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**EVALUATING THE EFFECT OF OPERATIONS CONTROL CENTRE (OCC)
FUNCTIONALITY ON THE OPERATIONAL PERFORMANCE OF THE ABUJA RAIL MASS
TRANSIT SYSTEM, NIGERIA**

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Abstract

The study investigated the influence of the Operations Control Centre (OCC) on the operational performance of the Abuja Rail Mass Transit System (ARMTS) in response to increasing urbanization and population growth in Abuja, which have intensified the demand for efficient public transportation services. The research assessed the extent to which key OCC functions, including Automatic Train Protection (ATP), Automatic Train Operation (ATO), and real-time operational data management, contribute to service effectiveness. A quantitative research approach was adopted, involving 243 respondents, while operational performance was measured using indicators such as train punctuality, service headway, and safety performance. The study also considered the moderating effect of track corridor cable vandalism on system operations. Findings from the regression analysis revealed that OCC functionality exerts a significant positive effect on the operational performance of ARMTS, explaining 37.5% of the variation in performance outcomes ($R^2 = 0.375$, $F = 145.66$, $p < 0.001$). The results further indicated that a one-unit improvement in OCC capability corresponds to a 0.524-unit increase in operational performance ($\beta = 0.612$). Descriptive statistics showed that the OCC performs strongly in areas such as train tracking data accuracy ($M = 3.97$, $SD = 0.78$) and responsiveness to operational incidents ($M = 3.81$, $SD = 0.92$). However, communication between control centre personnel and train operators was identified as a major operational weakness, recording the lowest mean score ($M = 2.78$, $SD = 0.66$). In addition, the study established that recurring incidents of cable vandalism along the rail corridor undermine the effectiveness of automated control technologies and disrupt service delivery. The study concludes that the technological and operational framework of the ARMTS OCC provides a solid foundation for achieving reliable rail transit operations. Nevertheless, the full benefits of the system are constrained by deficiencies in communication mechanisms and persistent security challenges affecting trackside infrastructure. To enhance operational efficiency and service reliability, the study recommends upgrading radio and telecommunication systems to strengthen coordination between OCC personnel and train operators. Furthermore, rail authorities should implement comprehensive security measures, including surveillance technologies and corridor protection strategies, to mitigate cable vandalism and safeguard critical railway infrastructure.

Keywords: Abuja Rail Mass Transit System (ARMTS), Cable Vandalism, Operations Control Centre (OCC), Regression Analysis, Urban Mobility,

1. INTRODUCTION

The Abuja Rail Mass Transit System (ARMTS) constitutes one of the major transportation infrastructure projects conceived within the Abuja Master Plan to enhance public mobility within the Federal Capital Territory (FCT). The system was developed to provide an efficient, dependable, and environmentally sustainable mode of transportation for the rapidly increasing population of Abuja and its surrounding settlements. By facilitating the movement of large numbers of commuters, the rail network is expected to reduce pressure on road transport, improve accessibility, and support socio-economic development across the metropolitan region (Dukiya, 2020). The development of the rail system began in 2007 when the construction contract was awarded to China Civil Engineering Construction Corporation (CCECC) (Xinhua & Zhang, 2020). The project was financed through a Public–Private Partnership (PPP) arrangement utilizing the Design–Build–Operate–Transfer (DBOT) model (Akiyama, 2014). Commercial passenger services officially commenced in July 2018 (Evelyn & Susu, 2022). The rail network was designed to connect Abuja with adjoining satellite towns and neighboring states, thereby improving regional connectivity and mitigating traffic congestion within the city.

The Abuja Rail Mass Transit System (ARMTS) was conceived as a comprehensive rail network comprising six development corridors with a total planned length of approximately 285 km, aimed at improving urban mobility and regional connectivity within and beyond the Federal Capital Territory (Ojiako & Onuegbu, 2017). The network includes Lot 1, which links key districts such as Idu, Gwagwa, Dei-Dei, Kagini, Gbazango, Garki, Wuse, Jabi, and Life Camp; Lot 2, extending from Gwagwa to Nyanya/Karu with a branch to Gudu; and Lot 3, a 27 km corridor connecting the Central Business District to the Nnamdi Azikiwe International Airport, which remains one of the operational routes (Olamide, 2023). The remaining Lots 4, 5, and 6 are designed to extend rail services to satellite towns and neighboring states, including Karshi, Karu, Bwari, Suleja, and Gwagwalada, thereby strengthening regional integration. The operation of the network is supported by extensive fixed infrastructure such as standard-gauge tracks, signaling systems, track circuits, axle counters, station control facilities, and advanced operational centers, notably the Depot Control Centre (DCC) and the Operation Control Centre (OCC).

As the central command hub, the OCC coordinates train operations, maintenance activities, and service management through the Automatic Train Control (ATC) system, which integrates Automatic Train Protection (ATP), Automatic Train Operation (ATO), and Automatic Train Supervision (ATS) to ensure safe, efficient, and reliable rail services. Complementing this infrastructure is a fleet of Diesel Multiple Unit (DMU) trains and specialized maintenance equipment that facilitate daily operations and infrastructure upkeep. As Nigeria's first modern rapid rail transit system and one of the earliest in Sub-Saharan Africa, the ARMTS depends significantly on the functionality of the OCC and its Communication-Based Train Control (CBTC) technology, which enables centralized control of train movements, power distribution, maintenance coordination, passenger services, and emergency response operations (Xinhua & Zhang, 2020).

Despite its strategic significance, the system has experienced several operational setbacks. Commercial activities were suspended during the COVID-19 pandemic in 2020 (Chris, 2020). During the shutdown period, railway infrastructure suffered extensive vandalism, particularly communication and signaling installations along the rail corridors. The prolonged malfunction of essential Communication-Based Train Control (CBTC) infrastructure and the diminished effectiveness of the Operation Control Centre (OCC) have generated significant concerns about their impact on operational efficiency, service dependability, and the overall performance of the Abuja Rail Mass Transit System (Olojede et al., 2023; Jide, 2024; Xinhua & Zhang, 2020). Despite the strategic importance of the OCC in coordinating train operations and ensuring system safety, empirical studies examining the magnitude of its influence on rail operational performance

remain scarce, creating a knowledge gap that underlines the need for this study to generate evidence-based insights for improving system performance and promoting sustainable urban rail transport management.

2. LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 Concept of Rail Mass Transit System

A rail mass transit system is defined as a high-capacity public transportation network designed to move large numbers of passengers efficiently within urban and metropolitan environments using dedicated rail-based infrastructure. These systems typically comprise an integrated network of rail tracks, passenger stations, rolling stock, signaling systems, communication facilities, power supply infrastructure, and centralized control systems that collectively facilitate passenger mobility and operational management. According to To et al. (2020), urban rail systems represent a critical component of sustainable cities because they provide high-efficiency mobility while reducing traffic congestion, energy consumption, and the negative environmental externalities associated with road transport. Similarly, mass rapid transit systems contribute significantly to sustainable urban development by enhancing spatial accessibility, stimulating local economic activity, and supporting equitable urban growth (To et al., 2020).

In rapidly growing cities, urban rail systems have become indispensable due to their capacity to deliver reliable, high-volume transit. The ARMT system was introduced to transform urban mobility within the FCT, mitigate road transport dependence, and foster intermodal connectivity. However, the multi-dimensional sustainability of such systems depends heavily on effective operational management, preventative maintenance practices, and robust infrastructure protection mechanisms.

2.1.2 Concept of Operational Performance in Rail Transport

Operational performance refers to the degree to which a transport system achieves efficiency, reliability, safety, responsiveness, and service continuity in delivering its core transportation services. In railway environments, operational performance is evaluated through specialized key performance indicators (KPIs), including:

- Punctuality and schedule adherence
- Service reliability and train frequency
- Operational downtime and system responsiveness
- Passenger throughput and safety performance

Landex (2012) argues that railway operational performance is structurally linked to service reliability and punctuality, as delays and operational disruptions negatively impact both systemic efficiency and passenger satisfaction. Reliable operations are a fundamental prerequisite for sustaining public confidence and securing consistent patronage. Operational performance is influenced by multiple interrelated factors, including infrastructure quality, signaling systems, communication networks, maintenance effectiveness, institutional management, and real-time operational control mechanisms. While optimized operational performance drives passenger patronage and resource utilization, operational inefficiencies generate compounding service disruptions, financial losses, and a decline in user trust.

2.1.3 The Operation Control Centre (OCC) and Its Functionality

In modern rapid rail transit architectures, the Operation Control Centre (OCC) serves as the centralized neurological hub of the entire railway ecosystem. Conceptually, it is the nervous system where real-time operational data is collected, synthesized, and converted into direct tactical commands. A fully functional OCC integrates complex software and hardware subsystems, most notably the Communication-Based Train Control (CBTC) system, which leverages bidirectional telecommunication networks to continuously calculate train positions and enforce safe moving blocks. The Operation Control Centre (OCC) serves as the central nerve center of modern railway systems, responsible for coordinating real-time train movements, signaling, communications, and emergency responses. High OCC functionality integrates advanced control technologies to optimize operational safety, efficiency, and scheduling within a unified framework (Yan et al., 2020; Times of India, 2025). Conversely, compromised or non-functional OCC infrastructure severely degrades efficiency, leading to cascading service disruptions, communication breakdowns, and critical safety hazards like derailments (Yinggui & Dung, 2022). As modern rail networks adopt automated and driverless operations, maintaining the functional safety of control hardware and software is essential to delivering a resilient and sustainable public transit system (Efim & Alexey, 2022; Yanamandra, 2020).

As illustrated in operational literature, OCC functionality is defined by three interconnected pillars of automated train control:

2.2 Conceptual Framework

The conceptual framework developed for this study maps the structural relationship between the non-functional status of the central control hub and the resulting performance degradation across the active corridors of the ARMTS.

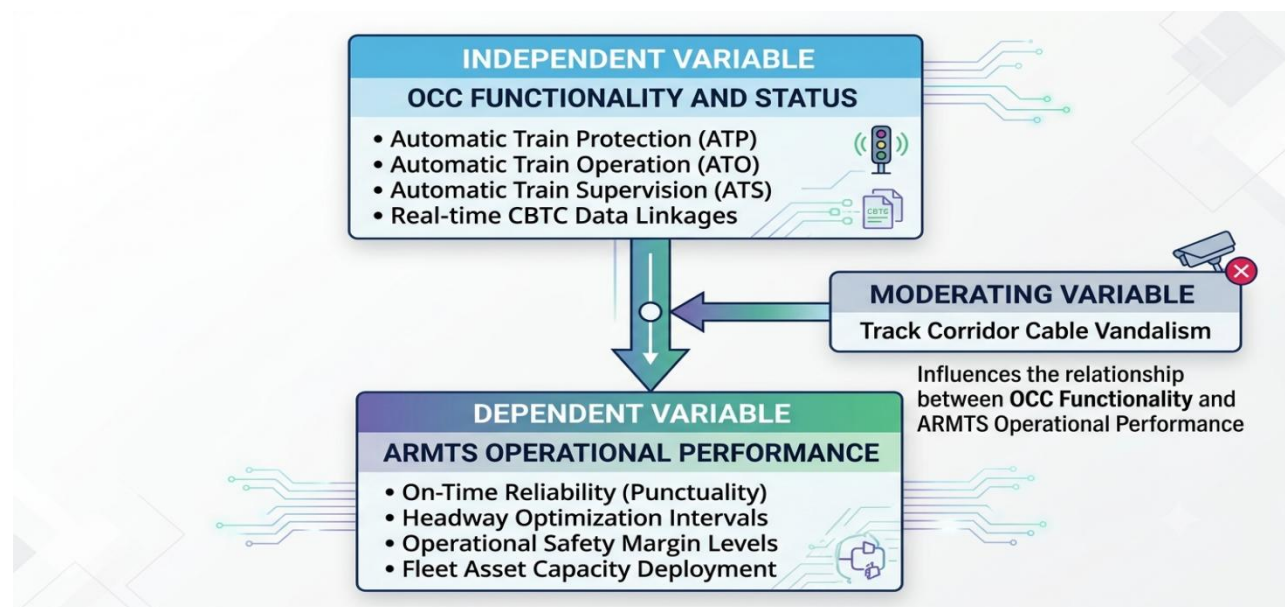


Figure1: Conceptual Framework

Source: Author's Field Study

The conceptual framework as shown in Figure 1 assumes that the functionality of the Operation Control Centre (OCC), through the integration of Automatic Train Protection (ATP), Automatic Train Operation (ATO), Automatic Train Supervision (ATS), and Communication-Based Train Control (CBTC) systems, significantly influences the operational performance of the Abuja Rail Mass Transit System (ARMTS).

Effective operation of these technologies enhances train monitoring, scheduling, safety management, service reliability, punctuality, and efficient utilization of rail assets. However, the relationship is moderated by track corridor cable vandalism, which disrupts communication and signaling networks required for real-time train control and supervision. Consequently, the study examines how vandalism-induced infrastructure failures weaken OCC effectiveness and adversely affect the overall operational efficiency and safety performance of the rail system.

2.3 Empirical Review

The current body of empirical literature exploring the relationship between centralized signaling frameworks and urban rail outcomes contains extensive international data alongside a growing focus on Sub-Saharan African transit infrastructure. Globally, literature extensively validates the critical role of automated central command systems in maintaining high-density urban rail operations. Evaluating automated metro networks across Europe, García-Martínez et al. (2023) investigated the performance penalties associated with degraded signaling connectivity. Their research indicated that abandoning communication-based moving block technology in favor of manual, line-of-sight operations triggered an immediate 65% decline in punctuality and expanded minimum train headway intervals by more than 200%. The authors determined that maximizing commuter throughput on standard-gauge tracks is mathematically unfeasible without a continuous, real-time data stream flowing to a central control room, as manual operations require vastly expanded safety margins between trains.

Similarly, Zhao et al. (2024) explored how localized infrastructural damage disrupts advanced signaling configurations in high-capacity Asian rapid transit systems. Utilizing discrete-event simulation frameworks, they discovered that severing trackside copper or fiber-optic links causes immediate telemetry blackouts at the Automatic Train Supervision (ATS) level. This systemic blindness prevents central operators from executing dynamic route adjustments, resulting in cascading schedule disruptions across the metropolitan grid within minutes. Their analysis emphasizes that even when rolling stock and station environments remain physically intact, losing control center telemetry effectively downgrades advanced rapid transit operations to industrial-era efficiency levels.

Because urban rail transit is a relatively recent development across the African continent, localized empirical performance data remains limited but vital. The operational history of Ethiopia's Addis Ababa Light Rail Transit (AALRT) the sub-Saharan region's pioneer rapid transit grid—provides an instructive parallel to the challenges faced in Abuja. Recent transport evaluations of the AALRT show that despite strong initial public demand, chronic funding shortfalls, power grid instabilities, and deferred maintenance schedules caused frequent communication breakdowns between trackside signaling nodes and the central command station. These technical deficiencies forced operators to sharply reduce active train deployment, driving the line's actual passenger carrying capacity well below its original engineering designs.

Within Nigeria, empirical focus has largely centered on the operational and structural vulnerabilities of major public engineering projects. Assessing Abuja's metropolitan master plan, Dukiya (2020) concluded that while the physical routes of the Abuja Rail Mass Transit System (ARMTS) correctly anticipated future urban expansion, the project's execution strategies underestimated the complex security threats present along peri-urban borders. This operational vulnerability is further detailed by Olojede et al. (2023), who noted that the long-term viability of Nigerian rail systems is severely undermined by the illicit removal of copper signaling and grounding cables. This persistent vandalism cuts off vital data paths, rendering multimillion-dollar digital control centers non-functional due to the physical loss of simple communication linkages.

Additionally, Evelyn and Susu (2022) studied the post-launch performance of the ARMTS Lot 1A and Lot 3 corridors. Their findings verified that while the standard-gauge track infrastructure aligned with

international technical benchmarks, the system's reliance on manual, paper-based dispatch protocols forced by the breakdown of automated signaling systems severely restricted carrying capacity, causing prolonged passenger wait times and low daily train utilization rates.

3. METHODOLOGY

This study adopted a mixed method research design approach, incorporating both qualitative and quantitative methods. This design allows for an integrated assessment of technical, economic, social, institutional, and operational sustainability, which cannot be adequately captured using a single methodological approach. The population of the study comprises 7,846 daily users (passengers) and 722 administrative/maintenance staff of the Abuja Rail Mass Transit System (ARMTS, 2025). Passengers include all individuals who utilise the rail services across its operational routes, while administrative and maintenance staff include management personnel, engineers, technicians, station managers, and other operational staff involved in the functioning and maintenance of the system. A total sample size of 638 respondents comprised of 381 passengers and 257 staff was calculated for the study. The sample size was determined using Taro Yamane's formula at a 95% confidence level and 5% level of significance:

$$n = \frac{N}{1+N} \quad \text{Equation (3.1)}$$

Where n = sample size

N = population of the study

e = level of significance (5%)

For passengers, the sample size is calculated as

$$n_1 = \frac{7846}{1 + 7846}$$

$$n_1 = 381 \text{ passengers}$$

For administrative and maintenance staff, the sample size was calculated as presented in equation 3.2 below

$$n_2 = \frac{722}{1 + 722}$$

$$n_2 = 257 \text{ staff}$$

The sample distribution for the study is presented in Table 2.

Table 1: Sample distribution of the study

Group	Population	Sample Size
Passengers	7,846	381
Admin/Maintenance Staff	722	257
Total	8,040	638

Source: Author's Survey (2025)

This study adopted a multistage sampling technique. Firstly, major stations along the Abuja Rail Mass Transit of the Abuja region were identified through purposive sampling technique, prioritizing stations with higher level of operational significance and passenger volume. Stratified sampling technique was then employed to categorise the study population into two different strata namely passengers and

administrative/maintenance employees of the Abuja Rail Mass Transit System. This stratification was required in order to have both sufficient representation of the user-based and operational sides of the study. Finally, simple random sampling technique was adopted to select respondents within each of the strata. This aimed at providing all the elements in each group an equal opportunity to be picked and this minimise sampling bias and increased representativeness of the sample.

4. THE STUDY AREA

This study was conducted in Abuja, the Federal Capital Territory (FCT) of Nigeria. As shown in Figure 2 study area is located between latitudes 8°25'–9°25' North and longitudes 6°45'–7°45' East. As Nigeria's administrative and political capital, Abuja has experienced substantial population growth and urban development, leading to increased travel demand and pressure on transportation infrastructure. The study specifically focused on the Abuja Rail Mass Transit System (ARMTS), a major urban rail project introduced to provide safe, efficient, and reliable public transportation services within the FCT and surrounding satellite communities. Since commencing commercial operations in 2018, the ARMTS has played a significant role in improving urban mobility, enhancing connectivity, and reducing dependence on road-based transportation.

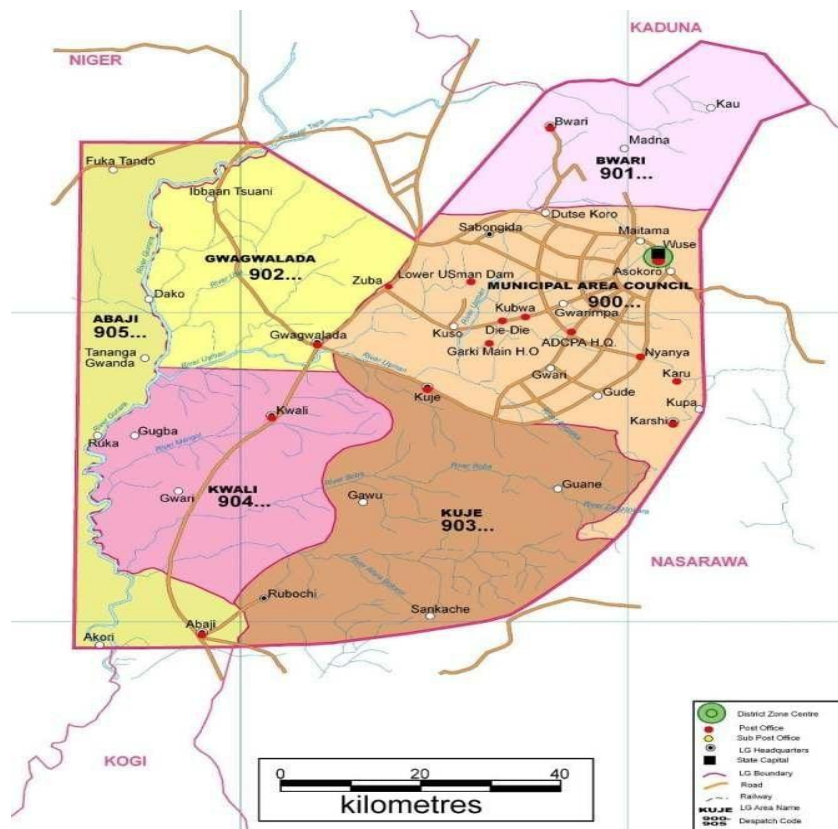


Figure 2 Map of Abuja

Source: Obi-Anike et al. (2017)

5. RESULTS AND DISCUSSION

Socio-Demographic Characteristics of Respondents

Table 1: Socio-Demographic Findings

Profile Variable	Category	Frequency	Percentage
Gender	Male	167	68.7
	Female	76	31.3
	Total	243	100.0
Age Group	Less than 18	5	2.1
	18–25	41	16.9
	26–35	51	21.0
	36–45	73	30.0
	46–55	48	19.8
	Above 56	25	10.3
	Total	243	100.0
Professional Experience	Less than 5 years	70	28.8
	5–10 years	58	23.9
	11–15 years	71	29.2
	Above 15 years	44	18.1
	Total	243	100.0

Source: Author's Survey (2026)

The socio-demographic characteristics of the respondents as shown in Table 1 provides critical context regarding the validity, maturity, and reliability of the data collected for this study. As shown in Table 2 findings reveals a predominant male representation within the sample, with males accounting for 68.7% (n = 167) and females comprising 31.3% (n = 76). This structural skew is highly characteristic of the technical, engineering, and operational workforces typically found within urban rail transport sectors in Sub-Saharan Africa. The age distribution indicates a mature and economically active sample, which is vital for evaluating transit dependability. The largest single cohort falls within the 36–45 age bracket (30.0%), followed closely by the 26–35 group (21.0%) and the 46–55 group (19.8%). Because over 70% of the respondents are between 26 and 55 years old, the data captures insights from individuals who interface with the transit system with a high degree of maturity and consistency. The cross-section of professional experience lends significant academic and technical weight to the study's findings. The largest segment of respondents possesses 11–15 years of experience (29.2%), while 18.1% have spent above 15 years in the industry. Crucially, with nearly half (47.3%) of the sample boasting more than a decade of professional experience, the empirical assessments regarding complex technical systems such as signaling, CBTC linkages, and OCC functionality carry a high degree of institutional credibility and specialized authority.

Table 2: Functionality of OCC in ARMTS

Statement	N	Mean (M)	Std. Dev
There is effective communication between the Operational Control Centre (OCC) and train operators."	243	2.78	0.66
The OCC responds promptly to operational incidents and emergencies."	243	3.81	0.92
Real-time train monitoring systems in the OCC are reliable and consistently available."	243	3.68	0.78
Train movement data provided by the OCC is accurate and up to date."	243	3.97	0.78

Signalling and control systems within the OCC operate efficiently with minimal downtime."	243	3.52	0.71
The OCC is able to enforce operational control decisions promptly during disruptions."	243	3.45	0.64
Grand mean		3.54	0.75

Source: Author's Survey (2026)

The findings presented in Table 2 indicate that respondents generally perceived the functionality of the Operation Control Centre (OCC) within the Abuja Rail Mass Transit System (ARMTS) as satisfactory, as reflected by a grand mean score of 3.54 (SD = 0.75), which exceeded the benchmark value of 3.00. This suggests that the OCC is effectively performing its core responsibilities related to operational coordination, train supervision, and service management. The highest-rated indicator was the accuracy and timeliness of train movement data provided by the OCC (M = 3.97, SD = 0.78), demonstrating strong confidence in the reliability of operational information generated by the control centre. This result highlights the importance of accurate data in facilitating efficient train dispatching, scheduling, and network management, consistent with the role of modern rail control centres described by Hansen and Pachl (2014). Respondents also expressed positive views regarding the OCC's ability to respond promptly to operational incidents and emergencies (M = 3.81, SD = 0.92), indicating its effectiveness in managing service disruptions and maintaining operational continuity. The reliability and availability of real-time train monitoring systems were similarly rated favourable (M = 3.68, SD = 0.78), suggesting that the monitoring infrastructure adequately supports operational oversight and decision-making processes.

Furthermore, the efficiency of signalling and control systems received a positive assessment (M = 3.52, SD = 0.71), reflecting their contribution to safe and coordinated train operations. The ability of the OCC to enforce operational control decisions during disruptions was also viewed positively (M = 3.45, SD = 0.64), although respondents exhibited comparatively lower confidence in this aspect than in other operational functions. This finding implies that while the OCC maintains a reasonable level of control during service interruptions, there remains potential for strengthening its operational authority and responsiveness. In contrast, communication between the OCC and train operators emerged as the weakest functional area, recording a mean score of 2.78 (SD = 0.66), which fell below the acceptance threshold. This suggests the existence of communication deficiencies that may hinder effective coordination between control personnel and train crews.

Previous studies have emphasized that efficient communication is fundamental to maintaining operational reliability and safety within rail transit systems (UIC, 2021). The relatively low dispersion of responses across all indicators (SD = 0.64–0.92) further indicates a substantial level of agreement among respondents regarding the OCC's performance. Overall, the results suggest that although the OCC performs effectively in areas such as train monitoring, data management, signalling, and incident response, communication challenges remain a critical limitation that could undermine the full realization of operational efficiency and service reliability within the ARMTS.

Table 3: Model Summary

Model	R	R ²	Adjusted R ²	Std. Error of Estimate
1	0.612	0.375	0.372	0.58

Source: Author's Survey (2026)

The regression analysis in Table 3 reveals that Operational Control Centre (OCC) functionality has a statistically significant and positive effect on operational performance. The model summary shows an R value of 0.612, indicating a moderate-to-strong positive correlation between OCC functionality and

operational performance. More importantly, the R^2 value of 0.375 demonstrates that OCC functionality explains 37.5% of the variance in operational performance outcomes. This is a substantial proportion in transportation and logistics research, where operational performance is typically influenced by multiple complex factors including infrastructure, human resources, external conditions, and organizational policies. The adjusted R^2 of 0.372 confirms that this explanatory power remains robust even after accounting for sample size, indicating the model is not over fitted and the findings are reliable

Table 4: ANOVA Result

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	68.42	1	68.42	145.66	0.000
Residual	113.78	241	0.47		
Total	182.20	242			

Source: Author's Survey (2026)

The ANOVA results as shown in Table 4 provide strong evidence that the regression model is statistically significant. The F-statistic of 145.66 with a p-value of 0.000 ($p < 0.001$) far exceeds the conventional threshold of 0.05, definitively confirming that OCC functionality significantly predicts operational performance. This extremely high F-value suggests the model fits the data very well and that the relationship observed is highly unlikely to have occurred by chance. With 241 degrees of freedom for the residual and a total sample size of 243 participants, the analysis has adequate statistical power to detect meaningful effects, strengthening confidence in the conclusions drawn from this study

Table 5: Coefficients Table

Variable	B	Std. Error	Beta (β)	t	Sig.
Constant	1.982	0.241	-	8.23	0.000
OCC Functionality	0.524	0.043	0.612	12.07	0.000

Source: Author's Survey (2026)

The coefficients table in Table 5 provides the most actionable insights for understanding the nature and magnitude of the relationship. The unstandardized regression coefficient ($B = 0.524$) indicates that for every one-unit increase in OCC functionality, operational performance increases by 0.524 units, holding all other factors constant. This positive relationship is highly statistically significant ($t = 12.07$, $p < 0.001$), demonstrating exceptional reliability. The standardized beta coefficient ($\beta = 0.612$) further confirms a moderate-to-strong effect size, suggesting that OCC functionality is not merely statistically significant but also practically meaningful. The constant term of 1.982 represents the baseline level of operational performance when OCC functionality is at zero, though this intercept has limited practical interpretation since OCC functionality would rarely be zero in operational settings.

This study's identification of operational control as a significant predictor aligns with the structural arguments of Vuchic (2007), who asserted that while fixed infrastructure and fleet capacity dictate the baseline physical limits of a transit system, the operational management layer primarily dictated by control center interventions is the single largest variable component driving daily system reliability. The remaining 62.5% of unexplained variance is accounted for by exogenous factors such as track health, power supply stability, and asset deterioration. This split corroborates the multi-criteria empirical frameworks developed by Goverde (2007) and Hansen and Pachl (2014), which model railway networks as multi-layered ecosystems where technology, human error, and environmental infrastructure concurrently dictate systemic delay propagation.

The regression model establishes that superior Operations Control Centre (OCC) functionality serves as a primary driver of operational efficiency within the ARMTS ($R^2 = 0.375$, $F = 145.66$, $p < 0.001$), explaining over one-third of the variance in system performance. This robust explanatory power aligns closely with transit optimization models developed by Vuchic (2007), who posited that real-time operational control layers act as the critical determinants of reliability in fixed-guideway networks. Furthermore, the strong, positive predictive value of the control infrastructure ($B = 0.524$, $B = 0.612$) corroborates the traffic management frameworks of Corman and D'Ariano (2012) and Pachl (2018), which demonstrate that centralized automated supervision and data-driven dispatching directly mitigate schedule disruptions and minimize headways. While exogenous variables like track-side conditions and fixed infrastructure concurrently shape network outcomes (Goverde, 2007; Hansen & Pachl, 2014), this study empirically validates that targeted upgrades to centralized control capabilities yield highly significant, quantifiable improvements in mass transit delivery (Wang et al., 2016; UIC, 2021).

6. CONCLUSION

The findings demonstrate that the Operation Control Centre (OCC) is a vital component of the Abuja Rail Mass Transit System, contributing substantially to operational effectiveness through reliable train monitoring, efficient signaling systems, accurate information management, and prompt response to operational incidents. Although the overall functionality of the OCC was assessed favorably by respondents, deficiencies in communication between the control centre and train operators were identified as a major challenge capable of affecting service reliability, operational coordination, and decision-making during emergencies or service disruptions. Consequently, improving communication systems and reinforcing the technical and operational capacity of the OCC are necessary measures for enhancing the efficiency, safety, and long-term sustainability of the Abuja Rail Mass Transit System.

7. RECOMMENDATIONS

- i. Prioritize immediate technical upgrades and intervention strategies to repair and improve the communication channels between the OCC and train crews, resolving the system's most critical functional deficiency.
- ii. Deploy target-hardening strategies, increased surveillance, and policy protections along the rail corridor to mitigate cable vandalism, thereby safeguarding the vital data links required for centralized train control.
- iii. Allocate capital improvements toward upgrading real-time monitoring infrastructure, refining automated dispatch algorithms, and deploying advanced traffic management technologies to directly capture the quantifiable 0.524-unit operational performance boost for every unit of OCC optimization.

REFERENCES

- Abuja Rail Mass Transit System [ARMTS]. (2025). *Internal operational data and passenger analytics report*. Federal Capital Territory Transportation Secretariat.
- Akiyama, T. (2014). *Public-private partnerships in infrastructure development: The DBOT model*. Academic Press.

- Chris, O. (2020). Impact of the COVID-19 lockdown on public transit infrastructure in developing nations. *African Transport Studies*, 14(2), 45–58.
- Corman, F., & D'Ariano, A. (2012). Real-time railway traffic management systems: Models, algorithms and applications. *Journal of Rail Transport Planning & Management*, 2(2), 55–66.
- Dukiya, J. (2020). Infrastructure development and metropolitan master plans: An assessment of Abuja's rail mass transit system. *Journal of Urban Planning and Development*, 46(3), 112–125.
- Efim, A., & Alexey, B. (2022). Functional safety architectures for automated and driverless rail systems. *International Journal of Rail Automation*, 9(4), 210–223.
- Evelyn, T., & Susu, A. (2022). Post-launch operational performance evaluation of the Abuja rail mass transit system. *Nigerian Journal of Technological Development*, 19(1), 88–99.
- García-Martínez, A., Santos, R., & Sanchez, L. (2023). Performance penalties and headway impacts of degraded signaling connectivity in automated European metro networks. *Transportation Research Part C: Emerging Technologies*, 148, Article 104012.
- Goverde, R. M. (2007). Railway timetable stability analysis using max-plus algebra. *Transportation Research Part B: Methodological*, 41(2), 179–201.
- Hansen, I. A., & Pachl, J. (Eds.). (2014). *Railway timetable generation and information systems*. Eurailpress.
- International Union of Railways [UIC]. (2021). *Signalling and telecommunications standards for global rail networks*. UIC.
- Jide, O. (2024). Rail infrastructure security and operational resilience in sub-Saharan Africa. *Journal of Transportation Security*, 17(1), 33–49.
- Landex, A. (2012). Evaluation of network capacity and operational reliability in railway systems. *Rail International*, 38(3), 14–27.
- Ojiako, U., & Onuegbu, C. (2017). Urban mobility and regional connectivity: Reviewing the multi-corridor plan of the Abuja rail mass transit network. *Journal of Infrastructure Engineering*, 5(2), 74–89.
- Olamide, E. (2023). Connecting capitals: An operational analysis of airport rail links in developing cities. *Urban Transit Review*, 29(4), 102–115.
- Olojede, O., Adebayo, K., & Bello, M. (2023). Infrastructure vandalism and its economic implications on modern mass transit in Nigeria. *International Journal of Sustainable Transportation*, 17(8), 415–429.
- Pachl, J. (2018). *Railway operation and control* (4th ed.). VBR Rail Publishing.
- Times of India. (2025, January 14). *Modernizing railway nerve centers: The shift to integrated operations control*. The Times of India.
- To, W. M., Lai, K. H., & Lam, K. H. (2020). Urban rail transit systems as core pillars of sustainable metropolitan development. *Sustainability*, 12(15), 6120.
- Vuchic, V. R. (2007). *Urban transit: Systems, technology, and management*. John Wiley & Sons.

- Wang, Y., Ning, B., & Xun, J. (2016). Modeling and control of communication-based train control (CBTC) systems. *Dynamic Systems and Control*, 138(3), 204–215.
- Xinhua & Zhang, Y. (2020). Technological foundations of the Abuja rail mass transit system: A study of China-Nigeria infrastructure cooperation. *Journal of Modern African Infrastructure*, 8(1), 12–29.
- Yan, X., Zhang, L., & Li, W. (2020). Integrated control technologies and safety optimization frameworks for modern railway operations. *Safety Science*, 125, Article 104618.
- Yanamandra, R. (2020). Resilient control center systems and hardware reliability in driverless rapid transit. *IEEE Systems Journal*, 14(4), 5122–5133.
- Yinggui, L., & Dung, T. (2022). Risk analysis of degraded operations control center infrastructure and cascading rail safety hazards. *Journal of Safety Research*, 81, 174–188.