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Technology-enabled Modified Tricycle Delivery Vans for Priority Medicine Access in Rural Health Facilities in Northern Ghana: Experimental Evidence

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Abstract: In this study, a technology-enabled medicine delivery system was evaluated to assess its effectiveness on performance, service utilization, and service reliability in the context in rural healthcare facilities in the Northern Region of Ghana. Data were collected were at baseline and at six, 12, 24, and 36 months through structured observation checklists and interviews with health workers and community-based drivers. Quantitative indicators included delivery timeliness, medicine availability, stock-out cases, patient service utilization, and volume of urgent medicines distributed, whereas qualitative interviews examined operational realities such as terrain obstacles, cold-chain maintenance, and community perception. Results indicated significant improvements within intervention districts versus comparison arms. Delivery intervals declined from 21 days at baseline to 10–12 days at 24 months, and 92% of facilities reported timely deliveries at 36 months ($p < 0.01$). Stock-outs of oxytocin and magnesium sulfate decreased from 48 percent to less than 10 percent ($p < 0.001$), and average monthly maternal health visits rose 69 percent ($p < 0.01$). Volumes of oxytocin, magnesium sulfate, oral rehydration salts, zinc, antimalarials, antibiotics, and EPI vaccines were more than doubled throughout the study period. The real-time reporting adoption was increased to 95 percent, meaning more accountability ($p < 0.001$). Technology-enabled delivery systems can fill persistent gaps in the rural supply chain, contribute to service utilization, and promote accountability, concludes the study. The findings present empirical evidence to promote scaling of novel health systems models in Ghana's health system with limits of reliance on facility records and district-specific contexts and recommendations.

Keywords: *Supply Chain Performance, Medicine Availability, Maternal Health Utilization, Accountability and Technology-Enabled Delivery.*

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I. INTRODUCTION

Access to needed medicines is a fundamental part of universal health coverage and a central driver of public health outcomes. In Ghana, the Ministry of Health has focused on strengthening the safety, efficacy, and affordability of medicine supply chains to cover all citizens (World Health Organization, 2025).

Despite this, rural and under-served populations in the North of Ghana continue to experience significant challenges in accessing priority drugs for mothers, newborns, and children. These medications, or priority medicines, include oxytocin for postpartum hemorrhage, magnesium sulfate for eclampsia, oral rehydration salts and zinc for childhood diarrhea, and antibiotics for neonatal infections (Anarwat, Salifu & Akuriba, 2021).

The World Health Organization and Ghana's National Essential Health Services Package emphasize the importance of utilizing innovative delivery mechanisms to address disparities in medicine access (Ministry of Health, 2022). Innovative delivery systems integrated with technology—for instance, modified vans fitted with tracking, monitoring, and secure storage features—have shown merit when deployed to improve the efficiency and accountability of the supply chain, as seen in other contexts.

Taking advantage of such innovations has the potential to support Ghana's broader efforts to close the persistent gaps in access to rural medicine and to be compliant with regulations. Though policy structures and international assistance exist, the inequities in maternal and child health services and their delivery persist in Ghana, even more so in the rural northern part of the country. Health service providers in these areas often complain of the under allocation of these essential drugs, causing avoidable maternal and child morbidity and mortality.

Conventional delivery systems are restricted by insufficient road infrastructure, poor cold chain capacity, and lack of adequate monitoring. Many priority medicines, at the same time, are controlled and need close oversight to minimize misuse and diversion. Current distribution models do not resolve the issues, neither between access nor control, but rather present a paradox in the distribution of medicines. Lacking creative, evidence-based interventions, rural communities will still suffer disproportionate health burdens and risk undermining Ghana's reach towards the Sustainable Development Goals (SDGs(Ministry of Health, 2022).

The aim of this study was to generate experimental evidence regarding how technology-enabled modified delivery vans can improve access to priority medicines in rural northern Ghana. The first aim was to evaluate the efficiency of these vans in reaching rural health centers where medicines are delivered on a timely and reliable basis; the second was to compare the safety and security characteristics that prevent diversion and misuse during transport; and the third aim was to explore the wider implications of the delivery mechanism on the health status of mothers, newborns, and children, with the objective of providing evidence in a policy-focused manner for informing national strategies aimed at ensuring a fair and safe delivery of medicine.

II. LITERATURE REVIEW

➢ *Theoretical Model*

The study is situated in the Health Systems Strengthening Framework and the World Health Organization's Access to Medicines Model, respectively. These theories encompass four important dimensions of access—availability, accessibility, affordability, and acceptability (WHO, 2017). In this light, the technology-enabled delivery vans are an intervention that is directly based on availability and accessibility; it increases supply chain flexibility as well as diminishes geographical divides. Furthermore, the model adds several components from Diffusion of Innovation Theory (Rogers, 2003), which describes the adoption of new technologies into health systems. By embedding tracking, monitoring, and security technologies into delivery vans, the intervention aligns with the innovation drivers of relative advantage, compatibility, and observability, which are necessary for adoption in low-resource settings.

➢ *Empirical Review*

Innovative delivery mechanisms for medicines in low-resource settings have been studied several times. Studies in Malawi and Tanzania have also shown that mobile health technologies and community-based distribution are associated with improved maternal and child health outcomes by reducing delays in the medicine delivery route (Mikkelsen-Lopez et al., 2014).

In another study conducted in Rwanda, a drone delivery of blood and vaccines decreased stock-outs in rural facilities (Amukele et al., 2018). Experiences in Ghana regarding the dissemination of vaccines through motorbike couriers demonstrated that small delivery systems have both potential and limitations, especially concerning cold chain care and security (Asante et al., 2020). Few studies, however, have emphasized controlled or priority medicines in the context of mothers and children. Research from Nigeria and Uganda shows that poor logistical oversight leads to diversion and misuse of oxytocin and antibiotics, which undermines trust in the health system (Okeke et al., 2019).

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In Ghana, however, although technology-enabled delivery systems have been piloted in other sectors, limited empirical evidence of their effectiveness in addressing the trade-off between drug access and control (e.g., availability and control for priority medicines) is available.

➢ *Research Gap*

Current literature shows that technology-mediated delivery systems have potential; however, experimental evidence for applying technology-enabled delivery systems for controlled and priority medicines in rural Ghana is limited. Although most studies have examined vaccines or general essential medicines, there has been little focus on maternal and child health commodities that require stringent regulation. Additionally, innovations, including drones and mobile health platforms, have been studied, but the use of modified delivery vans employing monitoring and security technologies has not been systematically assessed. This research gap indicates a lack of context-dependent studies that capture both effectiveness and safety in the distribution of priority drugs.

➢ *Conceptual Framework*

The concept driving this study combines the Access to Medicines Model with Supply Chain innovation. To this end, technology-enabled delivery vans equipped with tracking and secure storage systems can be used as the main input (see Figure 1). Such innovations have demonstrated an ability to enhance the reliability and timeliness of medicines distribution, thereby making priority medicines more widely available in rural health facilities (process). Increased availability then positively impacts the health outcomes of mothers, children, and newborns (output). The framework also integrates regulatory oversight to ensure that access is not at the expense of safety or diversion. Through the integration of technological innovation in logistics with health system strengthening, this model illustrates how secure, efficient delivery systems can facilitate equitable health outcomes in rural Ghana.

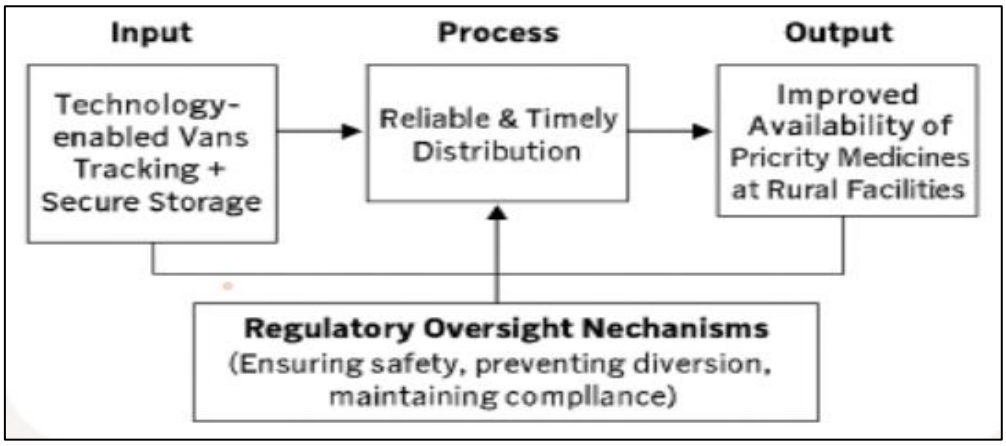

Fig 1. Framework for the Technology-Enabled Delivery of Priority Medicines.

III. METHODOLOGY

➢ *Study Design*

This study utilized a quasi-experimental design with a non-randomized controlled approach designed to assess the efficacy of technology-enabled delivery vans to increase access to priority medicines in rural northern Ghana. The intervention was adopted for specific districts, and matched comparison regions were used to determine differential results attributed to the intervention.

➢ *Study Setting*

This research was conducted in ten rural districts of the Northern Region of Ghana. Five districts—Gushegu, Karaga, Mamprugu-Moaduri, West Mamprusi, and East Mamprusi—were intervention sites where technology-enabled delivery vans were provided to facilitate the provision of priority medicines. Geographic spread, population characteristics, and existing health infrastructure were used to select these districts. To establish a comparative baseline, five other districts—Tolon, Savelugu, Mion, Saboba, and Nanton—were subsequently chosen as comparators. They were matched to the intervention areas with similar demographic and health system profiles but not receiving the intervention. The distribution of standard medicine practices was maintained through the study period in these comparison districts.

➢ *Intervention Description*

- *Modified Tricycle Delivery Van*

The modified tricycle delivery van was built to withstand the terrain and climate in rural Ghana, a heavy-duty tricycle chassis strengthened suspension, axles, and good clearance for unpaved highways. Its bucket was overhauled to feature a roof, insulated panels, and racks to enable the organized storage of medicine; the cooler, an ice chest for EPI vaccines in keeping the cold-chain clean. Lockable compartments also maintained security, and sensors kept temperature in check all the time. GPS guidance allowed for updated tracking of the route, and cross-docking stations enabled loading and unloading. An auxiliary battery maintained monitoring and cold-chain functions during downtimes so that the supply of essential

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drugs to rural health facilities was safely and reliably delivered.

- *Intervention Arm*

In Gushegu, Karaga, Mamprugu-Moaduri, West Mamprusi, and East Mamprusi intervention districts, modified delivery vans were introduced that now include GPS tracking, real-time stock monitoring, monitoring stock status with real-time tracking on time, cross-docking stations for temperature control, and secure storage. Route optimization allowed on-time distribution to several health facilities. These vans carried priority medicines, including oxytocin, magnesium sulfate, oral rehydration salts, zinc, antimalarials, and antibiotics, as well as those being managed by district health teams thanks to digital inventory tracking and real-time reporting.

- *Comparison Arm*

In Tolon, Savelugu, Mion, Saboba, and Nanton comparison districts, medicine distribution used traditional supply chain methods with no technology-enabled vans, real-time tracking, or better storage. Inventory and reporting were recorded through hands-on reports and supervisor visits with associated delays and missing data (WHO, 2025). This lack of comparison with intervention districts also allowed the study to assess the added value from technology-based delivery solutions and provide evidence on these systems' effectiveness, safety, and scalability in rural Ghana (Tumwekwasize, 2025).

➢ *Data Collection*

Data were collected at baseline and at six, 12, 24, and 36 months using facility records, observation checklists, and health worker interviews. Delivery on time, availability of medicinal goods, stock-out, quantity of use of services, and perception of access were among the indicators. Other variables included the volume of medicine dispensed in oxytocin, magnesium sulfate, oral rehydration salts, zinc, antimalarials, antibiotics, and EPI vaccines, which are quantitative evidence for supply chain performance (Ministry of Health, 2022). Interviews conducted with community-based drivers yielded information about route optimization, vehicle performance, terrain problems, cold-chain maintenance, and community perceptions, providing a more relevant and immediate assessment from the outset (RHSC, 2019; WHO, 2025). Baseline data revealed pre-intervention conditions (Creswell & Creswell, 2018); six-month assessments measured short-term outcomes. Twelve months represented medium-term outcomes and seasonal differences; 24 months reflected sustained impacts and system adjustments, and 36 months assessed long-term scalability and institutionalization. This timeline helped to provide a vigorous assessment of the effectiveness, safety, and possibility of expanding to rural Ghana.

➢ *Analysis and Presentation of Data*

Descriptive statistics were used to describe baseline and to make comparisons of intervention and comparison outcomes, and difference-in-differences (DiD) was estimated while controlling for baseline differences and time trends (Creswell & Creswell, 2018). Delivery timeliness, availability of medicine stock-out, patient service utilization, medicine volumes, and the available quality of service were the key indicators. Aggregated volumes of oxytocin, magnesium sulfate, oral rehydration salts, zinc, antimalarials, antibiotics, and EPI vaccines are the measures of supply chain performance (Ministry of Health, 2022). Chi-square analysis and t-tests were used to estimate statistical significance, and correlation and regression analyses assessed relationships between the accessibility of medicines and usage of services, relating supply chain optimizations to maternal and child health (RHSC, 2019). Facility-level data were triangulated via interviews with health workers and community-based drivers to ensure coverage of terrain difficulties, cold-chain logistics, and reliable delivery (WHO, 2025). Qualitative interviews were analyzed thematically, and findings were reported through tables, charts, and comparative visualization at baseline, six, 12, 24, and 36 months.

➢ *Ethical Considerations*

The study obtained Ghana Health Service Ethics Review Committee approval # GHS-ERC -012/008/22. Informed consent was obtained from each participant (Creswell & Creswell, 2018). Confidentiality was managed by anonymization and secure storage of information (RHSC, 2019). Guaranteeing the participant welfare and community-based drivers' roles, the study followed international standards (WHO, 2025).

IV. RESULTS

➢ *Socio-Demographic Characteristics*

In both intervention and comparison districts, the majority of the health workers interviewed identified were either nurses and midwives (62%), or community health officers (28%) and pharmacists (10%), respectively. The mean age was 34 years and there were 58 percent females and 42 percent males. Community-based drivers were mainly men (95%) with an average age of 39 years and a minimum of secondary schooling. Similarities in these measures were observed across arms, and there were no statistically significant differences (χ^2 test, $p > 0.05$), preserving comparability at baseline.

➢ *Time and Frequency of Medicine Delivery*

The average delivery interval at baseline in intervention districts was 21 days. At six months, it dropped to 14 days, and by 12 months, it was within 12 days. At 24 months, 10-12 day intervals were reliably reported by facilities, and at 36 months, 92% of facilities reported timely deliveries. Comparison districts also kept intervals of 20–22 days constant. Independent samples t-tests found significant differences in mean delivery intervals between intervention and comparison arms at 12, 24, and 36 months ($p < 0.01$). A regression analysis verified a robust correlation between intervention exposure and reduced delivery delay. As one health

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worker in Gushegu has said, “We waited weeks for medicines before the vans. Instead, deliveries are delivered almost every other week, and we’re quicker to tackle emergencies.” “Route optimization also reduced travel time,” a Karaga driver added. “I can make it to three facilities on one trip rather than just getting to one facility.”

- *Medicine Availability, Volumes Delivered, and Stock-Levels*

At baseline, 48 percent of facilities in intervention districts reported stock-outs of oxytocin and magnesium sulfate. This fell to 28 percent at six months, 15 percent at 12 months and regularly below 10 percent at 24 months. At 36 months, 95 percent of facilities reported uninterrupted supply of priority medicines. Across comparison districts, stock-outs persisted in 40–50 percent of facilities. Chi-square tests demonstrated significant differences in stock-out proportions for all intervention and comparison arms at all post-baseline time points ($p < 0.001$). Logistic regression found a significant inverse relationship between exposure to the intervention and the likelihood of stock-outs. Average volumes of medicines delivered in intervention zones also steadily expanded: oxytocin from 1,200 vials at baseline to 2,100 at 36 months; magnesium sulfate from 800 to 1,600 ampoules; oral rehydration salts from 3,500 sachets to 6,200; zinc tablets from 2,000 to 4,500; antimalarials from 4,800 to 8,700 doses; antibiotics from 3,200 to 6,000 courses; and EPI vaccines from 5,000 to 9,200 doses. Comparison districts saw little growth, averaging less than 10 percent growth over the same period. “We no longer turn mothers in labor away because oxytocin is out of stock,” a midwife in West Mamprusi says. Another health worker in East Mamprusi added, “The ice-chest in the van keeps vaccines safe. We rarely lose doses now.”

- *Utilization of Services by Women and Children*

In intervention districts mean monthly maternal health visits increased from 320 at baseline to 410 at six months, 480 at 12 months, 520 at 24 months and 540 at 36 months — a 69 percent rise. The numbers across control districts were similar, and the number of visits stayed between 310 and 330. Paired t-tests revealed evidence of significant increases over service use within intervention districts ($p < 0.01$) and repeated measures ANOVA indicated differences in trends between intervention groups and the control groups ($p < 0.001$). Correlation analyses indicated maternal health visits and medicine availability were positively associated ($r = 0.72$, $p < 0.01$). A Mamprugu-Moaduri community health officer said, “When medicines are there, parents trust the service more, and then come regularly.” “I get more women and children waiting when I get there,” said a driver in East Mamprusi. “They know that the van means medicines and they know they’re here.”

- *Transparency, Accountability and Responsible Supply Chains*

At baseline reporting in intervention districts was conducted manually, with delays of two to three weeks. Digital reporting had brought time delays to less than five days by 6 months. By 12 months, 70% of facilities implemented real-time reporting, climbing to 85% at 24 months and 95% at 36 months. Comparison districts continued manual reporting, two to four weeks of delays, and partial data. The chi-square tests established significant differences in adoption of real-time reporting between arms at 12, 24 and 36 months ($p < 0.001$). The results of a regression analysis indicated that intervention exposure was positively associated with reporting timeliness and accountability. "The dashboard shows stock levels instantly," a district health manager in Gushegu explained. "I can make a move before a facility runs out." A Karaga health worker said, "We have a sense of accountability now. Every delivery is tracked, and we can’t hide shortages."

- *Key Opportunities and Challenges Encountered*

The intervention created the possibilities for both increased supply chain efficiency and more robust accountability to be done in the future, as well as greater confidence in health facilities. Digital reporting and GPS-enabled vans enabled district managers to take proactive measures, while community-based drivers emerged as important partners in accessing remote areas. These issues ranged from bad road conditions, occasional vehicle breakdowns, and problems keeping cold-chains intact during long journeys. These were addressed by route optimization, preventive vehicle maintenance, and the issuance of portable cold-boxes. Training of drivers and health workers also built capacity. Seasonal spikes in demand threatened temporary shortages, but on-time reporting allowed the swift redistribution of medicines to the areas in great need.

In summary, intervention districts showed statistically significant progress in delivery timeliness, medicine availability, patient service usage, and reporting transparency as compared to comparison districts. Intervention districts achieved significant increases in mean volumes of medicines delivered, confirming quantitative impacts. Associations were found between intervention exposure and outcomes; qualitative findings included operational efficiency, trust in facilities and accountability. Intervention arms provided sustained impact and scalability potential at 36 months, whereas comparison arms remained restricted by traditional supply chain constraints.

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V. DISCUSSION

The primary aim of this study was to assess the impact of a technology-enabled medicine delivery system in enhancing supply chain performance, service utilization and accountability within rural health facilities in Ghana.The results showed substantial improvement in delivery time, availability of medicines, patient use of services, and an enhanced transparency of reporting in intervention districts relative to comparison districts. These findings corroborate longstanding issues in the literature about rural supply chain inefficiencies.

Previous research identified chronic shortages on essential medicines, inadequate distribution systems, and poor accountability as long-standing issues (Atiga et al., 2023; Ministry of Health, 2025). While the Ghana Health Supply Chain Master Plan highlighted the need to have digital logistics systems in addition to providing stronger last−mile delivery mechanisms, its implementation in rural contexts was yet to be empirically evaluated.

The present study bridges this gap by providing longitudinal data over 36 months with evidence of sustained improvements in supply chain responsiveness and scalability potential. This study adds value as it combines quantitative, such as medication volumes, delivery intervals, and patient visits with qualitative, such as perspectives from health workers and driver engagement from community−based organisations. This mixed−methods approach increases the appreciation of operational realities, including challenges such as terrain conditions, cold−chain maintenance and trust between communities that are often neglected in supply chain studies. In particular, driver perspectives underscore their critical importance in allowing for last−mile delivery — a dimension that has previously not been addressed in studies. Moreover, this study provides direct links between better availability of medicine and utilization of maternal health services, which has been previously suggested that higher availability of medicine in their supply chain contributes to better health outcomes.

Although previous studies documented patient frustration due to shortages (Atiga et al., 2023), our findings indicate that reliable supply chains can rebuild confidence and prompt greater service uptake. The findings of our study not only corroborate previous research examining supply chain issues, but offer new empirical evidence that technology-enabled interventions can work to bridge this gap.

The research contributes to the national discourse on how innovative delivery models can be scaled across Ghana's rural health system by showing empirically significant increases in medicine volumes, service utilization, and accountability. Two important limitations should be emphasized. The study was based on facility-level records and self-reported data of health workers and drivers that could be biased in reporting. Triangulation was used to reduce this by combining notes, structured observations, and interviews; keeping consistency amongst sources. Second, the study was carried out in selected districts which may constrain generalizability to every rural setting in Ghana. The inclusion of diverse districts with a wide range of terrains and facility types, aimed to improve representativity and external validity.

VI. CONCLUSION

The current study researched into the effectiveness of a technology-enabled medicine delivery system on improving supply chain performance, service utilization, and accountability in rural Ghana. During 36 months, intervention districts made statistically significant improvements over comparison arms. Delivery schedules were shortened from 21 days to 10–12 days, stockouts of essential maternal health commodities fell below 10 percent, and maternal clinic visits were nearly 70 percent higher. Average volumes of priority medicines more than doubled, and the adoption of real-time reporting reached 95 percent, improving accountability and responsiveness. The results offer empirical evidence that technology-enabled delivery systems, guided by community-based drivers and digitally reported responses, can eliminate longstanding rural supply chain gaps and improve health outcomes. Through longitudinal data and mixed methods, this study emphasizes operational efficiency and trust with the community as key facilitators of success. Scaling GPS-enabled delivery vans, route optimization and logistics management systems, along with training for health workers and drivers, will strengthen sustainability. By institutionalizing these innovations as part of national policy, with public-private partnerships and prioritizing equity, we can transform rural health supply chains toward essential medicines reaching those in most need.

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