

# IoT Drone Technology Integration in Medical Logistics Delivery

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**Abstract:** Drone technology has linked up several opportunities to enable direct connection with the medical consumable donors to receive request through mobile phone communication and deliver medical consumables via Drone device. The recent development in autonomous air navigation and implementation of Drones into mainstream geographical ecosystem have been recognized for adoption in healthcare emergency responses. At the center of the innovation is the Internet of Things (IoT) technology which had necessitated advanced mission specification for Drones to operate beyond visually line of sight (BVLOS) in responding to classified healthcare assignments. The use of Drones in the healthcare management, welfare support, emergency responses and health risk management was investigated in the selected country of the Central East Africa (Rwanda). The research discovered a system of dynamic connection between the tiers of governments in active partnership with the private sector initiative to exploit Drone technology innovation to improve healthcare service delivery up to the grass root level with an outstanding productivity. The article evaluated Africa's involvement in the society healthcare extreme automation using Drone technology capabilities and deliberated on the possibilities and benefits for implementation and adoption into the national healthcare sector in Nigeria. The paper concluded that future implementation of the research will accomplish the digital health demands of Nigeria government, public and private sector health maintenance to guarantee sustainable healthcare investment and effective healthcare service delivery.

**Keywords:** Healthcare Delivery, Health Informatics, Healthcare Automation, Drone Technology, Artificial Intelligence, Robots, Internet of Things (IoT), Public-Private Sector Initiative

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## 1. Introduction

The Health sector is presently experiencing transformation to revolutionize healthcare service delivery, which had resulted into intensified testing for Drone technology throughout the third-world countries with majority of African

countries origin, to speedily convey vaccines, blood samples, test kits and several other medical consumables [1]. The Public health organizations and healthcare insurance services and rural communities' health initiatives will prosper from the inclination to adopt Drone technology into healthcare automation. The Drone technology may perhaps be adopted to transverse the eastern and sub-saharan Africa to confront

diseases such as COVID-19, SARs, HIV/AIDS, Malaria, Tuberculosis, Hepatitis B, Snake bite and several other diseases that are pathological to African soils. The sustainable vaccine delivery programs with respect to current healthcare delivery automation will evolve into implementation of schemes that will compel high-ranking capital investment budget throughout the tactical partnerships for diverse institutions including African countries governments [2]. The Drones also known as unmanned aerial vehicles (UAVs) were initially deployed in early 1990s by defense departments for medical operational logistics [3]. As the technology advances, Drones today have become a viable means for multiple scales of services and complex operations ranging from civilian Drones usage to military predatory warfare Drones, performing certain actions such as healthcare computing, delivery logistics, journalistic expeditions, spying, espionage and intelligence gathering. Medical deliveries and healthcare computing in the remotest villages that are limited to roads and water transportation initially can now be reached through Drones in providing essential healthcare services in the most effective manner.

This article explored the use of civilian Drones in emergency and disaster responses requiring blood donation, healthcare service delivery in the remotest areas, logistics and healthcare preparedness. The opportunities for Drones adoption in the healthcare service delivery is highly thought provoking [4]. The Rwanda's improvements in the healthcare technology automation with respect to UAVs utilization in driving public and private healthcare services have been astonishingly enviable with touch of professionalism [5]. The quality of healthcare deliveries in Rwanda from the inception of the UAVs integrations into the mainstream healthcare supplies in 2016 till date have been exceptionally remarkable [6]. The UAVs have demonstrated potentials and have been effectively appraised in innumerable pilot programmes and are at present employed in so many situations for conveying healthcare items and supplying blood, vaccines, medicines, organs, lifesaving medical consumables and apparatus to boost healthcare deliveries in several progressive nation [7].

The wide scale adoption of medical Drones into the national healthcare grid in Rwanda in October 2016, in collaboration with an American multinational company Zipline Incorporation proved the capability of the Drone technology to boost healthcare services. Rwanda unarguably had become the first country in the Africa continent to integrate the UAVs technology into the mainstream healthcare sector with an unquantifiable returns on the investment. Such historic attainment, undoubtedly had made Rwanda's healthcare system amongst the paramount technology driven public and private healthcare partners in Africa. However, an encouraging assessment of impression "lab test on a Drone" was newly obtained, together with numerous pilot studies indicating that there are advantages of UAVs utilization in reconnaissance and epidemiology of contagious diseases and pest control in Africa [8]. From Central East Africa, Rwanda is championing the drone innovation in Africa continent, confirming that UAVs

technology possessed the potential to save lives. Along with the healthcare provisions being distributed in the remotest regions of the country through medical UAVs, access to healthcare services have immeasurably improved. Zipline Incorporation, an American multinational have been of enormous significance with the UAVs innovation for healthcare automation. Enhancing availability to emergency medical supplies, blood and vaccines to the rural parts of the country has been one of the company topmost priorities. The utilization of the UAVs commercial drones to convey indispensable medical commodities is a breakthrough for Rwandan healthcare delivery with prestige. The Rwandan doctors and healthcare managers will usually place requests on-demand via a simple app interface for any quantity of medical consumables from blood to remedial drugs and Zipline's Drone circulation centers processed the request through the medical warehouses and a drone will deliver the processed medical request. The UAVs drones are remotely piloted to fly Beyond Visually Line of Sight (BVLOS) to the destination to deliver the medical consignments and fly back to the central logistics warehouse all within few minutes [9].

Meanwhile, a comparable distribution could consume up to several hours by road in rural areas of Rwanda. As Rwanda had formulated some varieties of overwhelming technological innovation in tackling healthcare challenges, it is an expectation that the rest of the countries in the continent of Africa should take specific experiences from the East African country healthcare automation using Unmanned Aerial Vehicle technology. The speedy distribution of vaccines, medical consumables and healthcare essentials could necessitate quick response and recovery from outbreaks of life threatening contagious diseases [10]. Supporting communities and rural dwellers with cardinal healthcare facilities are not usually an easy task especially when essential infrastructure dilapidation can hinder land or typical air transport, such situation can only be surmounted through UAVs automation. The Unmanned Aerial Vehicles distribution makes it increasingly possible for the courier needed blood and the vaccines to be kept at a moderately regulated temperature during logistics transportation, otherwise it may not be useable [11]. This will enable everyone engaged with the payloads to be properly trained to ensure the products arrived destinations at the accurate temperature and all distributions are managed efficiently. Zipline Corporation have been improving the Unmanned Aerial System (UAS), recognized as Zips for several years. The Unmanned Aerial Systems have the capability to accomplished one hundred and fifty blood distributions a day to transfusing service centers in the western half of Rwanda [3]. The Medical Drones also raised some fundamental technological and regulatory issues which is significantly important for consideration within the tenet of Law enforcement and Regulatory Policy.

According to John Coglianese, the former U.S Special Operations Command director for Unmanned Aerial Systems, made several suggestion to this effect [12].

- i. Drones will eventually need the equivalent of

transponders to integrate them into the national air control systems.

- ii. The ground-to- Air Drone communications must be protected to prevent hackers from hijacking Drones or using their data for nefarious purposes.
- iii. Allowing Drones to travel beyond the operator's line of sight significantly increases the complexity and cost of pilot-to-Drone communications.
- iv. Medical Drones must be especially robust and capable of fulfilling missions far beyond what is presently in use in the present day.



**Figure 1.** The age of Drones: what might it mean for health Delivery of Medicare item using Drone [13].

That proposed that police, fire crews and Healthcare Providers have routinely and successfully used Civilian Drones in most scenario, despite some concerns about civil liberty violations by law enforcement Drones [14]. The contribution posit that society may sensibly wish to go slow on filling the skies with swarms of vehicles for myriad banal uses, and line-of-sight restrictions probably make good sense for recreational Drones. There are good arguments for advancing and supporting the goals set forth in the Federal Aviation Administration's Integration Pilot Program and for opening skies to emergency Medical Drones and other vital public services [15]. The Federal Aviation Administration being the governmental statutory agency of the United States of America saddled with the responsibilities and powers to regulate all aspects of Civil Aviation activities and as well as over its surrounding International water ways. This posit that, in operating those Drones, attentions must be paid to standard rules and conventions provided Lives and scarce resources are not likely going to be lost from the inability to use these Drones technologies to their full potentials [16].

## 2. Literature Review

Digital health communication technology implementation had enabled extreme information management and data transmission progresses which have accelerated the quantum of Internet of Things (IoT) computing connections, software system integration and lifeware manageability support to enable communications across platforms, promoting data sharing, information storage, data retrieval and use of

healthcare information and analysis of communication dynamics required for an updated multifunctional healthcare system [17]. The digital health communication technology is at the center of the contemporary healthcare civilization which have inspired several biomedical and clinical researches [18]. The healthcare extreme digital automation is a mix of several technological approaches, focusing on innovative combination of artificial intelligence (AI), robotics interactive (Drone) technologies, IoT, Internet of Medical Things (IoMT), data technology and numerous high computing paradigms. The IoT Drone technology has been adapted to deliver healthcare essential consumables in the healthcare supply chain monitored through the logistics base station to the destination with accurate precision. The IoT Drones made it potentially possible to transport vaccines, blood, birth control items, snake bite serum and other medical consumables to rural areas and have the ability to extend to remotest patients who may want urgent medical considerations, which in some cases could be in a situation of life or death.

The utilization of Drones for commercial purposes have attracted considerable attention in the contemporary time when several business corporation such as Amazon announced and effectively deployed Drones to transport packaged goods to remote customers [5]. The implementation is very complex, highly intriguing and transformational with several premeditated and consequential connotation that effect to the digital natives. The present and upcoming application of Drones technology in medical consumables distribution throughout the world are exceedingly reflective and exceptionally intriguing [19]. The conventions and how best the healthcare industry could adopt and utilize the Drone technology to advance safety and care delivery has been a very challenging issue to academics, diplomatic and environmental concern [20]. However, Drones technology adoption have been trailed to transport medical consumables, food aids and consumer goods to locations hit by disaster, like Haiti, Rwanda, Ghana, Malawi, Senegal and Madagascar among several others that have witnessed healthcare automation through the use of Drone innovation [21]. Rwanda is among the few countries in the continent of Africa to have accomplished comprehensive healthcare coverage owing to its farsightedness on extensiveness, equity and generality of purpose in incorporating quality service administration, with concentration on the Primary Healthcare (PHC) [22]. The Rwanda healthcare sector had witnessed remarkable advancement in recuperating the health condition of the citizens after the evil days of civil war and mass genocide [23].

The developments are symbolized in the amendments of provisions in access to Healthcare delivery and utilization of the amenities. Corresponding to Rwanda annual report on health information, the Primary Healthcare consumption rate become more intense from 0.81 to 0.94 measuring healthcare facility assessment per citizens from 2009 to 2013 [24] Incorporating technology into the healthcare system will significantly demands

superior investment in infrastructural build-up, ranging from education, social amenities, telephone communication connectivity (4G/5G generation support), transportation and logistics networking etc. The new upgraded systems like the distribution of medical supplies by Unmanned Aerial Vehicles into the healthcare system, new policies and other digital automation developed to standardize the services and sustain the benchmark for quality in service provisions can be authenticated. Furthermore, the healthcare system in Rwanda should strive to encourage collaborations with private sector professionals to guarantee technology diffusion and commendably unify all the healthcare service distribution. Such technology and extreme Healthcare automation will ensure that the present development does not deteriorate. While the Joint United Nations Programme on HIV and AIDS (UNAIDS) observed a significant diminution in AIDS funding, it is imperative to maintain the funding support to make sure countries that have recorded victory in diminishing the occurrences and prevalence of HIV transmission, like Rwanda, can attain the global aspiration of extricating AIDS as a Public Health risk by 2030 [25].

Among the factors propelling Rwanda's improvement in supplying evenhanded admittance to Healthcare delivery, is the country's willingness to implement high-tech society extreme automation and summarily assimilate them into the healthcare system. The extreme automation include adoption of Unmanned Aerial Vehicles in distributing blood to residents in the most remotest rural areas of the country through mobile phones electronic recording and transmission of indispensable Health information assembled from the community level to the Healthcare Central Data Warehouse [26]. The technology extreme automation with respect to Unmanned Aerial Vehicles integration into the Rwanda's healthcare system ensured equitable distribution of health services, as well as consistent and reliable information about critical health information at all levels of the health system. Numerous Health Policy Professionals recommended that the collaboration between the country political actors and the above-mentioned healthcare innovations have nurtured Rwanda's healthcare sector accomplishments. The capacity for developing a robust Public-Private partnerships, the Rwanda Ministry of Health had commenced medical UAVs distribution to ensure that access to quality healthcare services are negotiated equally among its twelve million citizens. The World Health Organization (WHO) had confirmed that Africa carries 25 percent of the global world's health challenges but its portion of global health spending is less than 1 percent [27]. Hopeless enough, Africa manufactures only a negligible fraction just less than 2 percent of the medical consumable required in addressing the Healthcare challenges of the continent [28].

In 2001, African Union countries approved an allocation of at least 15 percent of the entire national annual budget to healthcare in the submit held in Abuja-Nigeria regarded as "Abuja Submit 2001" [29]. However, after 15 years of the submit, it was only six countries of Africa (Rwanda, Botswana, Niger, Malawi, Burkina Faso and Zambia) were smart enough

to attain the recommendation of the submit. The fundamental question at this point is, where is Nigeria?, the country of approximately 200 million population with 3.2% annual growth rate [30]. Taking Rwanda as a case study, the country has achieved a milestone to have setup a functional National Health Insurance Scheme (NHIS) with 91% Healthcare coverage for 12.3 million Rwandans [31]. This phenomenal achievement should be contrasted to other African countries especially Nigeria where Medical Insurance Schemes or National Health Insurance Scheme (NHIS) cover only the Federal Government officials which on average is less than 8% of the entire citizens populace, according to World Health Organization [32]. In Nigeria for instance, the mean sum of household health expenditure per month stood at 7,595.00 Naira equivalent to (\$19.6) [33]. The outpatient essential services average monthly expenditure stood at 5,851.25 Naira (\$15.1), at the same time, the inpatient services cost stood at 1,976.25 Naira (\$5.1).

Moreover, higher health expenditures were encountered by metropolitan populaces and the better-off socioeconomic status (SES) classes [34]. Generally, 27% of households experienced Catastrophic Health Expenditures (CHE), greater for underprivileged socioeconomic categories and for rural inhabitants. Merely 1.0% of households had an associate that was registered in the National Health Insurance Scheme (NHIS). The Health expenditures are categorized as "catastrophic" once possibility exist that consumer (household) are at risk of going into further poverty [35]. The measurements are obtained by setting a benchmark and calculating the number of households to which their standard of health expenditure within the range of interval are justifiably catastrophic. According to, [34], Nigerians are predominantly at risk of encountering catastrophic health expenditures (CHE) syndrome on the account of high degree of prevailing consumer fees and prime use of out-of-pocket spending (OOPS) to settle for healthcare services in the public or private healthcare system. In the perspective of the Sustainable Development Goals (SDGs), the research paper summarized SDG #3 which purpose is to capture health system, healthcare delivery and healthy living, supporting the welfare of all citizens [36]. This current paper reviewed the state of healthcare systems in Africa and juxtaposed Rwanda healthcare system and Nigeria healthcare system with a view of addressing the obvious healthcare challenges in the continent of Africa for sustainable development.

### 3. Research Methodology

The research contributions towards IoT Drone services for medical logistics supplies were realized and confirmed on several healthcare computing projects as situations and results proved accountable and professional particularly in the countries of Africa where it has been adopted, henceforth the necessity to scholarly publicize the research findings to the academic communities. The research result is of essence to the healthcare administrators, countries policy makers, public, private healthcare investors and all key stakeholders

in charge of project implementations to evaluate options available in committing resources towards society healthcare extreme automation [37]. At present, the trending healthcare system automation via centralized and modified supply chain was designed to ensure consistency in deliveries of medical consumable commodities in the healthcare facilities in the 5 regions of the chosen case study. On the other hand, the implementation of IoT Drones technology in the medical logistics automation in healthcare service delivery are outstandingly impactful on the account that patients safety and health preservation should assume specification [1]. As a matter of fact, cost-effectiveness when contrasted with land conveyances within the metropolitan areas, IoT Drone delivery were much outstanding method of medical items distribution. In this research, the authors shared most applicably findings from computerized healthcare delivery system and logistics supply chain, introducing IoT Drones technology in its central discussions to enable patient safety evaluation and associated the benefits to Drone-based transportation to enable medical consumables deliveries to the rural localities in an attempt to advance society towards sustainable healthcare system computerization.

However, there exist several risk factors in incorporating unmanned aerial vehicles (Drones systems) into the main stream medical consumable workplace and logistics delivery management ecosystem. Taking into account of every unforeseeable circumstances and admitting that risk is an aspect of administration in mounting unmanned aerial vehicle program [38]. Therefore, comprehensive attention should be given in ensuring that every mandatory steps are followed in escaping every avoidable risk and demonstrating support for safer environment in ensuring that the program succeed. Exploring avenues to ensure that risk are reduced and conducive operational environment are created for everyone within the chain of distribution of unmanned aerial vehicle healthcare automation include:

### **3.1. Adopting Safety First Operational Approach**

While safety operational mechanism cannot be construed just as a concept, it is adjudged to be fundamental philosophy of every operational system. However, a safety operational modalities will always originate from the top management consideration in the Drone program and transcend to downward operational requirements. Usually, whenever an organization is in the process of unmanned aerial vehicle program establishment from the context of business automation process, in the program recommendations, regulations and policies, the safety consideration must always be the topmost priority [39]. In designing the safety requirements for the unmanned aerial vehicles as the chief item in the healthcare supply chain, the protocols requires reducing the risk and making sure that all workforces observed the regulations. Failure to adhere to the operational guidelines will always damage the reputation of the organization whenever things go wrong in the cause of business operation, cost the company loss of revenue, increase the operating logistics of the company and

potentially lower the company capacity for growth.

### **3.2 Inform the Human Resources / Organizations About the Potential Risk**

Under this consideration, it become very imperative that all members of the organization should comprehend what constitute risk to the company operation. Not including what could go wrong in the company business operation will cause the workforce to be less encouraged to adhere to the company safety guidelines. Therefore, it is highly recommendable that business organization should educate its employee about the potential risk in incorporating unmanned aerial vehicle and holding every person answerable for the safety maintenance and accomplishments of the unmanned aerial vehicle program.

### **3.3. Adopting Tools for Checking & Managing Airspace**

The key aspect of being a professional pilot is continuously examining the airspace before commencement of every flights operation. The Temporary flight restrictions (TFRs) module, might alter at an instant notification, and the flight attendant are required to be certain flights are in conformity with Federal Aviation Administration (FAA) guidelines always [40]. It is highly recommendable for improving an in-house protocol or technique for confirming airspace approval in advance before commencement of flight operation. Such procedure will assist in keeping each and every one answerable and diminish every possibilities of airborne in a confined airspace, or without the identifiable Federal Aviation Administration flight relinquishments necessary for the assignment. Paraphernalia such as Skyward, Flyte and Airmap makes the procedure effortless and are obtainable within the drone deploy App store.

### **3.4. Decreasing Risk Through Flight Automation Procedure**

Taking unmanned aerial vehicle to the air could be perplexing specifically at the initial time. On the practical implementation, there exist quite number of hypothetical impediments alternating from configuration issues to airspace atmospheric conditions and the whole things existing in-between hope and despair. However, automating unmanned aerial vehicle flights system and preventing all the potential risks such as a collision that wounds people or damages equipment [41]. The Flight computerization in unmanned aerial vehicle will enables setting of all the flight parameters (altitude, identification and specification of take-off and landing sites, speed, and direction, overlaps, number of flight lines, flying height) when planning a flight. Flight computerization enables the avoidance of obstacles that are well known in operation of unmanned aerial vehicles (Drones).

### **3.5. Generation of Pre-Flight, Post-Flight Specifications**

From the general perspective, a dependable set of pre-flight and post-flight methodology will improve safety and



lower the possibilities of approximated errors from occurring in the flight implementation. However, opportunities abound for conducting pre-flight and post-flight safety assessment to verify situations whenever the drones takes to the skies.

### 3.6. Automation of Pilot Record Tracking System, Flight Logs and Operations

Electronic record tracking system is a very essential aspect for logistic management to maintain track of indispensable department information and business activities in implementation of unmanned aerial vehicle for healthcare management [42]. The development of a system for accumulating the mission for number of business assignments will increase the opportunities for effectiveness and consolidation of all business decision making processes. Electronic archives are indispensable component of management information system, supposed something fails to accomplish its specification during or after the assignment, a comprehensive retrospective examination or a complete exhaustive information is required to furnish other departments within organization like the risk management or legal unit.

## 4. Interpretation & Analysis of Data

Zipline Drones deliveries have formed the spotlight of the commercial medical distributions within the supply chain in the healthcare logistics management in Rwanda [43], as the Drone implementation took effect in Muhanga in the middle

of 2016 when Zipline company began operations in two supply centers in Rwanda [44]. Rwanda being a country of many mountainous geographic topologies and deplorable motorway situations, requiring IoT Drones delivery system as the best economically viable means of medical consumable delivery. The comparative cost of medical consumable conveyance through IoT Drone were examined and was discovered to be cost-effective approach far better than land transportation particularly for emergency healthcare attendance. Zipline Drone delivery become preferable due to the deplorable state of the public transportation in the country [45]. As at September 2019, Zipline company had accomplished approximately 20,000 blood deliveries and have taken flight in excess of 1,000,000 km (620,000 mi), at the same time, around May 2019, about 65% of blood transportation in Rwanda which were deployed from the capital city Kigali employed Zipline IoT Drones delivery to complete its business delivery obligations [1]. There are five regions in Rwanda that witnessed the Drone delivery, which include of;

- i. Eastern region with a total of nine hospital centers.
- ii. Kigali City having a total of eight hospital centers (together with Military Hospital and Police Hospital).
- iii. Western region has twelve hospital centers.
- iv. Northern region has a total of seven hospital centers,
- v. Southern region has a total of twelve hospital centers, all together totaling forty eighty hospital centers for 12.3 million Rwandans corresponding to record as at 2018 [46].

*Table 1. Zipline IoT Drone Medical Distribution Centers in Rwanda.*

Location	Country	Year Opened	Delivery Centre
Muhanga	Rwanda	2016	Situated in the Central District of the country
Kayonza	Rwanda	2018	Situated in the Eastern District of the country

*Table 2. Zipline IoT Drone Distribution Arrangement to the Rwandan 5 Regional Healthcare Districts.*

Route	Distance (Kilometers)	Road Transport Time	UAVs (Drone) Delivery Time	Time Variation
Zipline Muhanga District to Kigali City	53.1km	3hrs	6mins	174mins
Zipline Muhanga District to Southern Region	40km	3hrs	15mins	165mins
Zipline Muhanga District to Western Region	100.1km	3hrs, 30mins	25mins	185mins
Zipline Kayonza District to Eastern Region	71.4km	2hrs, 45mins	20mins	145mins
Zipline Kayonza District to Northern Region	163.0km	4hrs	40mins	200mins



*Figure 2. Zipline Team simulating Medical Delivery Logistics using Drone Technology in Internet of Things in Digital Health Technologies [47].*

Zipline IoT Drone at the moment conveys vaccines, blood, test kits, medical consumables to Rwandan clinics employing Drones from the company's central logistics base stations in Muhanga and Kayonza province of the country. All the time in December 2016, Zipline Corporation began Drone medical consumable delivery through assemblage and Drone aircraft campaign in the central east Africa (Rwanda). At present, Zipline Company autonomous fixed-wing IoT Drones have actively become the mainstream Rwanda's medical-supply infrastructure, conveying medical consumables in and around hospitals across Rwanda. The Zipline Drones delivery in 2018 commenced East African operational command, expanding to accommodate Tanzania, Ghana and Malawi, delivering above 4000 units of blood products to twelve hospitals in the five regions of Rwanda district that might

require a number of hours when transported through the road. From table 1, Zipline operate two bases in Rwanda (Muhanga & Kayonza). Information on Table 2 shows time variation between road delivery and Drone delivery estimation. Above all, Drone delivery is faster and cost effective and it is highly recommended for adoption.

## 5. Discussion of Findings

The government of Rwanda eagerness to join forces with the technology professionals through public-private health sector scheme had compelled the accomplishment in attaining maximum automation into the country healthcare system with an extraordinary profits and reward on the investment. While Technology alone does not provide improvement on healthcare equity, instead the government of Rwanda through coordinated objectivism assembled people and leverage technology potential which offered opportunities for accessing state-of-the-art digital automation in the conventional healthcare delivery system. Those innovative approaches have commanded accomplishment in making use of technological modernizations to achieve all-inclusive, economical and equitable healthcare treatment benefits for the citizens [48]. In addition, the medical Drones involvement within the public healthcare civilization have symbolized positive disaster responses and pandemic management in the rest of the world particularly in Africa [49]. The medical Drones are utilized in the logistics supply chain in Malawi where the population are relatively served with regard to healthcare and related infrastructure [50]. The United Nations (UN) General Assembly in December 11, 2019, reached a consensus supporting the immediate termination of any development necessitating calamitous out-of-pocket healthcare expenditures through recommending methodologies that are in agreement with economic hazard treatments and exterminating impoverishment occasioned by health-related expenses through the year 2030 [51].

The UN while beckoning on the member nations, advised them to strengthen their distinctive nation's healthcare systems, to reinforce cooperative aspirations toward healthcare services delivery which will assist citizens that are vulnerable in funding their healthcare requirements to be part of the healthcare coverage. Every nation should invent reasonably adjusted guidance that are comprehensible to miscellaneous humanities, traditions, customs and in specific to deliver the requirements of children, women, and personalities with, ill health, disabilities and incapability. The Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030, reviewed the 7 unambiguous and instantly recognizable purposes and 4 highest meaningful proposition to reduce any predominant devastating risk insurgency: (i) Understanding the catastrophic hazards; (ii) Highlighting the devastating hazard governance to accomplish risk mitigation (iii) Investing on catastrophic diminution and (iv) Enhancing catastrophe responsiveness via appropriate responses and rebuilding the human civilization for revitalization, treatment and transformation.

## 6. Conclusion

In a specific term, the research observed that Healthcare provision around the world are notoriously skewed and grossly uneven. That posits that there may be no justification for the Sustainable Millennium Development Goal on global Healthcare policy if the remote rural areas do not get their fair share of Healthcare Supervision, Resources Management and Extreme Automation. To that effect, advances to attract Healthcare professionals to work in rural areas to readdress this imbalance have been only partially successful in most scenarios. Drones services and technologies might be potential solution to this logistical development and continental testimony. Fundamentally, cargo-carrying Drones service could also be deployed to assist remote areas with medical supplies such as point of care testing materials and therapeutic essentials including Pharmaceuticals, Blood, Sera, Vaccines and essential organs for Transplanting. Focusing on the newest technology for effective Healthcare computing in the remotest areas is essentially reliant on effectiveness and logistical support to transport samples to the available healthcare depot capable of taking delivery and to transmit all the results to the Healthcare unit (Clinics). Moreover, the use of Drones for emergency responses in the event of fire disaster, plane crash, ecological sensing, search and rescue mission are aspect of this research that are yet to be explored. From the findings of the current research, the government of Rwanda is taking a positive step in the perspective of healthcare delivery. This call for examination by the countries of the region more particularly Nigeria.

## 7. Research Recommendation

IoT Drones for medical consumable deliveries are effectively utilized generally in revolutionizing public healthcare system delivery. The countries in East African region are championing the adoption of IoT Drones for logistics delivery such as Madagascar, Rwanda, Malawi and Senegal were included in the list of Sub-Sahara African countries that have so far implemented the IoT mobility Drones for medical logistics delivery within the Sub-Saharan African region. This paper analyzed the healthcare perception of IoT Drones within the framework of healthcare automation in the assessment to comprehend the strengths, weaknesses, opportunities and threats (SWOT considerations) of implementation of IoT Drones in the automated healthcare management. In this paper, approaches for tackling supervisory challenges, practicability, satisfactoriness, supervising and appraisal were carefully communicated to model the upcoming applications in a more understandable approaches. Suggestions for the government agencies, Drone providers, key stakeholders, promoters and funders involved; (i.) Inventing exceedingly dependable technologies for IoT Drones delivery services (ii.) Comprehensive Vetting of IoT Drones manufacturer's competences in delivering logistical services throughout the period of selection development, (iii.) Proficiency in maintaining in-country markets and business

benefit for IoT Drone operations. However, the American skeptical disposition and subsequently declined all Chinese made Drones are ultimately propelled by apprehension over the unidentifiable circumstances that may arise when those Drones are deployed.(iv.) Capability in organizing efforts towards implementing multi-stakeholders and government decisions. (v.) Executing key plans while identifying funding for long-term projects sustainability (vi.) Across-the-board assessment of impressions through standardized indicators through vetting all standard practices for compliance. Meanwhile, the contributions of the current research have taken into consideration the methodologies to accommodate all details linking to occurrences. Communicating the experiences and demonstrating evidential proofs from the current health sector involvements are extremely attractive to promote the adoption IoT Drones for medical consumable delivery in response to healthcare emergencies. The authors enthusiastically advocated that upcoming investigators on the IoT Drones should focus on the issues of safety in event of beyond visually line of sight for IoT Drones needed for disaster management in smart healthcare computing.

## Conflict of Interest

The authors declare that they have no competing interests.

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## References

- [1] U. O. Matthew, J. S. Kazaure, O. Amaonwu, U. A. Adamu, I. M. Hassan, A. A. Kazaure, *et al.*, "Role of Internet of Health Things (IoHTs) and Innovative Internet of 5G Medical Robotic Things (IIo-5GMRTs) in COVID-19 Global Health Risk Management and Logistics Planning," in *Intelligent Data Analysis for COVID-19 Pandemic*, ed: Springer, 2021, pp. 27-53.
- [2] A. A. Nyaaba and M. Ayamga, "Intricacies of medical drones in healthcare delivery: Implications for Africa," *Technology in Society*, vol. 66, p. 101624, 2021.
- [3] R. F. Graboyes, D. Bryan, and J. Coglianese, "Overcoming Technological and Policy Challenges to Medical Uses of Unmanned Aerial Vehicles," *Mercatus Research Paper*, 2020.
- [4] M. Erdelj, M. Król, and E. Natalizio, "Wireless sensor networks and multi-UAV systems for natural disaster management," *Computer Networks*, vol. 124, pp. 72-86, 2017.
- [5] J. Euchi, "Do drones have a realistic place in a pandemic fight for delivering medical supplies in healthcare systems problems?," vol. 34, ed: Elsevier, 2021, pp. 182-190.
- [6] L. Strieber, "Safety Meets Efficiency: The Medical Device Drone's Role in Bringing about a Workable Regulatory Framework for Commercial Drones," *J. Air L. & Com.*, vol. 83, p. 421, 2018.
- [7] J. Chen, W. Wang, Y. Zhou, S. H. Ahmed, and W. Wei, "Exploiting 5G and blockchain for medical applications of drones," *IEEE Network*, vol. 35, pp. 30-36, 2021.
- [8] V. Kanellopoulos, A. Andrikopoulos, and C. Koutsojannis, "A Pilot Study of an Online Intelligent Environmental Observation System for Monitoring and Evaluating Public Health Hazard from Indoor and Outdoor Pollutants," *American Journal of Environmental Protection*, vol. 8, pp. 133-164, 2019.
- [9] L. Davies, R. C. Bolam, Y. Vagapov, and A. Anuchin, "Review of unmanned aircraft system technologies to enable beyond visual line of sight (BVLOS) operations," in *2018 X International conference on electrical power drive systems (ICEPDS)*, 2018, pp. 1-6.
- [10] S. Waring and S. Giles, "Rapid evidence assessment of mental health outcomes of pandemics for health care workers: implications for the Covid-19 pandemic," *Frontiers in public health*, vol. 9, p. 534, 2021.
- [11] J. R. Scalea, T. Pucciarella, T. Talaie, S. Restaino, C. B. Drachenberg, C. Alexander, *et al.*, "Successful implementation of Unmanned aircraft use for delivery of a human organ for transplantation," *Annals of surgery*, vol. 274, pp. e282-e288, 2021.
- [12] L. Agnel Tony, D. Ghose, and A. Chakravarthy, "Unmanned aerial vehicle mid-air collision detection and resolution using avoidance maps," *Journal of Aerospace Information Systems*, vol. 18, pp. 506-529, 2021.
- [13] D. Sachan, "The age of drones: what might it mean for health?," *Lancet (London, England)*, vol. 387, pp. 1803-1804, 2016.
- [14] J. P. West and J. S. Bowman, "Drones in domestic law enforcement," *Transforming government organizations: Fresh ideas and examples from the field*, pp. 213-237, 2016.
- [15] J. D. Scott, "Drone Surveillance: The FAA's Obligation to Respond to the Privacy Risks," *Fordham Urb. LJ*, vol. 44, p. 767, 2017.
- [16] A. Fotouhi, H. Qiang, M. Ding, M. Hassan, L. G. Giordano, A. Garcia-Rodriguez, *et al.*, "Survey on UAV cellular communications: Practical aspects, standardization advancements, regulation, and security challenges," *IEEE Communications Surveys & Tutorials*, vol. 21, pp. 3417-3442, 2019.
- [17] S. Dash, S. K. Shakyawar, M. Sharma, and S. Kaushik, "Big data in healthcare: management, analysis and future prospects," *Journal of Big Data*, vol. 6, pp. 1-25, 2019.
- [18] E. Hovenga, "Guideline and knowledge management in a digital world," in *Roadmap to Successful Digital Health Ecosystems*, ed: Elsevier, 2022, pp. 239-270.
- [19] A. Fish and M. Richardson, "Drone Power: Conservation, Humanitarianism, Policing and War," *Theory, Culture & Society*, p. 02632764211022828, 2021.
- [20] H. Begum, K. Abbas, A. F. Alam, H. Song, M. T. Chowdhury, and A. B. A. Ghani, "Impact of the COVID-19 pandemic on the environment and socioeconomic viability: a sustainable production chain alternative," *foresight*, 2022.



- [21] M. Azmat and S. Kummer, "Potential applications of unmanned ground and aerial vehicles to mitigate challenges of transport and logistics-related critical success factors in the humanitarian supply chain," *Asian journal of sustainability and social responsibility*, vol. 5, pp. 1-22, 2020.
- [22] A. M. Knoblauch, S. de la Rosa, J. Sherman, C. Blauvelt, C. Matamba, L. Maxim, *et al.*, "Bi-directional drones to strengthen healthcare provision: experiences and lessons from Madagascar, Malawi and Senegal," *BMJ Global Health*, vol. 4, p. e001541, 2019.
- [23] M. Popa and D. Beţco, "Rwanda's prosperous economic upgrade: from genocide to a fast-growing economy," *Center for Studies in European Integration Working Papers Series*, pp. 34-44, 2020.
- [24] E. Larson, "Measurement and Evaluation in Maternal and Child Healthcare: Diagnosing Poor Quality and Testing Solutions," Harvard University, 2018.
- [25] R. Kanazawa, "Governing Drugs Globally: The World Health Organization and Public Health in International Drug Control," *The Social History of Alcohol and Drugs*, vol. 36, pp. 000-000, 2022.
- [26] A. Otto, N. Agatz, J. Campbell, B. Golden, and E. Pesch, "Optimization approaches for civil applications of unmanned aerial vehicles (UAVs) or aerial drones: A survey," *Networks*, vol. 72, pp. 411-458, 2018.
- [27] O. A. Uthman, C. S. Wiysonge, M. O. Ota, M. Nicol, G. D. Hussey, P. M. Ndumbe, *et al.*, "Increasing the value of health research in the WHO African Region beyond 2015—reflecting on the past, celebrating the present and building the future: a bibliometric analysis," *BMJ open*, vol. 5, p. e006340, 2015.
- [28] C. E. Alozie, A. O. Ideh, and I. Ifelunini, "Coronavirus (COVID-19) pandemic, economic consequences and strategies for ameliorating macroeconomic shocks in Nigeria's economy," *Economic Consequences and Strategies for Ameliorating Macroeconomic Shocks in Nigeria's Economy (September 21, 2020)*, 2020.
- [29] F. A. Ogbo, A. Page, J. Idoko, F. Claudio, and K. E. Agho, "Have policy responses in Nigeria resulted in improvements in infant and young child feeding practices in Nigeria?," *International breastfeeding journal*, vol. 12, pp. 1-10, 2016.
- [30] I. Tukur, "A review of emergency obstetric care services and obstetric fistula in North Western Nigeria/Tukur Ismail," University of Malaya, 2017.
- [31] E. Al-Eisa, C. Tse, M. L. A. Thomas, B. Cox, S. W. Masho, M. A. Armstrong, *et al.*, "Abstracts from Women's Health 2013: The 21st Annual Congress March 22–24, 2013 Washington, DC," *Journal of Women's Health*, vol. 22, pp. 1-48, 2013.
- [32] O. Nwanaji-Enwerem, P. Bain, Z. Marks, P. Nwanaji-Enwerem, C. A. Staton, A. Olufadeji, *et al.*, "Patient satisfaction with the Nigerian National Health Insurance Scheme two decades since establishment: A systematic review and recommendations for improvement," *African Journal of Primary Health Care & Family Medicine*, vol. 14, p. 10, 2022.
- [33] B. Uzochukwu, M. Ughasoro, E. Etiaba, C. Okwuosa, E. Envuladu, and O. Onwujekwe, "Health care financing in Nigeria: Implications for achieving universal health coverage," *Nigerian journal of clinical practice*, vol. 18, pp. 437-444, 2015.
- [34] O. Onwujekwe, K. Hanson, and B. Uzochukwu, "Examining inequities in incidence of catastrophic health expenditures on different healthcare services and health facilities in Nigeria," *PloS one*, vol. 7, p. e40811, 2012.
- [35] Y. Li, Q. Wu, C. Liu, Z. Kang, X. Xie, H. Yin, *et al.*, "Catastrophic health expenditure and rural household impoverishment in China: what role does the new cooperative health insurance scheme play?," *Plos one*, vol. 9, p. e93253, 2014.
- [36] W. H. Organization, "Stronger collaboration for an equitable and resilient recovery towards the health-related sustainable development goals: 2021 progress report on the global action plan for healthy lives and well-being for all," 2021.
- [37] J. K. Roehrich and I. Kivleniece, "Creating and distributing sustainable value through public-private collaborative projects," in *Handbook on the Business of Sustainability*, ed: Edward Elgar Publishing, 2022.
- [38] U. O. Matthew, J. S. Kazaure, A. Onyebuchi, O. O. Daniel, I. H. Muhammed, and N. U. Okafor, "Artificial Intelligence Autonomous Unmanned Aerial Vehicle (UAV) System for Remote Sensing in Security Surveillance," in *2020 IEEE 2nd International Conference on Cyberspac (CYBER NIGERIA)*, 2021, pp. 1-10.
- [39] C. Stöcker, R. Bennett, F. Nex, M. Gerke, and J. Zevenbergen, "Review of the current state of UAV regulations," *Remote sensing*, vol. 9, p. 459, 2017.
- [40] R. M. Lusk and W. H. Monday, "An early survey of best practices for the use of small unmanned aerial systems by the electric utility industry," *United States: N. p.*, 2017.
- [41] J. G. Martinez, M. Gheisari, and L. F. Alarcón, "UAV integration in current construction safety planning and monitoring processes: Case study of a high-rise building construction project in Chile," *Journal of Management in Engineering*, vol. 36, p. 05020005, 2020.
- [42] H. Rajab and T. Cinkelr, "IoT based smart cities," in *2018 international symposium on networks, computers and communications (ISNCC)*, 2018, pp. 1-4.
- [43] K. Kuru, "Planning the future of smart cities with swarms of fully autonomous unmanned aerial vehicles using a novel framework," *IEEE Access*, vol. 9, pp. 6571-6595, 2021.
- [44] E. Ackerman and M. Koziol, "The blood is here: Zipline's medical delivery drones are changing the game in Rwanda," *IEEE Spectrum*, vol. 56, pp. 24-31, 2019.
- [45] A. K. Richmond, D. Malcomb, and K. Ringler, "Household vulnerability mapping in Africa's Rift Valley," *Applied Geography*, vol. 63, pp. 380-395, 2015.
- [46] S. Pierre, "Determinants of Effective Development Aid In Africa: Examining the Impact of International Assistance in Rwanda," Howard University, 2015.
- [47] A. Awad, S. J. Trenfield, T. D. Pollard, J. J. Ong, M. Elbadawi, L. E. McCoubrey, *et al.*, "Connected healthcare: Improving patient care using digital health technologies," *Advanced Drug Delivery Reviews*, vol. 178, p. 113958, 2021.
- [48] T. H. Grubestic and J. R. Nelson, *Uavs and urban spatial analysis*: Springer, 2020.

- [49] D. H. Caro, *Transforming Nations After the COVID-19 Pandemic: A Humanitarian and Planetary Systems Perspective*: Springer Nature, 2021.
- [50] N. Wang, "'As it is Africa, it is ok'? Ethical considerations of development use of drones for delivery in Malawi," *IEEE Transactions on Technology and Society*, vol. 2, pp. 20-30, 2021.
- [51] P. Messerli, E. Murniningtyas, P. Eloundou-Enyegue, E. G. Foli, E. Furman, A. Glassman, *et al.*, "Global sustainable development report 2019: the future is now—science for achieving sustainable development," 2019.