African Journal of Applied Research
Vol. 10, No. 1 (2024), pp. 178-200
http://www.ajaronline.com
http://doi.org/10.26437/ajar.30.06.2024.12

SHORTENING THE LAST-MILE: IMPACT OF ZIPLINE MEDICAL DRONE DELIVERY ON THE OPERATIONS OF HARD-TO-REACH HEALTHCARE FACILITIES IN NORTHERN GHANA.

Atiga, O.[1], Tanzubil, B. J.[2], Asaana, J.[3], Ayamba, E. C.[4], Seidu, M. T.[5], and Mohammed, I.[6]

[1,2,3,4,5,6]*Department of Procurement and Logistics Management, Bolgatanga Technical University, Box 767, Bolgatanga, Ghana.*
[1]*oswaldatiga@yahoo.com*
[2]*btanzubil@bolgatu.edu.gh*

ABSTRACT

Purpose: This research study investigated the impact of Zipline Medical Drone Delivery on the operations of last-mile healthcare facilities in northern Ghana.
Design/Methodology/Approach: The research study adopted an exploratory research design to determine the impact of Zipline's medical drone delivery on the operations of last-mile healthcare facilities in Northern Ghana. An online survey questionnaire was deployed to collect quantitative data from 159 trained employees of last-mile health facilities who were selected through a purposive sampling technique from last-mile drone-served healthcare facilities.
Findings: The study established that drone delivery speed, logistics efficiency and availability of drone delivery resources significantly impacted zipline delivery of medical commodities to last-mile public healthcare facilities in Northern Ghana, reducing commodity delivery lead-time and improving access to essential healthcare supplies for efficient service delivery.
Research Limitation/Implications: This research focused mainly on the impact of drone delivery of medical commodities on the operations of last-mile public healthcare facilities in Northern Ghana.
Practical Implications: The results of this study show that by enhancing drone delivery speed, logistics efficiency and drone resource availability, the operations of public healthcare facilities can be improved by ensuring that essential medicines are made available, patient waiting time is significantly reduced and outpatient services are improved.
Social Implication: The study recommends the establishment of a Zipline-Administrators partnership which will eventually result in a reduction of medical commodity lead-time, improved accessibility of patients to essential health commodity supplies and general cost savings to the community.
Originality/Value/Novelty: Although drone technology has been the subject of numerous studies in Ghana, none has investigated the impact of medical commodity drone delivery services on the operations of last-mile healthcare facilities in Northern Ghana. This study therefore explored the impact of drone delivery services from the last-mile healthcare facilities' perspective.

Keywords: *Health care. last-mile. medical commodities. Northern Ghana. zipline drone delivery*

ISSN: 2408-7920

INTRODUCTION

Within the past decade, the Government of Ghana (GoG) through the Ministry of Communication (MoC) has pursued a robust digitalisation agenda aimed at modernising the country's economy (Ayakwah et al., 2021). Aside the Government's Street naming programme through the digital address system, one other outstanding area has been the introduction of drones in the delivery of medical commodities to last-mile or hard-to-reach healthcare facilities in some parts of the country.

A drone is any aircraft that is meant to operate independently or electronically without the presence of a pilot (Besada et al., 2018). It is a short-distance technology that is capable of travelling for twenty (20) minutes or longer before replacing or charging batteries (Demuyakor, 2020). Technically, Unmanned Aerial Vehicle (UAV) drone technology is deployed for a broad variety of functions from several human fields and disciplines including movie making, data processing, architecture, racing, agriculture, photography, the military, consumer goods delivery, security and in the health sector to deliver medical commodities (Frachtenberg, 2019; Lamptey & Serwaa, 2020).

Irrespective of their nature and purpose, drones are economically cost-effective, flexible and very fast. Additionally, they have the capacity of shipping, distributing and delivering packages to destinations as and when required (Patil, 2021). Drones are eco-friendly, eco-sustainable vessels which possess with fewer carbon dioxide emissions since they operate on batteries and seamlessly glide ride in the skies without obstructions of any kind, shape or form as compared the traditional road infrastructure or traffic networks.

The GoG signed a contract in 2019 with Zipline Technology International, an American Drone Company to establish a medical drone delivery service to last-mile healthcare facilities in some key locations in the country including Anum, Kete-krachi, Omenako, Mpanya, Sefwi-wiawso in the southern sector and Vobsi in the Walewale municipality in the northern sector of the country. Ghana's motivation for embarking upon this initiative was to be part of the comity of nations using drone technology to supply medical commodities to Ghanaians living in hard-to-reach communities (Davison et al., 2021). Ghana's drone delivery system is designed to provide on-demand emergency deliveries of medical commodities such as blood samples, essential medicines and vaccines to such communities. The zipline operations in Vobsi, which constitute the reason for this study, were established in 2019 to deliver medical commodities to last-mile healthcare facilities in the Northern, North-East, Savanna and Upper East regions of the country (Stubbs, 2019; Ministry of Health, 2023).

The typical last-mile delivery is that very final and arguably most difficult step in the supply chain, beginning at the distribution hub or warehouse and ending at the consumers' doorstep. This part of the supply chain is estimated to account for about 40% of overall logistics costs (Cuong & Tein, 2022). Medical delivery systems in the last-mile in low-and middle-income countries (LMICs) are often inefficient, slow and broken (Cuong & Tein, 2022). As a result, the healthcare outcomes especially for children, women and rural communities are negatively impacted by the lack of timely access to blood and other emergency medical supplies, resulting in many avoidable deaths

(Rebeiz et al., 2023). While the use of UAV is certainly not the only solution to last-mile delivery challenges, it has gained much attention in developing countries over the past few decades for its potential to significantly improve the supply of essential medical commodities to hard-to-reach locations (Schroeder et al., 2020). In the context of healthcare supply chains, the application of drone delivery is of particular importance because healthcare delivery is both costly and poses a challenge for many stakeholders (governments, healthcare providers and patients), particularly when it comes to serving rural or hard-to-reach communities (Gabani et al., 2021).

Besides, several studies by Ackerman and Strickland (2018); Knoblauch et al. (2019); Amukele (2019); Lamptey and Serwaa (2020); Davison et al. (2021); Debangshi (2021) and Adu-Gyamfi et al. (2021) have made significant contributions to the discourse on drone delivery services on the Sub-Saharan (SS) African continent and beyond. These studies examined the state and nature of drones in healthcare systems, construction, agriculture, data collection, and entertainment among others. Other studies have focused on drone use for healthcare delivery in Rwanda and Malawi (Balasingam, 2017; Lin et al., 2018), Senegal and Madagascar (Knoblauch et al., 2019; Novet et al., 2019). The findings of these researches have centred on the benefits, prospects and drawbacks of drone technology on Africa's healthcare fortunes.

Zipline's operations from Vobsi in the North-East region involve a 24-hour medical commodity delivery service, serving over 250 last-mile healthcare facilities in the four (4) Northern Regions of the country. Despite these studies, no study in Ghana has determined the impact of medical commodity drone delivery services on the operations of last-mile healthcare facilities in Northern Ghana. How has the operationalization of drones in the delivery of medical commodities impacted healthcare delivery at last-mile hospital facilities in Northern Ghana? What has been the impact of drone delivery service on health commodity delivery lead-time at the various last-mile healthcare facilities in Northern Ghana? This research study therefore assessed the impact of Zipline medical commodity delivery service on the operations of last-mile healthcare facilities in Northern Ghana.

THEORIES UNDERPINNING THE STUDY

This section of the study reviews the extant literature on drone technology activities across Sub-Saharan (SS) Africa with particular reference to medical commodities delivery to last-mile healthcare facilities in Ghana. The section commences with a theoretical review and concludes with an empirical review.

Theoretical Review

The theories underpinning this study are discussed in this section.

Diffusion of Innovations (DOI) Theory

The Diffusion of Innovations (DOI) is one of the theoretical frameworks adopted for this study. The DOI was first propounded by E.N Rogers in 1962 to explain how over a period of time products or ideas gain momentum and spread over time. The DOI gauges technology users'

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http://doi.org/10.26437/ajar.30.06.2024.12

acceptance and subsequent adoption of new behaviour towards innovative technologies (Dube et al., 2020). This is the most commonly used theoretical model for studying the reason why individuals and governments acquire and apply new innovative technologies (Rogers, 1987). The model is built on two key components: perceived usefulness and perceived ease of use (Tahar et al., 2020). Perceived usefulness is the extent to which the user believes the new technology will improve the performance of the organisation. Perceived ease of use explains the extent of users' comfortability with using the features of the new technology. These two (2) factors then jointly determine the attitude of users towards adopting the new technology. The DOI is considered a valid model that appropriately explains why countries and individuals adopt and utilise new technologies (Taherdoost et al., 2018). According to Dube et al. (2020), the decision-making process and user adoption of technology are described by such attributes to include compatibility, complexity, observability, trialability and comparative advantage. Triche et al. (2020) used the DOI theory to show that speed and environmental friendliness, as well as complexity, performance risk, and security risk, all had impacts on the adoption of drone delivery technology. (Kelata et al., 2022) also employed the DOI theory to examine the level of adoption of drone technology in the delivery of essential health commodity supplies.

Technology Evolution Theory

Technology Evolution (TE) was developed within the field of scientific innovation studies. This theory explains the rate and nature of technological change within the business organisation or in the larger economy. This is an economic function through which new and innovative technologies are introduced into design, engineering, production and consumption (Coccia & Watts, 2020). It involves recognising the novel technological possibilities and organising the financial and human resources required to transform them into useful processes and products sustaining the requisite activities. Technological innovation is an element or a component of the complex system of technological innovation and advancement seeking to satisfy needs, attain goals and resolve problems of adopters. In research, the TE theory has been used to explore the adoption of new technology in a variety of sectors. Nyaaba and Ayamga (2021) adopted this theory to investigate the nuances and challenges associated with medical drones in healthcare delivery across Africa. Ayamga et al. (2021) applied the theory to study the multifaceted application of drones in South Africa. The study investigated the impact of Ziplines drone delivery technology on the operations of last-mile healthcare facilities in Northern Ghana. Hence, employing the TE theory enables an evaluation of the operations of medical drone delivery in the transportation of medical commodities to last-mile healthcare facilities.

Empirical Review

Overview of Unmanned Aerial Vehicle (UAV) System

The history of drones dates back to 1918, when the US Navy tasked Charles Kettering, one of the most brilliant engineers of his generation, with creating a militarised unmanned aerial vehicle (UAV) (Scott & Scott, 2020). The very first deployment of drones in Sub-Saharan Africa (SSA) for the delivery of medical commodities to last-mile communities was in Rwanda's capital, Kigali in 2016 (Jeon et al., 2022). Its mandate included the delivery of blood products and essential

ISSN: 2408-7920

medicines to rural clinics. Since its maiden deployment in Rwanda, Zipline has steadily expanded its operations across Sub-Saharan Africa to include other countries such as Malawi, Botswana, Madagascar and Senegal. By 2019, the services had been expanded to Ghana and Zipline is now capable of delivering 170 different vaccines, blood products, and other types of medication to over 2000 healthcare facilities serving about 22 million people (Ackerman & Strickland, 2018). Drones are used to deliver lifesaving medications and medical commodities such as blood, gloves, oxytocin and vaccines (Ling & Draghic, 2019). Ghana's drone service operates a 24-hour service, from four (4) distribution centres, with each location having 30 drones making up to 600 on-demand delivery flights daily (GBC, 2022; Ackerman & Koziol, 2019).

Figures from Ghana's Statistical Service indicate that the country's population is 30.8 million (Ghana Statistical Service, 2020), 45% of which reside in rural or hard-to-reach areas of the country (USAID, 2019). By World Health Organisation (WHO) estimation, there will be 270 cases of malaria per 1000 people by the year 2017 (Hussin et al., 2020). The deployment of drones has allowed Ghana to augment its healthcare system. It has given the country's citizens a substantial opportunity to adapt to changing healthcare needs and it is now easier to dispatch emergency medical commodities to last-mile healthcare facilities across the country [(Davison et al., 2021). Ghana's Ministry of Health (MoH) has established that Ziplines' operations have served about 2,421 healthcare facilities throughout the nation since its inception (Ministry of Health, 2023). The Ghana Health Service (GHS) has acknowledged that with over 12 million deliveries, Zipline has strengthened Ghana's position as the sub-regional hub of the largest drone medical delivery business within Sub-Saharan Africa (GHS, 2019). Approximately 8.63 million life-saving medical items or medicines, 1.9 million consumables for child immunisation vaccinations, and more than 1.4 million COVID-19 vaccines and PPEs have all been delivered across the country via Zipline as of April 2019 (GHS, 2019).

Last-mile delivery

The last-mile, as used in distribution, is the journey commodities take from the facility closest to the customer to the final recipient (Macioszek, 2018). The phrase is also frequently used in logistics, supply networks, and transportation businesses (Borghetti et al., 2022). Last-mile delivery, which serves as the final link in the supply chain, is crucial to the distribution of goods to the general public. Cardenas et al. 2017 also describe last-mile logistics as the final stage in delivery service, involving several activities and procedures that are necessary from the distribution centres to the final receiving points of a supply chain. In other words, it is the section of the supply chain that transports medical supplies from the final site of storage to the customer at the location where the service is provided (Patowary et al., 2023). It therefore serves as that final crucial link in the medical commodity supply chain (Nur et al., 2020).

In SS Africa, healthcare supply chains vary widely within and among countries. The transition from the last storage point to the remotest healthcare facilities could involve different tiers and levels, subsequently involving smaller volumes of medical commodities bound for numerous destinations in greater frequency. While delivery to urban hospitals may be made by truck in certain locations, it may be necessary in other locations to use ox-drawn carts across unmotorable fields to reach remote hospitals (USAID, 2019).

Ghana's last-mile delivery system comprises district clinics, healthcare centres and Community-based Health Care Planning System (CHPS) compounds in rural and far-to-reach areas (Atiga et al., 2023). These facility types constitute the final destination of Ghana's public health care delivery system that directly interfaces with the most remote parts of the rural communities, making these facilities at the district, sub-district and community levels the last-mile facilities. CHPS compounds, just like over-the-counter stores, deliver basic medical services and medical commodities to rural patients.

Drone delivery services and operations of last-mile health facilities

Drones have been considered a potential new means of delivery in Sub-Saharan Africa for logistics companies for about a few decades now. Therefore, the trend of drones has a moderately significant impact on logistics with a great promise of offering rapid, point-to-point shipping to customers (Patowary et al., 2023). No matter what purpose they serve, drones are driven by a general goal to speed up and broaden the range of possible procedures, while also improving their accuracy and economic viability (Kellerman et al., 2020). As a result, there are numerous business prospects related to the deployment of drones. Compared to human drivers, terrestrial drones can travel at favourable costs, bypass the complex urban and rural navigation challenges altogether at favourable speeds. This technology is therefore becoming the game-changer in efficiency (Braun et al., 2019; Figliozzi et al., 2018; Hii et al., 2019). Drone deliveries lead to reduced fuel and energy use. According to a study by the Johns Hopkins Bloomberg School of Public Health, drones could help with global immunisation campaigns and increase vaccination rates in the medical industry, especially in hard-to-reach or last-mile health facilities in developing countries (Johns Hopkins School of Public Health, 2016). Key potential benefits of drone deliveries include increased speed, shorter lead times, and reduced damages to packages leading to overall efficiency of the medical commodity delivery process (Johnson et al., 2021).

A 2016 study by Claesson et al. which concluded that drones arrive at a faster rate compared to traditional emergency response system (ambulance) in rural healthcare facilities areas supports the notion of drone use in delivering medical commodities to last-mile healthcare facilities (Braun et al., 2019). In their study, Ackerman and Koziol, 2019 also stated that it may take up to 5 hours for a Rwandan hospital to get blood transfer via road, which could spell death for patients. In addition, Patil (2021) indicated from a Ghanaian study that the transfer of blood and other medical commodities from a designated medical facility to remote areas or villages by road can be very costly and time-consuming. The drive or motivation for drone delivery services is a direct response to the growing demand for fast and efficient logistics within rural communities. The health system is not left out as the industry players' attention is on precision delivery with an efficient cost perspective than conventional delivery systems would (Kitonsa & Kruglikov, 2018).

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Vol. 10, No. 1 (2024), pp. 178-200
http://www.ajaronline.com
http://doi.org/10.26437/ajar.30.06.2024.12

Speed of drone delivery services and last-mile health facility operations

Drones are a conveniently viable option for bridging the health-care access gaps especially in rural and far-to-reach communities of the world while addressing infrastructural inadequacies and last-mile delivery challenges (Janszen et al., 2021). The advent of the COVID-19 pandemic has demonstrated the suitability and utility of drones for last-mile medical delivery. Drones have increasingly been used by Governments, healthcare delivery agencies and industries to deliver anti-venom solutions, vaccines, organ transplants, emergency medicines, and other medical supplies, including commercial, civil and social applications. With their manoeuvrability and speed, drones constitute a viable tool for healthcare providers to boost their ability to efficiently provide healthcare solutions to patients and individuals, particularly in difficult-to-reach locations in developing countries (Janszen et al., 2021). A study by Aggarwal et al. (2023) confirms that timely delivery of medical commodities is essential in the last-mile healthcare sector but such deliveries are usually hampered by such factors as poor traffic, transportation network, and adverse environmental conditions. Lin et al. (2018) further indicate that drone delivery technology drastically reduces waiting times at health centres and even minimises the time patients typically wait for essential medicines or those out of stock by quickly sending medications between last-mile health facilities. Nisingizwe et al. (2022) also established that the adoption of drone delivery services led to faster delivery times for medical commodities leading to less blood wastage in public health facilities in Rwanda. Drone operations can boost last-mile logistic solutions in difficult-to-reach environments. When competition is increasing and speed is a vital component for a business's success, the time it takes to deliver packages in last-mile logistics might be critical. Based on the literature discussed above, the following hypothesis is made.

H_1: Drone delivery speed has a significant effect on the operations of last-mile health facilities.

Logistics Efficiency of Drone Services and Last-Mile Health Facility Operations

Logistics efficiency refers to how smoothly or seamlessly a business organisation conducts its operations (Freichel et al., 2020). Logistics efficiency indicates the prudent use of resources by business organisations to generate value (Sheng & Kim, 2021). The concept of efficiency can be explained from two perspectives: achieving a particular degree of output with the minimum possible resources and obtaining the maximum degree of output with a given set of inputs/resources (Nguyen et al., 2023). In logistics just like in many other fields/disciplines, a business organisation can attain competitive advantage by finding ways of strategically performing logistics activities, or ensuring that these activities are performed, more efficiently compared to its competitors. Efficient logistics management can constitute a major source of competitive advantage to a business organisation (Sumah et al., 2020). Logistic efficiency can improve customer experience by measures such as information management system, frequent staff training programmes, logistics service capabilities and quality, logistics reliability and learning from competitors. Accordingly, the hypothesis below is advanced.

H_2: Logistics efficiency of drone services has a significant effect on the operations of last-mile health facilities.

ISSN: 2408-7920

Drone Delivery Resources and Last-Mile Health Facility Operations

From a last-mile context, medical delivery drones can reach/penetrate far-to-reach rural areas where primary healthcare professionals can acquire daily delivery of medical commodity supplies at the click of a button and in a matter of minutes. Under operational protocols, the drone commodity delivery process commences when the drone team receives the requested inventory from the last-mile healthcare facilities. After the requisite commodities are uploaded, standardised pre-flight checks such as GPS tracker, audio pilot systems and wind conditions are conducted, and the drone is then dispatched. The drone ascends to the prescribed altitude and flies to the designated healthcare facility. Upon arrival at the designated location, the drone descends and transmits a notification signal. The drone lands and releases the delivery when the healthcare facility (client) is ready to receive and retrieve the package at the designated place. The drone then subsequently ascends to the appropriate altitude and flies back to the command center where it descends completing a round of commodity delivery. Drones increasingly appear to be the panacea to human limits, expediting, facilitating and increasing logistic processes and transportation and minimising inaccuracy, unpredictability and overall operational cost (Euchi, 2021).

Studies by Nouvet et al. (2019); Demuyakor (2020); Adu-Gyamfi et al., (2021) and Lin et al. (2019) in Ghana and other SS African countries on the application of medical drones in the delivery of medical commodities have indicated significant contributions toward improved rural health care especially in last-mile communities. This comes up against the backdrop of inaccessible roads, inadequate communication and rural areas requiring the use of ox-drawn carts through flooded fields to isolated clinics and health centres across rural Africa. Not only has the adoption of drones helped to improve the last-mile healthcare delivery system in SS Africa, but inaccessible roads no longer constitute a barrier to the transportation and delivery of vaccines, essential medicines, blood and other suitable healthcare items (Scott & Scott, 2020; Davison et al., 2021). The study results by Nouvet et al. (2019) indicate that in remote and rural Madagascar, drones have been used to control the incidence of tuberculosis infection. Drones are an innovative way to enhance the last-mile of medical delivery and make healthcare more accessible, inexpensive and equitable. They offer a wide range of possibilities including timely delivery of blood supplies, health equipment, vaccines, medications, snake bite serum, and other medical supplies to remote areas (Jeon et al., 2022). Most hard-to-reach healthcare facilities have no provision or capacity to effectively store cold-chain products such as blood or platelets on-site and drones ensure that these supplies are available and remain potent on demand (Awad et al., 2021). Based on the review of the literature, the following hypothesis is put forth:

H_3: Drone delivery resources have a significant effect on the operations of last-mile healthcare facilities.

Last-Mile Health Facility Operations

The "last-mile conundrum" continues to present a formidable challenge to logistics and supply chain practitioners and scholars especially in the field of rural healthcare administration. The challenge becomes even more crucial in the hard-to-reach rural areas where packages must be distributed across vast and largely interspersed territories and where population density is lower

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http://www.ajaronline.com
http://doi.org/10.26437/ajar.30.06.2024.12

leading to more miles travelled in a non-clustered fashion (Aurambout et al., 2019). Davison et al. (2021) study on last-mile established that last-mile populations are not only poor but are also under-served and excluded from access to vital medical services. The last-mile delivery phase is the costliest and most complex stage of the entire commodity distribution process since the cost of transportation is no longer shared with other shipments (Besada et al., 2018). The authors further established that the closer the transportation process gets to the last-mile, the more the unit cost of transport increases and the challenges it encounters. Last-mile delivery therefore plays a critical role in the distribution of medical commodities to patients, providing the last phase of the commodity supply chain the reason for which such deliveries should be appropriately planned, designed and properly managed (Besada et al., 2018). Innovations that deliver medical commodities to the last-mile, utilising models that overcome hurdles to access, affordability, knowledge, and the low health worker to population ratio are necessary to meet the World Health Organization's objective for universal healthcare coverage (Horvath et al., 2022).

Conceptual Framework

A conceptual framework is critical in a research study to establish the essential concepts or variables that must be researched, as well as their relationships (Sachdeva et al., 2023). The framework entails structuring the researcher's ideas to achieve the specified goal of an intended study. The conceptual framework for this study describes the relationship between drone delivery of medical commodities and the operations of last-mile health facilities in Northern Ghana. Figure 1 presents the relationship between the independent variables (drone delivery speed, logistics efficiency of drone services and drone delivery resources) and the dependent variable (operations of last-mile health facilities).

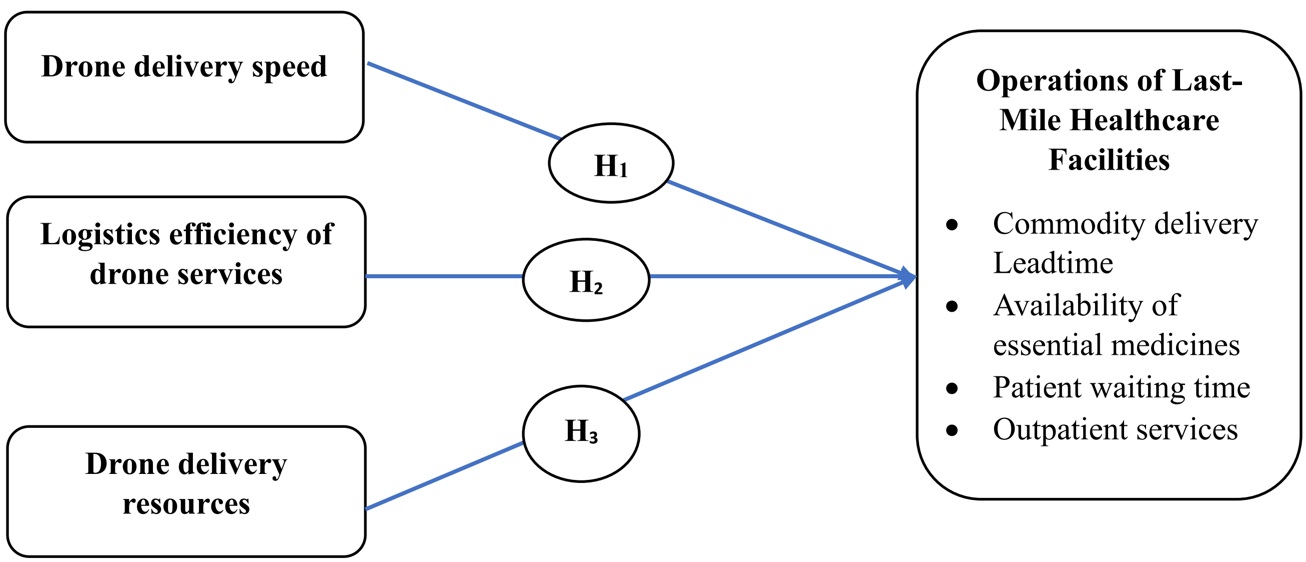

Figure 1: Conceptual Framework

Study Setting
Zipline's Vobsi Centre located in near Walewale in the West Mamprusi Municipality of the North East Region was officially commissioned in 2019. As the third largest distribution centre of its kind among Zipline's operations in Ghana, the centre supplies medical packages to various rural healthcare facilities across the four (4) Northern regions in Ghana. These include the Northern, North-East, Savannah and the Upper East regions. Zipline operations from the Vobsi centre cover over 250 healthcare facilities, 95 percent of which are located in rural and hard-to-reach areas of the aforementioned regions. On average, the Vobsi distribution centre flies 500 flights a day (GBC, 2022). The collaboration between Zipline Technologies of the United States of America (USA) and the Ministry of Health Ghana on the ***'Fly-To-Save-A-Life Project'*** sought to achieve rapid responses to medical emergencies, through the use of unmanned drones to various healthcare facilities in last-mile areas across the country (Ministry of Health, 2022).

METHODOLOGY
The study was guided by the positivist philosophical orientation which seeks to replicate happenings in the natural world to the social world. A descriptive research design was adopted to explore the relationship between Ziplines medical drone delivery services and the operations of last-mile healthcare facilities in Northern Ghana. The population of the study consisted of last-mile healthcare facilities serviced by the Zipline Vobsi Center in Northern Ghana. The study adopted an exploratory research design, where a survey method was used to collect quantitative data from the key staff of last-mile healthcare facilities in the Upper East, North-East, Northern and Savannah regions serviced by the Vobsi Zipline drone centre. The respondents for this study were selected through a purposive sampling technique because they had undergone technical training from Zipline on the requisition and receipt of medical commodities via drone technology (Klar & Leeper, 2019). Hence, these staff directly interphase with Zipline delivery activities in their various healthcare facilities.

A research questionnaire with 5-point Likert-scale question items was employed to collect quantitative data. An online survey questionnaire via Google Forms was used to collect the data for this study. Before the data collection, the survey questionnaire was sent out to the research unit of Zipline as well as other health professionals for their input to enhance the content validity of the constructs. The survey questionnaire was then shared through the official WhatsApp group page of last-mile healthcare facilities, assisted by officials from Zipline Vobsi Centre. 159 valid responses were received from key officers of each healthcare facility via the Google survey questionnaire. The data collection took four (4) months spanning from July to October 2022. The valid responses were downloaded into Excel and analysed using the Statistical Package for Social Sciences (SPSS) version 26. Multiple regression was used to determine the impact of drone delivery services on the operations of last-mile health facilities. The Cronbach's Alpha was used to measure the reliability of the research constructs.

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http://doi.org/10.26437/ajar.30.06.2024.12

Conceptualisation and operationalisation of variables

The major variables in this study were all latent variables that were adapted from previous research with minor alterations. The variables were transformed into measurable items and deployed to collect data. For the main variables, respondents used a 5-point Likert scale on a range of 1 = "Strongly Disagree" to 5 = "Strongly Agree" in expressing their views on the various questions posed during the research study.

Drone delivery speed was conceptualised as the rate at which medical commodities are delivered via drone technology to last-mile healthcare facilities in Northern Ghana. The items for measurement of drone delivery speed in this study were adopted from Janszen et al. (2021) and Aggarwal et al. (2023). Logistics efficiency of drone services involves all processes that ensure the flow, movement and positioning of resources for efficient drone delivery of medical commodity supplies. The measures for assessing the logistics efficiency of drone delivery were developed from (Figliozzi et al., 2018). Drone delivery resources refer to the infrastructure necessary to facilitate the efficient operation of medical drones (Johnson et al., 2021). Measurement items for assessing drone delivery resources were adopted from Coccia and Watts (2020) and Kornatowski et al. (2018). Commodity delivery lead-time, availability of essential medicines, patient waiting time and outpatient services were all conceptualised as part of the operations of last-mile healthcare facilities (Lin et al., 2018; Snouffer, 2022).

Regression Analysis

Regression models are used to explain the association between variables in a research study. Regression enables the researcher to determine the influence of the independent variables on the dependent variable (Bevan et al., 2020). Multiple regressions can also be used to determine the overall fit of the model as well as the proportionate contribution of each variable to the total variance explained. The model for this research study is presented below:

$$Y = \beta 0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

Y represents the dependent variable i.e., last-mile health facility operations. $\beta 1$, $\beta 2$ and $\beta 3$ are the coefficients or multipliers that describe the size of the effect that the independent variables have on the dependent variable. X_1, X_2 and X_3 represent the independent variables, Speed (SP), Logistics Efficiency (LE) and Drone Delivery Resources (Ddr) respectively. **ε** represents the error term.

FINDINGS AND DISCUSSION

The results from data analysis are presented in this section of the paper.

Demographic Data of Respondents

Table 1 presents the respondents' biographic information for this study.

ISSN: 2408-7920

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http://doi.org/10.26437/ajar.30.06.2024.12

Table 1: Demographic Data of Respondents

Biographic Factors	Frequency	Percent (%)
Gender of Respondents		
Male	120	75.5
Female	39	24.5
Total	**159**	**100.0**
Age of Respondents (in years)		
20-25	3	1.9
26-30	41	25.8
31-35	66	41.5
36-40	41	25.8
Above 40	8	5.0
Total	**159**	**100.0**
Educational Qualification		
Certificate	39	24.5
Diploma	75	47.2
Bachelor's Degree	37	23.3
Master's Degree	7	4.4
PhD	1	0.6
Total	**159**	**100.0**
Working Experience (in years)		
1-5	76	47.8
6-10	38	23.9
11-15	39	24.5
16-20	4	2.5
Above 20	2	1.3
Total	**159**	**100.0**
Job Designation		
Physician Assistant	18	11.3
Store Personnel	3	1.9
Pharmacist	1	0.6
Nurse	101	63.5
Facility Manager	13	8.2
Disease Control Officer	12	7.5
Laboratory Technician	4	2.5
Accounts Officer	2	1.3
Public Health Nurse	5	3.1
Total	**159**	**100.0**

ISSN: 2408-7920

Type of Health Facility		
CHPS Compound	95	59.7
Clinic	1	0.6
Health Center	45	28.3
District Hospital	10	6.3
District Health Directorate	6	3.8
Regional Hospital	2	1.3
Total	**159**	**100.0**
Facility experience with drone delivery services (in years)		
less than 1	4	2.5
1 – 2	70	44.0
3 – 4	60	37.7
4 – 5	10	6.3
Above 5	15	9.4
Total	**159**	**100.0**

Source: Survey Results, 2023.

The information in Table 1 indicates that concerning the gender of respondents, the majority were males (75.5%) while 25.5% were females. Most of the respondents were within the age range of 31-35 (41.5%) and possessed a Diploma (47.2%), Certificate (24.5%) and Bachelor's degree (23.3%) as relevant educational qualifications. A few respondents had masters (4.4%) and PhD (0.6%) as relevant educational qualifications for the roles they performed at their various healthcare facilities. Information on the job designation revealed that the majority of the respondents were nurses (63.5%) and physician assistants (11.3%) mostly from CHPS compounds (59.7%) and health centres (28.3%) within the operational zones of Zipline in Northern Ghana. The experience of respondents was assessed on two fronts; experience with general healthcare service delivery which revealed that 47.8%, 24.5% and 23.9% of respondents had worked in the healthcare sector for 20 years and experience with Zipline's drone delivery service which also revealed that majority of respondents (44%) have worked with the Zipline drone delivery service for about 4 years since its inception in Ghana. The demographic data of respondents for this study indicates that participants had the relevant educational qualification, were from various Zipline-serviced last-mile healthcare facilities, had adequate drone delivery service experience and thus provided informed responses to questions posed in the study.

Measurement Model

The validity and reliability of the various constructs employed to investigate the effect of zipline operations on last-mile operations of healthcare facilities are discussed in this section.

Reliability and Validity

Reliability is the consistency with which a method evaluates an item under study. The measurement is considered reliable if the same result can be produced consistently by using the same methods under the same conditions. The method used for establishing reliability in this research study is Cronbach's alpha (α). The Cronbach's alpha (α) values for the various research constructs are presented in Table 2.

Table 2: Construct Reliability

Research Construct	Cronbach's Alpha
Speed (SP)	0.822
Logistics Efficiency (LE)	0.827
Drone Delivery Resources (Ddr)	0.797
Last-Mile Health Facility Operations (Lhfo)	0.885

Source: Survey Results, 2023.

The Cronbach's alpha figures as presented in Table 2 ranged from 0.885 to 0.797, exceeding the required reliability threshold of 0.7. Hence, construct reliability was duly established in this study. The validity of the research constructs was assessed using Exploratory Factor Analysis (EFA) from which the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's Test of Sphericity were examined. Information from Table 3 indicates a KMO figure of 0.875 which can be said to be acceptable and high (Shkeer & Awang, 2019). Assessment from Bartlett's Test also revealed a Chi-Square value of 3861.772, a degree of freedom of 741 and a p-value of 0.000 < α – value of 0.05 which is highly significant at the 5% level of significance.

Table 3: Construct Validity

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**0.875**
Bartlett's Test of Sphericity	Approx. Chi-Square	**3861.772**
	df	**741**
	Sig.	**0.000**

Source: Survey, 2023

Impact of Zipline drone delivery on the operations of last-mile healthcare facilities

Multiple regression analysis was conducted to examine the influence of Zipline drone delivery services on the operations of last-mile healthcare facilities and the results are presented in Table 4.

Table 4: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.843[a]	0.711	0.705	0.43078

a. Predictors: (Constant), Drone Delivery Resources, Speed, Logistics Efficiency

Source: Research Survey Results, 2023.

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http://www.ajaronline.com
http://doi.org/10.26437/ajar.30.06.2024.12

The results of R^2 from Table 4 and the ANOVA results from Table 5 indicate that 70.5% of the variance in the operations of last-mile healthcare facilities can be accounted for by the three predictors collectively, F (3,155) = 126.838, p-value < 0.05. This suggests that at least one of the independent factors has an impact on the dependent variable and that the suggested model is a good indicator of how last-mile healthcare services will perform.

Table 5: Analysis of Variance (ANOVA)

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	70.612	3	23.537	126.838	.000[b]
	Residual	28.763	155	.186		
	Total	99.375	158			

a. Dependent Variable: Last-Mile Health Facility Operations

b. Predictors: (Constant), Drone Delivery Resources, Speed, Logistics Efficiency

Source: Survey Results, 2023.

The effect of the independent variables on the dependent variable is explained by the beta coefficients (B) in Table 6. The distinct individual contributions of the predictors, as shown in Table 6, suggest that all the three predictors, Speed (β = 0.506, t = 6.871, p = 0.000), Logistics Efficiency (β = 0. 281, t = 3.310, p = 0.001) and Drone Delivery Resources (β = 0. 246, t = 4.880, p = 0.000) had a significant positive effect on the operations of last-mile healthcare facilities in Northern Ghana. This implies that a unit change in the speed, level of logistics efficiency and availability of drone delivery resources will result in an increase in the efficiency of the operations of last-mile healthcare facilities by 50.6%, 28.1% and 24.6% respectively. Hence, the operations of last-mile healthcare facilities within Northern Ghana are significantly impacted by operational factors such as the speed with which drones deliver essential health commodities, the efficiency of logistics activities and the adequate availability of drone delivery resources.

ISSN: 2408-7920

Table 6: Multiple Regression Analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	p-value	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-0.326	0.227		-1.436	0.153		
	Speed	0.506	0.074	0.466	6.871	0.000	0.406	2.463
	Logistics Efficiency	0.281	0.085	0.236	3.310	0.001	0.368	2.717
	Drone Delivery Resources	0.246	0.050	0.263	4.880	0.000	0.644	1.553
a. Dependent Variable: Last-Mile Health Facility Operations								

Source: Survey Results, 2023.

Multicollinearity occurs when the multiple linear regression analysis includes several variables that are significantly correlated, making some of the significant variables under study to be statistically insignificant (Shrestha (2020). This study adopted the Variance Inflation Factor (VIF) technique to assess the presence or otherwise of multicollinearity. The VIF statistics in Table 6 show that there is no problem with multicollinearity because the VIF figures of all three independent variables are within the range of 1< VIF < 5 (Kim, 2019). Hence, each of the beta coefficients (speed, logistics efficiency and drone delivery resources) independently influence the dependent variable (operations of last-mile health facilities).

Discussion

The study sought to establish the relationship between Zipline drone delivery services and the operations of last-mile healthcare facilities in Northern Ghana. To achieve this, it was hypothised that drone delivery speed, logistics efficiency and drone delivery resources had a significant effect on the operations of last-mile healthcare facilities. The findings of the study revealed that drone delivery speed, logistics efficiency and drone delivery resources all had a positive significant impact on the operations of last-mile healthcare facilities in Northern Ghana. This implies that the operationalisation of Ziplines drone delivery technology significantly reduced commodity delivery lead-time as well as patients waiting times, ensured the availability of essential medicines, resulting in improved of general outpatient services, emergency response and optimised supply chain management at the last-mile. Consistent with the research findings of Yoo and Chankov (2018), the speed of drone delivery technology ensures that essential lifesaving medications get to patients within a short time as compared to existing traditional modes of delivery. Snouffer (2022) established that when drone delivery resources are sufficient and available, it results in the availability of essential medical supplies to last-mile healthcare facilities since patient waiting time is significantly reduced. Furthermore, this study is one of the first studies to investigate the impact of Zipline's drone delivery service on the operations of last-mile healthcare facilities in Ghana. The research model was constructed on the Diffusion of Innovations Theory and the Technology Evolution Model frameworks. The results of this study have theoretical ramifications and offer managerial insights into Zipline's last-mile drone delivery services to enhance the operations of last-mile healthcare facilities, particularly in developing countries like Ghana. As opined by Adu-Gyamfi et al. (2021), Ghana's use of drone delivery services has improved the prompt delivery of medical commodities, including test samples, blood, and personal protective equipment to a variety of healthcare facilities, with rural areas receiving special attention.

CONCLUSION

This study determined the impact of Zipline's drone delivery of medical commodities on the operations of last-mile healthcare facilities in Northern Ghana. Within the past decade, the Government of Ghana has followed in the footsteps of other countries in the Sub-Saharan Africa region to adopt drone technology to deliver medical commodities to deprived healthcare facilities with the ultimate objective of attaining quality healthcare delivery at the last-mile level. The findings revealed that Zipline's drone delivery services had a significant effect on health commodity delivery lead-time, availability of essential medicines, patients waiting times and an improvement in general outpatient services. Hence, effective collaborations between Zipline Ghana and last-mile healthcare facilities will significantly improve the health fortunes of patients within Northern Ghana and by extension the entire country.

Recommendations

The following recommendations are made for the improvement of drone delivery services to healthcare facilities;

Management of last-mile healthcare facilities should build strategic collaborations with Zipline Ghana to ensure timely exchange of information and sharing of resources where necessary to facilitate and improve healthcare delivery.

Management of Zipline Ghana should invest in areas such as drone delivery speed, logistics efficiency and drone delivery resources to significantly improve the delivery of medical commodities to last-mile healthcare facilities in Ghana.

Continuous training of hospital personnel by Zipline Ghana on healthcare drone delivery technology to improve delivery and receipt of healthcare commodities.

ACKNOWLEDGEMENTS

The researchers express their profound gratitude to the management of Zipline Ghana for their vital support and grant of access to collect data for this study. Additionally, the researchers are grateful to all representatives of last-mile healthcare facilities in Northern Ghana who participated as respondents in this study.

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