

Functionality of the compressed natural gas (CNG) refuelling stations in Lagos, Nigeria

Funkcjonowanie stacji tankowania sprężonego gazu ziemnego (CNG) w Lagos (Nigeria)

Deborah O. Bolaji, Kazeem A. Bello, Tunde O. Ogundana, Bukola O. Bolaji,
Israel A. Olumoroti, Friday A. Onuh, Olatude A. Oyelaran

Department of Mechanical Engineering, Federal University Oye-Ekiti, PMB. 373, Oye-Ekiti, Ekiti State, Nigeria

ABSTRACT: The worldwide transition to sustainable and environmentally friendly energy sources has become increasingly important due to the environmental concerns associated with fossil fuel dependency. Among the various alternatives, Compressed Natural Gas (CNG) has emerged as a viable option. Assessing the operation of CNG refuelling stations in Nigeria is critical for measuring their performance and determining potential and obstacles to increasing CNG usage. This research assesses the functionality and operational standards of CNG refuelling stations in Lagos, Nigeria, with an emphasis on effectiveness and adherence to international regulations. The data show significant performance discrepancies among the stations. While Station C had the maximum functional efficiency and conformity with practically all important international indicators, other stations, notably Station D, showed significant flaws. These consist of prolonged normal refuelling times, bad upkeep, and not enough training for the workers. A comparison with international standards highlighted systemic issues: the assessed stations had an average refuelling duration of 7 minutes, exceeding the global norm of 5 minutes, and they conducted only one maintenance cycle per month, instead of the required four. Staff training compliance was 60%, and system downtime reached 12%, greatly surpassing the worldwide norm of 5%. These shortcomings threaten the reliability, safety, and public acceptance of Nigeria's CNG infrastructure. The paper highlights the necessity of adhering to strict regulations, conducting periodic evaluations, and providing training for employees. Addressing these deficiencies is essential to improve station performance and support Nigeria's transition to more environmentally friendly transportation through wider adoption of CNG technology.

Keywords: compliance, refuelling stations, infrastructure, CNG.

STRESZCZENIE: Globalna transformacja w kierunku zrównoważonych i przyjaznych dla środowiska źródeł energii nabiera coraz większego znaczenia ze względu na problemy środowiskowe związane z uzależnieniem od paliw kopalnych. Wśród dostępnych alternatyw sprężony gaz ziemny (CNG) wydaje się najkorzystniejszym rozwiązaniem. Ocena funkcjonowania stacji tankowania CNG w Nigerii ma kluczowe znaczenie dla pomiaru ich wydajności oraz określenia potencjału i przeszkód w zwiększaniu wykorzystania CNG. W niniejszym badaniu dokonano oceny funkcjonalności i standardów operacyjnych stacji tankowania CNG w Lagos, ze szczególnym uwzględnieniem ich efektywności oraz zgodności z międzynarodowymi regulacjami. Dane wskazują na istotne rozbieżności w wydajności między stacjami. Stacja C charakteryzowała się najwyższą efektywnością funkcjonalną oraz zgodnością z niemal wszystkimi istotnymi wskaźnikami międzynarodowymi. Niestety, w przypadku pozostałych stacji, w szczególności Stacji D, wykazano znaczące uchybienia, takie jak wydłużony czas normalnego tankowania, zły stan techniczny oraz niewystarczające przeszkolenie pracowników. Porównanie z normami międzynarodowymi uwypukliło problemy systemowe: średni czas tankowania na analizowanych stacjach wynosił 7 minut, podczas gdy globalna norma wynosi 5 minut, a także przeprowadzano na nich jedynie jeden cykl konserwacji miesięcznie zamiast wymaganych czterech. Zgodność w zakresie szkoleń personelu wynosiła 60%, a przestoje systemu sięgały 12%, znacznie przekraczając światową normę wynoszącą 5%. Niedociągnięcia te zagrażają niezawodności, bezpieczeństwu oraz powszechnej akceptacji infrastruktury CNG w Nigerii. W artykule podkreślono konieczność przestrzegania rygorystycznych regulacji, przeprowadzania okresowych ocen oraz zapewnienia szkoleń dla pracowników. Wyeliminowanie tych niedociągnięć ma zasadnicze znaczenie dla poprawy wydajności stacji oraz wspomagania przejścia Nigerii na bardziej przyjazny dla środowiska transport poprzez szersze wdrażanie technologii CNG.

Słowa kluczowe: zgodność, stacje tankowania, infrastruktura, CNG.

Introduction

Petroleum fuels have long been a major source of energy in the transportation sector. The consumption of fossil fuels, especially petroleum, has increased significantly throughout the years, owing to factors like rising populations and changing consumer habits. The rise in fossil fuel usage has several negative consequences, notably for the ecosystem, people's health, and economic activity (Achakulwisut et al., 2023). Among them are the release of greenhouse gases, which cause global warming, water and air pollution, diminishing resources, and economic instability. The increasing usage of fossil fuels can be ascribed to the ongoing population growth. For example, in the United States alone, fossil fuel usage made up 68% of the overall utilisation in 2022. Furthermore, importations of energy topped 30% in 2023, demonstrating continuing dependence on these scarce resources (Abbasi et al., 2024).

The worldwide transition to sustainable and greener energy sources has grown to be more important because of the ecological problems faced by fossil fuel dependency. Among the numerous options, CNG has been identified as a feasible choice due to its decreased greenhouse gas emissions, low cost, and widespread availability. CNG, being a cleaner-burning fuel, has substantial environmental advantages since it reduces pollutants including carbon monoxide, nitrogen oxides, and particulate matter. These benefits have prompted numerous nations, including Nigeria, to investigate the incorporation of CNG into their transportation and energy networks (Okafor et al., 2025).

Nigeria, before the advent of Dangote refinery, encountered shortages of petrol and diesel. Inoperative or partially operative refineries increased the scarcity and cost of these items for the common Nigerian. Importation constitutes the primary source of the specified petroleum products, accelerating the loss of the nation's much-needed foreign reserves. In contrast, Nigeria has substantial natural gas reserves, currently valued at 209 trillion cubic feet (Oduka et al., 2025). A substantial amount of her natural gas resources are generated and exported, leaving her local market with a meagre share of domestic consumption by her growing population, with little influence on national development (Odoi et al., 2022).

Nigeria is Africa's largest crude oil producer and a significant exporter of crude petroleum. However, due to inadequate local refining ability, a large share of refined products, particularly petrol, had to be imported, causing strain on foreign exchange reserves and contributing to supply volatility (Omoregie, 2019). The Dangote Refinery's commissioning in 2024 marks a significant structural shift in the downstream industry. Nigeria presently manufactures and sells refined petroleum products such as petrol, diesel and aviation fuel

due to its vast refining capability. This invention increases domestic energy security, decreases dependency on imported refined fuels, boosts industrial self-sufficiency, and improves trade balance. It also puts Nigeria as a refinery center in West Africa (Andah and Guttena, 2025).

However, this development does not lessen the tactical significance of gas-based transportation fuels like CNG. While increased refining production increases petroleum supply, petrol still represents a higher-emitting fuel than natural gas. Nigeria has abundant natural gas resources, and advancing CNG adoption is consistent with worldwide energy transition movements, initiatives to lower costs, and broader environmental sustainability objectives (Neumann, 2025). Thus, expanding refining capacity and promoting CNG are not mutually incompatible. Rather, these are complementing strategies: refining increases the economic value of oil, whereas CNG diversification strengthens energy security, improves environmental outcomes, and supports the long-term sustainability of the transportation sector.

As a result, the Nigerian government has established the Ten Years of Gas Strategy (2020-2030) and accompanying programmes such as the National Gas Expansion Programme (NGEP) to transition local energy usage from liquid energy sources to natural gas (Daser-Adams et al., 2025). The drive for natural gas utilisation garnered traction with this government-sponsored programme, which intends to tap into the country's massive gas reserves to fulfil domestic energy demands, diversify the economy, and lessen dependency on petrol and diesel fuels. The achievement of these programmes is strongly dependent on the accessibility and effectiveness of CNG refuelling facilities. Efforts to transition to more sustainable energy sources may fail if there is no effective and accessible infrastructure in place (Oduka et al., 2025).

The adoption of CNG as a transportation fuel gives a dual chance to minimise petroleum importation reliance while also reducing economic strain, particularly on foreign exchange and subsidy spending. There is currently a demand for the introduction of Compressed Natural Gas throughout the country, but if not properly guided, this might become a massive disaster, exacerbating the country's economic condition. There is a necessity for a strategically planned and intentional deployment of CNG to ensure that the population benefits from this natural and readily available resource (Oluwakoya, 2023).

Nigeria's transport industry contributes significantly to economic growth by facilitating the transportation of people and goods around its extensive urban and rural environments. It contributes significantly to national GDP and is a key engine of trade and job creation. However, the transportation industry's dependence on petrol and diesel fuels creates significant problems for the environment, such as greenhouse gas emissions

and rising carbon footprints. Using CNG as a transportation fuel helps reduce dependence on petroleum imports and lowers economic pressure, especially by saving foreign exchange and cutting subsidy costs.

Nigeria's swift deployment of Compressed Natural Gas (CNG) as a viable transportation fuel has been significantly propelled by the Presidential Compressed Natural Gas Initiative (PCNGI) in recent years. This government initiative seeks to diminish reliance on imported petrol and diesel, decrease transportation expenses, and alleviate environmental pollution by advocating for a cleaner, more economical home-grown fuel. By 2025, roughly 68 CNG refuelling stations are operating countrywide, with an expanded network of over 175 stations in construction as part of current facilities enhancement initiatives. The proliferation of CNG conversion centres has significantly increased, with a projected total of 369 centres, offering services for the switch of traditional petrol cars to CNG or dual-fuel systems.

Vehicle adoption has increased in lockstep, with over 100,000 vehicles, comprising buses, cars, and tricycles, being reported to operate on CNG nationwide. This represents an enormous rise above initial estimates and demonstrates the upward trend of public and private sector funding, which has mobilized several hundred million dollars in investments within the sector. The federal government's stated goal for the effort is to switch one million cars to CNG by 2027, which would significantly extend CNG's position in Nigeria's transportation energy mix (Orhuebor et al., 2025). Although there is growing national demand for the adoption of Compressed Natural Gas (CNG) as an alternative transportation fuel, inadequate regulatory oversight, planning, and implementation frameworks could result in significant safety, economic, and operational risks, potentially exacerbating existing macroeconomic challenges (Emeke et al., 2023).

There is a need for a well-planned and purposeful deployment of CNG to guarantee that the population benefits from this natural and available resource. Using CNG as a transportation fuel helps reduce dependence on petroleum imports and lowers economic pressure, especially by saving foreign exchange and cutting subsidy costs. There is currently a demand for the introduction of Compressed Natural Gas throughout the country, but if not properly guided, this might become a massive disaster, exacerbating the country's economic condition. There is a need for a well-planned and purposeful deployment of CNG to guarantee that the population benefits from this natural and available resource.

Nigeria has pledged to decrease its carbon footprint as a contributor to global efforts to tackle global warming through its Nationally Determined Contributions (NDCs) in accordance with the Paris Agreement. Reducing emissions from the

transport industry is a crucial method for attaining these aims. In this setting, CNG has become known as a promising transitional fuel. CNG-powered automobiles have fewer pollutants, better engine efficiency, and cheaper fuel costs. They also have identical refuelling periods and driving ranges as traditional combustion-engine cars, resulting in their being suitable for broad usage (Olujobi, 2024).

Lagos, Nigeria's commercial powerhouse and one of its largest and most populated metropolitan areas, will play a critical role in the shift to CNG-powered cars. The operation of CNG fuelling stations in Lagos is vital to the successful execution of this policy move. The elimination of petrol and diesel subsidies has led to the high cost of traditional fuels, putting a financial strain on households and companies alike. CNG is a cheaper option, projected to be 40 to 60% cheaper than petrol in Nigeria (Abu et al., 2023). Functional refuelling stations can render these savings more tangible and readily available, particularly for public transport providers, intercity carriers, and logistics organisations. When fuelling facilities are operational, fleet operators may include CNG in their company's activities, considerably lowering operating expenses.

Njiran et al. (2022) conducted a comprehensive evaluation of CNG and autogas, as well as the reasons hindering its use in Nigeria. The research investigated the technical adjustments required to increase the use of CNG as a transportation energy source. It also investigated the possibilities of CNG and autogas as vehicle fuels in the transportation industry, employing a strategy for placing priority based on resemblance to the ideal solution. The investigation took into account both life-cycle greenhouse gas emissions and fuel life-cycle performance. In respect to carbon dioxide emissions, CNG and autogas outperformed conventional transport fuel options. According to the research, CNG stations must be made visible and functioning in order for the government's incentive programme to be successful. It further established that expanding CNG stations could help Nigeria achieve its goals of energy security, foreign exchange savings, and economic diversification.

Hamidieh and Ghanbari (2023) examined the necessity to increase CNG refuelling facilities in light of the growing acceptance of dual-fuel automobiles. The research developed an analytical model utilising algorithms for data mining to evaluate the safety of refuelling stations and to create appropriate safety protocols. It also developed a thorough model based on safety criteria obtained from the appropriate research outputs. The data were analysed with the Apriori (projection) and Naive Bayes (grouping) algorithms. The results indicated that Naive Bayes outperformed other methods for determining faults, with a predicted accuracy of 89.3%. The Apriori algorithm identified crisis steps needed to improve CNG station safety. These measures covered environmental and worker safety,

infrastructure and system maintenance, adherence to regulations, and site and traffic safety. Employee and driver safety (65%) and equipment safety (35%), according to the sensitivity assessment, were especially reliant on CNG station safety, with retraining being the most influential safety indicator.

Okoro et al. (2024) examined the storage, transportation, and uses of CNG in Nigeria. It examined the main components and attributes used to evaluate the effectiveness of CNG as a substitute for traditional fuels. The study concluded that the general acceptance of CNG would assist in minimising dependency on scarce petroleum products and avert excessive fuel prices. It was discovered that CNG transmission involves more than just transporting energy from the point of production to the point of use. It also helps address temporary inconsistencies in energy consumption, demonstrating how CNG transportation and storage can work together effectively.

Reji et al. (2025) assessed the performance of CNG as an effective substitute vehicle fuel for reducing CO₂ emissions in Agartala city. The study looked at the energy consumption and emissions of airborne contaminants like nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO₂), and volatile compounds from CNG automobiles. The results show a considerable shift regarding ecological status, leading the study to suggest that using CNG as a vehicle fuel is the most sustainable option for metropolitan transportation and for drastically reducing urban air pollution.

Worldwide, the configuration and operational efficiency of CNG refuelling infrastructure differ, with the choice between time-fill and fast-fill systems significantly affecting vehicle servicing duration. While some established networks have optimised refuelling processes to be equivalent to traditional fuels, in many metropolitan locations, delays and equipment restrictions can cause refuelling times to be longer. Most public CNG stations in Europe use a fast-fill technique that refuels vehicles in under five minutes, a process equivalent to refilling diesel or petrol vehicles (Carbone et al., 2025). According to media reports from India (Bhopal), lines and a lack of active dispensers cause refilling delays of more than 30 minutes, demonstrating that infrastructure capacity has a direct influence on user experience and operational performance in high-demand scenarios (Lakum, 2025).

Maintenance procedures are essential for safe and dependable CNG systems. In many developing nations, preventative maintenance is infrequent, with filling stations and vehicle systems frequently missing strict servicing plans and leak detection checks, increasing the risk of equipment failure and safety issues. In contrast, in industrialised nations such as sections of Europe and North America, periodic maintenance regimens linked with safety requirements such as ISO and NFPA standards are more widely enforced, enhancing

operational dependability and decreasing unscheduled downtime (Raslavičius, 2026). International standards, such as ISO 14469-2:2007 for CNG refuelling connections and NFPA 52 norms in the United States, establish baseline safety and design criteria. However, loopholes in harmonised international rules remain, which might impede uniform safety practice across areas. In Europe, tight vehicle and station regulations have encouraged broad adoption in public transit and business fleets, resulting in strong safety outcomes (Lynch et al., 2021).

The presence of refuelling infrastructure is a fundamental factor influencing CNG uptake. Europe has established one of the most extensive CNG networks globally, comprising more than 4,200 stations that serve approximately 1.5 million CNG vehicles, particularly in countries such as Germany, Italy, and Spain (Raslavičius, 2026). In North America, especially within the United States and Canada, the network is primarily oriented toward fleet and municipal operations along major freight corridors, illustrating infrastructure development driven by emissions control policies and regulatory frameworks (Wanniarachchi, 2024). The Asia-Pacific region dominates in scale, with nations such as India and China representing a substantial share of the global CNG vehicle population, while simultaneously experiencing significant opportunities for network expansion alongside persistent gaps in refuelling coverage (Saurabh and Majumdar, 2022).

Although CNG is widely acknowledged for its environmental and economic advantages, its uptake is chiefly constrained by insufficient refuelling infrastructure, especially in rural and low-demand regions. This inadequacy leads to range anxiety and deters prospective users. A cyclical dilemma emerges in which investors are unwilling to establish new stations without an adequate vehicle base, while consumers are hesitant to convert their vehicles without dependable refuelling availability. Expansion is further limited by the substantial upfront capital required for compressors, storage vessels, dispensers, and safety installations. In addition, the cost of conversion kits and access to specialized maintenance services can impose a significant financial burden on private vehicle owners and small-scale operator (Mitrică, 2023).

Public safety perceptions likewise affect adoption rates. Although robust regulatory frameworks established by organizations such as the International Organization for Standardization and the National Fire Protection Association provide comprehensive technical and operational guidelines, lingering concerns about the handling of high-pressure gas systems can hinder broader public acceptance. In Europe, the combination of an extensive refuelling network and strict regulatory enforcement has encouraged greater uptake, whereas North America's emphasis on fleet operations and cross-border transport corridors has promoted more targeted and strategic expansion

(Kulušić et al., 2024). The rapid urbanization and extensive vehicle fleets in Asia have fuelled substantial growth in CNG vehicle numbers, yet the region continues to contend with significant infrastructure and logistical constraints (Saurabh and Majumdar, 2022).

This research looks at the present situation of CNG refuelling stations in Lagos, Nigeria, with an emphasis on their functioning. Functionality, in this sense, relates to how well these stations satisfy operating requirements, meet user expectations, assure safety, and offer dependable service. Key characteristics assessed in the study include service availability and accessibility, equipment maintenance, personnel training, and user happiness. Understanding the operation of these facilities is critical not only for evaluating the efficacy of present expenditures, but also for identifying potential and obstacles for increasing CNG usage in Nigeria's transportation sector. Furthermore, this study aims to help execute national energy policies by giving factual knowledge on the strengths and shortcomings of Lagos' existing CNG infrastructure.

Methodology

This study used a qualitative research approach to investigate the functional status and challenges facing CNG fuelling stations in Lagos. To capture the multifaceted reality of infrastructure development and delivery of services in a growing urban setting, field-survey, observational, and interview-driven methodologies were employed. This technique is excellent for investigating interpersonal interactions, organisational dynamics, and environmental impacts that solely quantitative approaches are unlikely to capture (Worika and Thomas, 2024).

Study Area

The study took place at five operational CNG refuelling stations in significant urban and peri-urban districts of Lagos State, Nigeria. Lagos was chosen because of its high vehicle density, significance in Nigeria's energy transformation plans, and reasonably mature in CNG usage. The areas include both high-traffic business districts and key energy routes with gas infrastructure.

Sampling and Site Selection

The research locations and participants were selected using a purposive sampling approach. The five CNG refuelling stations, designated as Stations A, B, C, D, and E, were chosen based on their operational functionality, geographical diversity across the Lagos metropolis, participation in the National Gas Expansion Programme, and management's willingness to grant access to interviews and site visits. The station names have

been anonymised to protect the organisations' identities and commercial confidentiality.

Data Collection Methods

Over a six-week period, data were collected via semi-structured interviews, field surveys, and documentary evaluation. The interviews were performed with station managers and lead technicians at each selected location. There were 16 interviewees in all. The interviews discussed operating methods, infrastructure problems, safety standards, customer usage patterns, and regulatory compliance. The use of broad enquiries enabled respondents to comment on their encounters and thoughts, resulting in rich, detailed data. To support the interview data, direct observations were conducted across all selected locations. These focused on equipment type and condition, safety protocols, refuelling procedures, customer interactions, environmental cleanliness, and station layout. Relevant secondary sources, including best practice standards from the International Gas Union (Austvik, 2016; Worika and Thomas, 2024), provided context for the primary data. These references helped evaluate Nigeria's CNG facilities against global standards and practices.

Average Refuelling Time

Average refuelling time (ART) per vehicle was assessed to evaluate operational efficiency and throughput at each CNG station. Data were collected by directly timing multiple refuelling events across peak and off-peak hours, complemented by station records where available. The ART in minutes was quantified as (Kelley and Kuby, 2017):

$$ART = \frac{\text{sum of refuelling time for all vehicles}}{\text{total number of vehicles refuelled}} \quad (1)$$

Average Daily Vehicles Refuelled

Average daily vehicles refueled (ADVR) was assessed to evaluate station throughput and operational capacity. Data were collected from station logbooks, automated dispenser counters, and direct observation over the assessment period. The total number of vehicles refuelled each day was recorded, and the average daily refuelling rate per station was calculated as (Kelley and Kuby, 2017):

$$ADVR = \frac{\text{total vehicles refuelled within assessed period}}{\text{number of operating days within assessed period}} \quad (2)$$

Daily Safety Inspections

Daily safety inspection (DSI) compliance was evaluated to determine the proportion of operating days on which documented safety inspections were conducted at each CNG station. Data were collected through review of daily inspection logs, maintenance records, and supervisor sign-off sheets, comple-

mented by brief staff interviews. Inspections were considered valid where routine checks of dispensers, compressors, gas leakage indicators, emergency shutdown systems, and fire protection equipment were formally recorded in line with applicable safety guidelines. DSI's compliance was quantified as (Widodo et al., 2024):

$$DSI = \frac{\text{inspection days within assessed period}}{\text{operating days within assessed period}} \quad (3)$$

Refuelling Protocol Compliance

Refuelling protocol compliance (RPC) was assessed to determine adherence to established CNG refuelling procedures and safety steps during dispensing operations. An observational checklist was used to monitor critical actions such as engine shutdown, prohibition of mobile phone use, proper nozzle connection, leak checks, and safe disconnection after refuelling. Observations were conducted across multiple refuelling events at each station to ensure consistency and reliability. RPC was quantified as (Garba and Musa, 2024):

$$RPC = \frac{\text{refuelling events that followed protocol}}{\text{total observed refuelling events}} \times 100\% \quad (4)$$

Equipment Maintenance Compliance

Equipment maintenance compliance (EMC) was assessed to determine the extent to which routine and preventive maintenance activities for critical CNG infrastructure, such as compressors, dispensers, storage cascades, valves, and emergency shutdown systems, were conducted in accordance with prescribed schedules. Data were obtained through review of maintenance logs, service reports, manufacturer-recommended maintenance schedules, and verification of documented corrective actions. Compliance focused on whether inspections, servicing, calibration, and component replacements were performed within the stipulated timeframes during the assessment period. EMC was quantified as (Bangun et al., 2022):

$$EMC = \frac{\text{completed scheduled maintenance activities}}{\text{total scheduled maintenance activities}} \times 100\% \quad (5)$$

Emissions Control Compliance

Emissions control compliance (ECC) was assessed to determine the extent to which CNG stations implemented measures to minimize and monitor gaseous emissions, including methane leak detection, compressor seal integrity, vent management, and adherence to environmental protection requirements. Data were obtained through review of environmental monitoring records, leak detection logs, maintenance reports, and on-site verification of gas detection systems and ventilation controls. Compliance was evaluated based on the availability, functionality, and documented monitoring of emissions control

mechanisms within the assessment period. ECC was quantified as (Mustafi and Agarwal, 2020):

$$ECC = \frac{\text{emissions control measures implemented}}{\text{required emissions control measures}} \times 100\% \quad (6)$$

Staff Training Compliance

Staff training compliance (STC) was assessed to determine the proportion of personnel adequately trained in CNG safety, emergency response, and operational procedures. Data were obtained through structured interviews with station managers and review of training records. For each station, the total number of operational staff was documented alongside the number who had received formal CNG safety training within the last 24 months in accordance with guidelines of the Nigerian Midstream and Downstream Petroleum Regulatory Authority and relevant safety standards. The STC was quantified as (Morgado et al., 2019):

$$STC = \frac{\text{number of staff trained}}{\text{total operational staff}} \times 100\% \quad (7)$$

Visibility of Safety Signage

A checklist based on guidelines from the Nigerian Midstream and Downstream Petroleum Regulatory Authority, Standards Organisation of Nigeria, National Fire Protection Association (NFPA), and International Organization for Standardization, ISO 7010 (Morgado et al., 2019) was used for assessment. Key areas assessed included the station entrance, dispensing area, compressor house, and emergency facilities. Signage was inspected for presence, visibility, legibility, and proper placement. Compliance was rated on a three-point scale: 2 for fully compliant, 1 for partially compliant and 0 for absent. The percentage Visibility of Safety Signage (VSS) was calculated as (Morgado et al., 2019):

$$VSS = \frac{\text{total score obtained}}{\text{maximum possible score}} \times 100\% \quad (8)$$

User Satisfaction

User satisfaction was assessed to evaluate customers' perception of service quality, safety, waiting time, refuelling efficiency, and overall experience at each CNG station. Data were collected using structured Data were obtained through structured interviews with users immediately after refuelling. User satisfaction level was quantified as (Salehin et al., 2024):

$$\text{user satisfaction} = \frac{\text{satisfied responses}}{\text{total valid responses}} \times 100\% \quad (9)$$

Monthly Operational Downtime

Monthly operational downtime (MOD) was assessed to evaluate the reliability and service continuity of each CNG station. Data were obtained from operational logs, maintenance

records, and incident reports documenting periods when refuelling services were completely unavailable due to equipment failure, maintenance activities, power outages, or safety-related shutdowns. The total downtime duration within each calendar month was computed in hours and related to the total scheduled operating hours for that month. The MOD frequency was quantified as (Morgado et al., 2019):

$$MOD = \frac{\text{total downtime hours in the month}}{\text{total monthly scheduled operating hours}} \quad (10)$$

Data Analysis

Thematic analysis was used to analyse the qualitative data acquired from interviews and field notes, which included familiarising with the data, creating initial codes, looking for themes, evaluating themes, defining and identifying themes, and writing the report (Ahmed et al., 2025). The following themes emerged: infrastructure dependability, regulatory compliance, technician skill, public trust and adoption, and operational issues. Comparative assessments were also carried out across stations to discover variances in performance and compliance with safety and operational norms.

Data from secondary sources were triangulated with field results to establish reliability and corroborate patterns seen in the original data. The study guaranteed ethical compliance during data collection and analysis by implementing methods such as informed consent, voluntary participation, and data protection. In addition, coded identities such as Stations A through E were used to guarantee the secrecy and identity of persons and organisations. The findings are presented visually, using bar charts and tables to show trends in station effectiveness, regulatory compliance, and service dependability.

Results and discussion

Refuelling Efficiency of CNG Stations

Average Refuelling Time per Vehicle

The average time required to refuel one vehicle at each station was used to evaluate refuelling effectiveness. As shown in Figure 1, operational efficiency varies among the five stations. Station C is consistent with global averages of 3 - 5 minutes for fully equipped stations (Sgaramella et al., 2024). Stations A and E (6 minutes) and Station B (7 minutes) are moderately efficient, exceeding the ≤5-minute benchmark by 1 – 2 minutes. Station D (9 minutes) is non-compliant, exceeding the benchmark by 4 minutes. Operationally, shorter refuelling times reflect efficient compressor performance, stable pressure delivery, and competent staff handling, which enhance throughput and customer turnover. Longer refuelling times,

particularly at Station D, may indicate compressor inefficiency, high operational load, inadequate maintenance, or procedural delays. Reduced efficiency lowers daily vehicle capacity, increases equipment strain, and can raise maintenance costs. These results suggest the need for technical and operational improvements at some stations, especially Station D, to optimize service delivery in Lagos.

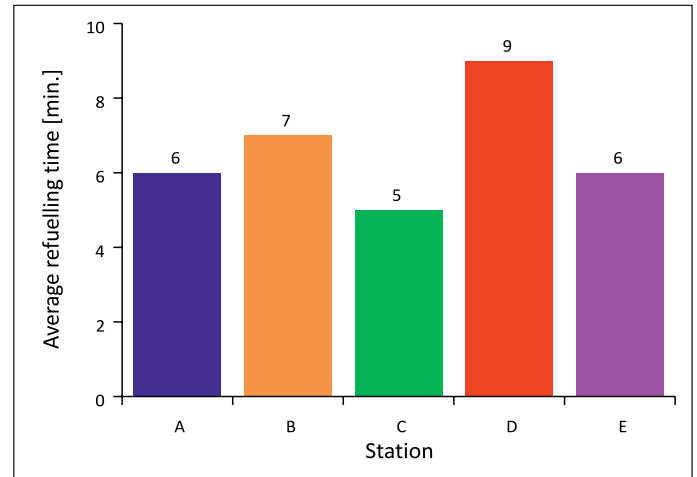


Figure 1. Average refuelling time per vehicle at CNG stations

Average Daily Refuelling Activity

Figure 2 depicts the average number of vehicles refuelled each day at the five stations examined. The figure shows that Stations C, E, and A operate at high capacity (≥100 vehicles/day) and are fully compliant with the study benchmark. Stations D and B (60 and 92 vehicles/day, respectively) are non-compliant with the ≥100 benchmark. Higher vehicle volumes reflect stronger operational performance, efficient refuelling processes, reliable compressors, and effective staff coordina-

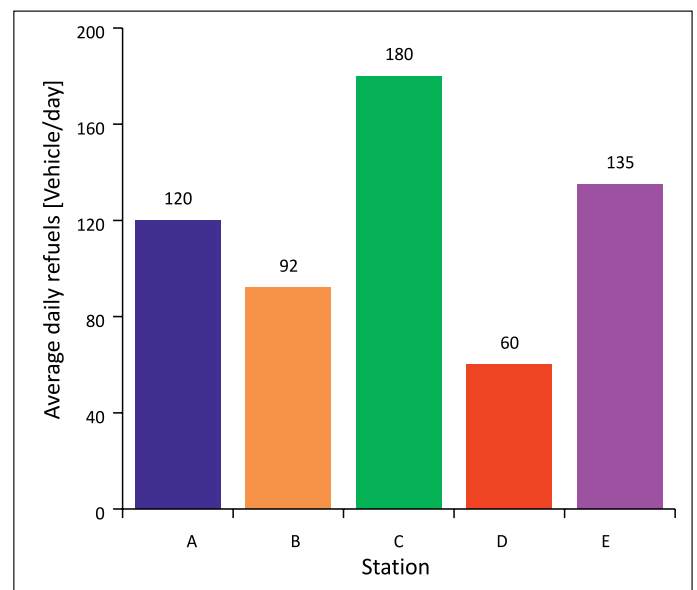


Figure 2. Average daily refuelling activity

tion. Station C demonstrates superior throughput and high utilization, while the lower-volume Stations D and B suggest possible operational constraints, such as limited compressor efficiency, lower demand, downtime, or procedural inefficiencies. High throughput increases revenue potential but may elevate maintenance demands due to equipment loading. The disparities in functional capacity among Lagos CNG stations indicate uneven operational efficiency across facilities.

Operational Standards and Safety Compliance

Daily Safety Inspection

The daily safety inspection results, shown in Figure 3, depict variation in safety oversight across the stations. Station C is fully compliant, exceeding the $\geq 80\%$ benchmark by 10%. Stations A and E are moderately compliant but fall short by 10 and 5%, respectively. Station B is non-compliant, falling 25% below the benchmark, while Station D is critically non-compliant, indicating a complete absence of documented inspections. Frequent inspections support early fault detection, stable compressor performance, and uninterrupted service delivery. Higher compliance (Station C) suggests stronger operational control and a lower risk of unplanned downtime. Poor compliance exposes stations to undetected leaks, equipment failure, safety incidents, and higher corrective maintenance costs. These results indicate uneven safety management across Lagos CNG stations, directly affecting reliability, throughput, and overall operational sustainability.

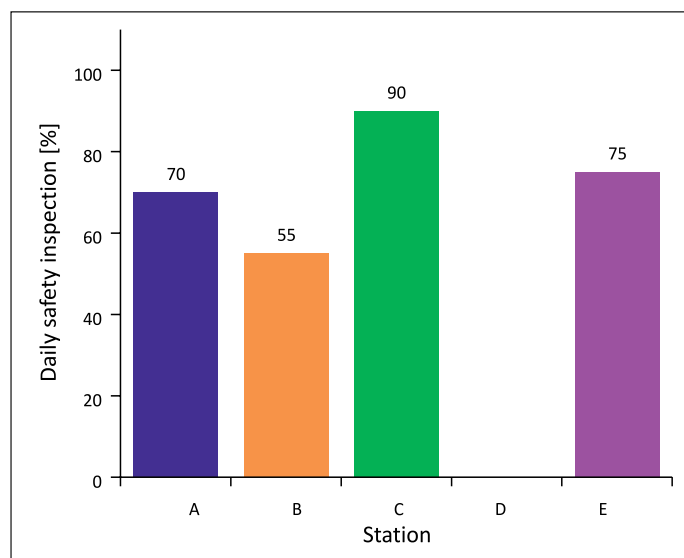


Figure 3. Daily safety inspection

Refuelling Protocol

The refuelling protocol results, shown in Figure 4, reveal varying levels of procedural adherence across the five CNG

stations assessed in Lagos. Stations E and C are fully compliant with the $\geq 80\%$ benchmark, demonstrating strong adherence to prescribed safety steps, such as engine shutdown before refuelling, proper nozzle connection, leak checks, grounding, and prohibition of mobile phone use (Garba and Musa, 2024). This level of compliance supports efficient operations, reduces the risk of accidents, and reflects well-trained staff and effective management oversight. Stations B, A, and D are non-compliant, falling 15–20% below the recommended standard. These lower values suggest occasional deviations from safe refuelling procedures, arising from gaps in staff training, high workload during peak periods, inconsistent supervision, and lapses in following standard operating procedures. Such lapses increase the likelihood of gas leaks, equipment damage, emergency shutdowns, and operational delays.

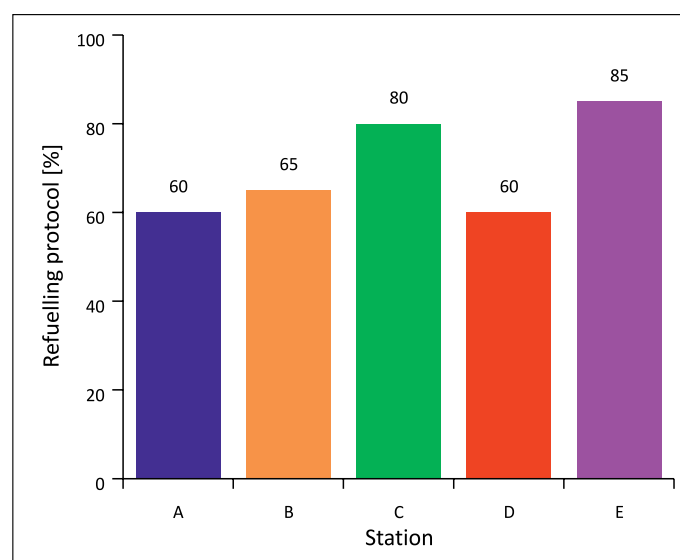


Figure 4. Refuelling protocol

Equipment Maintenance

Figure 5 shows equipment maintenance compliance across the five CNG stations. The results reveal that Station C is fully compliant with the $\geq 80\%$ benchmark, reflecting well-maintained compressors, dispensers, and safety systems. Stations E, A, and B are moderately compliant, falling 10–20% below the standard, while Station D is critically non-compliant, 40% below the benchmark. Operationally, high compliance supports reliable refuelling, minimal downtime, and safer handling of high-pressure gas. Moderate compliance indicates occasional equipment faults that may reduce throughput and increase corrective maintenance, while poor compliance at Station D raises significant safety and operational risks. Variations stem from station load, preventive maintenance culture, staff competence, and management oversight. Only Station C fully meets the recommended standards of the Nigerian Midstream and Downstream Petroleum Regulatory Authority, highlighting

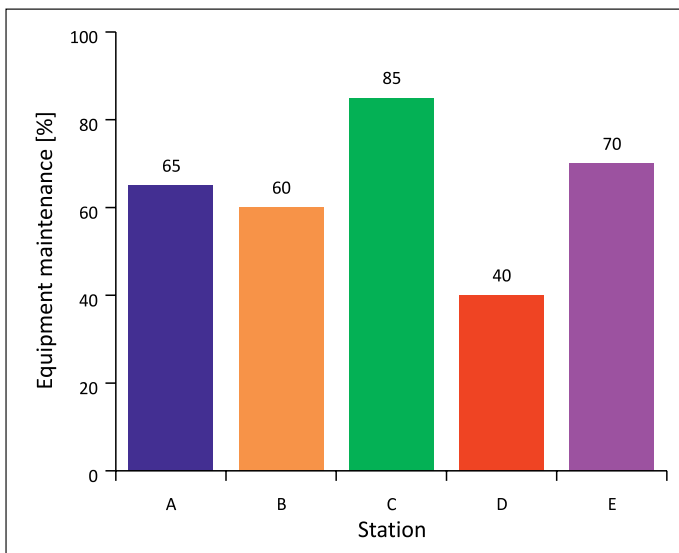


Figure 5. Equipment maintenance

the need for strengthened maintenance practices across Lagos CNG stations.

Emissions Control

The emissions control results, shown in Figure 6, reveal serious deficiencies across the five CNG stations. Only Station C, which has a leak detection system installed, demonstrates partial compliance, falling 30% below the $\geq 80\%$ benchmark, while Stations A, B, D, and E are entirely non-compliant. This indicates poor monitoring of gas leaks and ineffective environmental management, which can reduce throughput and increase safety risks. The absence of effective emissions control elevates the risks of fire, explosion, and costly corrective maintenance. These findings highlight a major functional gap in Lagos CNG stations, emphasizing the urgent need for effective emissions monitoring systems to ensure safe and sustainable operations.

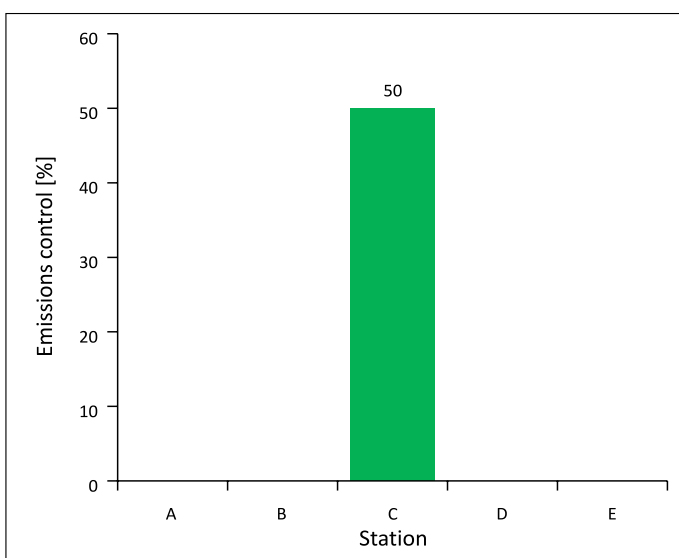


Figure 6. Emissions control

Staff Training Compliance

Figure 7 illustrates staff training compliance across the five stations. The results reveal that Station C is fully compliant, Station E is moderately compliant (5% below the 80% benchmark), and Stations A, B, and D are non-compliant, falling 25, 30, and 40% below the recommended 80% threshold, respectively. These findings indicate that operational effectiveness is strongly influenced by staff competence, not just infrastructure. Operationally, low training coverage (particularly in Stations A, B, and D) suggests a higher risk of procedural errors, weak emergency response, and inconsistent maintenance practices, potentially reducing throughput and increasing downtime. Higher compliance in Stations C and E supports safer refueling operations, quicker fault detection, and better equipment handling. The variations may arise from differences in management commitment, workload, staff turnover, and adherence to the guidelines of the Nigerian Midstream and Downstream Petroleum Regulatory Authority. The inadequate training in most stations may constrain safety performance, increase maintenance costs, and limit sustainable operational functionality.

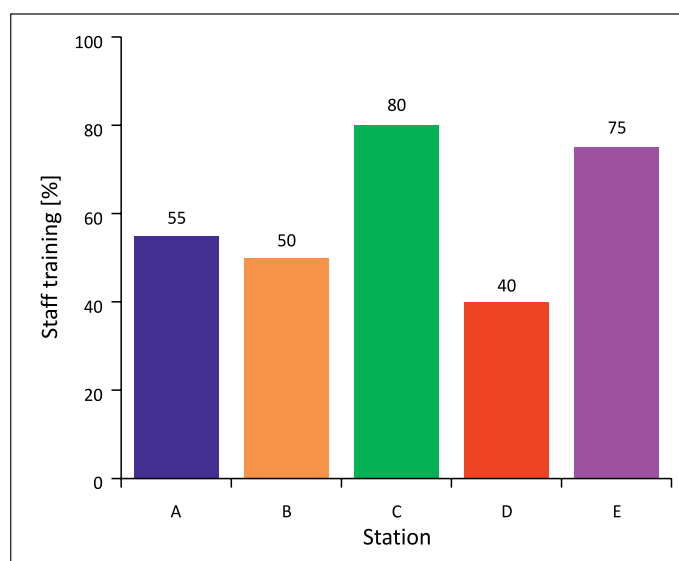


Figure 7. Staff training

Visibility of Safety Signage

Figure 8 depicts safety signage visibility across the five CNG stations. The results show that Stations C and E exceed the $\geq 80\%$ benchmark, while Stations A, B, and D meet the minimum standard. High signage visibility ensures that staff and customers are aware of hazards, emergency procedures, and operational rules, thereby supporting safe and efficient station operations. Minor variations may arise from signage placement, maintenance practices, staff awareness, and exposure to weather conditions. Adequate signage reduces accidents, operational errors, and downtime, whereas poorly maintained or missing signs can increase safety risks and maintenance

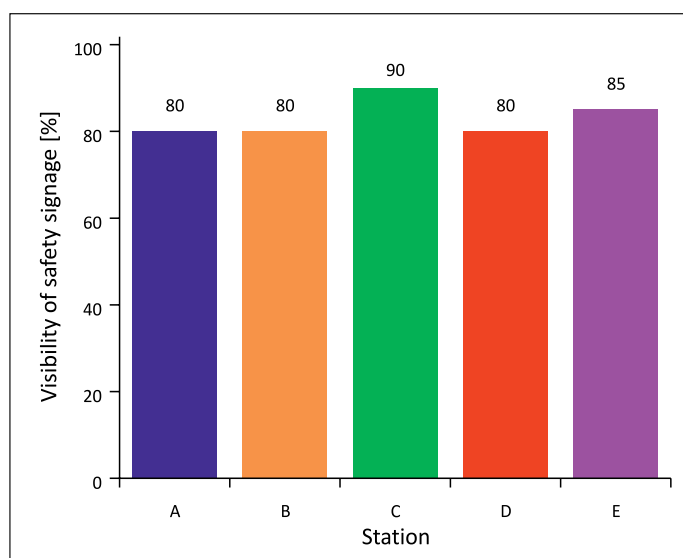


Figure 8. Visibility of safety signage

costs. The stations demonstrate functional compliance with the Nigerian Midstream and Downstream Petroleum Regulatory Authority guidelines (Ambituuni et al., 2014) and the safety sign specifications of ISO 7010 (Wogalter, 2006).

User Satisfaction

The results of user satisfaction across the five CNG stations are presented in Figure 9. As shown, Stations C and E are fully compliant with the $\geq 80\%$ benchmark, reflecting efficient operations, safe procedures, and competent staff. Stations B and A are moderately satisfactory, falling 10 - 20% below the standard, while Station D is poorly rated, at 30% below the benchmark. High satisfaction indicates smooth refuelling, minimal waiting time, and reliable service, thereby supporting throughput and operational efficiency. Lower satisfaction suggests procedural lapses, slower refuelling, or weaker staff

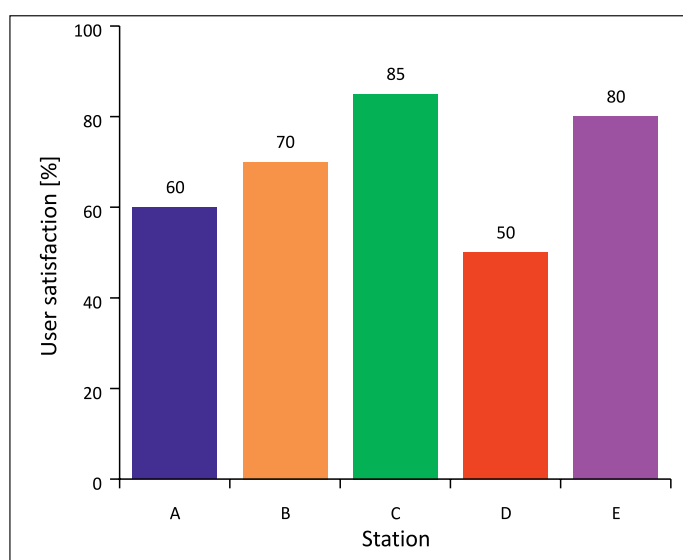


Figure 9. User satisfaction

performance, which may reduce customer confidence and increase maintenance or operational costs. These results show that only Stations C and E meet the standards of the Nigerian Midstream and Downstream Petroleum Regulatory Authority, highlighting the need for service improvements in the other stations to enhance functionality, safety, and customer trust in CNG refuelling services.

Monthly Operational Downtime

Figure 10 illustrates the results of monthly operational downtime across the five CNG stations. As shown, Station C (4%) is fully compliant with the $\leq 5\%$ benchmark, demonstrating high reliability and stable operations. Stations E and A fall within the moderately reliable range (6 - 10%), exceeding the optimal 5% target by 1.5 and 3.5%, respectively. Stations B and D are non-compliant, exceeding the optimal threshold by 12 and 18%, respectively. Lower downtime reflects efficient maintenance practices, reliable compressors, and competent operational management, which directly support station functionality and throughput. Conversely, higher downtime suggests frequent equipment failure, poor maintenance culture, or operational inefficiencies, leading to reduced daily refuelling capacity and increased corrective maintenance costs. Only Station C meets the recommended reliability standard consistent with the Nigerian Midstream and Downstream Petroleum Regulatory Authority.

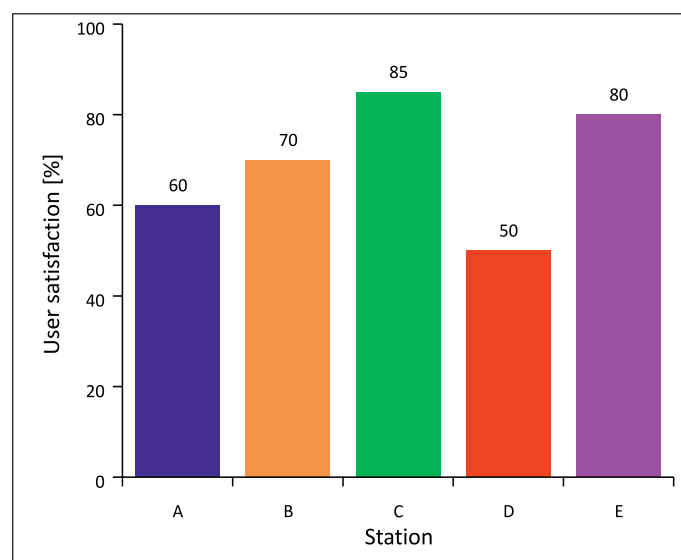


Figure 10. Monthly operational downtime

Comparison of Functional Efficiency of Lagos' CNG Stations with International Benchmark

Figure 11 compares the functional efficiency of Lagos' CNG with international benchmark across five major operational metrics. These findings indicate major inefficiencies and compliance shortcomings. The average refuelling duration at

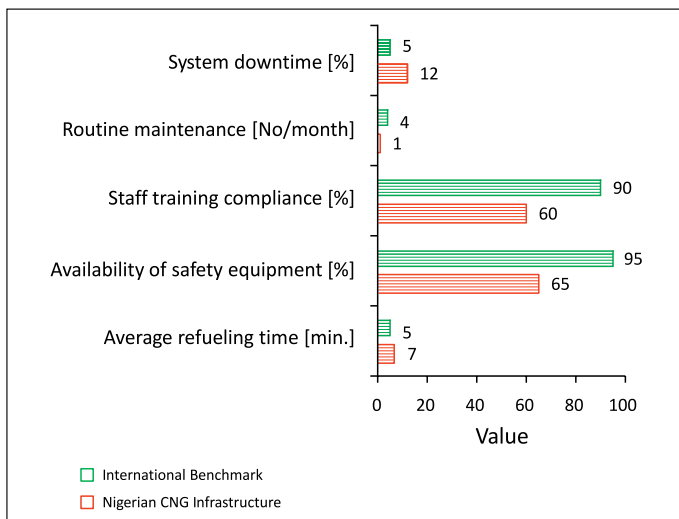


Figure 11. Functional efficiency of Lagos CNG stations against international benchmarks

the chosen Nigerian CNG stations is 7 minutes, which exceeds the worldwide requirement of 5 minutes, potentially leading to service delays and consumer discontent. The average availability of safety equipment is 65%, compared to the worldwide standard of 95%, suggesting inadequate emergency readiness and increased risk exposure.

As observed in Figure 11, staff training compliance is severely low at 60%, well below the international benchmark of 90%, jeopardising operational safety and competency in handling high-risk equipment. Furthermore, routine maintenance is only conducted once a month at Nigerian stations, as opposed to the necessary four times, resulting in increased failure rates and equipment degradation. Most dangerously, the average system downtime at analysed stations is 11.8%, over two times the international benchmark of 5%, indicating serious reliability difficulties. These problems, taken together, impede functional efficiency, and safety of the CNG system. Addressing these gaps via targeted investments, policy enforcement, and capacity development is critical to ensuring operational excellence and supporting Nigeria's overall transition to greener energy.

Conclusion

Lagos' CNG stations are functional but insufficient to accommodate the anticipated shift. The study finds considerable differences in the operational performance and safety compliance of CNG refuelling in the five assessed stations in Lagos, Nigeria. Station C regularly displayed exceptional functional efficiency, reaching major international criteria for average refuelling time, daily vehicle throughput, and operational dependability. Stations B and D, on the other hand, performed

poorly, with long fuelling times, insufficient maintenance, and frequent operational outages. Station D, in particular, had the lowest performance across the board, including safety compliance, personnel training, and pollution control measures. The inclusion of a leak detection system in Station C, despite the lack of methane capture capabilities, represents a modest but respectable effort at environmental responsibility. The widespread non-compliance in emissions monitoring and the variability in daily safety inspections indicate systemic weaknesses in preventive safety culture. Similarly, moderate staff training and maintenance compliance in several stations suggest that human and technical capacity gaps limit sustainable functionality.

From a regulatory standpoint, only a minority of stations consistently met the recommended benchmarks aligned with the Nigerian Midstream and Downstream Petroleum Regulatory Authority guidelines. This implies that while CNG infrastructure expansion in Lagos shows promising operational potential, full functional integrity in terms of integration of efficiency, safety, reliability, and environmental responsibility has not yet been uniformly achieved. When compared to international benchmarks, Lagos CNG infrastructure shows significant shortcomings in important areas. Strengthening these areas would not only align Nigeria with global best practices, but will also speed up the country's transition to a cleaner, more sustainable energy future

Generative AI statement

The authors declare that they used artificial intelligence (AI) tools (QuillBot and Grammarly) solely for language editing purposes, specifically to improve grammatical accuracy and enhance the fluency of the article. These tools were not used in the development, analysis, interpretation, or presentation of the scientific content. All scientific ideas, data analyses, interpretations, and conclusions presented in this article are entirely the original work of the authors.

References

- Abbasi K. R., Zhang, Q., Ozturk I., Alvarado R., Musa M., 2024. Energy transition, fossil fuels, and green innovations: Paving the way to achieving sustainable development goals in the United States. *Gondwana Research*, 130, 326–341. DOI: 10.1016/j.gr.2024.02.005.
- Abu R., Patchigolla K., Simms, N., 2023. A Review on Qualitative Assessment of Natural Gas Utilisation Options for Eliminating Routine Nigerian Gas Flaring. *Gases*, 3(1), 1–24. DOI: 10.3390/gases3010001.
- Achakulwisut P., Erickson P., Guivarch C., Schaeffer R., Brutschin E., Pye S., 2023. Global fossil fuel reduction pathways under different climate mitigation strategies and ambitions. *Nature Communications*, 14(1), 5425. DOI:10.1038/s41467-023-41105-z.
- Ahmed S.K., Mohammed R.A., Nashwan A.J., Ibrahim R.H., Abdalla A.Q., M. Ameen B.M., Khdir R.M., 2025. Using thematic

- analysis in qualitative research. *Journal of Medicine, Surgery, and Public Health*, 6, 100198. DOI: 10.1016/j.gmedi.2025.100198.
- Ambituuni A., Amezaga J., Emeseh E., 2014. Analysis of safety and environmental regulations for downstream petroleum industry operations in Nigeria: Problems and prospects. *Environmental Development*, 9, 43–60. DOI: 10.1016/j.envdev.2013.12.002.
- Andah R.A., Guttena R.K., 2025. The Dangote Refinery: pioneering Africa's energy independence amid challenges. *Emerald Emerging Markets Case Studies*, 15(4), 1–8. DOI: 10.1108/EEMCS-02-2025-0078.
- Austvik O.G., 2016. The Energy Union and security-of-gas supply. *Energy Policy*, 96, 372–382. DOI: 10.1016/j.enpol.2016.06.013.
- Bangun C., Jalil A., Amperajaya D., Rasjadin R., 2022. Preventive Maintenance Scheduling with Age Replacement Method at CNG Station. *Aptisi Transactions on Technopreneurship (ATT)*, 4(2), 153–163. DOI: 10.34306/att.v4i2.260.
- Carbone C., Sanzò N., Dorsini R., Nigliaccio G., Di Florio G., Cigolotti V., Agostini A., 2025. An economic and environmental assessment of different bus powertrain technologies in public transportation. *Cleaner Environmental Systems*, 16, 100250. DOI: 10.1016/j.cesys.2024.100250.
- Emeke C., Chijioke N., Nteegah A., 2023. A Techno-Economic Analysis of Using Natural Gas as Alternative Transport Fuel in Nigeria. *Journal of Energy Technology and Environment*, 5(2). DOI: 10.5281/zenodo.8025661.
- Daser-Adams J.L., Ogundari I.O., Owolabi H.A., Lawal O.R., Adebajji O.T., Adedigba S.A., Ademiluyi D.D., Ademiju A.I., Malomo B.O., 2025. Compressed Natural Gas Utilization in Nigeria's Transport Sector: Fuel Balance, Economics and Environmental Considerations. *Journal of Energy Research and Reviews*, 17(3), 34–41. DOI: 10.9734/jenrr/2025/v17i3400.
- Garba U., Musa M., 2024. An overview of key safety concerns and sustainability of CNG retrofitted vehicles in Nigeria. *Fudma Journal of Sciences*, 8(6), 264–270. DOI: 10.33003/fjs-2024-0806-2921.
- Hamidieh A., Ghanbari M., 2023. *Developing a Decision Model for Enhancing the Safety of CNG Stations Using Data Mining and Safety Indicators Classification*. DOI: 10.21203/rs.3.rs-3256371/v1.
- Kelley S., Kuby M., 2017. Decentralized refueling of compressed natural gas (CNG) fleet vehicles in Southern California. *Energy Policy*, 109, 350–359. DOI: 10.1016/j.enpol.2017.07.017.
- Kulušić I., Jukić L., Smajla I., and Karasalihović Sedlar, D., 2024. The Role of Natural Gas in the Socio-Technical Transition to a Carbon-Neutral Society and a Review of the European Union's Framework. *Sustainability*, 16(9), 3791. DOI: 10.3390/su16093791.
- Lakum M., 2025. Narratives of transport transitions: the shift from diesel and petrol to Compressed Natural Gas in Delhi (1980–2012). *Cities and Health*, 9(5), 799–808. DOI: 10.1080/23748834.2025.2536414.
- Lynch L.A., Browning L., Snelling A., 2021. *Evaluation of Safety Standards for Fuel System and Fuel Container Integrity of Alternative Fuel Vehicles*. <https://www.nrel.gov/docs/fy21osti/77455.pdf>. (access: 17.04.2026).
- Mitrică E., 2023. Economic analysis of the initial investment for intermediary introduction of compressed natural gas in Romania. *Energy for Sustainable Development*, 76, 101270. DOI: 10.1016/j.esd.2023.101270.
- Morgado L., Silva F.J.G., Fonseca L.M., 2019. Mapping Occupational Health and Safety Management Systems in Portugal: outlook for ISO 45001:2018 adoption. *Procedia Manufacturing*, 38, 755–764. DOI: 10.1016/j.promfg.2020.01.103.
- Mustafi N.N., Agarwal A.K., 2020. Combustion and Emission Characteristics, and Emission Control of CNG Fueled Vehicles. [In:] *Energy, Environment, and Sustainability*, 201–228. DOI: 10.1007/978-981-15-0418-1_12.
- Neumann T., 2025. Green Energy Fuelling Stations in Road Transport: Poland in the European and Global Context. *Energies*, 18(15), 4110. DOI: 10.3390/en18154110.
- Njiran O.-O.E., Ajienka J.A., Okoro F., 2022. Performance Evaluation of Transportation Fuel Technologies from Natural Gas-A Comparative Analysis. *International Journal of Latest Technology in Engineering, Management and Applied Science (IJLTEMAS)*, 11(2), 19–25.
- Odoi N.U., Joel O.F., Ikiensikimama S.S., Jacob N.B., 2022. Simulation of natural gas infrastructure for CNG and LPG recovery – a case study. *African Journal of Engineering and Environment Research Vol*, 4(1), 73–100.
- Oduka U., Odotola T., Oriji A., 2025. Impact of Domestic Natural Gas Utilization on the Power Sector in Nigeria. *American Journal of Energy Engineering*, 13(1), 9–22. DOI: 10.11648/j.aje.20251301.12.
- Okafor C.C., Madu C.N., Nwoye A.V., Nzekwe C.A., Otunomo F.A., Ajaero C.C., 2025. Research on Climate Change Initiatives in Nigeria: Identifying Trends, Themes and Future Directions. *Sustainability*, 17(9), 3995. DOI: 10.3390/su17093995.
- Okoro E.E., Aimikhe V.J., Sanni S.E., Ogali O.I.O., 2024. Compressed natural gas storage and transmission. [In:] *Advances in Natural Gas: Formation, Processing, and Applications. Volume 6: Natural Gas Transportation and Storage*, 81–106. Elsevier. DOI: 10.1016/B978-0-443-19225-8.00011-1.
- Olujobi O.J., 2024. Nigeria's Climate Change Act 2021: A pathway to net-zero carbon emission, energy security and sustainability. *Environmental Science and Pollution Research*, 31(25), 36834–36848. DOI: 10.1007/s11356-024-33347-1.
- Oluwakoya A., 2023. A comprehensive assessment of transportation emissions in Nigeria: Trends, drivers, and impacts. *Proceedings of the Nigerian Academy of Science*, 16(1s), 61–71. DOI: 10.57046/BQUV9709.
- Omorieg U., 2019. Nigeria's Petroleum Sector and GDP: The Missing Oil Refining Link. *Journal of Advances in Economics and Finance*, 4(1). DOI: 10.22606/jaef.2019.41001.
- Orhuebor E.N., Isangadighi G.E., Akpololohor C., Akinboboye R., 2025. Data-Driven Techno-Economic and Environmental Assessment of Compressed Natural Gas (CNG) Vehicles as a Source of Transportation in Nigeria. *European Journal of Applied Science, Engineering and Technology*, 3(5), 142–152. DOI: 10.59324/ejaset.2025.3(5).12.
- Raslavičius L., 2026. The Prerequisites for Development of LNG/CNG Filling Stations Network: The Crucial Role of Lithuania and the Baltic States in the North Sea–Baltic Sea Corridor. *Infrastructures*, 11(2), 45. DOI: 10.3390/infrastructures11020045.
- Reji A.K., Das B., Ray T.K., Boral E., 2025. Assessment of compressed natural gas as an alternative transportation fuel in reducing CO₂ emission: a case of Agartala city. *Environment, Development and Sustainability*. DOI: 10.1007/s10668-024-05777-x.
- Salehin M.S., Jubailee T., Sourav M.M.I., Afnanin S., Muniruzzaman S.M., 2024. A structural equation modeling approach to understand users' perceptions of app-based CNG autorickshaw services in Dhaka City. *Journal of Engineering and Applied Science*, 71(1), 32. DOI: 10.1186/s44147-024-00368-z.
- Saurabh K., Majumdar R., 2022. Fuels for Sustainable Transport in India, 27–55. DOI: 10.1007/978-981-16-8747-1_3.
- Sgaramella A., Pastore L.M., Lo Basso G., Mojtahed A., de Santoli, L., 2024. HCNG refuelling station to accelerate the transition towards a real hydrogen economy: A techno-economic analysis. *International Journal of Hydrogen Energy*, 69, 1403–1416. DOI: 10.1016/j.ijhydene.2024.05.145.
- Wanniarachchi S.T., 2024. Refueling infrastructure and policy planning for hydrogen-powered road freight transportation in Canada:

a life cycle thinking approach [University of British Columbia].
DOI: 10.14288/1.0447586.

Widodo E.M., Munahar S., Zada N.A., 2024. Inspection scheduling decision model at CNG charging station using risk-based inspection (RBI) method. *BIS Energy and Engineering*, 1, V124022. DOI: 10.31603/biseeng.70.

Wogalter M.S., 2006. ISO design standards for safety signs and labels. [In:] *Handbook of Warnings*, 485–491. CRC Press.

Worika I.L., Thomas C.N., 2024. International Institutions of the Oil and Gas Industry: A Critical Examination. *International Journal*

of Human Research and Social Science Studies, 1(4), 78–86. <https://ijhrsss.com/articles/44>.



Bukola Olalekan BOLAJI, Ph.D.
Professor at the Department of Mechanical Engineering
Faculty of Engineering, Federal University Oye Ekiti.
PMB 373, Oye Ekiti, Nigeria
E-mail: bukola.bolaji@fuoye.edu.ng



Deborah Olufunke BOLAJI, M.Eng.
Lecturer at the Department of Mechanical Engineering
Faculty of Engineering, Federal University Oye Ekiti
PMB 373, Oye Ekiti, Nigeria
E-mail: deborah.bolaji@fuoye.edu.ng



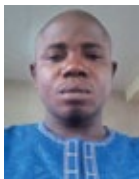
Israel Adebayo OLUMOROTI, M.Eng.
Lecturer at the Department of Mechanical Engineering
Faculty of Engineering, Federal University Oye Ekiti
PMB 373, Oye Ekiti, Nigeria
E-mail: israel.olumoroti@fuoye.edu.ng



Kazeem Aderemi BELLO, Ph.D.
Senior Lecturer at the Department of Mechanical Engineering
Faculty of Engineering, Federal University Oye Ekiti
PMB 373, Oye Ekiti, Nigeria
E-mail: kazeem.bello@fuoye.edu.ng



Friday Adejoh ONUH, M.Eng.
Lecturer at the Department of Mechanical Engineering
Faculty of Engineering, Federal University Oye Ekiti.
PMB 373, Oye Ekiti, Nigeria
E-mail: friday.onuh@fuoye.edu.ng



Tunde Oluwatotin OGUNDANA, Ph.D.
Senior Lecturer at the Department of Mechanical Engineering
Faculty of Engineering, Federal University Oye Ekiti
PMB 373, Oye Ekiti, Nigeria
E-mail: tunde.ogundana@fuoye.edu.ng



Olatunde Ajani OYELARAN, Ph.D.
Professor at the Department of Mechanical Engineering
Faculty of Engineering, Federal University Oye Ekiti
PMB 373, Oye Ekiti, Nigeria
E-mail: olatunde.oyelaran@fuoye.edu.ng