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The Role of Drone Technology for future Smart City Concept Implementation in Developing World. The Case of Kigali City - Rwanda

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Abstract
A smart city is a place where traditional networks and services are made more efficiently with the use of digital solutions for the benefit of its inhabitants and business. A smart city goes beyond the use of digital technologies for better resource use and less emissions. Smart city concept in developed and developing countries is the right choice because people need to increase their efficiency and their effectiveness during their projects implementation like production industries, construction industry and many fields for sustainable rural and urban cities development in all sectors. On one hand, smart city idea has to manage the issue of transportation or solve high resolution aerial photos problem which is extremely needed for suitability analysis in cartography and construction sector. On the other hand, smart city idea can be used in monitoring remote medical delivery as well as accident locations especially where human lives can't reach easily. Despite the importance of smart city concept in making traditional networks and services more efficiently through digital solutions. The issue of accessibility in remote communities/households where cars can't access is still challenging. Therefore, this study aimed to examine the role of Unmanned Aerial Vehicles (UAVs) for future smart city concept implementation in developing world using Kigali City in Rwanda as specific case study. Specifically, to document the current situation of smart city concept implemented in the case study area; to examine the role of Drone technology in managing accessibility of hard-to-reach areas/remote community in both rural and urban areas; and finally to capture community perspectives about the idea of Drone technology for future development of urban and rural areas in Africa. Closed and open questions were used in interviewing Kigali city residents to understand more about the role of UAVs in smart city concept performance. Additionally, another tool used to collect data including physical observations on Drone technology for smart city concept. The study revealed that among the challenges most city managers do face in using UAVs to implement smart city idea includes insufficient of financial capacity as well as good internet connectivity to connect together smart city projects and drone technology for future sustainable urban and rural development.
Keywords: Smart City Concept, Drone Technology, Developing Countries, Kigali City

1. Introduction and literature review

Procedure of urbanization is nowadays taking place at a rapid speed at a global level. Each year, millions of population shift to cities from rural areas to advantage economic opportunities and stability. Based on UN research, 6.5 billions of people will live in urban areas by 2050 and more than 60% of people at global level will concentrate in urban areas (Attaran, Kheibari, & Bahrepour, 2022).

CEA industries are keen in the use of UAVs during their projects studies and implementation. Thus Drones is good technological concept applied in for many CEA related projects .Drones are able to manage accessibility of hard to reach areas or even hard to reach places such as Irelands and mountains. Additionally UAVs are gifted of carrying out different duties on low price and quickly. The users can mount any type of sensor depending on the task they would like to perform. However Drone flight management platforms are very cheap and demand few technical teams to conduct flight operations which is good and which can lead to more performance of projects as well as minimal site associate problems. It is for this reason that drone technological advanced power saving during flight operations, data collection and automation capabilities

had made UAVs much being recognized and trusted for CEA relation uses (Albeaino, Gheisari, & Franz, 2019).

Therefore, the use of these technologies is effectively adopted in the process of city management. ICT add to the advancement of smart city sustainability together with population's higher better quality of life (Vodák, Šulyová, & Kubina, 2021). It is for that reason that population concentration happening in areas where the living standard and environment is not properly developed, cities be disposed to poorer areas. The problem which countries have faced for instance solid waste, traffic jams and air pollution are also inevitable. Thus managing them is not easy as social infrastructure do not cope with the increase in population (JICA, 2021).

Smart city concept is the vision which will yield sustainability, wealth and well-being through technological means to solve complex city problems. Therefore smart city concept is being looked by city planners and policy makers but experimental research is highly recommended to give the full meaning and understanding of the urban management and technology new marriage (Meijer, Gil-Garcia, & Bolı´var, 2015).

The formation of smart cities as the new concept of city planning and development has been both in practice and theory for instance some of developing countries including Rwanda started to use smart city idea in managing their urban associated problems. Thus results from different studies show that various cities in developing countries are implementing strategic planning and smart city concepts. For example the study by Lee and Hancock reports that in 2012 there were 143 cases all over the world. It is in 2014 where 28 EU Member States explained that 240 cities with 100,000 people and above have initiated working in the area of smart cities even before 2014. Moreover the number of smart city cases will continue to grow as well as the number scientific publication will continue to take place (Komninos & Mora, 2020).The main objectives of the study is to explore the role of UAVs for future smart city concept implementation in developing countries. Therefore, the following are specific objectives for this study: *[1] To analyze current use of drone in managing accessibility in remote community in relation to smart city concept implementation ; [2] To examine community perspectives on the importance of drone for future smart city concept implementation in Africa. [3]To recommend suitable use of UAVs for future smart city concept implementation in developing world.*

2. Theoretical Perspectives, Methods, techniques, studied material and area descriptions

2. 1 Theoretical Perspectives on the Concept of Smart City and Drone Technology

The idea of smart city it was not static. There had been evolution in recent decades. This section looked how the idea has been discussed by various scholars.

2.1.1 Drone Technology (UAVs)

Drones, UAVs or UASs are the small or big planes which can manage to fly without the presence of pilot and travelers on board. Drones management and control is being done autonomously or remotely throughout the use of radio waves. Normally drones do not possess exact size or any kind of pilot. Thus the first countries that initiated studies on UAVs were Germany, US, UK, Israel and Russia where the first drone was used by Australians in 1849 August (Kardasz, Doskocz, Hejduk, Wiejkut, & Zarzycki, 2016). Additionally to make sure that drones fly in lower attitude airspace their efficiency and safety must be taken into consideration. It is for that reason numerous countries all over the World are looking together technical ways and policies to manage UAVs operations (XU, LIAO, TAN, YE, & LU, 2020).

2.1.2 Smart City concept

The idea of smart cities has been formed in literature for 30 years of time since the beginning of 1980s of the first writings up to the existing publication. It was during 1985-1995 where the term was used and the concept was formulated while the full meaning of urban planning and management literature appropriately used and came after 2000. Furthermore the smart city concept definition came in parallel together with the same concepts like cyber city, digital city and intelligent city. In the very early literature review and writings

all these terminologies attempted to gather and express the same meaning based as well as skills and knowledge process development procedure of urban areas (Komninos & Mora, 2018).

It was found that smart land idea is the extension of smart city concept and it is linked to green economy as well as sustainability .It is really essential to build community whom are capable of constructing new opportunities in local context or local system to solve the complex problem in most urban areas faced by people's daily lives and all of these ideas should convert themselves into economic actions which can also create global network to find solution together (Rosati & Conti, 2016).

The concept of smart cities with appropriate planning can help cities and rural communities at a high level, while minimizing the use of workforces in long term. However the idea of intelligent cities is silent and unclear to more people, some studies were carried out to respond the questions concerning smart city improvement (Sujata, Sakshamb, Tanvi, & Shreya, 2016).After conducting research in various domains including IT, e-governance six pillars which make the pillar of intelligent city were identified. Consequently this research paper explored the major role drone of technology or UAVs can perform for a sustainable future smart city in Developing World (ibid).

2.2 Overview of the study area

The city of Kigali is the major city of Rwanda and is exactly situated at the heart of the country of Rwanda geographically. The city of Kigali is positioned at a longitude of 30° 7'E and altitude of 10° 58' S. As well as occupying an area of 730 Km^2.The city of Kigali is made with three (3) Districts which are Nyarugenge District, Gasabo District and Kicukiro District. Gasabo District is the largest District with total area of 429.3 km^2, followed by Kicukiro District with the area of 166.72 km^2 as well as Nyarugenge District with 134 km^2 area (Kigali City, 2023). According to 2012 population census Nyarugenge District has 148,242 males and 136,578females while Gasabo District had the highest population number 256,565 females and 274,342 males and the District of Kicukiro with 156,906 females and 162,755 males in the city of Kigali. Also 27. 7% of the household within the city are female headed households (Kigali, 2013). Based on the fifth PHC conducted in August 2022, Rwanda's population has extended to 13,246,394 people demonstrating inter-censual annual growth rate of 2.3% between 2012 and 2022 (NISR, 2023). The city of Kigali Vision is to be "The center of Urban Excellence in Africa" which comes from community participation in the planning processes for the city's character sustainability, exciting economy from durable partnership with various stakeholders to provide quick responses and effective urban resilience development (Kigali, 2013). Figure 1 shows the selected study area in the City of Kigali, Nyarugenge District which are Nyarugenge Sector, Kanyinya Sector and Muhima Sector.

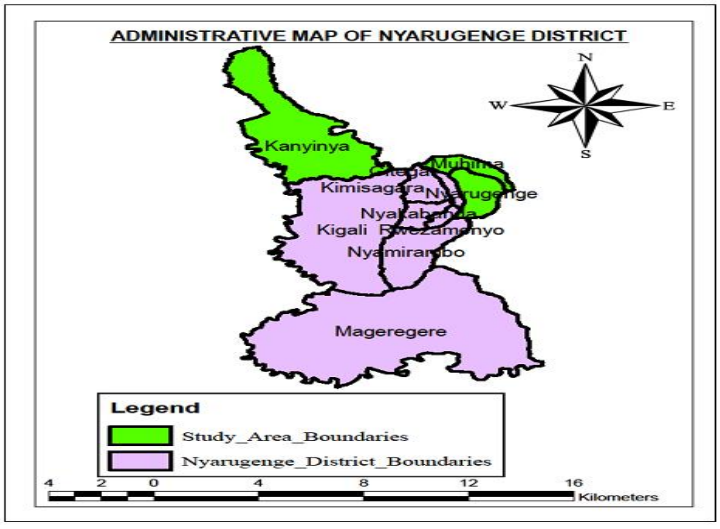

Figure 1: Location Map of the study area
Source: Author, 2021

2.3 Data Collection Procedures and analysis

For every research project methods, theory and background are the major building blocks. Thus this paper case study approach was adopted to get the community understanding on the use of Drone technology for future smart city concept implementation not only in Kigali City but also in developing countries. Therefore, this study explored overview of smart city concept in Kigali city specifically the role of Drone Technology for future smart city concept implementation in Third World Countries. To achieve objectives of this study structured questions were addressed to Nyarugenge district residents to give their understanding on the importance this UAVs can play during smart city concept. 50 Households interviews were conducted to collect primary data and important information from communities on the use of Drone Technology. Field observations were used to cross check with what the local community explained on how this emerging technology of Drones can contribute to the purpose of Smart city concept. During this survey both closed and open questions were developed and used to Kigali City residents selected randomly in Three (3) Sectors of Nyarugenge, Kanyinya and Muhima. Concerning ethical issues during field data collection it was taken into consideration for the entire process of this study. Additionally Nyarugenge District residents were introduced and briefed on this study, its objectives and privacy of their responses before data collection begins. Participation in this study was done voluntarily; none of the respondents were obligated to respond on the questions formulated. Finally both qualitative and quantitative data were analyzed where qualitative data were analyzed using Microsoft Word while quantitative data were compiled together and analyzed using Microsoft Excel to influence the statistical data and to produce frequencies as well as percentages (%). Additionally, various criteria were considered in selecting Kigali city, in Nyarugenge district including: [1] Nyarugenge district is the district the author is living which is good and economical for him to collect data easily without travelling districts or villages looking for data. [2] The author is permitted to conduct the study in Nyarugenge district, Appendix 1 demonstrate permission for data collection in the city of Kigali. [3] Nyarugenge district comprises districts which makes the city of Kigali which are: Gasabo District, Kicukiro District and Nyarugenge District. [4]Nyarugenge district hosts the location of Kigali city center which also good for author to connect the study with transformation taking place in the city of Kigali and for better results of the study.

4. Results

4.1 Socio-demographic characteristics of the respondents

During field work and data collection different people participated in the interview to share the point of view on how Drone Technology can be used in the future smart city concept. Therefore, both men and women give the responses where male had the big number with 62% and female constituted 38%. According to their age 50% were the age between 28 – 38 years old and shared more comparatively to other individuals. This implies that young people constitute a group with vision in technology and who seemed to understand more about the role of Drone Technology in the concept of smart city. Regarding their level of education, the majority (54%) had University education. 245 had attained secondary school education, and 22% of the respondents had primary school education level. Finally based on the Economic Sector 58 % of the respondents were from the private Sector where they are doing different activities for their daily lives and development. Then the remaining 42% were from public sector. Among economic activities including businesses of land parcel, selling of agri-products such as Maize, beans or potatoes. Figure 2 stipulates all necessary information concerning demographic data of the people who participated in the interview.

№	Types of information	Characteristics of Individual	Classifications based on sub-categories	Frequency	%	Total
1	Socio demographic characteristics	Gender	Female	19	38	50
			Male	31	62	
2		Age	Age 18-28,	15	30	50
			Age 28-38	25	50	
			Age above 50	10	20	
3		Level of Education	Primary Education,	11	22	50
			Secondary Education	12	24	
			University Education	27	54	
4	Economic Variable	Residence Area	Urban area			50
		Activity Sector	Public Sector,	21	42	
			Private Sector	29	58	

Figure 2: Socio - Demographic characteristics of the respondents
Source: Field Work (2021)

4.2 Drone Technology

4.2.1 Drone technology in Rwanda

According to RNAA, RCAA flying drone in Rwanda is legal, especially when you are travelling to Rwanda and want to come with your drone, you must register your UAV with the CAA earlier to come in Rwanda, the registration process can take up to Three(3) months and the cost is about 150 USD which approximately 150,000 RWF. Therefore, the lowest age to pilot UAV in Rwanda is 21 years old, where the maximum altitude accepted to fly a drone is 100 meters above the ground level. Insurance is obligatory for all drones in Rwanda. Finally, Drones are allowed to carry the weight of 25 Kg (UAV Coach, 2023). In additional to this, the country of Rwanda has been discovering the incorporation of UAVs in different sectors since 2018 from blood carrying, easing medicines distribution for chronic patients as well as taking photos to promote tourism in Rwanda. During Covid-19 pandemic UAVs were used to spread messages such as obey physical distancing, wash hand, stay home and mask wearing (WHO, 2020).

4.2.2 Community perspectives on Drone Technology

It is during data collection where 70% of the respondents (35 out of 50 respondents) answered that Drone Technology can contribute much and more in development. While 30% of the respondents do not know more about UAVs concept and how it can be integrated in the smart city concept. They said that Land Surveyors currently are using Drone Technology as an important tools for their clear aerial image capturing compared to aerial images taken by planes before UAVs. Figure 3 shows the picture of Drone technology which can be used for development purposes in different sectors either in delivering different items or remote work monitoring. According to the respondents Drone technology for development contribute much input to community activities particularly sectors such as construction industry, Agricultural activities during crop mapping and in assessing the situation of crop health as well as future crop production predictions as well as fisheries projects in developing countries. In Rwanda Drone also are used to spray chemicals on Mosquitos especially in Rice farms and planted in marshlands to avoid Mosquitos going into community settlements and neighborhoods then cause them malaria.

Figure 3: Drone Technology in development
Source: (LVC, 2018)

4.2.3 The role of Drone Technology in Smart city concept implementation

In Kigali city Zipline Company in Health sector is saving community lives during blood delivery and blood samples to hospitals in remote villages in time and without any accident. This company soon will bring another innovative idea of delivering Pizzas up to community households based on the order sent to the company, location and pieces of Pizza to deliver. This is among emerging concept of drone technology in delivery as well as lifesaving in developing countries. Figure 4 below shows Drone technology in helping community in their daily lives and in the smart city concept, as you can see some drones they are doing plots surveying while giving clear images for further land management and land right registration, Environmental monitoring as well as crop mapping for the assessment of plant damages or crop growth, additionally, traffic monitoring such as accidents occurred there to know exactly where this accident came from and who caused the accident. Industries control and remotely management to know personnel who are working well their job as well as the management of stocks. Housing development monitoring using drone technology is taking place without the presence of site Engineers to the construction sites. 80% of the participants replied that during implementation of smart city concept Drones will be in better position to play great role while helping community, technicians and hospitals to solve different challenges smart city might face in different sectors where it is hard for community to reach.

Figure 4: Drone Technology in Smart City Concept
Source: (Mirzaeinia & Hassanalian, 2019)

Drone port concept was mentioned by 78 % of the respondents that this idea can generate more activities while giving room for many people to perform various projects like playgrounds (tennis, Volleyball, basketball) as well as business activities around the port and touristic view for visitors who might come for study tour at the Drone port. Figure 5 illustrates the idea of Drone Port which can bring together community and different activities for example commercial activities and not only in helping landing and taking off of Drones operations. It is at the Drone port where you can find Pharmacies which facilitates temporally medical storage brought by Drones to be distributed in the Village or Community centers. Technical schools can also be created which can help the surrounding youth and young people to learn new technologies while solving their own urban complex problems without waiting for international experts to come and solve these problems. This goes hand in hand with the concept of smart city once drone ports are available will facilitate smooth drone landing and taking off and all together will be connected to different areas in cities the same time offering more services to people in time and to those who need them the most.

Figure 5: Drone Port Concept
Source: (LVC, 2018)

4.3 Smart city Concept

Figure 6 states the concept of a smart city where all activities will be connected and this will offer facilitation of handling different tasks in an easy and simple way while reaching a high level of performance. Smart city concept Drone Technology will perform miscellaneous tasks not only in the Health sector while delivering light medical items like medical gloves, blood samples to different hospitals in cities but also in rural hospitals to save people's lives whose lives are at high risks. Before UAVs were used in military purposes but currently they are used in various sectors such as Agriculture, construction, mining and many more for the development of both African countries, Asia and developed countries where necessary.

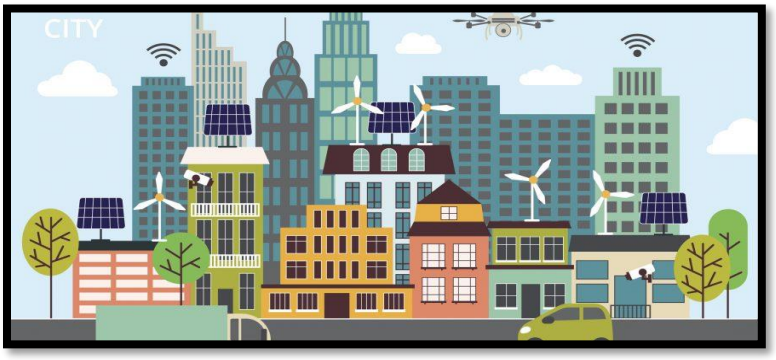

Figure 6: Smart City Concept
Source: (Horwitz, 2020)

4.3.1 Community understanding on Smart City Concept

In general all the respondents 100% said that smart city is good idea and they think that will transform many sectors. The respondents were of the opinion that several countries will achieve their development such as in hospitals. In the near future these countries will have smart and online services without physical presence of the doctors to perform surgery or coming to the hospital to operate a patient in contrary all of these tasks will be done remotely when patient is at his or her home country while the doctor is abroad. In Rwanda hospitals adopted use of Drone technology through Zipline in receiving blood, blood samples and light medical items at right time and save people's lives in Rwanda's villages this include Butaro hospital located in the Northern Province of Rwanda. Appendix 2 demonstrates Zipline Company delivering blood to hospitals in Rwanda. Thus, this added value to existing transportation system where ground transportation used to take time in transporting blood, medical items and blood sample to rural hospitals in hard to reach areas and sometimes some of the medical items face problems due to the road situation and rain seasons.

4.4 Challenges of adopting Drone technology use in Smart City Concept

The study as revealed that among the challenges encountered during the use of Drones in Smart city concept include high qualified personnel to navigate Drones and funding to buy more and high quality of drones for development especially in the concept of smart city.

Nº	Challenges	Frequency	Percentage (%)
1	High qualified personnel	13	13
2	Financial capabilities	27	27
3	Weak Policies of using Drones	3	3
4	High price of Drones	7	7
5	**Total**	**50**	**100**

Figure 7: Community perspectives on Challenges of Drone Technology in Smart City Concept
Source: Field Work (2021)

Figure 7 determines the challenges specified by the respondents in the interview during fieldwork where financial capacity was highly ranked with 27%, while qualified engineers and technicians were ranked second with 13% to use UVAs for sustainable smart city concept implementation.

5. Discussion

This study has demonstrated the role of drone technology for future smart city concept implementation in the developing world. The study has discovered that drone technology is highly needed not only to fill the gap of transportation for inaccessible areas, but also in the development projects. This is simply because smart city idea aims to connect the future cities and development projects where community can manage and control their building sites and other projects like industries remotely without being there physically. Drone can be deployed on construction sites to monitor construction activities as well as industries then transmit information to the control room where those information can be treated and used for different cities development purposes. According to (Stannard, 2022) high resolution images created by drones can be used into 3D models, which permits the construction identify the challenges before construction as well as saving money and time in the long term.

Previously drone technology was known in war and other conflict actions, especially when deployed for surveillance of military locations and thereafter enemies knew what next after knowing how many soldiers are in a certain area and type of guns they have. Nowadays also drones are used for military purposes to assist soldiers in war or to fight with their enemies. Beyond all of these currently (UAVs) are being used by several sectors for the development of the country including agriculture sector, health sector, construction and industrial management. It is for this opportunity authors assessed the role of drone technology for future smart city concept implementation in developing world, where this technology will

have much contribution not only in smart city concept but also in the implementation of development projects in any nation of both developed and developing countries. Therefore regardless the use of this technology in wars, they can be used to strengthen the concept of smart city in future where they can even reach patients to their households bring medicines and transport back samples taken by recognized nurses who are making a tour within the settlement to check and test patients in hard to reach areas for example community living in island and high mountains and thereafter those samples are taken to the nearest hospitals as well as health clinics for further testing. In large industries drones can be used for various purposes like in monitoring stores and workers whether they are performing their jobs and other tasks without forgetting maintenance checking in industries. Drones can be small, medium or even bigger in size depending on which task to accomplish. As argued by (JICA, 2021) the management of pressing challenges which cities face is not easy to but with the use of tradition method of managing cities associated with emerging technologies the idea of smart city can be implemented not only in developed countries but also developing countries. Furthermore those technologies can assist engineers in construction sites management, mining site assessment and detection of people who disappears during excavation of minerals as well as crop health monitoring until to the final harvest.

6. Conclusion and Recommendation

6.1 Conclusion

This study aimed to explore the major role of drone technology for future smart city concept implementation in developing countries the case of Kigali City, in Rwanda. Authors, conclude that in intelligent cities and countries, the use of drone technology is inevitable and these must be the National agenda or program to solve problems associated with transportation which many cities do face. These are such as inaccessible areas or construction of high elevated buildings and bridges which need scaffoldings to reach those affected areas. These drone technology can not only be used in the absence of scaffoldings to give the solution on this issue, but also other fields where drones are needed the most. This goes in line with community empowerment in terms of education especially these emerging technologies which need experts to handle complex problems all over the world.

6.2 Recommendation

The study provides the following recommendations for suitable use of drone technology and for better future smart city concept implementation in developing countries:

1. Creation and construction of Drone Technology (UAVs) development Center or Hub for future management and control of drone technology activities as well as projects in line with smart city concept
2. Drone port project implementation to connect facilities like health centers, buildings while delivering items in time to community or people who requested them. But this Drone ports must have connection with Drone technology development centers in their home countries.
3. Consideration of Drone technology projects in Country's agenda for future smart city development while assisting smooth use of drone technology specifically for development not for insecurity acts.
4. Take into consideration the concept of smart city for sustainable development of any country not only in Kigali but also in other African countries for suitable achievement of intelligent cities. When all cities are connected to services include drone technology.

7. Acknowledgement

Authors would like to express their appreciation to the Almighty God Father from Heaven for His love and protection during difficult times of Covid-19, during data collection and formulation of this study up to the final output. Without forgetting city of Kigali residents who took their time and gave their opinion as well as providing data for this research.

Appendix A

Appendix 1: Letter for data collection

Republic of Rwanda
City of Kigali

Ref.n°. 0766/07.01.16/22 Kigali on: 17 FEV 2022

Mr. David MIHIGO
Tel: (+25)0788808339
Email: mihigodavid7@gmail.com

Dear Sir,

Re: Your request for research paper/ dissertation data collection in Kigali City

Reference is made to your letter dated on 30th December 2021 requesting for research paper/ dissertation data collection in the City of Kigali on " **Emerging technologies, smart city like smart housing, smart transportation, urban agriculture, urban and regional planning and land management**";

We would like to inform you that your request is hereby granted. However, before starting data collection, you must first introduce you to the department of **Human Resource and Administration** to be guided.

Sincerely,

Joseph NIYONGABO
Director General of Corporate Services

Cc:
-City Manager of the City of Kigali
KIGALI

City of Kigali, P.O.Box 3527 Kigali, Hotline 3260, Email: info@kigalicity.gov.rw, Website: www.kigalicity.gov.rw

Appendix 2: Blood delivery by Zipline Drone in Rwanda

Source: (Sabiiti, 2023)

Appendix 3: Drone in the Sky

Source: (LVC, 2018)

Appendix 4: Authors contact details and their respective nationalities

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