

Exploring perceptions of intracity vehicle owners on adopting compressed natural gas (CNG) as an alternative fuel in Dar es Salaam City, Tanzania

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Abstract

The rapid expansion of urban areas in developing countries has significantly increased transportation demand, leading to air pollution and posing serious health and environmental risks. This situation calls for alternative fuels, especially in the transport sector. Thus, this study aimed to understand how vehicle owners within the city perceive the adoption of CNG as an alternative fuel in Dar es Salaam, Tanzania. A sample of 384 participants was selected using stratified and purposive sampling methods. Data collection involved questionnaires via Google Forms and interviews. The data were analyzed descriptively and inferentially using IBM SPSS version twenty seven (27) and Microsoft Excel, with both descriptive and inferential methods. Results indicate that while general awareness of CNG is moderate, those with direct experience have a much better understanding of its environmental and cost-saving advantages. Adoption is limited by technical knowledge gaps and infrastructure issues. Still, attitudes toward adopting CNG are mostly positive, driven by economic and environmental concerns. The study highlights the need for public campaigns and supportive legal and institutional frameworks to increase awareness and convert positive attitudes into actual use, offering valuable guidance for policy efforts to promote sustainable urban Transportation.

Keywords:

Perception, Intracity Vehicle Owners, Compressed Natural Gas, Awareness, Attitude.

Introduction.

Rapid urbanization in developing countries has led to a rise in transportation demand in cities. The increase in transportation demand is significantly contributing to air pollution and environmental degradation (Wang et al., 2022; Krause et al., 2024). This rising demand has driven increased vehicle ownership, particularly in urban centers, and heightened dependence on fossil fuels (He & Li, 2022). As a result, higher oil consumption has intensified greenhouse gas (GHG) emissions, worsened air quality, and elevated public health risks in already polluted cities (Greyson et al., 2021; UN, 2021; IEA, 2023). Transport-related emissions now pose a threat to environmental sustainability and energy security globally, as surging oil demand puts pressure on supply and market stability. In response, the transition to cleaner and more sustainable energy sources for transport has become a global agenda. Among the proposed alternatives is the adoption of compressed natural gas (CNG) and liquefied petroleum gas (LPG), which gained traction for mitigating transport-related GHG emissions (IEA, 2020; UNEP, 2021). Yet, while policy efforts and initiatives are placed in many cities worldwide to increase adoption of alternative fuels, the situation is not mesmerizing in many cities of developing countries, Africa in particular where even in some of the rich CNG rich countries in the continent (Africa Business Insider, 2024)). By 2023, the global natural gas vehicles (NGV) stand at 30 million units (Greyson et al., 2021; NGV Global, 2022), with Iran, China, Pakistan, Argentina, India and Brazil leading the way (Greyson et al., 2021; Santos & Ribeiro, 2019; NGV Global, 2022).

In Africa, the transition to cleaner energy seems slow and is facing various socioeconomic, political and environmental challenges. The current market value of CNG and LPG in Africa stands \$ 1.28 billion and is expected to reach \$ 1.9 billion by 2029, with countries such as Egypt, Nigeria, Morocco, South Africa, Kenya and Tanzania leading in this shift (Africa Business Insider, 2024). Most vehicle owners in Africa, Tanzania, including, are yet to adopt CNG as they still use oil vehicles regardless of the huge NG reserve uncovered (Olanrewaju, 2024; Anderson et al., 2023; Usiayo et al., 2025). The critical issues lie not only in technical and infrastructural readiness but also in social, political and economic reasons for owners' perceptions. The understanding of CNG, environmental concerns, and sources of information, trust in CNG technology, perceived economic benefits, and willingness to use CNG are important in adoption

(Mohareb & Kennedy, 2014; Teoh & Khoo, 2020). These behavioral aspects are crucial yet underexplored and underrepresented in policy frameworks.

Recognizing the unsustainable nature of fossil-fuel-reliant transport, many developing countries are implementing policies to mitigate climate risks and promote sustainable urban transport by adopting CNG and LPG. For example, China has experienced an eightfold increase in passenger transport and a 15-fold increase in freight over the past two decades, prompting stricter environmental and transportation regulations (World Bank, 2023). In Mexico, the adoption of CNG is limited but growing, primarily driven by environmental policies and cost-saving measures for public transportation fleets (Vicente-Serrano et al., 2019). India has one of the largest CNG networks globally, with cities like Delhi and Mumbai relying heavily on CNG to reduce urban air pollution (Goyal & Kumar, 2017; Kaur & Jain, 2023). Government incentives and a wide distribution infrastructure support its expansion. Pakistan was once the largest user of CNG in vehicles, especially during the early 2000s, but supply issues and policy changes have reduced its dominance (Haq & Weiss, 2016; Shaarawi et al., 2024).

CNG remains a more affordable alternative fuel in the country. Meanwhile, Egypt has improved its climate governance through institutions like the Egyptian Environmental Affairs Agency (Shaarawi et al., 2024). Nigeria, rich in natural gas reserves, has also launched CNG initiatives to cut its dependence on imported petroleum (Ibeneme & Ighalo, 2020; Nigerian National Petroleum Company Limited, 2023). Nevertheless, behavioral barriers continue to impede progress. Studies across Asia and Africa indicate that a limited public understanding of CNG's operation, safety, and long-term benefits hampers acceptance. For example, Sharma and Jain (2021) reported that over half of intracity vehicle owners in India lacked basic knowledge of CNG systems. Similar patterns are observed in Pakistan and Nigeria, where perceptions of risk and inadequate environmental messaging restrict adoption (Khan et al., 2019; Awoyemi & Fagbohun, 2019; Okafor & Ogbuabor, 2020). Bangladesh's experience demonstrates that structured awareness campaigns through official channels can boost trust and confidence (Rahman & Islam, 2020). Additionally, Onyango & Ouma (2020) identified high conversion costs in Kenya, and Goyal and Kumar (2017) noted that safety concerns limit adoption in India.

Moreover, fuel economics continue to be a major driver of adoption. In Pakistani cities, CNG users report fuel cost savings of up to 50%, leading to broader uptake (Nasreen et al., 2020). Yet, persistent concerns over infrastructure such as insufficient refueling stations and trained maintenance technicians undermine public trust and discourage behavioral shifts (Mwita et al., 2023). Nonetheless, where governments combine clear communication, economic incentives, and reliable infrastructure, CNG adoption has shown both environmental and financial benefits (Ngassa et al., 2019). These advances, however, have not been evenly distributed across the Global South, particularly in Sub-Saharan Africa (Spherical Insight, 2024).

Tanzania possesses significant natural gas (NG) reserves, with discoveries dating back to 1974 at Songo Songo and Mnazi Bay in 1982, along with offshore finds in 2015 (IMF, 2023). The country's reserves are estimated at 57 trillion cubic feet (IMF, 2023; Nuhu et al., 2020). Despite this abundance, NG utilisation as an alternative fuel lags behind that of countries like South Africa, Nigeria, Kenya, and Egypt (cite). In Tanzania, CNG adoption is still in early stages, primarily focused in Dar es Salaam, where interest is gradually growing. Although environmental incentives are increasing, public awareness remains limited. Mussa and Nyaruhucha (2021) observed that initial exposure to CNG often came via informal channels such as word of mouth and radio ads rather than structured campaigns or government efforts to boost adoption, especially in the transport sector, a major source of GHG emissions. The transport sector relies solely on oil, with over 85% of NG utilised for power generation and less than 1% in transportation, despite the country having over three million registered vehicles (Irudukunda, 2021). This dependence on informal sources, coupled with limited infrastructure and weak promotion, hampers adoption, as nearly all intracity transport owners continue to use oil. Although interest in CNG is slowly rising, driven by expectations of cost savings and environmental benefits, a comprehensive understanding and institutional support are still lacking. Dar es Salaam thus provides a vital case for studying early CNG transition dynamics in East Africa. This study aims to answer: *What are intracity vehicle owners' perceptions of adopting CNG in Tanzania?* It explores two variables related to awareness and attitudes among these vehicle owners.

According to Ajzen's (1991), "*Theory of Planned Behavior*", attitudes and perceptions significantly influence behavioral intentions. Therefore, successful adoption of cleaner fuels depends not only on infrastructure but also on user-level behavioral factors. This study aims to address this gap by examining how intracity vehicle owners in Dar es Salaam city perceive CNG. Gaining insights into their cognitive and emotional drivers is essential for crafting targeted awareness campaigns, incentive programs, and regulatory strategies. Without addressing these behavioral dimensions, the shift to cleaner fuels may remain slow and ineffective despite policy and infrastructural investments.

Conceptual framework

This study was guided by the conceptual framework that examine the relationship of intracity vehicle owners' perceptions on the adoption of CNG as an alternative fuel, using Dar es Salaam city as a case study.

Table 1: Operationalization of variables

Variable	Parameter	Indicators	Measurement	Data Collection Tool
Awareness of Intracity Vehicle Owners	Understanding of CNG Technology	Knowledge of how CNG works, its advantages, conversion process	Likert-scale items	Structured Questionnaire / Interview
	Environmental Concern	Awareness of CNG's environmental benefits and pollution reduction	Likert-scale items	Structured Questionnaire
	Source of Information	Type and reliability of information sources	Likert-scale items	Structured Questionnaire / Interview
Attitude of Intracity Vehicle Owners Toward CNG	Trust in CNG Technology	Perceived safety, reliability, and performance of CNG	Likert-scale items	Structured Questionnaire / Interview
	Economic Benefits	Beliefs about cost savings, maintenance costs, fuel price stability	Likert-scale items	Structured Questionnaire / Interview
	Willingness to use CNG	Beliefs about social acceptability and peer influence regarding CNG use	Likert-scale items	Structured Questionnaire / Interview

INDEPENDENT VARIABLE

DEPENDENT

VARIABLE

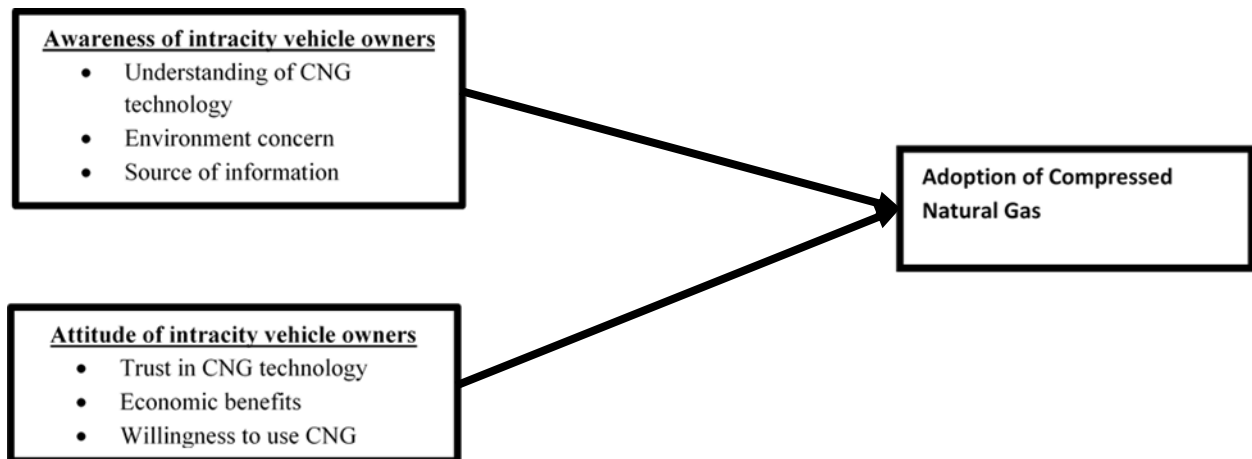


Figure: Conceptual Framework on the perception of intracity vehicle owners on the adoption of CNG as an alternative fuel

Source: Adopted from Aswin (2024)

Methodology

The study was conducted in Dar es Salaam City, Tanzania's largest urban center and economic hub, known for its diverse socioeconomic activities such as trade, transportation, and manufacturing (URT, 2020). Given the city's dense population (4863 km²), more than 6 million population, and heavy reliance on intracity transport modes like tricycles and *daladala*, Dar es Salaam provides a strategic setting to investigate the adoption of compressed natural gas (CNG) as an alternative fuel. The dynamic nature of the city's transport sector, coupled with increasing environmental concerns, underscored its selection as the study area.

A cross-sectional research design was utilized to capture the perceptions of intracity vehicle owners regarding CNG adoption at a single point in time (Kothari, 2004). The target population included tricycle and *daladala* operators in Dar es Salaam, along with other key stakeholders such as representatives from UDA Rapid Transit Company Limited (UDART), Dar es Salaam Commuter Bus Owner Association (DARCOBOA), Land Transport Regulatory Authority (LATRA), Compressed Natural Gas (CNG) workshop specialists, and academic experts engaged in CNG technology. The sample size was determined to be 384 respondents based on the Cochran formula (Cochran, 1977), ensuring statistical representativeness and sufficient power for detecting significant results. Stratified sampling was employed to categorize respondents according to vehicle type, ensuring proportional representation across groups. Additionally, purposive sampling was used to select knowledgeable stakeholders for in-depth interviews, providing rich qualitative insights (Kumar, 2019).

Given from Cochran's formula (1977)

$$x = \frac{Z^2 P(1-P)}{e^2}$$

Where by

x = required sample size

Z = Z-score (1.96 for a 95% confidence level)

P = Estimated proportion of the population with the characteristic of interest (Assumed 50% or 0.5 if unknown)

e = margin of error (0.05 or 5%)

Data collection involved structured questionnaires both physically and through Google Forms to capture quantitative data. This was complemented by semi-structured interviews with selected stakeholders to gain deeper understanding of attitudes and awareness related to CNG adoption (Patton, 2015). Quantitative data were analyzed using descriptive and inferential statistical methods through IBM SPSS version twenty-seven (27), while qualitative data underwent thematic analysis to extract key patterns and insights using Microsoft Excel.

Results

Table 2: Demographic Information of Intracity Vehicle Owners

Attribute	Categories	n	%
Age	18–24	34	8.9
	25–34	126	32.8
	35–44	141	36.7
	45–55	66	17.2
	55+	17	4.4
Role	Tricycle owner/operator	146	38.0
	<i>Daladala</i> owner/operator	155	40.4
Current CNG use	Using CNG	61	15.9
	Not yet using	323	84.1

Awareness of Intracity Vehicle Owners on the Adoption of CNG

The quantitative and qualitative findings on awareness of CNG adoption among intracity vehicle owners in Dar es Salaam present a generally aligned picture, particularly regarding environmental understanding, but diverge somewhat in technical awareness. Quantitatively, a majority of respondents demonstrated strong environmental awareness, with 68.2% agreeing or strongly agreeing that CNG helps reduce air pollution, and 66.1% recognizing its role in lowering Particulate matter (PM)/Nitrogen Oxides (NOx) emissions. This aligns closely with qualitative insights from institutions such as UDA Rapid Transit Company Limited (UDART), and Dar es Salaam Institute of Technology (DIT), which emphasized CNG's environmental benefits and its technical suitability for urban transport. For instance, a UDART representative noted awareness of CNG's role in improving urban air quality, while (DIT) provided technical validation of CNG's clean combustion properties.

However, both data types also reveal gaps in technical understanding. Quantitative data show only 57.0% of respondents understood how a CNG kit works and is certified, and just 52.6% were aware of vehicle compatibility requirements. This limitation is echoed qualitatively by concerns raised by Dar es Salaam Commuter Bus Owner Association (DARCOBOA) and TAQA Workshop, where respondents pointed to skepticism not rooted in lack of awareness, but in practical and technical challenges such as infrastructure, conversion costs, and earlier issues with power loss due to poor installations. Importantly, cross-tabulation analysis indicated that current CNG users possess significantly higher awareness than non-users (MeanAWR_users = 3.87 vs. 3.33; $t(382) = 6.18, p < .001$), suggesting that hands-on experience fosters deeper understanding. In summary, the quantitative and qualitative data are largely similar in identifying high environmental awareness but moderate technical understanding. Both perspectives underline the importance of structured, credible, and experience-based information particularly around conversion procedures, installation standards, and operational reliability. Bridging the gap between general awareness and procedural knowledge remains key for wider CNG adoption. The coefficient results on awareness in Table 5 findings ($\beta = +0.18, p < .001$) contributes positively greater technical and environmental knowledge aligns with stronger intention.

Table 3: Item-Level Awareness

Dimension	Item	SD %	D %	N %	A %	SA %	A+SA %
Understanding	I know the basics of how a CNG kit works and is certified.	7.7	15.3	20.0	38.2	18.8	57.0
	I know which vehicles are compatible with CNG conversion.	9.1	18.3	20.0	35.2	17.4	52.6
Environmental concern	CNG can reduce urban air pollution compared to petrol/diesel.	4.6	9.2	18.0	43.6	24.6	68.2
	CNG reduces particulate and NOx emissions relevant to Dar es Salaam.	5.3	10.6	18.0	42.3	23.8	66.1
Sources of information	I have received CNG information from official/government channels.	13.8	27.6	25.0	24.2	9.4	33.6
	I primarily rely on peers/word-of-mouth for CNG information.	6.7	13.4	20.0	40.1	19.8	59.9

Source: Field Data (2025)

Attitude towards Adoption of CNG

The findings in quantitative and qualitative data reveals a strong alignment in attitudes toward the adoption of Compressed Natural Gas (CNG), particularly regarding its economic benefits,

while also identifying consistent barriers that inhibit broader adoption. From the quantitative data, economic considerations emerge as a major driver, with 74.7% of respondents agreeing or strongly agreeing that CNG lowers operating expenses. Notably, 43.3% of these respondents strongly agree, indicating a firm conviction in its cost-saving potential. Only 15.3% remain neutral, suggesting that support is solid rather than tentative. This sentiment is strongly echoed in the qualitative data. For instance, UDART provides real-world validation, showing that under operational conditions, CNG fuel costs are nearly half those of diesel, delivering substantial savings per kilometer. Similarly, the Dar es Salaam Institute of Technology (DIT) estimates a 50–60% reduction in running costs under Tanzanian conditions. With over 4,756 vehicle conversions and daily throughput of 8 conversions, market interest appears robust. These findings corroborate the strong economic rationale identified in the quantitative data.

However, both data sets also point to persistent barriers. While the quantitative findings show strong peer recommendation (60.9% agreement) and general support for personal conversion (55.2%), both areas exhibit significant neutral segments (29.1% and 34.8%, respectively). This indicates hesitation due to unresolved concerns. These concerns are reflected qualitatively. According to DARCOBOA, the high initial conversion cost often exceeding TZS 2 million per vehicle is a significant burden, especially for fleet operators. This aligns with the hesitancy in quantitative measures of personal conversion. Additionally, a TAQA engineer emphasizes the role of public misunderstanding and safety fears, particularly regarding explosions, which slow adoption despite strong satisfaction among current users. This concern is evident in the sizable neutral group on safety and trust within the quantitative data, highlighting a critical opportunity to shift perceptions through education and safety assurances.

In summary, the quantitative and qualitative data are highly consistent, particularly on the economic benefits and key adoption barriers such as conversion costs, infrastructure limitations, and public safety concerns. Both data sets point to a clear strategy: continue emphasizing cost advantages, address conversion affordability, and build public trust through education and transparent safety protocols. As these practical barriers are addressed, the sizable neutral population is likely to shift toward confident endorsement supporting the conclusion that attitude remains the strongest predictor of CNG adoption intent.

The coefficient results on attitude in Table 5 ($\beta = +0.41$, $p < .001$) reveals the strongest positive driver of adoption intention: owners with more favorable views of CNG's benefits and safety report markedly higher intention to adopt.

Table 4: Item-Level Attitude

Dimension	Item	SD %	D %	N %	A %	SA %	A+SA %
Trust	CNG vehicles are reliable for daily intracity operations.	5.0	5.0	28.5	30.7	30.8	61.5
	Certified workshops and inspections make CNG safe.	5.0	5.0	31.1	32.4	26.5	58.9
Economic benefit	Operating cost with CNG is lower than with petrol/diesel.	5.0	5.0	15.3	31.4	43.3	74.7
	Fuel price stability with CNG improves predictability.	5.0	5.0	26.5	31.7	31.8	63.5
Willingness	I plan to convert within the next 24 months (if stations increase).	5.0	5.0	34.8	30.4	24.8	55.2
	I would recommend CNG to peers.	5.0	5.0	29.1	30.5	30.4	60.9

Source: Field Data (2025)

Table 5: Coefficient

Predictor	β	T	P	Interpretation
Awareness (AWR)	+0.18	4.09	<.001	Positively related to adoption
Attitude (ATT)	+0.41	8.75	<.001	Strong positive predictor

Source: Field Data (2025)

Discussions

Awareness of Intracity Vehicle Owners on the Adoption of CNG

The study reveals a moderate level of awareness (Mean = 3.41/5) regarding the environmental and economic benefits of CNG vehicles, such as reduced emissions and lower fuel costs. However, it also identifies a significant knowledge gap concerning technical aspects, including kit components and certification procedures. This disconnect suggests that while the perceived usefulness (PU) of CNG vehicles is well-established, the perceived ease of use (PEOU) remains a barrier reflecting a pattern consistent with the Technology Acceptance Model (TAM), which posits that both PU and PEOU significantly influence technology adoption. These findings echo those of Sharma et al. (2020) and Mehta and Singh (2019), who similarly noted that limited technical understanding and complex regulatory requirements hinder user adoption, particularly among non-users. Moreover, the current study's focus on perceived behavioral control and user

confidence aligns with the Theory of Planned Behavior (TPB), reinforcing the observations of Kumar and Bansal (2018), who emphasized the role of self-efficacy and perceived control in shaping behavioral intentions. In contrast to studies such as Verma et al. (2021), which found a strong correlation between improved information accessibility and increased adoption rates, this research underscores the persistent challenge of translating technical information into accessible formats. This highlights the need for practical interventions such as simplified checklists, visual aids, and user-friendly certification briefings to bridge the gap between policy goals and the real-world adoption of CNG technology

Attitude Towards Adoption of CNG

The findings in Table 4, indicate that attitude emerges as the strongest predictor of adoption, consistent with prior research applying both the Technology Acceptance Model (TAM) and the Theory of Planned Behavior (TPB). UDART's data show significant fuel cost savings from CNG buses, aligning with TAM's Perceived Usefulness construct. This is in line with findings by Davis (1989), who emphasized usefulness as a key determinant of technology adoption, and echoed in more recent CNG adoption studies such as Nasreen et al. (2021), where economic benefits were pivotal in shaping attitudes. Tanzania-specific evidence also confirms rapid payback from CNG conversions using modern kits (Gerutu et al., 2023), comparable to results from India and Pakistan (e.g., Sharma & Sharma, 2018; Ali et al., 2020), where financial incentives accelerated CNG uptake.

From the TPB perspective, these tangible economic benefits strengthen behavioral beliefs, thereby fostering favorable attitudes similar to Ajzen's (1991) assertion that beliefs about outcomes influence attitudes. Trust and safety perceptions further enhance adoption intentions, a pattern also reported by Umeh et al. (2019) in Nigeria, where public confidence in standards (e.g., ISO compliance) and institutional enforcement (e.g., EWURA and TBS in Tanzania) positively influenced adoption. These findings align with TAM extensions that incorporate trust and risk, as shown in the work of Venkatesh et al. (2012). Additionally, experience from Nigeria highlights the role of supportive policy and infrastructure in reinforcing attitudes, demonstrating how external variables shape both Perceived Usefulness and Ease of Use (Oni & Oyewo, 2020).

Overall, the Dar es Salaam case confirms that favorable cost and policy signals activate strong attitudes and enable behavioral intention, supporting both TAM and TPB frameworks, in agreement with regional and global evidence on clean fuel adoption.

Conclusion and recommendations

A key insight is that attitude shaped primarily by perceptions of cost savings and performance advantages is the strongest predictor of adoption intention. However, the study also shows that positive attitudes alone are insufficient in the face of systemic barriers such as infrastructure gaps, regulatory uncertainty, and limited access to reliable information. These findings have practical implications for policymakers: interventions should go beyond promotional campaigns and invest in technical education, certification programs, and infrastructure development to support informed adoption. This study offers a novel contribution to the understanding of Compressed Natural Gas (CNG) adoption in Dar es Salaam by highlighting a critical gap between general awareness and technical knowledge particularly concerning kit components, vehicle compatibility, and certification requirements. Unlike previous research that often aggregates awareness as a single dimension, this study disaggregates it and shows that in-depth technical understanding remains limited, especially among non-users. However, methodologically, the study is limited by its cross-sectional design, which restricts causal inference, and its reliance on self-reported data, which may introduce bias or inaccuracies. Furthermore, the research is confined to the urban context of Dar es Salaam, limiting the generalizability of the findings to rural or peri-urban areas where conditions may differ significantly. To address these limitations, future research should adopt longitudinal or quasi-experimental designs, incorporate objective behavioral data such as GPS tracking, maintenance logs, and utilize qualitative methods to gain richer, context-sensitive insights into adoption dynamics and intervention outcomes.

To accelerate CNG adoption, vehicle owners need receive financial support through soft loans or subsidies to ease high conversion costs, while gaining access to real-world operational data to inform decisions. Policymakers must expand refueling infrastructure with strategically placed satellite stations and enhance safety through QR-coded inspection certificates and clear national guidelines. The government can lead by example with phased fleet conversions, a streamlined

permitting system, and regular monitoring of key metrics. Academic institutions like DIT and TAQA should offer modular training programs and accredit service providers to ensure consistent technical standards. Industry stakeholders must align with national standards, support training, and share service data to improve trust. Collaboration across these actors is essential to build confidence and reduce uncertainty. Together, these efforts will drive systematic, safe, and widespread CNG adoption across Tanzania.

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