6. Waiting Time and Response Delay Impact

The obstruction leads to a delay in the driver's response. We define the response delay $T_{response}$ as proportional to T_{wait}:

$$T_{response} = \alpha \cdot T_{wait}$$

where α is an empirical factor dependent on driver reaction time under obstructed view conditions.

7. Interswitch and Cell Transmission

Lane-switching viability can be represented with the cell transmission model. Given a congested adjacent lane, the probability of lane-switching, (P_{switch}), approaches zero:

$$P_{swicth} = \max\left[0, 1 - \frac{\rho_{adj}}{\rho_{crit}}\right.$$

where ρ_{adj} is the vehicle density in the adjacent lane and ρ_{crit} is the critical density for lane-switching feasibility.

Simulation And Analysis

The model allows simulation of scenarios where:

- H varies to determine the minimal headway avoiding occlusion.
- d_s is adjusted to test its effect on visibility with constant H.
- Different vehicle heights h_{va} and h_{vf} are analyzed to understand how variations affect signal sightlines.

Simulation Steps:

1. Initialize Variables: Set H, d_s, Θ, h_s, h_{va}, h_{vf}, L_{occl}, T_{wait}, α.

2. Calculate H_{crit}: Compute the minimum headway required for visibility using the angle of view.

3. Assess $T_{response}$: Calculate potential delays due to signal occlusion.

4. Run Scenarios: Simulate scenarios for various headway distances and lane-switch probabilities using the cell transmission model.

5. Optimize Parameters: Identify the headway and angle of view combinations that mitigate signal occlusion.

Limitations

This study presents an innovative approach to mitigating visibility obstruction at urban intersections using IoT and GPS-enabled Intelligent Traffic Management Systems (ITMS). However, several limitations exist:

1. Limited Field Observations: The empirical investigation focused primarily on a single intersection (Agodi Gate), with only one detailed case involving a Peak Milk truck. This limits the generalizability of the findings across other high-traffic intersections in Ibadan or Nigeria at large.

2. Narrow Geographic Scope: While Agodi Gate is representative of congestion-prone intersections, the absence of comparative data from other intersections restricts the study's broader applicability.

3. Simulation-Heavy Approach: The use of VISSIM simulation modeling, although insightful, does not fully reflect real-world system dynamics. No pilot deployment of the ITMS was conducted to validate performance under actual traffic conditions.

4. Infrastructural Feasibility: The study does not provide a comprehensive cost-benefit analysis or feasibility assessment of implementing IoT/GPS systems in resource-constrained settings typical of many Nigerian cities.

5. Lack of Stakeholder Input: There is minimal engagement with key stakeholders such as drivers, law enforcement agencies, or transport authorities. Their perspectives on system usability, operational challenges, and compliance are not yet considered.

6. Unmodeled Weather Conditions: Although visibility obstructions due to environmental factors like rain and fog are acknowledged, these were not simulated or analyzed within the scope of the current study.

These limitations provide a clear direction for future research efforts aimed at strengthening the practical relevance and scalability of the proposed ITMS solution.

CONCLUSION

The reconnaissance survey at the Agodi Gate intersection provided a comprehensive understanding of the factors contributing to traffic signal occlusion at signalized T-junctions. The data and analysis revealed that the primary contributors to the problem include vehicular height disparities, headway distances, obstructing vehicle dimensions, and lane congestion. These elements significantly affect visibility and driver response times, creating delays and potential risks at intersections. The observed scenario involved a truck blocking the view of a traffic signal, primarily due to its height and width, which exceeded the visibility line of the approaching Jeep. The height disparity between the vehicles was identified as a critical factor, especially at shorter distances. The truck's dimensions, combined with the narrow headway of approximately 30–50 meters, created an obstruction angle that rendered the traffic signal invisible from the Jeep's position. This issue was exacerbated by the jammed condition of the adjacent lane, which prevented the Jeep from switching lanes to improve visibility.

Waiting time at the intersection, recorded as 45 seconds, was extended by the driver's inability to see the signal, leading to response delays. The lack of alternative sightlines, even with adjustments via rearview mirrors or steering alignment, indicated that traditional driver compensations are insufficient under such conditions. Furthermore, the absence of traffic wardens or real-time assistance during the off-peak period underscored the limitations of manual traffic management in addressing visibility challenges. The comparative analysis of parameters showed that occlusion is more likely during peak periods when lane congestion is higher, and maneuvering space is reduced. This suggests that traffic density plays a significant role in amplifying visibility issues, making the integration of intelligent traffic management systems essential. Such systems, leveraging IoT and real-time data, could dynamically adjust signals or provide alternative guidance to drivers to mitigate the impact of occlusion. This paper introduces an Intelligent Traffic Management System (ITMS) that utilizes IoT and GPS technology to improve signal visibility and reduce delay at urban intersections in Nigeria, with a specific focus on the Agodi Gate axis of Ibadan metropolis. The research demonstrates that visibility obstructions caused by large vehicles (such as trucks) significantly affect signal interpretation, leading to increased intersection delay and heightened safety risks. Through a combination of field observation, system design, and simulation, the study presents a functional prototype capable of transmitting real-time traffic signal information to drivers via mobile and dashboard interfaces. The approach enhances decision-making efficiency at intersections and can support broader urban traffic decongestion strategies.

In summary, the study highlights the need for innovative solutions to address traffic signal occlusion. Improving road infrastructure, implementing intelligent systems, and considering vehicle dimensions in urban planning are critical steps toward enhancing visibility, reducing delays, and ensuring smoother traffic flow at intersections. These findings pave the way for future research to develop technologies and strategies that address visibility-related challenges in modern traffic systems.

Furthermore, this analysis provides insight into mitigating traffic signal occlusions through adjustments in headway, signal positioning, and potential use of driver-assist technologies. Simulation models based on this data can be applied to other intersections, aiding in the design of Intelligent Traffic Management Systems that account for visibility dynamics under varying traffic conditions. Further studies and real-world tests will validate this model's effectiveness and refine parameters like driver response delay and occlusion thresholds. Despite its limitations, the proposed solution represents a step forward in integrating smart technology into Nigeria's urban mobility planning. The framework holds significant potential for replication in similar urban centers and can be expanded with stakeholder input, real-world testing, and multi-site validation. Future research should also consider cost-effective hardware alternatives, broader stakeholder collaboration, and environmental adaptability to facilitate full-scale adoption of ITMS as part of smart city initiatives in developing regions.

This mathematical model helps identify the critical headway and angle of view needed to prevent signal occlusion at the Agodi Gate intersection. Using simulated conditions, the model can guide modifications in traffic signal placement, height adjustments, and lane management strategies to improve visibility and reduce response delays. Future work will involve field testing to validate model predictions and refine parameters based on empirical data.

Contribution To Knowledge

This study will contribute an ITMS framework specifically for addressing visibility obstructions at urban intersections. The system's design is intended to be replicable for other cities facing similar challenges. Additionally, by addressing headway and traffic flow in tandem with visibility, this ITMS prototype stands to improve intersection efficiency, reduce economic costs associated with congestion, and enhance road safety for Ibadan and potentially other urban centers. This proposal incorporates insights from real-world observations and past studies to address the pressing visibility challenges in urban traffic management, using IoT and GPS technology to improve safety and efficiency at intersections.

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