The Use of UAV/Drones in the Optimization of Nigeria Vaccine Supply Chain

Omole Timilehin Michael, Aturaka Olusegun, Olaiya Abiodun Paul, Sanni Olaniyi Felix, Freddy Rukema Kaniki, Oluwasola Stephen Ayosanmi, Djibril Wade, Ajani Olumide Faith, Gwa Zachary Terna, Abdulsalam Musa,Olaide Lateef Afelumo, Jimmy Aiden, Ajani Love Adeiye

Abstract: UAVs are known for their cost-saving benefits, security, preservation of lives and most importantly their speed and ability to reach hard-to-reach areas. They can also be used to mimic human effects in picking and capturing data. It is, therefore, correct that drone technology is one of the ways to overcome the challenges of the vaccine supply chain. This study is aimed at determining the potentials of UAV/Drones in the optimization of Nigeria Vaccine Supply Chain (VSC). An electronic questionnaire was used to reach different professionals with experience of Nigeria supply chain of vaccines. A cluster of professionals whose works relates to the supply chain of public health commodity was selected as the sampling frame. This involved number of professionals in Nigeria who have identified as part of the International Association of Public Health Logisticians, IAPHL. From the survey, a total of 200 valid responses were received and analyzed using SPSS and Microsoft excel combined. There were 141 (70.5%) males and 59 (29.5%) females. The most frequent age group was 31 – 40 (56.5%). A majority, 81 (40.5%) of respondents were health/public health/development professional, 86.0% had experience with Nigeria VSC, 57.0% had at least 5 years' experience, 60.5% had good knowledge of VSC while 27.0% were very aware of UAVs. Overall acceptability and feasibility of UAV technology in Nigeria VSC were 88.5% and 75.0% respectively. Nigeria was rated in the area of private sector involvement, regulatory and policy, workforce knowhow and technical/technological infrastructure ready to take up innovations/technologies such as UAVs. UAV/drones is a promising option for a secured vaccine supply chain in Nigeria and should be given more consideration.

Keywords: UAV, drones, vaccine, supply chain, optimization, acceptability, Vaccine challenges

1. Introduction

The use of drones, or Unmanned Aerial Vehicles (UAV) as a new and additional option for transporting public health commodities, safe blood for transfusions, and laboratory samples to the last mile is generating a lot of interest [1]. UAVs are part of an emerging world of transportation. A new and exciting field within this emerging world is humanitarian use as employees of non-governmental organizations are at risk of insecurity during conflict conditions and this affects their services relating to vaccine supply. The use of drones to perform this task may be an alternative to reduce the insecurity risk of human lives [2]). Drones can also serve as an alternative transport option to reach locations with insufficient infrastructure [3].

In 2016, Stony Brook University's Global Health Institute and Vayu started a pilot project in which a drone start-up successfully delivered drugs and laboratory samples to remote places in Madagascar in 2016 [4]. similarly, a drone may be effective and efficient in reaching localities with difficult access due to poor road networks.

Faster drone deliveries could provide a valuable alternative to reach populations that are difficult to reach, especially the area where health facilities are not adequately equipped to store medical products that require cold storage and careful handling during transport [5]–[7].

Six countries in Africa (Ghana, South Africa, Tanzania, Rwanda, Malawi and Madagascar) have been identified as feasible for commercial drone operations in the healthcare sector (Wuerbel, 2018). The analysis considered the size of the healthcare market through comparison of public and private healthcare expenditure. In addition, the logistics and healthcare infrastructure were analyzed. To determine the healthcare infrastructure the Healthcare Sustainable Development Goal (SDG) Index, a composite index of health-related indicators was used. To determine the logistics infrastructure the Transport Composite Index of the African Development Bank was used. The final feasibility was obtained by the level of drone regulations in place in addition to a drone supplier presence or pilot project in the country [3], [9]. Although Gavi did not include Nigeria among the countries stated as feasible for commercial drone operations in the healthcare sector, it is imperative for us to analyze the acceptability, feasibility and preparedness of UAVs to optimize the Nigeria vaccine supply chain.

1.1 Acceptability, feasibility and preparedness considerations

Acceptability and feasibility of drone use in local communities need to be assessed to make sure they are not a limitation to the successful use of drones for the delivery of vaccines. However, pilot projects in many countries have shown that the local communities rather embraced this new technology given they were informed about the intended use prior to the implementation (Wuerbel, 2018). Concerns about drone use in conflict zones exist; however, no hostility in existing cases of drone use in conflict zones has been described to date. The Humanitarian UAV Network Guidelines on Conflict Sensitivity can provide further guidance in case drone delivery is considered in such a setting [10].

For preparedness, not only the cost and immediate performance improvements in supply chain operations such as speed and responsiveness should be considered, but also preparedness of Nigeria and her supply chain. For example, by using drones it would be possible to reach populations that are difficult to reach using traditional means of transport [5] and thus increase the coverage of vaccination. The question we should ask ourselves is how prepared we are to take up new innovation such as UAVs in the areas of political will, regulatory and policies, private-government collaborations, workforce know-how as well as our technical infrastructure readiness?

1.2 Return on investment (ROI), quality considerations and environmental benefits of UAVs

A cost-benefit study translates health-outcomes into monetary terms to make the benefits of the new intervention more comparable. An example of such an economic evaluation is the study "Return on Investment from Childhood Immunization in Low- and Middle-Income Countries, 2011-20" conducted in 2016 for ten antigens using the Gavi 2014 adjusted vaccine demand forecast. The results showed that for every dollar invested in countries supported by Gavi, 18 USD is expected to be saved. Those cost savings are possible through direct savings in the medical field such as healthcare cost and lost wages due to illness, but also due to indirect economic benefits. Those include cognitive development, education, and employment. It is possible to include even a wider range of benefits such as the value of a longer and healthier life. This would increase the return of one dollar invested to 48 USD. [3], [11]. It is expected that using drones to deliver vaccines that

would otherwise not be provided will also save money, although the exact ROI ratio is yet to be determined. Nevertheless, such a cost evaluation could be a helpful tool for decision-makers in the health sector.

Most vaccines require refrigeration throughout the whole supply chain from manufacturer to service delivery to not compromise the quality of the product. The shorter time window for the drone delivery can provide an advantage over traditional transport where refrigerated transport conditions need to be assured for much longer time periods [6].

Another advantage of the use of drones is the environmental aspect. Many drones do not require fuel and drone batteries can be charged using solar energy and thus they are environmental friendly sustainable solution. The use of drones can minimize carbon emissions through diesel-powered cars or motorcycles used traditionally for the last mile delivery [3].

In Nigeria, some of the challenges of vaccine cold chain include:

1. Poor maintenance of vaccine cold chain supply.
2. Insecurity due to conflicts prevents manpower services for vaccine cold chain transportation.
3. Poor road network affecting the delivery of vaccine cold chain supply within the stipulated time interval and preventing the universal distribution of vaccine

Drone vaccine delivery may be an alternative means of solving the above problem based on prior evidence. However, we need to be certain if it will be accepted by the end-users and will be feasible in our setting. The objective of the study is therefore to determine the potentials of UAV/Drones in the optimization of Nigeria Vaccine Supply Chain

2. Methods

An electronic survey was used to reach different professionals with experience of Nigeria supply chain of vaccines. The samples cut across different levels of operation, geography and areas of practice. The population size of professionals in Nigeria's development/health public health was estimated at over 5000. A cluster of professionals whose works relates to the supply chain of public health commodity was selected as the sampling frame [12]. This study used a target sample frame, though growing stands at 1,047 as at the time of this data collection in December 2017 [13]. This involved number of professionals in Nigeria who have identified as part of the International Association of Public Health Logisticians, IAPHL. The IAPHL is an association of public logistician from all over the world coming together to share knowledge, best practices and network. Using this sample frame, sample size calculator was used to calculate the expected sample size. At a confidence interval level of 95%, the sample size of 281 professionals was needed using sample size calculator [14]. This was considered a good and credible representation of the population for this phase of the research.

The questionnaire was shared on the listserv of the IAPHL and other smaller internet-based social network (Whatsapp, Telegram and LinkedIn) and opened for one (1) calendar month after which it was closed to further responses. At the end of one-month time horizon, (December 3, 2017, to January 2, 2018) a total of 200 valid responses were received and the questionnaire closed to further responses using the switch on the Google form. Following this stage, the data were harvested for onward analysis. We ensured that questionnaires were easy to use and understandable and only take 5-10 minutes of a participant's time. The permission and support of the administrator of the different platforms were also secured to give the process speed and credibility. This approach follows the strategy by Easterby-Smith et al [12] on how to improve the response rate [12]. The data analysis combined SPSS version 25 and Microsoft Excel. With SPSS, we better managed data with case selection, file reshaping, and creating derived data. A metadata dictionary was stored with the data. Statistical analysis tasks performed with the base package include the generation of descriptive statistics, prediction of numerical outcomes, and prediction of identifying groups.

3. Results

3.1 Demographic and experience of respondents

There were 200 valid responses from professionals in various fields related to supply chain management in Nigeria. Males were 141 (70.5%) while females were 59 (29.5%). There were 39 (19.5%) within 21 – 30 age group, 113 (56.5%) for 31 – 40 while 48 (24.0) were above 40 years. There are 52 (26.0%) supply chain professional only, 81 (40.5%) health/public health/development professional only and 49 (24.5%) supply chain and health/public health development. Others included information technology (IT), financial/business, project management and regulatory and safety professionals (Table 1). Eighty-six percent (172) had experience with Nigeria supply chain, 114 (57.0%) had at least 5 years' experience while 83 (38.5%) had 6 -20 years' experience in supply chain (Table 2).

Table 1: Demography of respondents (n = 200)

Parameter	*Frequency*	*Percentag*
Gender		
Male	141	70.5%
Female	59	29.5%
Age category		
21 - 30	39	19.5%
31 - 40	113	56.5%
41 and above	48	24.0%
Profession		
Supply Chain Professional Only	52	26.0%
Health/Public Health/Devt Professional Only	81	40.5%
Supply Chain and Health/Public Health/Devt	49	24.5%
IT professionals Only	3	1.5%
Financial/Business and Project Mgt	8	4.0%
Regulatory and Safety Professionals	7	3.5%

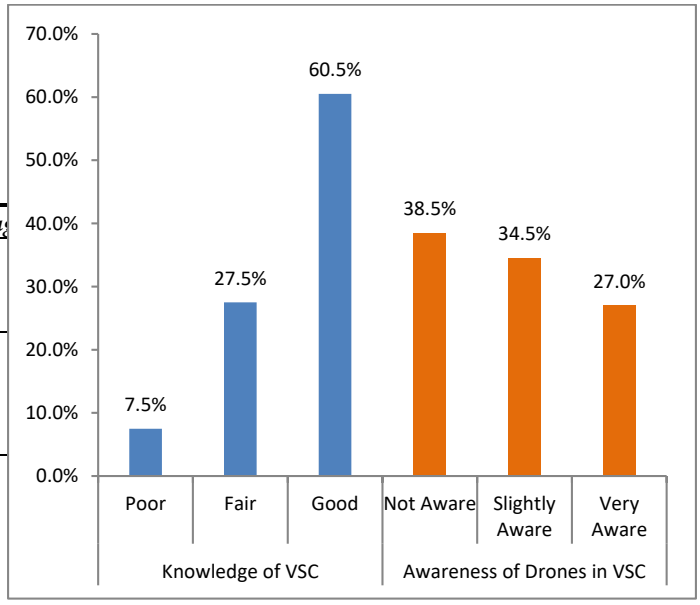

Figure 1: Knowledge of vaccine supply chain and awareness of UVA/Drones in VSC

Table 2: Experience with Nigeria Supply Chain (n = 200)

Parameter	*Frequency*	*Percentage*
Do you have Experience with NSC?		
Yes	172	86.0
No	28	14.0
Year of experience		
≤ 5	114	57.0%
6 – 10	57	28.5%
11 – 20	26	13.0%
>20	3	1.5%

NSC-Nigeria's Supply Chain/Development work

3.2 Comparison of knowledge of Nigeria VSC and awareness of UAV in VSC

The majority (60.5%) of the respondents had good knowledge of VSC, 27.5% had fair knowledge while just 7.5% had poor knowledge of VSC. In contrast, only 27.0% were very aware of UAVs, 34.5% were slightly aware while 38.5% were not aware at all.

3.3 Acceptability and Feasibility of UAVs in Nigeria vaccine supply chain, professionals' views

Acceptability of UAV/Drones was averagely rated 88.5% while feasibility was 75.0% by all professionals (Figure 2). Supply chain professionals rated 92.3% acceptability and 75.0% feasibility. For financial/business and project management, acceptability and feasibility were rated 81.5% and 65.4% respectively, Supply Chain and Health/Public Health/Development rated them 91.8% and 85.7%, IT professionals - 100% and 100%, financial/business and project managers - 100% and 87.5% while regulatory and safety professionals rated them 100.0% and 85.7% respectively. Those who had a maximum of 5 years working experience acceptability of UAV 95.3% and its feasibility 93.9%, 6 – 10 years rated them 100.0% and 94.7% respectively while those who had more than 10 years' experience rated both 100%.

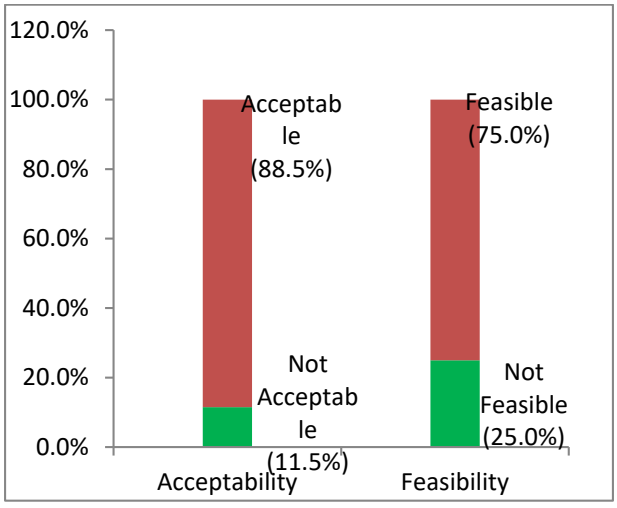

Figure 2: Acceptability and feasibility of UAV/Drones in Nigeria vaccine supply chain

Table 3: Acceptability and Feasibility of Drones as rated by profession

Parameter	*Acceptability*	*Feasibility*
Profession	**P < 0.001**	**P < 0.001**
Supply Chain Professional Only	92.3%	75.0%
Health/Public Health/Devt Professional Only	81.5%%	65.4%
Supply Chain and Health/Public Health/Devt	91.8%	85.7%
IT professionals Only	100.0%	100.0%
Financial/Business and Project Mgt	100.0%	87.5%
Regulatory and Safety Professionals	100.0%	85.7%
Year of experience	**P = 0.007**	**P = 0.001**
≤ 5	95.6%	93.9%
6 – 10	100.0%	94.7%
11 – 20	100.0%	100.0%
>20	100.0%	100.0%

3.4 Preparedness to take up new innovation/technology in Nigeria VSC

Preparedness of Nigeria vaccine supply chain was rated as 96.0% for international political will, 54.0% for national political will, 76.5% for regulatory and policy, 82.0% for private sector participation and collaboration, 60.0% for technical or technological infrastructure and 73.0% for workforce know-how.

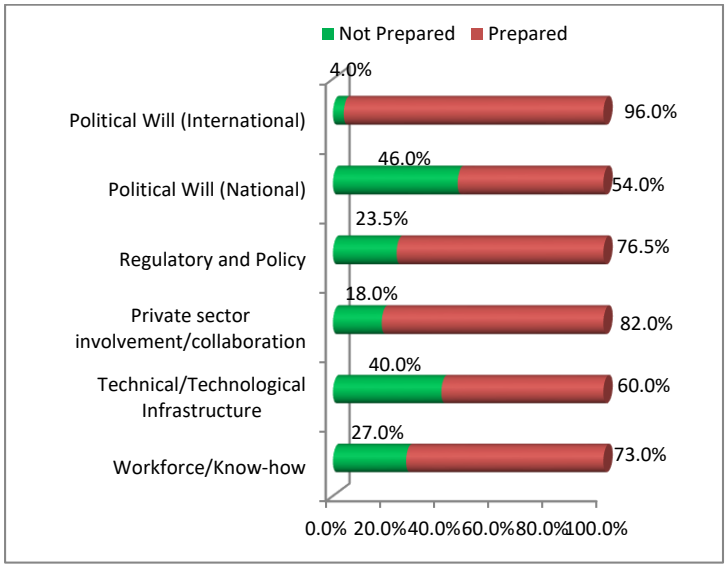

Figure 3: Preparedness to take up new innovation/technology in Nigeria VSC

4.0 Discussion

Despite the political, financial and human implications of vaccine cold chains so far, the overarching challenges of decision making in technology-supported cold chain management have received little attention in humanitarian logistics research [15]. To begin bridging that knowledge gap, in this paper, we focus on knowledge, acceptability, feasibility and preparedness to take up UAV technologies to support decision-makers in cold chain management, operational decisions and planning. This study comprised of professionals from various supply chain related fields with a wide range of years of experience. Over 60% of the respondents have had experience with the vaccine supply chain even though UAVs are part of an emerging world of transportation [1]. Although Nigeria was not among the six countries identified as feasible for commercial drone operations in the healthcare sector as rated by Gavi in 2016 [3], our current findings revealed that UAV is well acceptable and feasible in Nigeria vaccine supply chain with overall acceptability and feasibility of 88.5% and 75.0% respectively.

Humanitarian last-mile challenges so far have been conceived primarily in the context of rural areas, accelerating urbanization with attendant problems of congestion, safety and infrastructure problems will likely be increasingly come to the fore [15]. The utility and ethics of so-called "humanitarian surveillance drones" have been the subject of much discussion in the humanitarian community over the last couple of years [16]. More recent talk about the potential of cargo drones to help bridge the last mile to bring vaccines, blood supplies or HIV diagnostic kits to suffering African populations in countries like Lesotho, Malawi, Rwanda or Madagascar has been heavily promoted by the drone industry and has received

significant attention from global media [17]. It is also possible to overcome humanitarian last mile challenges in Nigeria and other low-income countries using drones, based on acceptability and preparedness to take up UAV technologies in Nigeria. Professionals in information technology rated acceptability and feasibility of UAVs 100% while the lowest rating by other professionals was 65.4%. This finding contradicts our null hypothesis that UAVs are generally unacceptable and not feasible in Nigeria ($p<0.05$). Acceptability and feasibility of UAVs were also found to increase with an increase in years of experience ($p<0.05$). Wuerbel [3] reports that pilot projects in many countries have shown that the local communities rather embraced this new technology given they were informed about the intended use prior to the implementation. It may be also essential to enlighten and train professionals in Nigeria base on the findings of the current research, to maximize acceptability of UAVs.

For preparedness to take up the new technology, Respondents rated Nigeria politically prepared, ready to collaborate with the private sector. They also rated Nigeria ready to take up new innovation/technology such as thermostable vaccine in terms of regulatory and policy, workforce knowhow, and technical/technological infrastructure.

Based on our findings on the feasibility of UAV technologies in Nigeria vaccine supply chain, we can affirmatively say that Nigeria vaccine supply chain is a potential investment opportunity for manufacturers or investors in UAV technologies. The benefit is not only limited to investors but also to promote disease prevention through prompt and quality immunization programs. Adoption of UAV will also minimize the economic losses associated with wastage and ineffectiveness of vaccines.

Conclusion

UAVs are known for their cost-saving benefits, security, preservation of lives and very importantly, their speed and ability to reach hard to reach areas. They can also be used to mimic human effects in picking and capturing data. It is therefore inarguably correct that drone technology is one of the ways to overcome the challenges of vaccine supply chain in LMICs. Our findings revealed that despite little knowledge of UAV technology among professionals in fields related to vaccine supply chain, the technology is perceived as highly feasible for adoption in Nigeria.

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