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School of Transportation Sciences

Master of Transportation Sciences

Master's thesis

The impact of the future European u-space regulation and a comparative study with the United States regulatory framework

Elvis Ekane Ngalle

Thesis presented in fulfillment of the requirements for the degree of Master of Transportation Sciences, specialization Transport Policy and Planning

SUPERVISOR :
Prof. dr. ir. Ansar-Ul-Haque YASAR

CO-SUPERVISOR :
dr. ir. Wim ECTORS

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PREFACE

This thesis focuses on drone technology and its regulation in Europe, the basis of which is an in-depth interview that was conducted among several stakeholders from diverse backgrounds. This work has been written to fulfil the graduation requirements for the Masters of Transportation Sciences with specialisation in Transportation Policy and Planning at Hasselt University, Belgium. I was engaged in writing this thesis from September 2021 to June 2022.

The research process was not an easy task especially working with a disruptive technology like drones whose industry is fast growing and presenting a lot of complexities. However, resilience and commitment to the investigation allowed me to answer the research questions and also learned and networked with a lot of people which could not have been possible without doing this work.

I would like to thank my Supervisor and Mentor Prof. dr. ir. Ansar-Ul-Haque YASAR and Dr. ir. Wim ECTORS respectively for their excellent guidance and support throughout this research process for without them, this won’t have been possible. Their constructive feedbacks and comments helped me to further finetune this work to meet the required standards. Special appreciation to Hana GHARRAD who initially guided the development of my thesis plan of approach before commencement. Special thanks also go to all the stakeholders who participated in the interviews for without their inputs this analysis won’t have been realised.

To my parents, Mejame Joshua Ngalle and Ngalle Joisy Ebude I would like to thank you for your constant support and encouragement, your wise counsel and advise always sharpens my ambition to strive pass every impediment. Finally, to my siblings, Delan Ebong, Betrand Ndelle, Emmanuel Ewang and Theresia Dione Ngalle, thanks for your continuous support.

SUMMARY

The rapid growth of the global drone industry and particularly that of Europe has brought about a revolution in urban air mobility. The current Air Traffic Management rules cannot not directly apply to Unmanned Aerial Vehicles, and this is why their integration into the airspace is associated with several challenges. Drones are operated without a pilot onboard, they fly at low altitudes, they are numerous, and therefore not compatible with the rules designed for manned aviation. This creates challenges ranging from safety, privacy, the management of traffic between the drones and manned aviation. As a panacea to these challenges, regions of the world are enacting separate regulations to guide the smooth integration of drones in their national airspace.

In Europe, the European Union adopted the U-Space regulatory framework (EU Regulations 2019/947 and 945 representing the Commission Implementing Regulation and the Commission Delegated Regulation) in April 2021 which provides a set of technical requirements, services, and operational standards for drones in the Open, Specific and Certified categories of the U-Space Airspace. This U-Space concept aims at facilitating the integration of drones in the European airspace in a safe and efficient manner. This thesis seeks to investigate the current and potential impacts of this regulation as it drives to full operation as well comparing the regulation to the American regulatory framework.

In order to effectively answer the problem at stake, a qualitative research method is used. The first part involved an exploratory process by means of in-depth interviews conducted with industry players including manufactures, service providers, regulators, and drone insurance companies. The second part involved desk research on the European and United States regulatory frameworks whereby some key variations and common grounds were deduced. A total of 12 stakeholders participated in the interview sessions which were virtually conducted and lasted an average of 45 minutes. The results from the interview reveal that there are certain barriers that currently impede the smooth integration of drones in the European airspace including the dynamics of the U-Space regulation itself, segregation of airspace management, bureaucratic and administrative processes, etc. Despite these impediments, the interview results also show that drone technology will have huge positive impacts in Europe economically, socially, and environmentally. The results of the desk research also revealed some striking differences and similarities between the European and U.S regulations. They proved similar regarding Remote

Identification, and air space classification while differing in aspects such as drone registration procedures.

The study predicts a complete high-level automation of the drone industry in the nearest future as well as a robust internet of drones' collaboration in cities for various applications. It is also expected that new use cases for drones will emerge such as emission detection while the existing applications will become more sophisticated with the growth of Artificial Intelligence and Computer Vision. The thesis recommends a reinforced collaboration between public and private stakeholders, provision of funding to Small and Medium Size Enterprises, the promotion of drone education and training for pilots, manufacturers, service providers, civil aviation authorities; and incorporating the technology into the curriculum of schools in order to create more awareness and foster public acceptance. The study concludes that the drone industry is very important in the growth of the EU member states and the U-Space regulation is the solution to the safe integration of drones in the airspace.

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ABRREVIATIONS AND ACRONYMES

ADW	Amsterdam Drone week
ANSP	Air Navigation Service Provider
ATM	Air Traffic Management
BCAA	Belgian Civil Aviation Authority
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
CIS	Common Information Service
CISP	Common Information Service Provider
EASA	European Aviation Safety Agency
EU	European Union
EVLOS	Extended Visual Line of Sight
FAA	Federal Aviation Administration
FIMS	Flight Information Management Systems
FPS	Federal Public Service
HLC	High Level Conference
ICAO	International Civil Aviation Organisation
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NPAs	Notices of Proposed Amendments
PDRA	Pre-Defined Risk Assessment
SAR	Search and Rescue
SDSP	Supplemental Data Service Provider

SORA	Specific Operations Risk Assessment
UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicle
USA	United States of America
UTM	Unmanned Traffic Management
VLOS	Visual Line of Sight
VTL	Vertical Take-off and Landing
WHO	World Health Organisation

CHAPTER ONE

1. INTRODUCTION

This section provides an overview of the thesis research project which includes the background to the study, the problem statement, research questions, the aim, and objectives of the study as well as a definition of the study area.

1.1. Background to the study

Unmanned Aerial Vehicles (UAVs) popularly known as Drones, have been attracting a drastic increase in attention in recent years. Their ability extends to performing a broad variety of applications in the civil and public sectors whereas they were initially used in military applications. Some of the prominent areas of application include agriculture, research, inspection, logistics, urban air mobility. The increasing demand for these UAVs and their safe integration into segregated and non-segregated airspace has raised several concerns of safety especially in populated urban environments with regards to the people on the ground, other air space users, critical infrastructure, privacy, security, and the environment. The current lack of UAV regulations and standards impedes UAVs from being certified to operate on a file and flight basis in unsegregated civilian air space. This inability for UAVs to be certified creates a serious challenge in its operability. If principles such as "Equivalence" which was initially proposed by Eurocontrol are adopted in Europe, it will therefore follow that the same standards used by manned aircrafts will be used by UAVs. UAVs must therefore be constantly tested and evaluated to ascertain their compliance with equivalent manned aircraft regulations already in place.

The drone revolution foresees thousands of flights per day in metropolitan cities in the EU like Brussels, Paris, Amsterdam, managed with little human oversight. It is therefore imperative to establish a guidance and control network for autonomous drones and emphasize on the rules governing the future use of the airspace by these UAVs. A city-scale drone operation poses significant challenges in managing the new type of air traffic and to address these challenges, came about the birth of a whole new discipline known as Unmanned Traffic Management (UTM) which is the UAV-focused counterpart of the current Air Traffic Management (FAA, 2013). UTM involves how the airspace will be managed to enable multiple drone operations conducted beyond virtual line-of-sight (BVLOS), where traffic services are not provided. This system will ensure a collaborative approach of operation amongst the different stakeholders to determine and communicate real -time airspace status.

In Belgium and Europe in general, the management of drone traffic will be done through the U-Space framework which is a set of services that will be deployed in the urban airspace where heavier traffic is anticipated to occur. This framework will ensure the smooth interoperability of both manned and unmanned aviation in a safe manner to prevent collision. Fortunately, after serious deliberations amongst stakeholders from the European Union member states for several years, the U-Space regulatory framework (EU Regulations 2019/947 and 945 representing the Commission Implementing Regulation and the Commission Delegated Regulation) was finally adopted in April 2021 (European Union, 2021). But the question remains that given this green light in UAV applications, what are the potential impacts that will accrue as a result of their operations in the European U-Space airspace?

1.2. Problem Statement

It is presumably the case that most of the UAVs will carry out their operations at very low altitudinal levels in combination with the already existing usage of the airspace by general aviation, people, ships, infrastructure, amongst others. Drone usage is anticipated to have significant impact on the quality of life, health, and social and economic wellbeing of the population (Kyrkou et al., 2019). This technological disruption creates issues that require the management and minimisation of the adverse impacts as well as maximising the positive potentials (Kwon et al., 2017). Therefore, compliance to current safety standards by unmanned aircrafts is imperative if they must share this space. The development of more standards is also needed now to ensure smooth operations. The absence of pilots on board the UAVs raises concerns as to how to detect and avoid the traffic, other objects present, and how to handle or intervene in dangerous situations.

Now, the Air Traffic Management System is reliant on few powerful radars in their operations, but these radars do not possess the ability to detect diminutive drones. These sensors are also not efficient at low altitudes because their signals are usually obscured by topographic features like mountains and infrastructures like buildings (Austin, 2010). It will therefore be impossible to use a system of human-based operators to regulate UAV operations given the fact that UAVs are expected to multiply in the airspace soon. An incident whereby a drone hit a passenger jet from British Airways while attempting to land was reported in the Heathrow Airport in London. Whitlock (2017), reported that even though the airbus landed safely, had the impact occur while the plane was higher, it would have led to the destruction of the cockpit and if the drone crashed on the engine of the plane, the effects could have also been disastrous.

In recent years, there have been numerous reported incidents of drone operational encounters. A typical example to this effect occurred on the 16th of August 2015 when the pilot of a JetBlue airplane got startled by a white drone with its sudden appearance of the left wing of the airplane a short period before landing at the Los Angeles International Airport (Harris, 2017). The number of encounters between UAVs and airplanes have increased over the years as the demand for the former increases. The Federal Aviation Administration of the United States of America reported 700 of such incidents in the year 2015 (Whitlock, 2017).

Drone traffic management has therefore become an important issue that needs to be addressed to prevent the ever-growing problem of low altitude traffic and that's why the European Union has adopted the U-Space framework as earlier mentioned. The crux of the matter is that; in recent years, several studies (Ruwaimana et al., 2018; Bujak & Sliwa, 2017) have focused only on the potential benefits of large-scale deployment of drones such as its usage in monitoring traffic, infrastructure inspections, search and rescue operations, improvement in accessibility to places of opportunities like health care, jobs, education; and contribution to a more efficient, safer, and sustainable transport system. But it remains unclear why there are limited studies that examine the potential impacts that may accrue from the full implementation of the European U-Space regulatory framework on drone operations. On this premise therefore, the primary purpose of this thesis is to fill this gap that exists in the literature by assessing the potential impacts that will be associated with the large-scale deployment of UAVs into the European U-Space airspace and how policy makers can mitigate these impacts with the kind of policies they enact.

1.3. Research Questions

This Thesis will focus on answering the following research questions.

1.3.1. Main Research Question

What is the state of the future European U-Space Architecture for UAV traffic management and its associated potential effects on Europe? And what similarities and differences exist between the U-Space Architecture and the US Architecture?

1.3.2. Sub-Research Questions

- What are the potential impacts of the integration of UAVs in the European Airspace?
- What are the impeding factors to the smooth integration of Drones in the European airspace?

- What differences and similarities exist between the European U-Space traffic management Architecture and that of the United States of America?

1.4. Research Objectives

To answer the research questions, the following objectives have been set.

1.4.1. Main Research Objective

The main objective is to assess the current state of the future European U-Space Architecture and its potential impacts in Europe, and to compare this architecture with the United States of America's NASA developed architecture for UAV traffic Management. This will be achieved through in-depth focused interviews with stakeholders in the industry and an extensive literature review.

1.4.2. Sub-Objectives

- To identify the potential impacts of the integration of UAVs in the European Airspace.
- To identify the current challenges hindering the smooth integration of drones in the European Airspace.
- To carry out a comparative study between the European U-Space Architecture and the United States' NASA developed Architecture.

1.5. Definition of Study Area

Europe is a continental landmass located in the northern hemisphere and it is bordered by the Artic Ocean to the north, the Atlantic Ocean to the west, the Mediterranean Sea to the south, and Asia to the east. It is imperative to note here that the European U-Space framework applies only to the member states of the European Union and European Economic Area as other European countries such as the United Kingdom and Russia are not part of this framework. Therefore, Europe in this thesis refers to the member states of the EU and European Economic Area like Switzerland.

The European Union's member states cover a total surface area of 4,233,263 square kilometres with a total population of about 447 million people as of February 1, 2020 (Eurostat, 2020). This means that the EU contains about 5.8% of the world's population with about 40 urban areas that have a population of over 1 million inhabitants (Eurostat, 2020). Map 1 shows the map of the EU member states that fall within the framework of the U-Space system.

MAP 1: The European Union Member States (Source: EU Agenda, 2021)

1.6. Significance of the study

The relative absence of studies on the potential impact of drone operations in the European U-Space airspace presupposes that there is limited knowledge on this and therefore this study will provide an in-depth knowledge on this.

The study will also provide policy experts and stakeholders with state-of-the-art recommendations as countermeasures to the potential impact of drones including but not limited to the economic, social, and environmental domains.

1.7. Structure of the Thesis

The thesis is organised in the following parts; Firstly, chapter 1 focuses on the introduction, definition of the problem and purpose of the study, research questions and objectives, the study area definition as well as the significance of the study. Chapter 2 will review the related literature in order to understand the state-of-the-art knowledge in the field of UAV traffic management with regards to the U-Space regulation, UAV types and Applications and the potential impacts of UAVs, and lastly the U.S architecture. Furthermore, Chapter 3 will focus on the methodology for qualitative data collection and how these methods address the research questions, the techniques of data analysis and how they address the research questions. Chapter 4 will present the research findings of the study and lastly Chapter 5 will present the conclusions, discussions, Limitations and recommendations for future research.

CHAPTER TWO

2. LITERATURE REVIEW

This section of the thesis will focus on reviewing a range of relevant literature in order to give a clear and concise understanding of the key issues that already exist, and which are relevant for the purpose of this research. The review will help to infer whether the findings of this study are in line with the available literature or are in contrast. It will contain what drones are, their types, applications, the smart city concept which is core to this study as smart cities are the hosts of these drones, the U-Space framework, and its services as well as the stakeholders involved, the potential impacts of UAVs, and the USA regulatory framework.

2.1. Unmanned Aerial Vehicles (UAV)

An Unmanned Aerial Vehicle or a drone is defined by the International Civil Aviation Organisation (ICAO, 2011) as an aircraft operated without a human pilot onboard. UAV flights operate with varying degrees of autonomy as they can be remotely controlled by a human operator, or they can be intermittently or fully autonomous, and lastly by onboard computers. The initial usage of drones can be traced from military applications around the 1960s and since then, the recent technological developments have led to its spread in civilian applications especially in the agricultural, transportation and medical sectors (Vacca and Onishi, 2017). The military application of drones was largely driven by cost, less risk of losing personnel and a reduction of military spending (Mclean, 2014). Figure 1 shows an example of a UAV.

FIGURE 1: UAV (Source: Circuits Today, 2018)

2.2. The Different Types of UAVs

Drones can be classified on several basis such as usage but for this thesis, they will be classified based on aerial platforms. Depending on the specific type of aerial platform used, drones can be classified in to four types including multi rotor, fixed wing drones, single rotor helicopter, fixed wing hybrid VTOL.

2.2.1. Multi Rotor Drones

This type of drones are the most common types used amongst hobbyists and professionals in aerial photography and surveillance. In comparison to the other drone types, multi rotor drones are the easiest to manufacture as well as the cheapest available in the market. Professional multi rotor drones range from $500 to $3000 while those used for hobby activities like leisure flying, drone racing, range from $50 to $400 (Circuits Today, 2018). Multi rotor drones can be further disintegrated based on the number of rotors found on the platform. They include a Tricopter with three rotors, Quadcopter with four rotors, Hexacopter with six rotors, and Octocopter with eight rotors. Despite all these types, Quadcopter is the most used. Some of the limitations of multi rotor drones are their limited flight times, limited speed, and endurance. Figure 2 illustrates a typical multi rotor UAV.

FIGURE 2: A Multi Rotor UAV (Source: Circuits Today, 2018)

2.2.2. Fixed Wing Drones

The fixed wing drones are different in model and design, and they are integrated to multi rotor types. Their wing is just like that of a normal manned airplane. But, unlike the multi rotor types, fixed wing drones don't utilise energy to stay afloat on air fighting the force of gravity. They instead move forward in the direction of their planned course if their energy source permits. Majority of fixed wing drones have an average flying time of few hours, but gas-powered drones can fly for up to 16 hours or more (Circuits Today, 2018). Fixed wing drones are suited especially for long distance operations based on their higher-flying times and fuel efficiency but unfortunately, they cannot be used for aerial photography where the drone needs to be kept still in the air for a specific time period. Figure 3 depicts a fixed wing drone.

FIGURE 3: Fixed Wing UAV (Source: Circuits Today, 2018)

Like multi rotor drones, fixed wing drones are also associated with some downsides such as the higher costs and higher training skills required in flying. To put a fixed wing drone in the air is not an easy task as runway or catapult launcher is required to set the drone on its course in the airspace. This is also required to land them back to the ground.

2.2.3. Single Rotor Drones

Single rotor drones are very interesting because they have similar structural and design features like actual helicopters. Contrary to a multi rotor drone, a single rotor drone has just one big sized rotor with a small sized on the tail to control its heading. This single rotor drones are far more efficient than the multi rotor types because they have higher flying times and have the capability to be powered by gas engines (Circuits Today, 2018). Despite their high efficiency, they are mostly embedded with high complexity and operational risks with higher costs. They also demand proper training and skills to fly them in the airspace. The large sized rotor blades pose a great risk if the drone is mishandled or involved in an accident. This is something to watch out for in the European airspace since the greenlight has been given already for their integration with manned aviation. Figure 4 shows an example of a single rotor UAV.

FIGURE 4: Single Rotor UAV (Source: Circuits Today, 2018).

2.2.4. Hybrid Vertical Take-off and Landing (VTOL)

Just like the name implies, this drone type combines the benefits of fixed wing drones especially its higher-flying time, and that of rotor-based models. It should be noted that this concept has been tested since the 1960's without much degree of success. Nevertheless, with the advancement in technology and the development of new generation sensors like gyros and accelerometers, this concept has got some new direction and hope (Circuits Today, 2018). The Hybrid VTOLs are normally an interplay of automation and manual gliding. A vertical lift is used to lift the drone from the ground to the airspace. The Gyros and accelerometer sensors work in automatic modes (autopilot) in order to keep the drone stabilised in the air while remote based or manual control is used to direct the drone to its desired course. Some versions of this type are available in the market with the most popular being the one used in Amazon commercials for their Prime delivery services. Figure 5 shows an example of a hybrid VTOL drone.

FIGURE 5: Hybrid VTOL UAV (Source: Drone Assemble, 2020).

2.3. UAV Operational Categories

The operational categories for drone operations are of three types based on remotely piloted flights. They include the Visual Line of Sight, Extended Visual Line of Sight and Beyond Visual Line of Sight.

2.3.1. Visual Line of Sight (VLOS) Operation

In this operational category, the remote pilot can keep a continuous unsupported visual contact with the unmanned aircraft at any time during the flight, which allows the remote pilot to control its flight path in relation to other aircrafts in the airspace, people, and obstacles for the purpose of avoiding a possible collision which could have disastrous effects (ICAO, 2019; EU Commission, 2019).

2.3.2. Extended Visual Line of Sight (EVLOS) Operations

In this category, the remote pilot ensures an uninterrupted situational awareness of the airspace in which the drone operation is being performed through visual airspace surveillance and through some human observers aided by technology. There is always direct control of the drone by the remote pilot (EASA, 2021). The observers in this category communicate critical information through radio to assist the pilot in keeping a safe and reasonable distance from other aircrafts both manned and unmanned as well as other obstacles.

2.3.3. Beyond Visual Line of Sight (BVLOS) Operations

Here, the remote pilot is in no visual contact with the aircraft as the drone will be operating out of human visibility. This kind of operation is therefore anything other than EVLOS and VLOS (ICAO, 2019; EU Commission, 2019). An Unmanned aircraft being operated under this category no longer has the protection of the observer or remote pilot to avoid collision with other aircrafts, the terrain. This operational category requires careful planning by the operators with a framework process strictly in place with aviation authorities.

FIGURE 6: The Operational Categories of Drone Flights (Source: European Commission, 2020).

2.3.4. The Three EASA Categories of Operation

As a panacea to improving the safety and reducing the operational risks involved in drone flights, the European Union Aviation Safety Agency (EASA) further defined three categories of operation which are the Open, Specific and Certified Categories. The open category is further subdivided into three subcategories namely A1, A2, and A3 with all operational categories associated with a level of operational risk together with an appropriate risk assessment and mitigation approach.

The Open Category entails operations that represent the lowest risks and it does not require UAVs that are subject to standard aeronautical compliance procedures. They are rather conducted with the use of the drone classes that are defined in the Commission Delegated Regulation (EU) 2019/945. The maximum height in this category is 120m (European Commission, 2020).

The Specific Category on its part involves operations that pose a greater risk. The risk assessment in this category will be conducted to provide an indication of which requirements are necessary for a safe operation. The maximum height in this category is 120m for standardised scenario, or it can be higher provided it is authorised by the competent authority (European Commission, 2020).

The Certified Category is strictly subjected to the rules governing the certification of the operator and the licencing of remote pilots. This comes in addition to the certification of the aircraft pursuant to Delegated Regulation (EU) 2019/945. The maximum height in this category is dependable on the height established by the certification (European Commission, 2020). These categories are illustrated by figure 7.

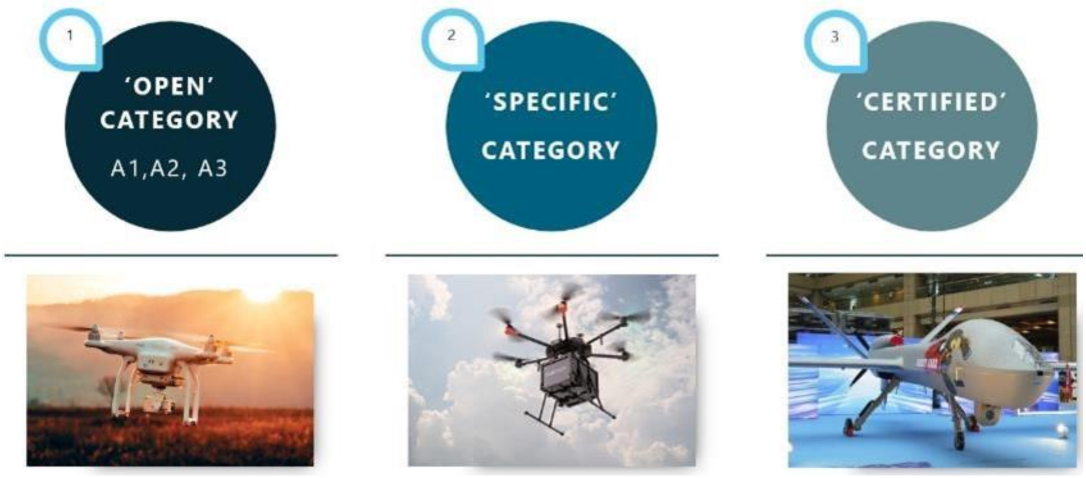

FIGURE 7: The EASA Categories of Drone Operation (Source: European Commission, 2020).

2.3.5. The Smart City Concept

It is impossible to talk about drones without the platform in which they are expected to operate which are smart cities. Drones are expected to provide diverse and important contributions to cities, by offering cost efficient services for everything ranging from environmental monitoring to traffic management. The Concept of smart cities has been around for decades now though recently it has been linked to one that prioritises technological developments like advanced robotics to improve the life of citizens. This is done by developing efficient infrastructure with state-of-the-art technology with low cost while increasing sustainability.

Several definitions of a smart city are available in the literature, however, there are some common grounds found within these definitions. A common definition which engulfs the views of several authors (Chourabi et al., 2011; Foina et al., 2015), describes a smart city using web 2.0 and smart computing technologies for the integration of all the elements composing a city, leading to an automated self-decision making and a forward-thinking development and sustainable approach. As a result of the constant development associated with smart cities, there is need for a framework that helps to promote innovation and invention. To this effect therefore, authors like Mohammed et al. (2014a and 2014b) and Chourabi et al. (2011), posited 8 core elements that are the driving forces for smart city initiatives, and which determine their success or failure. These 8 core elements include the following.

- **Organisation and Management:** This involves the stakeholders in charge of the functioning of the smart city, their leadership qualities, skills, attitudes, and their flexibility to accept changes. The organisational and city goals and objectives must comply to each other.
- **Governance:** This examines the way the stakeholders in their management duties communicate with the inhabitants of the city. Citizen participation is of vital importance in the smooth functioning

of every society or city as well as regulating in collaboration with private stakeholders and organisations (Mohammed et al., 2014a, 2014b). This means there should be strong and effective Public-Private partnerships.

- **Technology:** The role of technology in the functioning of a smart city is very important as every smart city must be supported by a developed and reliable set of hardware, software, and network technologies. Concepts like internet of drones' collaboration in smart cities are rapidly evolving. Internet of things, big data analytics, and advanced sensors that allow data collection are current trends that must be considered for the execution of real time monitoring and awareness, forecasting and prevention of possible disruptions in the city.
- **Communities and People:** The people in the city have a vital role to play in the efficient functioning of a smart city. Their acceptance or rejection has a vital role to play in the success or failure of certain initiatives or changes within a smart city. The interaction between the management authorities of the city and its inhabitants becomes very important at this juncture. A typical example can be deduced when the European Union in 2020 launched a survey to get the opinion of European citizens about drones. This is because they understand the importance of citizen participation and opinion in such a disruptive technology.
- **Policies:** The functioning of a smart city is also embedded in the types of policies that govern the city. This includes all the laws and regulations that impede or enable certain initiatives or activities within a smart city.

- **Infrastructure:** A smart city cannot function properly without the presence of a well-developed and structured Information and Communication Technology infrastructure that enables a host of activities. It is required here that the level of privacy and security are efficient and up to date with cost effective operations.

- **The Economy:** This involves the various activities carried out in the city and how competitive it is. The economic activities, entrepreneurship, economic growth, investment opportunities are all strategic drivers of a typical smart city.
- **The Natural Environment:** City sustainability through reduction in pollution levels, enhancement of renewable energy usage, protection, and conservation of natural resources, are of vital importance and these must be supported by current technologies.

Based on the 8 core elements and for the integration of drones in smart cities, Mohammed et al (2014a and 2014b), developed a model that suits this purpose. This model contains five main elements which affect this goal and will become a reference for the smooth and safe integration of drones in smart cities. These elements include the UAV itself, the Infrastructure, Technology, External factors and lastly, Initiative acceptance. Figure 8 illustrates this model.

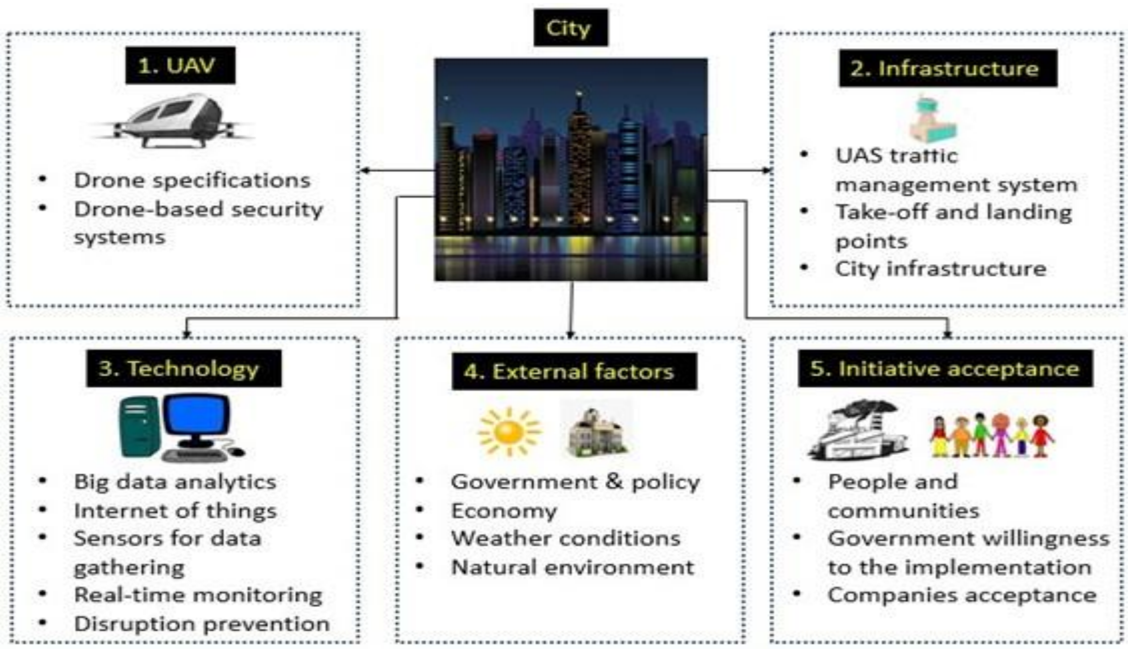

FIGURE 8: Elements Required for UAV Integration in Smart Cities (Source: Mohammed et al., 2014a and 2014b).

2.4. UAV Areas of Application

The primary objective of UAVs is to accomplish a specific mission that it is programmed for. This mission or task could be scientific, military, economic or commercially oriented. The use of drones in larger commercial applications is rapidly skyrocketing (Bartsch et al., 2016), with their massive deployment in remote work which leads to capability enhancements and massive cost reductions such as in engineering and transport network management, mining, agriculture, logistics, amongst others. Drone operations in proximity to other users is expected to have significant impacts on the quality of life, health, and wellbeing of European citizens (Kyrkou et al., 2019). This technological disruption will create problems and issues that will require management to minimise the adverse effects while maximising the positive effects associated with it (Kwon et al., 2017). The literature broadly classifies UAV applications in to four broad spectrums and they include Logistics application including passenger, photography, monitoring/ inspection, and the acquisition of data, and lastly recreation. These groups are further explored as follows.

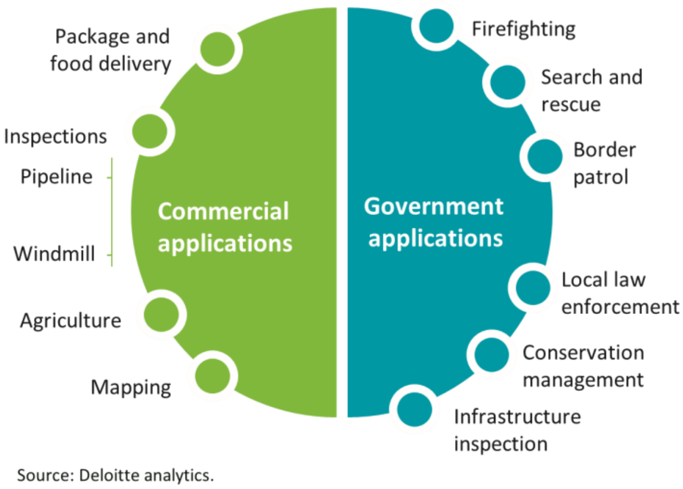

FIGURE 9: UAV Broad Areas of Operation and their Subcategories (Source: Bartsch et al., 2016)

2.4.1. UAV Application in Logistics

The current debate on the use of UAV for logistical purposes argues that their use is going to precipitate supply chain efficiency and operational effectiveness (Druehl et al., 2018). Most logistics companies now utilise the services of drones in the management of inventories (Xu et al., 2018). The use of drones for this application has been heavily exploited during the COVID-19 period in many parts of the world with the use of the people free nature of the technology in the modification of current delivery services. This idea was evident in the delivery of face masks in remote areas in South Korea and the delivery of prescribed medical supplies to retirement villages in the state of Florida. This situation was also witnessed in Africa whereby medical supplies were delivered using drones to rural areas in Rwanda. Food delivery trials are being carried out with their usage predicted to potentially span the broader delivery services. For example, the Drone-as-a-Service concept may result to a paradigm shift in the execution of delivery services (Asma et al., 2017; Kang and Jeon, 2016; Shahzaad et al., 2019). The revolution in the logistics industry brought about by drones is fascinating and keeps attracting the attention of many companies with the possibility of its extension to personal logistics which involves humans (Lee et al., 2019). It is safe to say that the advent of COVID-19 has led to massive technological advancements in many sectors of the society and drones represent a revolution in the transportation of goods especially last mile delivery which is very costly.

2.4.2. UAV Application in Inspection, Monitoring and Data Collection.

UAVs have provided new and easy ways to collect data with greater capabilities and lower capital cost. Industrial users are taking advantage of the drone technology to exploit its opportunities for better output. Several sectors make use of this technology and have therefore replaced costly team inspections with drones. Some examples are road maintenance inspection (Abaffy, 2015a, Abaffy, 2015b), railway infrastructure inspection (Vong et al., 2018), and network management such as pipelines for energy transmission (Li et al., 2018). There are drones used for inspection which possess real time analytical capabilities and quickly report objects or issues they are monitoring for investigation back to the centre. This saves time for separate analysis that could have been carried out.

The Agricultural sector is also a popular user of the drone technology to capture new information on the cultivated fields. Drones have been deployed for crop monitoring to detect possible health issues in these crops which was initially done through the analysis of satellite information to effectively plan the application of fertilizers and pesticides (Na et al., 2017). This of course entails some financial implications and impact the environment as a reduction in the inputs will directly lead to a declined adverse impact on the same output.

Mining operations have similarly made use of drones in the optimisation and remote management of their production processes (Wendland and Boxnick, 2017), as well as the monitoring of iron ore stockpiles, accessing important waterbodies in remote areas to facilitate their sampling for environmental management and imaging of mines for rehabilitation purposes (Moudry et al., 2019).

Another industry that heavily makes use of drones is the construction sector. This sector uses drones in the planning of construction sites which is relatively cheaper than other means of performing same function. This leads to lower risks of personnel (Abaffy and Sawyer, 2016; Li and Liu, 2019). Hazardous industrial plants also make use of drones to monitor the production of gas (Kovacs et al., 2019).

The use of drones by governments and other regulatory authorities cannot be over emphasized. These authorities use UAVs for surveillance purposes and to monitor compliance to certain principles. The drone technology has been applied in New South Wales in the monitoring of land clearing to ensure that permits are clearly complied with and to checkmate illegal land clearing. In inaccessible areas, drones have been deployed for air pollution monitoring (Alvear et al., 2017), and in the assessment of urban damage in flood and hurricane aftermaths including the Fukushima nuclear reactor disaster in 2011 (Hultquist et al., 2017). Drones are also heavily used in emergency services like in search and rescue (SAR) operations which has greatly improved the capabilities of rescue activities (Lygouras et al., 2017; Kamlofsky et al., 2018). Drone potential in fire safety intervention is also a green light to this technology (Athanasis et al., 2019) as it expands even to security and humanitarian relief operations (Bravo et al., 2019; Carli et al., 2019).

2.4.3. UAV Application for Recreational Purposes

Drones have found their way into the recreation industry and have become very popular as people take advantage of the third dimension for leisure, which for a long time have been a luxurious aspect enjoyed by only those that could fly or participate in risky sports. Drones are rapidly being used in the tourism industry today (Song and Ko, 2017) with competitive racing tournaments with drones also on the rise (Barin et al., 2017). Their application in this industry is also seen through their use in three-dimensional art installations with the aim of generating linked visual structures with the sole purpose of entertainment (China Global Television Network, 2019). The rapid application to this industry can be closely linked to the growing acceptance of the technology amongst the public as people are becoming more familiar with the technology and are pleased with the opportunities associated with it. Some popular applications are visible over parks and other natural spaces.

2.4.4. UAV Application in Photography

A popular method of data collection is through photography. Despite the monitoring and inspection applications by industries to acquire data using photography, its main purpose is to convert these virtual imageries into data to be able to support quality decision making. The use of drones for photography as also become an aesthetic interest for personal goals such as the documentation of one's memories of specific events and sites, and for commercial marketing campaigns and sporting event coverage (Royo-Vela and Black., 2018 Stankov et al., 2019).

Figure 10 shows a pictorial representation of the various areas of UAV application.

FIGURE 9: UAV Areas of Application (Source: Bartsch et al., 2016).

The previous section sections have examined UAV areas of operation as well as the concept of a smart city where they will operate. UAV operations therefore are associated with a variety of potential environmental, economic, social and market impacts which are the core areas of investigation of this thesis. The next section will review the U-Space framework which had granted the greenlight to UAV operations in Europe to see how its structured, to better understand the level of these potential impacts.

2.5. The European U-Space Framework

The U-Space framework is a representation of the European ecosystem of services and procedures specifically designed to ensure a safe, efficient, and secure access to the airspace for UAV operations (European U-Space Blueprint, 2017). These ecosystems of services are largely a function of high levels of automation and digitisation irrespective of whether they are onboard the drones or are a component of the ground based-based environment.

2.5.1. Key Principles of the U-Space Framework

The delivery of U-Space services is reliant on some key principles (European U-Space Blueprint, 2017), and they include:

- To ensure the safety of all airspace users operating in the U-Space framework, including people on the ground.
- The U-Space is also aimed at providing a scalable, adaptable, and flexible system that responds to changes in volume, demand, technology, business models and applications, while ensuring a smooth management of the interface with manned aviation.
- Enabling high density operations with a multitude of automated UAVs under the auspices of fleet operators.
- To guarantee an equitable and fair access to the airspace for all users.
- Enabling an all-time competitive and cost-effective service provision that supports the business models of all drone operators.
- The U-Space is aimed at minimising the deployment and operating costs by capitalising on existing aeronautical services and infrastructure as well as those from other sectors such as mobile communication services.
- Accelerating deployment by the adoption of technologies and standards from other sectors where they meet the needs of U-Space.
- Lastly, the U-Space is bound to follow a risk-based and performance-driven approach in the setting up of appropriate requirements for

safety, security, which includes cyber security, and resilience, while ensuring a minimisation of environmental impacts and respecting the privacy of the citizens and ensuring data protection.

In order to attain a safe and efficient integration of UAVs and manned aviation, the U-Space framework involves a rollout approach with different levels of sophistication. This rollout approach is illustrated in figure 10.

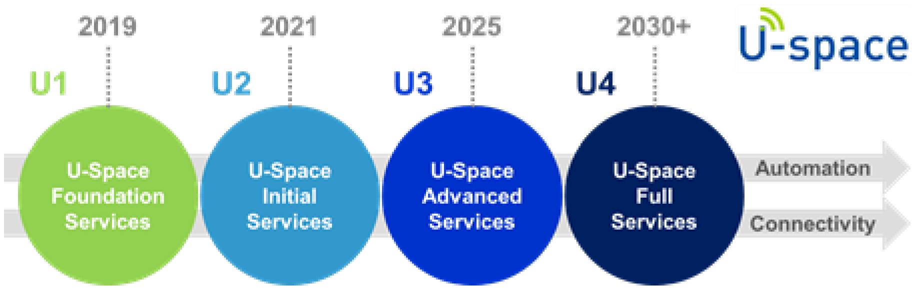

FIGURE 10: U-Space rollout roadmap (Source: SESAR JU, 2019)

The various step in the rolling out of the U-Space services in an incremental manner will propose a new set of services, while continuously upgrading the service versions already existing in the previous phase. This set of services is presented in table 1.

TABLE 1: The U-Space Service Framework (Source: SESAR JU, 2019).

Phase	Service	
U1 Foundation Services	U1.1	e-Registration
	U1.2	e-Identification
	U1.3	Pre-tactical Geo-fencing
U2 Initial Services	U2.1	Tactical Geo-fencing
	U2.2	Flight Planning Management
	U2.3	Weather Information

		U2.4	Tracking
		U2.5	Monitoring
		U2.6	Drone Aeronautical Information Management
		U2.7	Procedural Interface with ATC
		U2.8	Emergency Management
		U2.9	Strategic De-confliction
U3	Advanced Services	U3.1	Dynamic Geo-fencing
		U3.2	Collaborative Interface with ATC
		U3.3	Tactical De-confliction
		U3.4	Dynamic Capacity Management
U4	Full Services	-	TBD

2.5.2. The U-Space Actors and their roles and responsibilities

The presence of main actors in the Air Traffic Management system is undebatable as well as their presence in the U-Space operations is undeniable due to its interaction with manned aviation. However, there are new recognized stakeholders in the U-Space ecosystem (SESAR Joint Undertaking, 2019) as illustrated by figure 11 and table 2. The former illustrates these stakeholders while the later defines their roles and responsibilities.

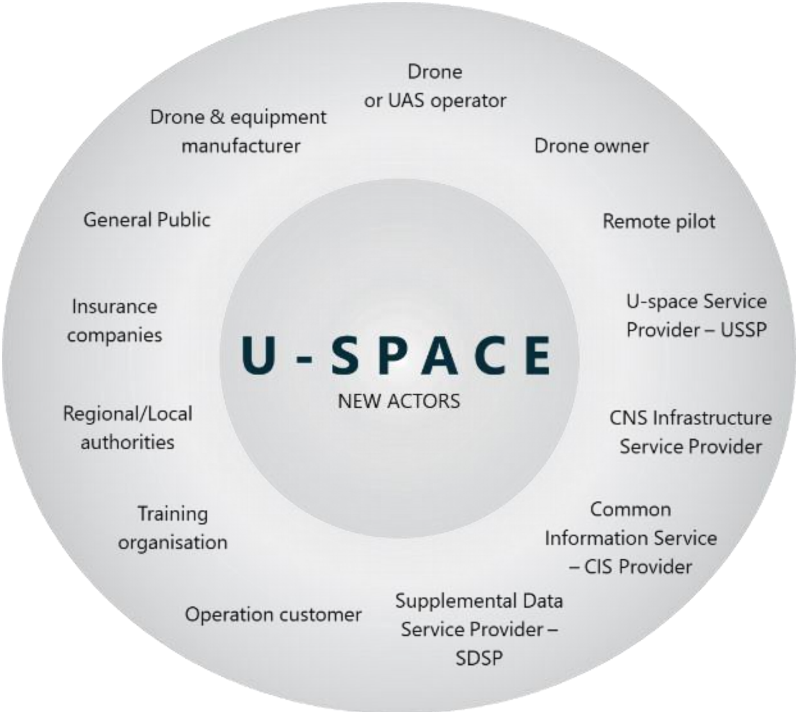

FIGURE 11: U-Space new actors (Source: SESAR JU, 2019).

TABLE 2: U-Space Stakeholders and their associated responsibilities

Actors/Services	Definitions and roles
Drone or UAS Operator	Any legal or natural person, accountable for all the drone operations it performs. Could be civil, military, an authority (special) or a flight club. (European Commission, 2019), (SESAR Joint Undertaking, 2019)
USSP – U-space Service Provider	Any legal person certified as U-space service providers providing or intending to provide U-space services (EASA, 2020)
Common Information Service Provider (CISP)	The CISP provides the common information services in respect of all or some of the U-space airspaces under their responsibility.

	This provider ensures that all the necessary information for the functioning of the U-space can be granted to relevant authorities, air traffic service providers, U-space service providers and UAS operators on a non-discrimination basis, including the same data quality, latency, and protection levels. (SESAR Joint Undertaking, 2019)
Drone Owner	The legal entity, which can be a natural person, owning the drone. It may be different from the Drone Operator legal entity (e.g., leasing rental mechanisms). (SESAR Joint Undertaking, 2019)
Remote pilot	A natural person responsible for safely conducting the flight of a UA by operating its flight controls, either manually or, when the UA flies automatically, by monitoring its course and remaining able to intervene and change its course at any time. (European Commission (2019)
CNS Infrastructure Service Providers	Provide the technological infrastructure with which the CNS service providers provide the actual CNS services. Where applicable, they also provide relevant monitoring and coverage services. Satellites, for example, are infrastructure, provided by one or more infrastructure providers that are used by

	the different providers of all three CNS services. Then: Communication service provider, responsible for the provision of a reliable and safe communication link between systems. For the C2 Link, also known as a C2-Link service provider. Navigation service provider, responsible for the provision of a reliable navigation infrastructure to allow safe drone operations. E.g., Satellite Navigation Service Providers. Surveillance service provider, responsible for the provision of surveillance services with different technologies/methodologies and SLA. This encompasses anti-drone surveillance for non-cooperative traffic. Provides services to check coverage and monitor the status of the surveillance service offered. (SESAR Joint Undertaking, 2019)
SDSP – Supplemental Data Service Provider	SDSP provides access to supplemental data to support U-space services. Multiple services could be provided by different Supplemental Data Service Providers. Specific providers of this category are:

	Weather Data Service Provider, which provides weather information data (hyper local weather data, solar flare information and TAFs and METARs) and ensures that these are reliable, accurate, correct, up-to date and available. Ground risk observation service provider provides supplemental data which contribute to the knowledge/observation of the ground. It encompasses ground and terrain data modelling (building heights, digital elevation model) and population density, ensuring that these are reliable, accurate, correct, up-to-date and available. (SESAR Joint Undertaking, 2019)
Operation customer	The final stakeholder of the drone operation who may have some roles in the authorisation of the mission itself. (SESAR Joint Undertaking, 2019)
Training organisation	Remote pilot schools & Training centres are responsible for pilot and operator training (SESAR Joint Undertaking, 2019)
Regional/Local authorities (government/city/prefecture)	Supports the definition of operating procedures and rules. Explores applications of U-space to urban needs – for example active measures limit noise “dose” in any one place. (SESAR Joint Undertaking, 2019)

Insurance companies	Collect statistics about drone accident rates in U-space. They propose more affordable insurance for drones that use enabling factors that lowers the risk of incident. They offer per operation insurance based on the specific operational plan. They can be providers of supplemental data related to the insurance. In that case it is an insurance data service provider. (SESAR Joint Undertaking, 2019)
General Public	Those who may hear, see or otherwise be concerned by a drone (SESAR Joint Undertaking, 2019)
Drone Manufacturer	Produces drones and ensures their compatibility with U-space (technical feasibility, interoperability). (SESAR Joint Undertaking, 2019)
Equipment Manufacturer	Develops solutions needed or effected by U-space services. Scope is equipment for drones, manned aircraft and U-space infrastructure. (SESAR Joint Undertaking, 2019)

As earlier mentioned, even though U-Space has a set of new stakeholders, Air Traffic Management stakeholder are directly and indirectly impacted by the U-Space as seen in table 3.

TABLE 3: Air Traffic Management Stakeholders and their role in U-Space

Actors/Services	Roles in U-space
Member States	Have full authority on the U-space airspace designation (how the airspace is designed, accessed restricted, they should be able to require that other U-space services than those stated as mandatory by the Commission IR are mandatory etc.)
Civil Aviation Authority (CAA)	Oversees, in particular: Transposing U-space and drone regulations into national or local law and supervise its application. Providing a certificate to USSP and CIS providers and the related oversight process. Establishing, maintaining, and making publicly available a registration system for certified U-space service providers. (EASA, 2020)
(Airfield/Airport) Aerodrome operator (Civil, military)	Supports the definition of operating procedures and interoperability requirements to ensure safe integration of drones in airspace, especially in airport vicinity. (SESAR Joint Undertaking, 2019)
ANSP – The Air Navigation Service Provider (civil, military)	In controlled airspace: ANSP remains responsible for the provision of Air Navigation Services to operators of certified manned and unmanned aircraft, as well as for the dynamic reconfiguration of the airspace within the designated U-space airspace to ensure that manned and unmanned aircraft remain segregated. If a certified drone operates under IFR, the ANSP remains responsible to the provision of ANS as for the other IFR flights. If the certified drone does not comply with IFR

	rules, the USSP shall be responsible for the provision of U-space services to operators of unmanned aircraft. In non-controlled airspace: ATS remains responsible for the provision of Flight Information Service to the operators of manned aircraft. (EASA, 2020)
Manned aircraft operator	Refers to the person or an organisation which is engaged in, or offering to engage in, an aircraft operation
Airspace User	Organisations operating aircraft and their pilots
Safety and Security Authority	Publishes danger areas in real time – relating to medical evacuation, police helicopter or similar. (Police only) Develops law enforcement methods related to illegal drone use. (SESAR Joint Undertaking, 2019)

2.5.3. U-Space Development in Belgium

Although the EU has defined a common U-Space framework for UAV operations, it is important to note that member states are adopting different approaches in its implementation. This is as a result of disparities in terms of geography and level of U-Space development. Belgium has adopted a unique approach for the implementation of the European regulation 2019/947. Skeyes the Belgian Air Navigation Service Provider (ANSP) has been preparing for the Implementation of this regulation for several years.

The Drone Guide map is the tool that is being used to consult the restrictions and measures associated with the Belgian airspace which includes the military airspace status whether it is active or not, as well as the conditions of accessibility. Skeyes created a commercial subsidiary in 2020 called Skydrone which oversees service delivery to drone operators (Skydrone, 2020). Since UAVs are now capable of operating in the entire airspace excluding when there is the presence of an Unmanned Aircraft System (UAS) geographical zone, Skydrone developed a UAS Geo-zone management software stationed around airports in order to ensure safety in operations. This software is rich with a variety of applications which enable the management and monitoring of flight authorizations in complex UAS geo-zones (Skydrone, 2020). This Drone service application is used for controlled airspace found above and around six (6) major airports in Belgium. Skydrone is also involved in other solutions like the 6th NeTWork (NW) that aims to implement a 24/7 drone network infrastructure which will allow drones to carry out on-demand missions for business purposes (Skydrone, 2020). The Skydrone Geo-zone management software is shown in figure

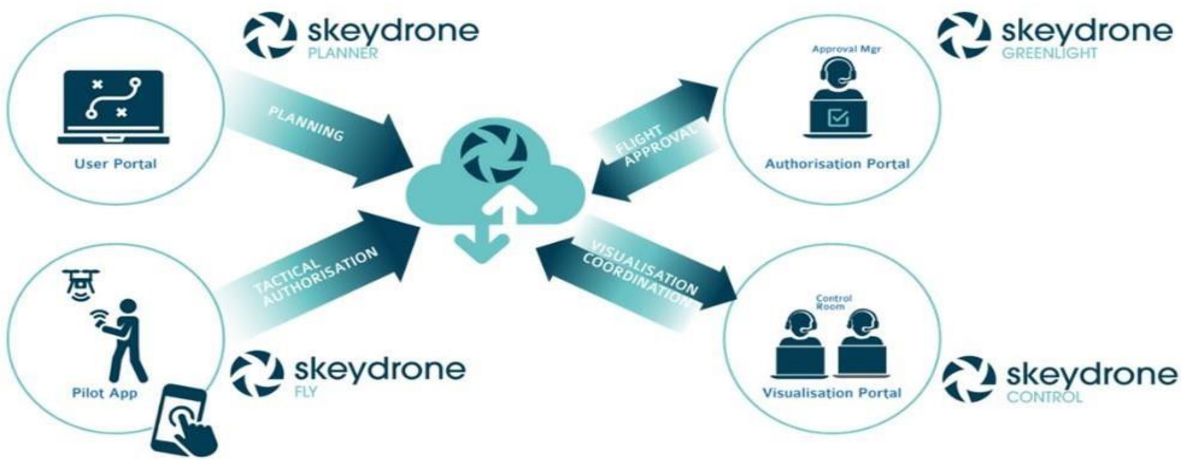

FIGURE 12: The Skydrone Geo-zone management Software (Source: Skydrone, 2020).

2.6. The U.S Drone Traffic Management Architecture

Just like the U-Space framework for the management of UAVs has been adopted in Europe, the United States of America is also developing an Unmanned Aircraft System Traffic Management (UTM) framework to control the operations of UAVs in their airspace. This research development is being carried out by the National Aeronautics and Space Administration (NASA). NASA's research began with the creation of the Concept of Operations which clearly defined the way drones could safely operate in low altitude airspace.

According to the Federal Aviation Administration (FAA), there were 469,950 registered users of drones in the U.S in 2016 and this included mostly those who use it as a hobby. It was also anticipated that the potential sales for drones could grow to about 2.7 million by the year 2020 (FAA, 2016). The U.S.A has been at the apex of developing methods to integrate civilian drone usage into the National Airspace System (NAS). In 2008, the UAS Aviation Rule making committee was established to review the FAA's approach to integrating drones into the National Airspace (FAA, 2018). This was later followed in 2011 by the Unmanned Aircraft Systems Aviation Rulemaking Committee (FAA, 2011). In 2011, NASA's Unmanned Aircraft System in the NAS project was launched to work on identifying, developing, and testing the technologies and procedures that will make it possible for UAS to have routine access to airspace occupied by manned aviation (NASA, 2019). The FAA finally published its 'Integration of Civil Unmanned Aircraft Systems (UAS) into the National Airspace System (NAS) Roadmap' report in 2013 (FAA, 2013).

NASA is developing a UAV traffic management system to facilitate UAV operations at low altitude where mid-air collisions with manned aircrafts are not possible. This development is led by Dr. Parimal Kopardekar. NASA compares the Unmanned Traffic Management to modern vehicular transportation infrastructure that consists of roads, lanes, stop signs and rules. NASA posits that the goal of the UTM is to enable safe and efficient low altitude airspace operations by providing critical services such as airspace design and geofencing, separation management, weather avoidance, routing, and contingency management (Edgar G, 2015). At the centre of this NASA UTM design will be the inclusion of strictly geofenced areas where the operation of UAV's is prohibited, and corridors where most UAV traffic will operate through which are like streets.

The intension of NASA is to build two different types of UTM systems. The first, known as Portable UTM, would be mobile and aimed to support specific UAV functions including precision agriculture and disaster relief. The second type called Persistent UTM, would be fixed to a certain geographical area and support continuous low-altitude UAV operation in the area. NASA plans on developing the UTM systems through a series of four "builds" with increasing capability, and each delivered at 12–16-month intervals (AMES, 2014). The first build will focus on geo-fencing, altitude control, and vehicle trajectory scheduling with up to 6 vehicles, and should be completed by the first quarter of 2016. Following builds will compound upon each other until build 4, which will include contingency planning on a large-scale, failure planning, collision avoidance, a UTM web portal, and be tested on at least 20 heterogeneous vehicles over a variety of geographical conditions including dense urban environments. Build 4 was expected to finish testing by the first quarter of 2020. Within the UTM ecosystem, the Federal Aviation Administration remains at the helm of the regulation and authority over the airspace and traffic management.

The NASA proposed Architecture could provide the required scalability for Unmanned Aircraft Management. The architecture is a function of primary roles and responsibilities distribution that incorporates three main components at the heart of the UTM ecosystem. These components include UAS Operators, UAS Service Suppliers (USS), and the Regulator/Air Navigation Service Provider (The FAA in the US). Figure 13 shows the proposed NASA Architecture.

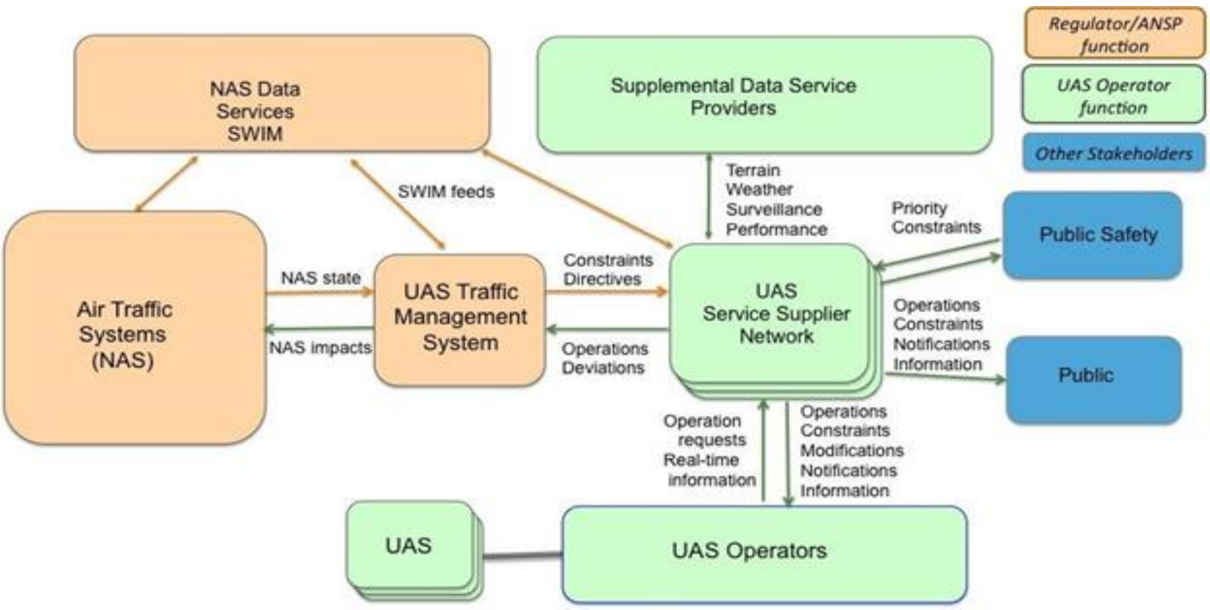

FIGURE 13: NASA Potential architecture (Source: FAA, 2016)

In this NASA developed Architecture, the UTM system is strictly operated by the regulator/ANSP. It relates with the other NAS systems and gives profound directives and possible constraints to the UAS operations through the UAS service suppliers. The roles of the UAS operators and regulators are enumerated in table 4.

TABLE 4: The Roles and Responsibilities of Unmanned Aircraft System Operators (Source: FAA, 2016)

Regulator/ANSP Responsibility	UAS Operator/USS Responsibility
• Se performance based regulatory environment • Define and update airspace constraints • Foster collaboration among UAS by setting up architecture for data and information exchange • Define data and information exchange specifications for collaboration among multiple stakeholders/operators • Real-time airspace control if demand/capacity imbalance is expected • Provide notifications to UAS operators and public • Set static and dynamic geo-fence areas	• Register UAS • Training and qualification of operators • Avoid other aircraft, terrain, and obstacles • Don't harm people and animals • Respect airspace constraints • Avoid dangerous and incompatible weather situations • Follow performance-based regulation • Broadcast identity – no anonymous flying • Broadcast intent • Provide access to operations plans • Detect, sense and avoid manned aircraft predicated on right of way rules • Status and intent exchange according to ANSP standards • Participate in collaborative decision making • Contingency planning and response (large-scale outages – cell, GPS, security, an unanticipated severe weather)

• Provide flexibility as much as possible and structures (routes, corridors, altitude for direction, crossing restriction) only if necessary • Manage access to controlled airspace and entry/exiting operations	

2.7. The Potential Impacts of Drones

Drones can provide significant benefits associated with their various use cases from parcel delivery, traffic monitoring, passenger transport, infrastructure surveillance, amongst others. Passenger drones maybe used to connect large urban areas or to connect these urban cities to areas that are inaccessible to surface transport. Despite these potential benefits, drones also have potential adverse effects from economic, social, and environmental perspectives.

Economically, UAVs are anticipated to ensure faster accessibility to goods by making up a less costly and faster air transport which is not limited by the costly and extensive infrastructure required by manned aviation. A more recent update with regards to the use of UAVs in maritime logistics was presented by the company F-DRONES during the Dubai Air show which took place from November 14 to 18, 2021. F-DRONE exhibited the World's first transition drone delivering 100kg loads over 100km to ships and offshore platforms with autonomous landing on non-static vessels. They are more likely to create more technological developments and create new jobs. On the other hand, these drones can also lead to a fall in property values especially in environments where they are perceived to be an annoyance due to noise pollution, visual disturbance, privacy concerns, amongst others.

On the social perspective, drones have the potential to increase connectivity to areas that are poorly served by other existing modes of transport at a reduced cost. With such benefits, the level of social acceptance amongst citizens will be very high. A problem with drones being used for passenger transport is that at the beginning the cost will be high in attempt to recover investment funds and this may create customer segregation as it will be available only to the rich. The level of public acceptance also plays a crucial role in the society. The concerns of the public in the areas of privacy, security are strong elements that need to be taken into consideration.

Environmentally, drones are also a potential threat to the environment in terms of noise that comes from their operations. This will also be as a result of the perceived noise from people and if this is not properly addressed, it could be an impediment to the integration of drones in the airspace especially with their proximity to residential areas. Drones produce small tailpipe emissions, but they contribute greatly to greenhouse gas emissions since all drones are powered by energy. Their production of drones also uses energy and therefore creates emissions (Bachmann, Hidalgo, and Bricout, 2017). Drones will also have significant impacts on wildlife species and generate visual disturbance to them.

2.8. Conclusion

This section reviewed the related literature on the subject under investigation from UAVs, their types and applications, the smart city concept, the U-Space framework, and its level of implementation in Belgium, as well as the potential impacts of UAVs in the European society. This provides a firm foundation for understanding the existing research and debates on the topic as well as aiding knowledge acquisition.

CHAPTER THREE

3. RESEARCH METHODOLOGY

The research methodology adopted for this thesis aims to answer the research question on "What is the state of the future European U-Space Architecture for UAV traffic management and its associated potential effects on Europe? And what similarities and differences exist between the U-Space Architecture and the US Architecture?". The research methodology adopted an exploratory Qualitative Approach and made use of a mixture of primary and secondary methods of data collection being semi-structured interviews through open-ended questions, and literature review on previous works respectively in order to get an in-depth insight of the topic at stake.

3.1. Sampling Method

The Sampling method that was applied in this thesis is a non-probability sampling method. The participants were selected based on a non-random criterion. The sampling method adopted is the Purposive sampling method. This method is suitable in order to select participants that were most useful for this study. This ensured an output of in-depth knowledge on the research questions rather than drawing statistical inference. The list of participants selected fall under manufacturers, service providers, drone insurance providers, policy makers and other related drone users.

Participants were contacted through emails by the researcher (Appendix B). Initially, 30 participants were contacted for the interview with the intention of getting a target 15 for the study, but some of them gave no responses. At the end, 12 stakeholders participated in the interview, and they accounted for 80% of the target sample (12/15). These stakeholders are represented in table 5.

TABLE 5: List of Interview participants (Source: Own Elaboration)

Manufacturers	Service Providers	Policy Agencies	Drone Insurance Providers	Other Industries
ANAVIA	Eurocontrol	Belgian Drone Federation	Getsafe Drone Liability	Port of Antwerp
Sensefly	UniFly	European Aviation Safety Agency (EASA)		International Transport Forum
Wingcopter		Belgian Civil Aviation Authority (BCAA)		
		European Commission (Directorate General Defence Industry and Space)		

3.2. The Interview

In order to get a better understanding of the European U-Space framework, and how this will have an impact on Europe, a semi-structured interview with open-ended questions (Appendix A, B, C) was carried out with 12 stakeholders that were relevant for the study. This system was preferable because it adopted a conversational approach that will create a rapport between the researcher and the interviewee and enable the later to reveal more information that was not limited to the few defined questions from the researcher. This method was also flexible and allowed the researcher to ask follow-up questions based on the new information provided. These interviews were 100% performed virtually through Teams, Google meet, and Webex. The responses were recorded through jotting and recording with prior permission from the interviewee. The interviews were initially scheduled for 30 minutes but all exceeded this time as some lasted up to a maximum of 1h: 30 minutes.

Also, literature review as a secondary method of data collection was explored in this thesis to gain a proper understanding into the related works and trends regarding the topic at stake especially with the continuous changes that occurred with the U-Space regulation in the course of the thesis such as the modification of the timeline of implementation.

3.3. Method of Data Analysis

The interviews were fully transcribed verbatim using the Otter.ai Pro software, and a manual thematic analysis performed. This involved coding the data after transcription to identify broad themes and patterns that were reviewed. Each identified theme was examined to gain a proper understanding of the perceptions and motivations of the participants regarding the research questions. The codes applied represent keywords that are used to organise text, and which are considered essential aspects of qualitative research (Sarantakos, 1998). The data was then analysed and interpreted by identifying any reoccurring themes throughout and highlighting any differences or similarities that existed in the data.

3.4. Ethical Considerations

Ethics is the discipline of dealing with what is right and wrong within a moral framework that is built on obligation and duty (Nation, 1997, p.92).

The collection of data for this thesis was strictly based on ethical considerations for research. There was voluntary participation which allowed the participants to be free to opt out at any time. Also, the participants were informed about the purpose of the research while ensuring anonymity and confidentiality where necessary.

3.5. Justification of Research Method

According to Creswell (2007), Qualitative research is the best method for exploring research and interviews is part of the four techniques for data collection which he identified for researchers to adopt.

Sampling is a method of deducing information about the total population instead of measuring every unit of the population. The obvious importance of sampling in research was mentioned by Punch (1998, p.193) when he stated that…

"We cannot study everyone, everywhere doing everything. Sampling decisions are required not only about which people to interview or which events to observe, but also about settings and processes".

Regarding representation in the sample, this thesis will not make use of random sampling to eliminate bias and ensure representation but rather it will make use of a purposive sampling method. This is justified in the literature by Flick (1998, p. 41) when he wrote in his book that; *"It is their relevance to the research topic rather than their representativeness which determines the way in which the people to be studied are selected"*. Therefore, in an ideal manner, sample is a representation of the whole population based on the characteristics of interest (Burns & Grove, 2009).

According to Burns and Grove (2009), qualitative research is a systematic and subjective method to proper explanation to life experiences and to give them further meaning. It also allows the researchers to have a deeper exploration of meanings, behaviours, perceptions, different perspectives and to further discover complexities of the situation through a holistic framework approach (Halloway and Wheeler, 2002). Qualitative research is also a distinct method to explore a human or social phenomenon or problem in a natural setting (Creswell, 2007).

Semi-structured interviews allow and enable the researcher to have prepared relevant questions to be covered with each participant in a particular setting (Polit & Beck, 2008). Furthermore, the face-to-face interview allows the researcher to deeply observe the participant for any non-verbal communication but also allows both the interviewer and the interviewee to clarify the ambiguities and necessary points regarding the questions and topic at stake.

According to Neuman (2011, p.141), ethics begins and ends with the researcher. Ethical considerations are important in qualitative research as it often intrudes into the lives of participants (Punch, 1998). Neuman (2011) added that, it is the responsibility of the researcher to maintain ethical integrity even in the event where the participants are unaware or unconcerned about ethics. According to Punch (1998), the researcher is aware of the potential benefits or loses associated with the research and so the researcher must disclose any potential benefit or loss that may affect the participant.

3.6. Conclusion

This chapter discussed the methodological approach that was adopted for this research. The chapter recapitulated the research questions, the method that was employed for data collection, the sampling method and how the data was analysed, and the ethical considerations involved.

CHAPTER FOUR

RESULTS

4. Introduction

This section will be based on the main themes and presents the key findings of the in-depth interviews that were carried out.

4.1. Participants

The participants of the study are presented here with some of them written in anonymity as they didn't give their consent to the use of their identities.

- Participant One is from the European Aviation Safety Agency (EASA) (Natale Di Rubbo; Drone Project Manager at EASA, 22/01/2022). This is an agency of the European Union charged with the responsibility of civil aviation safety. It is involved in the certification, regulation, standardisation, investigation, and monitoring of aviation related processes in Europe.
- Participant Two is from the Belgian Civil Aviation Authority (BCAA) (Laurent Quesnel, member of the UAS Team, 15/02/2022). The BCAA is part of the Federal Public Service (FPS) Mobility and Transport in Belgium, and the authority is responsible for the investigation of aircraft accidents and incidents, licensing, international and EU affairs, quality services, company approvals, airspace, airports, and air navigation services in Belgium.
- Participant Three is from the Belgian Drone Federation (Laurent Geeraerts, Flight Training Instructor at EspaceDrone 23/02/2022). This is an independent organisation for all actors of the drone world that are active in the Belgian market, such as drone pilots, drone service providers, training centres, test centres, importers, and manufacturers.

- Participant Four is from the European Commission's Directorate General Defence Industry and Space (Belen Niceas Martinez, Senior Legal and Policy Officer, 08/02/2022). The directorate was established in January 2021 and is in charge of the European Commission's activities in the defence industry and space sector.
- Participant Five is the CEO of ANAVIA (Jon Andri Joerg, 01/02/2022). This company specialises in the design, development and manufacturing of vertical take-off and landing (VTOL) systems of up to 500 kilograms. The company offers industry leading unmanned helicopter systems for various mission profiles, such as surveillance and reconnaissance, inspection or mapping and cargo.
- Participant Six is from SenseFly (Daniela Arimondi, Regional Sales Manager, 31/01/2022). SenseFly is an AgEagle company that develops and produces a propriety line of eBee-branded, high performance fixed wing drones for professional use. Their autonomous drones are utilised in various application sectors like agriculture, government surveying and construction, amongst other verticals, to collect actionable aerial intelligence data that enables them to make better and informed decisions.
- Participant Seven is from Wingcopter (17/03/2022). This is an aviation company that operates both as a manufacturer of aviation-grade drone technology and as a service provider for a wide range of drone deployments including the delivery of medical goods, parcels etc as well as mapping/surveying and inspection/monitoring.
- Participant Eight is from Eurocontrol (23/03/2022). This is a Pan-European civil-military organisation dedicated to supporting European aviation. Their expertise spans research, development, operations, and performance monitoring and highly committed to the European Union's vision of a single European sky.
- Participant Nine is from UniFly and Co-founder of regulatory affairs (Koen Meuleman, 15/01/2022). UniFly's primary mission is to

enable the safe and efficient integration of drone traffic around the world.

- Participant Ten is from the Port of Antwerp and member of the Innovation team (Bob Spanoghe, 21/01/2022). The port of Antwerp utilises the services of drones for safety as it enables the port authorities to manage, inspect and control a large area in a swift and safe manner.
- Participant Eleven is from the International Transport Forum (Elisabeth Windisch, Policy Analyst at OECD-ITF, 26/01/2022). The International Transport Forum is an intergovernmental organisation with 63 member countries and acts as a think tank for transport policy and is in charge of organising the annual summit of transport ministers.
- Participant Twelve is from Getsafe Drone Liability Insurance (Alexander Braun, 12/02/2022). Getsafe is an insurance company that offers insurance coverage for drones as well as other insurance policies.

4.2. Potential Impacts of the Integration of UAVs in the European U-Space Airspace

The Unmanned Aerial Vehicles' legal framework typically represents a complex and multi-level field of the European Union law. However, the adoption of the European U-Space regulation for Unmanned Aerial Vehicles is a green light to the integration of UAVs into the airspace. The stakeholders of this research believe that this anticipated increase in the number of drones will however be accompanied with a variety of economic, social, and environmental impacts in Europe.

4.2.1. Economic Impacts

- **Increase Efficiency of Companies and Organisations**

All the stakeholders felt that the integration of drones into the European Airspace will have a positive impact on the operational efficiency of companies and organisations in Europe as the risk of delays will be minimised. This will lead to the delivery of results at a comparatively cost-effective manner leading to an increase in profit margins. The expression of one of the stakeholders on the level of efficiency they experience right now as a result of integrating drones into their operations is clear evidence to the potentials drones could have in Europe.

The use of drones is adding extra information and possibilities to the tasks we are already doing. For example, oil spill detections in the port were done by people going around in ships and little boats saying they smell oil or benzene, but we did not have an overview of the extent of the incident. The drones now provide us with an overview of information which was not available upfront.

(Participant 10)

Another participant who is involved in Geospatial data collection using drones also explained the ease and robust efficiency that the use of drones brought to them.

As someone involved in geospatial data collection for different projects, we have been using other methods like airplanes, and hot air balloons in the past for capturing aerial photographs. However, the transition to the use of drones for this activity has provided us with a certain level of detail and customisation that wasn't possible using past methods as these drones can easily access any area right now.

(Participant 2)

- **Employment Opportunities**

The participants also believed that the drone industry is Europe is a potential sector for a lot of job opportunities. With the sector being a promising one, this means that there will be more operators, more pilots, engineers, researchers in order to keep the industry growing and this will contribute enormously to the upscaling of European economies.

It is obvious that the drone technology industry will create millions of jobs in Europe. As a manufacturer, a lot of jobs have been created in the company for both software and hardware engineers, marketing, and sales, just to name a few and as the industry is still growing, the number of jobs to be created will also be on the rise.

(Participant 7)

The amount of data captured through the use of drones and the required level of detail has proven to be far more sophisticated than what could be extrapolated in previous years. This volume of data requires the expertise of people who are able to design and create workflows and programs that will enable a proper review and analysis of the data to achieve expected results.

(Participant 1)

- **Increase in Innovation**

The participants were optimistic of the fact that there will be a climate of innovation in the drone industry all over Europe. Insights from the participants reveal that the rapid growth being experienced in the industry has led to a lot of investments in research and development, collaboration between industry and academia, market-based collaborations, as well as sustained competition which is a principal driver of innovation.

Having collaboration between different industry players is really important even though the European drone manufacturing industry is like the Silicon Valley in the United States of America for software, and everyone tries to *bring the best output in the market. But I think there is a common point between us and if we are able to understand the market needs and the value we can bring to the operations and to work together, it is going to be good for all of us.*

(Participant 6)

An interesting finding revealed by a participant is on the downside of the competition in Europe.

Europe is dominated by Small and Medium Size Enterprises who face a lot of challenges competing with giant firms to the point that most of these enterprises exit the market prematurely.

(Participant 9)

4.2.2. Social Impacts

- **Safety and Security Enhancement**

The participants were also in agreement of the fact that the integration of drones into the European U-Space airspace is going to improve the level of security and safety in Europe in the areas of disaster management and recovery, and border patrol. Some stakeholders recounted their experiences with such incidents.

We carried out a fire rescue operation in the port with the use of drones by streaming live footage of the fire over a 5G network. The RGB image showed that there was no fire left but the drones made use of both RGB and Infrared images in which the later showed that there was still fire in the area. This gave the fire department more detail to attack the fire efficiently.

(Participant 1)

On March 25th, 2022, a working agreement was signed by Frontex which is the European Border and Coast Guard Agency, and the European Union Aviation Safety Agency (EASA). This agreement will involve an inter-agency exchange of operational experience, combined training activities and capacity development in relation to the use of aircrafts for surveillance by Frontex. EASA will assist in the monitoring of safe operations of the manned and unmanned aircrafts of Frontex.

EASA's Executive Director declares:

"We are happy to be able to support Frontex as it is an important task of protecting the External borders of the European Union. This cooperation will enhance the safety of border control and coast guard activities and also support wider safe usage of drones for border control".

(Patrick Ky,2022)

- **Improvement in Health Conditions**

The stakeholders also foresee a significant improvement in health conditions as a result of the integration of drones in European cities for different operations. The World Health Organisation's 2020 survey on more than 4300 cities globally showed that only 20% of the urban population reside in areas that are complying to the air quality guidelines for PM2.5 and this puts the lives of many at risk of adverse health problems as a result of pollution (WHO, 2020).

Drones have the potential to reduce urban air pollution especially those that rely on battery to operate. Even though more work needs to be done on the flight time of the battery, it however will be more sustainable for applications such as last mile parcel delivery against fuel powered vans. This will reduce pollution in our cities to a certain threshold.

(Participant 2)

4.2.3. Environmental Impacts

Concerns for the environment has become a priority in the agenda of most businesses, organisations, and governments. The participants raised some similar concerns with regards to the increasing usage of drones in Europe. The main concerned was noise pollution and previous research by the WHO found out that noise emanating from transport is the second most influential cause of health issues in Western Europe after air pollution (WHO, 2010). This comes in the form of annoyance, disturbance, stress, as well as impacting mental health.

The noise from drones is a combination of a number of factors such as the size and design of the drone, the configuration of the propeller and its spinning speed level. The problem with the noise will depend on the perception of people as most people perceive drones to have loud noises more than they actually do. This might as well have an effect on acceptance level in some places.

(Participant 3)

4.2.4. Impact on the Transport Sector

The impact of drones on the transport sector cannot be over emphasized. The stakeholders strongly believe that the use of drones will greatly impact the mobility and transportation sector in Europe. Urban Air Mobility has been a trending topic in Europe in recent years especially with constant talks on integrating autonomous drones into the urban mobility system. Drones are used for both freight and passenger transport operations and they even go as far as servicing the same sector when they are used for the monitoring and inspection of transport infrastructures like roads, bridges etc.

Today, we see an emerging consensus as drones are being developed for passenger transport and this has led to the emergence of an entirely new industry segment as drone manufacturers are competing to create drones that could be used for passenger transport through vertical take-off and *landing. This is going to revolutionise urban air mobility in Europe and most of these projects will have a pilot onboard in the early stages of experimentation to ensure safety.*

(Participant 11)

Drones are expected to play an important role in the transport sector as seen in the literature such as for the delivery of parcels, monitoring of traffic, amongst others. This will go a long way to reduce the cost of such operations and ensure profit maximisation for the operators.

Nonetheless, this section examined the potential impacts of the use of drones in Europe and the stakeholder in-depth interview revealed several possible impacts that have been discussed under economic, social, and environmental sectors.

4.3. What is Holding us Back? Factors Impeding the Smooth Integration of Drones into the European U-Space- Airspace

It is clear that the full integration of drones into the European Airspace is not yet a reality. The U-Space regulation follows a timeline of events and activities but besides this, the stakeholders also provided significant insights on why the full-scale integration of drones in Europe is not yet a reality at this moment. Their responses are categorised as follows.

4.3.1. The U-Space Regulation as a Barrier

Although the stakeholders acknowledged the importance of the U-Space regulation and the potential benefits associated with it when fully implemented, they are however discontent with the content and framing of the regulation as well as the slow pace of its implementation. Some expressions to this regard include.

The U-Space regulation might be rewritten for it lacks a good concept of operations. There are clear differences in interpretation across member states and there is also no clear definition on state operators like the police, emergency services on flight request and authorisations. The regulation still needs to be clear enough and to me it will constantly be updated as time goes on.

(Participant 9)

There are four main troubles of UAV introduction in the European airspace at the moment and they are safety, security, privacy, and environment. The European regulation is currently focusing only on the safety aspect, and this still poses a challenge since every aspect is not yet considered. Currently it is very difficult to anticipate the future of UAS activities. A lot of declarations are made but currently the main use of UAS is for VLOS operations with aerial camera shoot or surveillance purpose. Other uses are not yet available, not because of the regulation but because of the technical devices that are not ready yet. You may also question the economic viability too.

(Participant 2)

I don't see the possibility of the U-Space coming into full operation in the nearest future, not 2023 and not even in 2024. I say this because the U-Space regulation has been discussed for several years now but no tangible advances and so it will really take time to realise this in Europe.

(Participant 3)

From the expert views of the stakeholders, it is clear that the European U-Space regulation is still a work in progress. This situation could be seen on February 9th, 2022, when EASA published a new document extending and updating the drone guidance rule in order to support the safety of drone operations in its member states. This was contained in ED Decision 2022/002/R on geographical zones, cross-border operations, and predefined risk assessment for beyond visual line of sight operations (EASA, 2022)._This new decision specifically addressed the following aspects of the regulation:

- The establishment of geographical zones identifying EUROCAE ED 269 as the acceptable standard identification for the common unique digital format.
- A definition of the compilation of a training objective for remote pilots operating in the Specific Category. These drones' operators are requested to select only those that are appropriate for their operations.
- A revision of application and issue forms for operational authorisations in the Specific Category and a detailed and comprehensive description of the application process in order to allow cross-border flight operations in different EASA member states.
- The introduction of a new predefined risk assessment (PDRA) specifically for Beyond Visual Line of Sight (BVLOS) operations for linear inspections of infrastructure such as the case of power lines and railway tracks.

EASA also stated at this time that there will be more time needed to continue discussions with stakeholders on the possible amendments of the Specific Operations Risk Assessment (SORA) in relation to the design verification of unmanned aerial vehicles. This only goes ahead to confirm the views of the stakeholders about the uncertainty surrounding the U-Space regulation.

Just a month after the publication of the extended and updated guidelines of the aforementioned decision (Decision 2022/002/R), the EU Commission published Regulation (EU) 2022/425 modifying some applicability dates in regulation (EU) 2019/947. This new updated timeline involves the following:

- Drones with class identification will now be used in the Open Category from January 1st, 2024.

- Drones without class identification label can be used in the “limited” open category according to Article 22 of Regulation 2019/947 until 31 Dec 2023.
- Drones without class identification label purchased before 31 Dec 2023 can be continued to be used in A1 or A3 (depending on their weight) also after 1 Jan 2024.
- Remote identification for drones in the specific category mandatory from 1 Jan 2024.
- EU standard scenarios applicable from 1 Jan 2024.

This new updated timeline can be seen on figure 14.

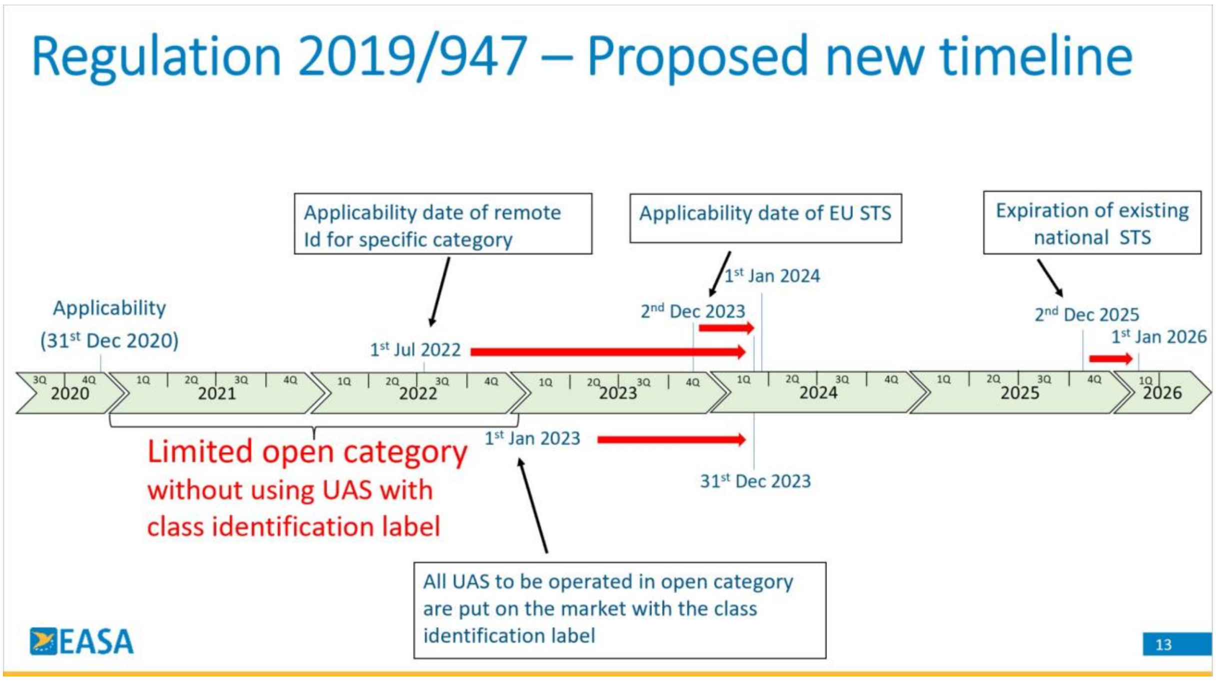

FIGURE 14: Updated timeline of the U-Space Regulation (EASA, 2022)

The red arrows in figure 14 illustrate the transitions from the old dates to the new dates.

During the recently ended Amsterdam Drone Week (ADW) which took place from March 29th – 31st 2022 ,on the theme “Adding Value to Society with Urban Air Mobility”, and the EASA High Level Conference (HLC) on Drones which occurred concurrently on March 29th -30th, 2022 on the theme “Urban

Air Mobility becoming a Reality", listening to the speakers further revealed to me that the U-Space regulation is void of clarity and applicable standards on the means of compliance.

One of the speakers Ralph Schepp the Managing Director at Droniq raised an issue about the certification of U-Space Service Providers as to how it should be done and who should be responsible for doing so. He further said that there is need for an adequate certification process which will not be an impediment to the growth of the market, or which will not be too costly, as well as the need for a standard source of truth which will be based on Common Information Service (CIS). He continued by exclaiming that this has to be cost effective because it will be impossible to pay for a given quantity of data in advance which might eventually become a burden to the market.

Following the concerns raised by the stakeholders attending the event, it was honourable to see that the EASA team acknowledged these gaps in the regulation and were prepared to look into them. According to Ken Engelstad a Drone Project Manager at EASA, they are aware of these issues associated with the regulation and the agency will try as much as possible to fix these concerns through the review of the Notices of Proposed Amendments (NPAs) even though they are bound by what industry standards they can actually depend on.

Another Agency representative Maria Algar Ruiz who is the Drone program manager at EASA also acknowledged the fact that they did not have a mature concept, clear definition of services with fewer standards in the beginning and they needed something to start with. She revealed that with the feedback gotten from organisations like the SESAR Joint Undertaking, they will be able to carry out modifications and adjustments to the regulatory framework to further improve it. One of the most surprising statements from her was that she said she doesn't believe that by 26th January 2023 there will be U-Space applicability everywhere needed so that all U-Space Service Providers can plug and operate. But she was hopeful that it is important to keep the date in mind since it is only when we start the implementation of things that we are able to monitor and assess the progress together.

It's imperative that the regulation even though originally designed to aid the smooth and safe integration of drones in the European U-Space Airspace, is equally acting as an impeding factor to the realisation of this objective as a lot of things still remain unclear. This is supported by the stakeholder reviews which have been validated and reinforced by the constant updates on the regulation by the European Commission and EASA, as well as the revelations from the debates in the ADW and EASA HLC.

4.3.2. Segregation of Airspace Management (Air Traffic Management VS Unmanned Traffic Management)

Another important key finding is the fact that airspace segregation is a pull factor to the smooth integration of drones into the European U-Space Airspace. The airspace is generally regarded as a collective resource even though we have to acknowledge the presence of existing users who have been operating there before. But with the rapid development of technologies, the airspace is required to become a shared airspace for the benefit of all users provided it is effectively managed. The stakeholders believe that the current approach for the regulation of drones which is based on airspace segregation is not the best.

Europe started in a bad way with segregation of airspace and there is need for an effective harmonisation even though it will take time to be realised.

(Participant 9)

The collaboration and pathway for the management of manned and unmanned aviation is imperative if drones are to be integrated into the European airspace. For this to become a reality, the stakeholders believe that there has to be a large body of data available that could clearly support the fact that it will be safe for conventional aircrafts to share the airspace with unmanned aircrafts, but the crux of the matter remains that for this data to be collected, the airspace needs to be shared initially. This means that there has to be trust between the systems in order to achieve the shared space objective. This is the more reason why the Unmanned Traffic Management architecture is still being developed

Some stakeholders however believe that it will be difficult to have a centralised airspace management architecture and so it will therefore be in the form of geo-zones management like the case of the port of Antwerp where the Belgian CAA has granted authority to the geo-zone manager to manage the airspace around the port since they properly understand the terrain themselves. Despite the segregation, they still believe that it cannot be possible without some sort of information and data sharing since they interact with manned aviation as well. This still leads to the conclusion that harmonisation is key in a successful integration of drones in the European airspace.

If you look at harmonisation from a theoretical way, you will say well, obviously this is something we will have to go for, but on the other hand, and that's why BCAA said in Belgium for example, the people who know the best what's going on, and what are the risks in the port area is the Port Authority. We are in Brussels; we cannot say what's safe or not safe in a port area. So, the best people to cover a geo-zone are the geo-zone managers who know the risks involved and how to mitigate it. So, I believe that we will not evolve with one UTM system, there will be overall UTM systems on a higher level to superimpose information but in areas like big cities or big industrial sites, there will be local UTM's which will be interconnected to a central UTM and also to ATM.

(Participant 10)

From the analysis, it is evident that the segregation of airspace management is a huge impediment to the effective integration of drones into the European Airspace. Different countries are adopting different approaches to integrating drones into their national airspaces and this needs a harmonisation framework to ensure smooth operations. This is the more reason why ongoing research is interested in developing sense and avoid or collision avoidance technologies to this effect.

4.3.3. Administrative and Bureaucratic Tendencies

The complex bureaucratic processes associated with the drone business is also one of the main hindrances reported by the stakeholders. These administrative and bureaucratic processes affect almost every stakeholder involved ranging from manufacturers, service providers, pilots etc. The stakeholders generally agree that the difficulty in interpretation of the regulation and the continuous amendments on it as earlier seen, makes the administrative process to become more complicated. This relates to the delays experienced in certification and authorisation approvals.

The Civil Aviation Authority in Belgium for example lacks the manpower, vision, and competence to effectively process the volume of authorisation requests and also on time.

(Participant 9)

I think Authorisation approvals are not slower than before rather there are just too much more people and more professionals who want to fly, and these flights are requested in complex environments. The authorities just want to be sure that there are no incidents with regards to safety of flights because if you want to fly at night, then that's different from flying during the day. Also, Beyond Visual Line of Sight flight is different from Visual line of Sight and as the market and industry is demanding to go forward with drones, the legislation will have to cope with it. Nobody else has done this in the past and so its new to everybody since there is no reference point hence the delays experienced.

(Participant 10)

The analysis shows that the bureaucratic and administrative challenges are impeding factors to not only the growth of the drone industry in Europe, but also a huge blow to the rapid integration of drones in the U-Space airspace.

4.3.4. The Prevalence of Privacy, Security and Safety Concerns

The rising concerns about privacy, security and safety was another motive reported by the stakeholders as a key setback to the smooth integration of drones in the European Airspace. Privacy and safety are very important and even though a recent study by the European Union Aviation Safety Agency on the perception of drones by 3,690 European citizens across 6 European cities, proved that a majority of them accept the integration of drones into the Urban Air Mobility system (EASA, 2021). The stakeholders believed that this issue of safety and privacy will be around for a while until people fully have trust in the technology.

Policy makers also have a very important role to make sure that the public is on board. So, they should make sure that things are properly communicated, that people know what Drone Services are, why they're being deployed, what the purpose of them is, and where this may lead to in the long term. So, I think this is the role of the public authority. They have to really be sure to understand the concerns of the public, whether it's about privacy, whether it's about annoyance, like because of the noise or because of what they see in the sky, so all these things have to be hedged against basically. There have to be strategies in place how such concerns can be mitigated or avoided completely.

(Participant 11)

The concerns regarding privacy and safety are significant variables if there should be an effective introduction of drones in European cities. There need to be safety and privacy requirements that need to be met and this is the role of the regulation but unfortunately the instability associated with it and the difficulty in interpretation slows down the realisation of eliminating safety and security concerns. The stakeholders also mentioned cyber security attacks and the protection of personal data as a hindrance that needs to be taken seriously. For example, in the registration process, personal information is mandatory for drone operators such as their names, address, date of birth, amongst others. Based on the fact that data protection laws are strictly enforced by individual EU countries, the idea of data sharing at the European wide level will not be feasible at the moment according to the stakeholders. They reported the need for a high-level system that will ensure maximum security and privacy.

As a recapitulation, this section aimed at answering the research question on the issues that are currently impeding the smooth integration of civilian drones into the European U-Space Airspace. The factors included the U-Space regulation, airspace segregation, administrative and bureaucratic exigencies, and the continuous concerns about privacy, security, and safety. It is worthy of note that the section was primarily based on the interviews that were conducted but the following section 4.4 will be based on a comprehensive literature review analysis of both the EU and US regulatory approaches to the use of Drones.

4.4. The Differences and Similarities between the European U-Space and the United States Regulatory Frameworks.

The last research question aimed at exploring whether there is a dichotomy and also common grounds between the European approach to drone regulation and the approach adopted in the United States of America. No comparative studies have been done on this issue at the time of this thesis and so the research question comes in handy to fill this gap. A critical comparative analysis was carried out by the researcher and the following key outcomes were derived.

4.4.1. Differences in the EU and US Regulatory Frameworks

A critical look at both regulatory frameworks depicts some striking contrasts with regards to a host of issues. This was not based on the interviews but on a thorough review of both regulations.

4.4.1.1. Variation in Registration Procedures

One of the fundamental distinctions between the EU and US regulatory frameworks lies in their registration procedures. In Europe, there is no need to register your drone except for the Certified Category, rather you have to register as a pilot with the Civil Aviation Authority in your country and a registration number is given to you which is easily accessible by the aviation authorities of all member states. Conversely, the United States of America requires a different process as the pilot needs to get a certification and then the drone itself has to be registered with the Federal Aviation Administration. A sub difference within the registration procedure is that while in the EU the registration is done by the aviation authorities in individual member states, in the USA it is done at the federal level. Also, in the USA, there are two tests which must be completed by the drone user before operations, and they include the Aeronautical Knowledge Test and a Safety Screening test which is conducted by the Transport Safety Administration of the United States. For flying in the Specific and Certified Categories of the EU-Space regulation, it is mandatory to carry out a Specific Operations Risk Assessment (SORA) to ensure the level of safety and security compliance.

4.4.1.2. Differences in Common Information Ownership

Another distinction in both regulatory framework stems from the point of ownership of the Common Information Services (CIS). The European U-Space regulatory framework regards flight information services or the CIS to be privately owned and operated in Europe which means that governments may have little or no role with regards to this service. This situation is quite different in the U.S.A because the Flight Information

Management Systems (FIMS) is envisaged to be developed and operated by the Federal Aviation Administration itself. This shows that Europe advocates for a privately administered Common Information System while the U.S.A roots for a publicly owned and operated FIMS.

4.4.1.3. Homogeneity Vs Segregation Approaches in the Regulation

From January 2021, the European Union adopted a standardised regulation for drones which was directly applicable to all member states including Norway, and Liechtenstein. The EU therefore follows a harmonised and uniform approach to regulating drones. Even though the Federal Aviation Administration is the pioneer organ in the drafting of rules and regulations regarding drones, there are different rules governing the use of drones across the 50 states in the USA. This shows a segregated approach to drone regulation in the various states. For example, the state of Kentucky has drone laws different from the state of Alabama.

4.4.2. Similarities Between the EU and the U.S Regulatory Frameworks

Despite the contrasts that exist in both regulatory systems, there are a lot of areas of common similitude and some of them include.

4.4.2.1. Airspace Differentiation

Air space classification is embedded in both the EU and the US regulatory frameworks. In the EU, there are three categories of Drone operations; the Open Category, which is further subdivided into A1, A2, A3; the Specific Category; and the Certified Category (EASA, 2019). The Open Category involves the lower risk drone operations where operational safety is ensured based on compliance of the operators with the necessary requirements. In this category, due to the low risk involved, no pre-flight authorisation is required.

The Specific Category is involved with operations that are risky and therefore it is required to obtain an operational authorisation from your competent national authority before operation. Before this authorisation is granted, the drone operator needs to carry out a risk assessment that will ascertain the necessary requirements for operation.

The Certified Category involves operations with a higher risk, and this requires the certification of the drone operator as well as the drones including the licensing of remote pilots for safety purposes. This classification is shown in figure 15.

<table>
<tr><th>Category of operations</th><th>Open
low risk</th><th>Specific
medium risk</th><th>Certified
high risk</th></tr>
<tr><td>Authorisation needed</td><td>None</td><td>Authorisation from NAA based on operational risk assessment or specific scenario</td><td>Authorisation from NAA/EASA</td></tr>
<tr><td>UAS</td><td>Compliant with Commission Delegated Regulation on UAS</td><td>Compliant with requirements included in the authorisation</td><td>Certified UAS</td></tr>
<tr><td>Operations allowed</td><td>Restricted to:
▪ VLOS
▪ Altitude < 120 m
▪ Other limitations defined by:
- Commission Regulation on UAS operations
- National airspace zones</td><td>Restricted to:
▪ Operations specified in the authorisation
▪ Limitations defined by national airspace zones</td><td>Controlled airspace
U-Space</td></tr>
<tr><td rowspan="2">Regulations</td><td colspan="2">Commission Regulation on UAS operations in open and specific</td><td rowspan="2">Revision of existing aviation regulation</td></tr>
<tr><td>Commission Delegated Regulation on UAS</td><td>No regulatory requirement (UAS requirements included in the authorisation)</td></tr>
</table>

FIGURE 15: European U-Space-Airspace Categories (Source: EASA, 2019)

Similarly, the FAA in the USA also classified the airspace into several categories. The designations range from Class A to Class G with the former being the most restrictive and the latter being the least restrictive.

Class A reflects the airspace from 18000feet including the airspace overlying the waters within which there are air navigational signals.

Class B depicts airspace from the surface to 10,000feet mean sea level which covers the busiest airports of the country.

Class C airspace involves airspace from the surface to 4000feet above the elevation of the airports that have operational control towers.

Class D is airspace from the surface to 2500feet above the airport altitude which surrounds airports with operational control towers.

Class E airspace is not classified as one of the A, B, C, or D airspaces. This is the controlled airspace and a large fraction of the airspace in the United States is classed as Class E because this allows for a safe control and segregation of aircrafts due to the large space available. The classification classes are illustrated in figure 16.

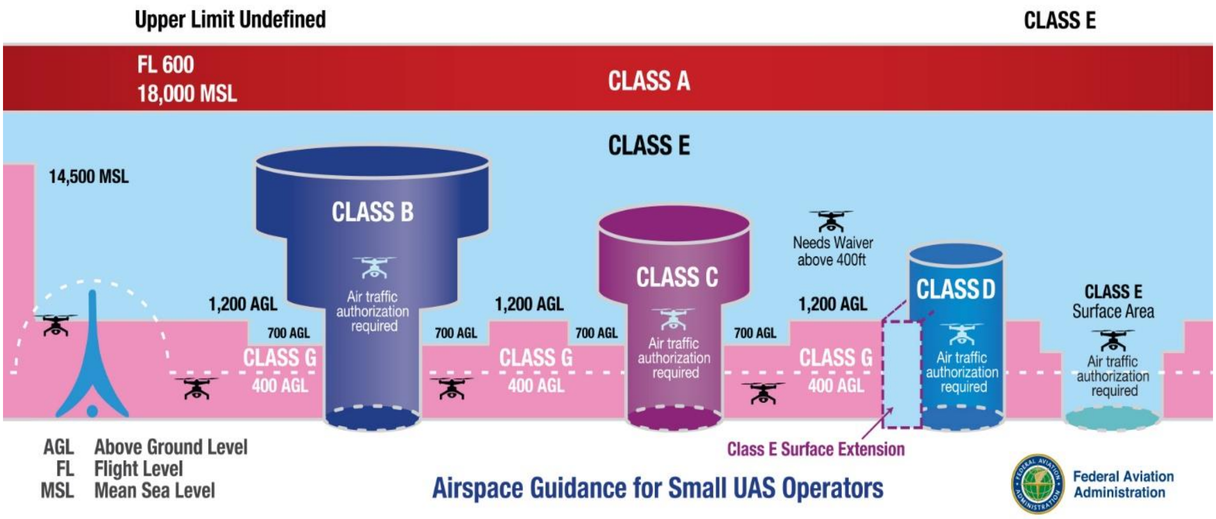

Figure 16: The FAA Airspace Classification in the USA (Source: FAA, 2014)

4.4.2.2. Remote Identification

Another significant concept in both regulations is the Remote Identification rule. A very important element needed for the smooth integration of drones in the airspace with manned aviation whereby safety and security concerns will be addressed, requires policies or rules that will enable drones and manned aircrafts to be able to identify each other as well as other users of the airspace. The Remote Identification rule went operational in the European Union as from December 2020 as a result of the Commission Delegated Regulation (EU) 2019/945. This rule requires all drones operating in the open and specific categories below 120 m must be equipped with a remote identification that ensures the provision of wireless communication signals to the operator's registration number (EU, 2019).

Similarly, the Federal Aviation Administration also adopted the remote identification functionality. All drones that are greater than 250grams must be equipped with a remote identification while any drone without a remote identification only flies within designated areas established by the FAA. In the USA, only drones with remote IDs are allowed to fly at night and/or over people. The drone pilot is also required to be in possession of their remote pilot certificate when in operation. The standard remote identification unmanned aerial vehicle has to broadcast information such as the drones' and the control station's longitude, latitude, geometry, velocity, and altitude, a time mark, and an emergency status indication (FAA, 2020).

4.5. Conclusion

The primary purpose of this chapter was to highlight the key findings resulting from the stakeholder interviews that were carried out as well as from a comparative analysis of the European and US drone regulations. It is clear from the research findings that drones will have a huge positive impact in Europe economically, socially, and environmentally when they are fully deployed at scale but however, there are several factors that are impeding the integration of these drones in the European U-Space Airspace such as the dynamic nature of the regulation, Bureaucracy etc. The chapter also highlighted some key differences and similarities between the regulatory frameworks in Europe and United States of America.

CHAPTER FIVE

DISCUSSION

5. Introduction

The main objectives of this thesis were to determine the potential impacts of drones in Europe when the U-Space regulation is fully operational, to outline the reasons impeding the smooth integration of drones in the European U-Space airspace, and to carry out a comparative study on the drone regulations of the European Union and the United States of America who are key pioneers in the development of the sector. This chapter will therefore present an interpretation of the findings that have been derived from this research and to compare it to the literature.

5.1. An Understanding of the Findings with regards to the Research Questions

As it was expected, the operational efficiency and cost savings that drones could potentially bring to its users emerged as the primary theme across all stakeholders interviewed. The participants reported the profit maximisation and cost minimisation they will derive as a result of the integration of drones into their operations. This means that drones can carry out specific tasks with less time, less cost and with greater efficiency. This will have a multiplier effect on the manufacturers who will now have a huge potential of selling more drones, the service providers who offer services like Drone-as-a-Service to individuals and organisations, as well as to the organisations themselves who will adopt drones into their processes. This finding concurs to the research carried out by Fassbender et al., (2018), whereby many companies they interviewed reported an increase in productivity by at least 50% as a result of the implementation of drones in their operations. This shows that drones have a huge potential for reducing cost, increasing productivity, and increasing profit margins for companies.

Drones as a disruptive technology in the market exhibit so much market potential to drive innovation in Europe. There are so many drone start-ups emerging in Europe for the development of hardware, software or both solutions and this creates competition as everyone wants to put in the best product in the market. This situation will continue to skyrocket in the future thereby creating a lot of job opportunities in Europe. The stakeholders were very optimistic of the fact that the drone industry will become one of the largest employers in Europe with its application encompassing different areas of application including but not limited to surveying, photography, infrastructure inspection, precision agriculture etc. This finding also resonates with the report by the European Parliament which states that the drone industry is capable of creating more than 150,000 new jobs in Europe by the year 2050 and that in ten years' time, the industry is anticipated to account for 10% of the European Union aviation market which is equivalent to 15 billion euros per year. This only goes a long way to show the level of significance that drones could play in Europe in the coming years.

However, despite the fact that drones have a huge market potential and prospects for job creation, some studies (PricewaterhouseCoopers, 2016) reveal that over $127 billion of present business and humans are likely to be replaced by drone-based solutions especially autonomous drones. It is true that automation will cause great disruptions in labour markets, but this still remains uncertain because even though drones could possibly replace human labour such as pilots, photographers, surveyors, they will also act as catalysts to the development of new jobs or careers that will require high level skills and trainings such as data analysts to analyse the data gotten by drones, software and hardware developers, maintenance, and repairs technicians etc. The drone technology can be viewed in this respect as a double-edged sword but overall, its benefits to the European society will be huge and tremendous.

The constant changes and the uncertainties surrounding the European U-Space regulation was also a prominent hotspot that was uniform across the stakeholders. It is surprising to see that the regulation that has been put in place to ease the implementation of drones in the European airspace becomes a challenge to the attainment of its own objective. The stakeholders expressed dissatisfaction with the lack of clarity of the regulation and the continuous amendments meted upon it. This is an indication that more work needs to be done by the regulatory authority by bringing all stakeholders on board to collaborate and come out with easy access rules that will be suitable for all. This regulatory challenge proves to have an impact on the manufacturers, the service providers, the pilots etc. But since we are dealing here with technology which constantly evolves especially as companies keep investing in research and development, the regulation is bound to also follow these technological updates in order to strike a balanced scenario.

Also, the fact that Europe adopted a segregated or decentralised approach to space management was also a key issue amongst the stakeholders. Some believed that Europe started on a rough foundation and therefore there is need for harmonisation or the adoption of a centralised architecture. It should be noted here that the U-Space framework advocates for a uniform and single European sky but with the current state of affairs in its slow implementation, various member states are adopting individual approaches to airspace management. However, despite this debate, the regulation should be credited for providing a comprehensive guideline on operations, risk identification and analysis of complex situations prior to the deployment of the drones which these individual countries now use as a template and means of compliance. Harmonisation is feasible and under serious development currently.

Furthermore, even though public acceptance of drones is on a high level in Europe, the issues of privacy and security still remain a point of contention amongst stakeholders. Registration of drones for example requires the submission of demographic variables like names, date of birth, address etc and so if there is to be an interoperability of systems across member states, then there should be an advanced technological system put in place to ensure personal data is protected. This should be further reinforced by stringent laws. Public acceptance of a new technology doesn't come that easy but gradually with the potential benefits to be derived from drone use, more and more people will accept the technology. This also agrees to the research of Anania et al., (2019) which states that different parts of a community are more accepting drone technology than others.

Europe and America have been at the forefront in regulatory developments for manned and unmanned aviation and are both working in their respective regions to ensure the smooth integration of drones in their airspace. Even though their approaches may differ at some point, they however have some things to share in common like the remote identification rule which is of vital importance for information sharing on flight status, location etc.

In comparison to other research studies, drone technology is a relatively recent field of studies and most research have been done on its use cases or areas of application, but few have actually discussed about the regulation of drones. There is no concrete discuss on the drone regulation in Europe as the main focus of a research work but rather as a passive element and some were based on speculations rather than actual facts. For example, authors like Hirling and Holzapfel (2017) had predicted that the European regulation will focus only on the operation of the flights rather than the aircrafts itself, but this is not the actual situation that is seen today. The U-Space regulation has clearly covered aspects of flight operations as well as requirements for the drones themselves with regards to variables like weight, remote identification etc. Even though the relation is in a constant state of flux, this thesis has clearly deciphered the regulation and what it means for the future of drones in Europe.

5.2. What should the Society Expect in the (nearest) Future?

The drone industry in Europe is a rapidly growing sector which will play a vital role in shaping Europe's digital future and maintaining the global competitiveness of its industries. The drone industry has a bright future especially with the full implementation of the U-Space regulations. We should expect to experience a number of developments in the coming years, and these include the following.

Besides the already well-known use cases of drone technology such as for infrastructure maintenance, traffic control, precision agriculture, logistics etc, there will be the emergence of new use cases while there will be continuous innovation carried out on the old current use cases. This will see European companies trying to find a balance between sustained and disruptive innovation strategies in order to keep pace with the changing market conditions. Some examples of futuristic use cases could be to detect the emission of particulate matter such as nitrogen oxide and ammonia provided, they are well equipped with specialised sensors. Drones could also be used to measure light and sound radiation levels, and all these will improve environmental health thereby adding more benefits to the society. Drones could also be used in the future to track animal population and their behavioural patterns (Klonoski, 2013). Another potential use case of drones will be in the area of advertisement as the drones could be mounted with banners, speakers, or objects to spread important marketing messages to the population. Furthermore, another potential use case of drones in Europe could be that of pixels in space as this use case has been tested in Singapore. In this use case, drones are equipped with LED lighting and flown at night such that they are able to draw 3D representations of objects in the sky, a scenario synonymous to that of fireworks.

In the future, the drone industry will become a complete autonomous one. Even though there are existing technologies that support autonomous drone operations such that the remote control by a human operator is partially or completely excluded, the most widely commercially available drones are still remotely piloted (Burkle et al., 2011). With the soon to be fully functioning of the U-Space regulation which will permit flights in the Specific and Certified Categories, we expect to see greater autonomy in drone operations, and this will eliminate the probability of human errors. Also, just like autonomous vehicles which are increasingly becoming popular, we expect to see a massive use of drones for passenger transport in the near future. Drones will become an integral part of the urban transportation system in Europe.

The full operation of the U-Space regulation in Europe will also permit an internet of drone collaboration in European smart cities. Drones will be deployed in swarms for various applications such that there is an effective maximisation of efficiency. This aspect will also be propelled by the increase in the level of autonomy in drone operations. This can be exemplified by the fact that one drone could take over the task of another drone in case of an exhausted battery life when they are operated in a swarm, and this extends the flight range and time. This scenario also makes it easier for the smooth replacement of drones that might have gone beyond the reach of signal controls as well as enable the distribution of heavy payloads to several drones. A key technological challenge emanates from the fact that these drones will have to communicate with each other as well as with the ground control station which will require several communication channels. This challenge however is gradually becoming a myth because it is under rigorous research as experts and researchers have begun developing the capabilities of sense and avoid or collision avoidance algorithms to curb the situation.

Finally, the U-Space concept is coming to harmonise all national registers of drones into an interoperability platform to ensure effective management and communication among EU member states. Drone electronic and identification registries are already a normal procedure in some European countries which require operators to report certain information about their drones and flights. The key challenge with this existing system of registration is the segregated and isolated nature as there is no connectivity between them. The U-Space however comes in as a viable panacea to this problem since it advocates for a digital, real time accessible and an interoperable registration process. The U-Space becomes a solution by combining laws and contemporary technological developments to ensure the smooth integration of drones in the European U-Space airspace.

5.3. Limitations of the Study

In the course of the study, the researcher was faced with some limitations. The most prominent limitation stems from the fact that the small number of participants means that one has to be cautious in generalising from the findings even though they represent the state-of-the-art of the industry at the moment. In conducting research of any kind, it is important to conduct it on a large scale in order to get a comprehensive understanding of the study. However, the fact that a semi-structured interview method was used in this research was very significant and useful as it allowed for the collection of an in-depth and reliable data from the participants. Though the interview process was time consuming and energy sapping, it however proved to be a vibrant and efficient way of getting honest opinions from the participants. Also correlating the findings of the study with peer-reviewed research during the interpretation of the findings also proved to be a viable approach to mitigate this limitation.

Another limitation was the fact that some respondents that were contacted didn’t give any response while others responded late. It is also important to note that some explained that the interview request email went to their spam folders, and it was only after the several reminder emails that was sent that they realised it. This means that the reminder emails were very important for the success of the research.

Lastly, the COVID-19 Pandemic also affected the thesis because 100% of the interviews were conducted online and therefore this gave no room for a face-to-face interaction with the stakeholders. Provided these interviews were conducted face-to-face, it could add some extra meaning and insights to the whole process as the interaction level could be best.

5.4. Recommendations

The outcome of this thesis cannot be complete without possible suggestions to improve the current state of affairs of the U-Space regulatory framework in Europe.

Firstly, given the fact that European drone industry is characterised by Small and Medium Size Enterprises (SMEs), there should be full support and protection for these companies in terms of funding availability as well as the criteria for obtaining them. This will enable them to become more competitive and improve their level of innovation to meet up with market needs and standards.

Also, the collaboration between the public sector and private sector should be further reinforced and promoted in order to achieve the objectives of the U-Space. It is no doubt that the U-Space is made up of a compendium of public and private stakeholders, but this relationship needs to be further strengthened to encourage mutual agreements and understanding as a block in order to ease the full implementation of the U-Space concept. This multi-stakeholder collaboration is essential at all levels in the drone industry to enable the safe and efficient integration of drones in the European airspace.

Another proposition is the promotion of drone and regulatory education and training. Specialised institutions should be created to provide knowledge and skills to pilots, national aviation safety authorities, manufacturers, service providers etc in order to keep them better informed on regulatory requirements and technical details of drone operation such as flight control, communication, and navigation. Building on this same idea, drone education should also be integrated into higher education curriculums in a broader scale as this will create more awareness about the technology hence fostering more public acceptance. It is also worthy of note that, technological developments are often materialised as a result of collaborative efforts between the industry and academic research institutions. This will make it possible for companies to become closer to the source of knowledge from professors and students thereby encouraging the diversity and growth of the industry.

Finally, as a direction for further research, more attention should be given to operational deficiencies of drone technology such as battery lifespan, possibilities of battery recharge during flight, as this will further improve flight efficiency and safety. Also, most of the testing or experiments have largely been done in controlled environments for safety reasons, but more research needs to be done on the possibilities of direct testing in actual real environments. This means that all safety and operational protocols need to be properly checked and cross checked to make sure that the level of safety is at its maximum.

5.5. Conclusion

This thesis has provided a clear answer to the research questions about what are the potential impacts of the U-Space regulation in Europe? What are the challenges currently being faced in the integration of drones in the EU airspace? as well as a comparative analysis of the EU regulation and that of the United States. To effectively address these questions, a qualitative methodology was adopted an in-depth interview conducted with stakeholders of the industry. Even though the sample size was small initially, the result of this research is valid and reliable because it represents the current state of the industry and the regulation at the moment. This is supported by the fact that the Amsterdam Drone Week and the EASA High Level Conference involved a compendium of industry stakeholders including the ones interviewed for this research and they all shared the same views as expressed in this research. This multistakeholder meeting involved industry players from all over Europe and the concerns raised are uniform with this research with the regulatory loopholes acknowledged by EASA itself.

The facilitation of the integration of Unmanned Aerial Vehicles into the national airspace has become one of the most prominent challenges in the aviation industry in contemporary times. In order for Europe to remain the leader of this revolution, there should be a robust collaboration at all levels with all actors and this explains why the U-Space regulation is the solution to this challenge. The U-Space regulation is of course providing a dual solution approach to these challenges based on a technological solutions level and regulatory requirements level. This is particularly important for Europe because the drone regulation is keeping pace with technological developments in the industry and such flexibility is commendable. The future of urban air mobility in Europe is already here, and the anxiety and expectations are high at all levels to see this becoming fully a reality soon.

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APPENDIX A

INTERVIEW QUESTIONS

The interview questions for this thesis are directed towards the key stakeholders of the drone ecosystem in Europe. They include the manufacturers, Service providers, the regulators and Insurance providers. These are the main questions to be asked per category, however, some follow up questions might be impulsively asked in the course of the conversation.

1. Questions for Drone Manufacturers

1.1. What are the key technological strengths of your products? And which are the areas where you are still trying to improve upon?

1.2. Before the regulations were put in place, you already had drones in the market without certain requirements in the regulation such as class labels and different risk levels. what challenges do you face with complying with these new requirements and the regulations as a whole?

1.3. Does the delay or uncertainties in the upcoming U-Space legislation cause any disturbances in the marketing that impacts your sales? Because in the past there were many start-ups that went bankrupt as a result of the slow rate of development of the sector due to the difficult legislation.

1.4. Who are your current and potential customers?

1.5. The drone industry is a rapidly growing one with great prospects and we see a lot of new industry players emerging. How do you cope with this intense competition that already exists? And do you foresee a possible collaboration or merger with another company in order to gain market strength and dominance?

1.6. What is the maximum payload of the drone(s) you manufacture?

1.7. Can you highlight some of the socio-economic and environmental impacts of drone manufacturing?

1.8. I realised you have branches out of Europe in America for example. How do you cope with operating under different markets and regulatory frameworks? ***(This is applicable to some companies on my list)**

1.9. What has uncertainties like COVID-19 impacted your manufacturing process and strategies to adapt?

1.10. What are your forecasts for the drone manufacturing industry by 2030 in Europe and the world?

2. Questions for Drone Service Providers

2.1. Drones have become commercially applicable to a variety of domains nowadays. Which application sector(s) are you involved in?

2.2. What are the challenges that you face in your operations and how do you manage to solve them?

2.3. How does your company as a whole address the adoption of new technologies?

2.4. Was the adoption of drone technology a key challenge in itself or rather it was the change in conventional business processes/procedures that was?

2.5. The processing of flight authorisation requests in Belgium is faced with a lot of delays as a result of the fact that the Belgian Civil Aviation Authority is not capable to process all requests. Is this also an issue for you? And are you hopeful that the U-Space architecture will make it easier for pilots to conduct their flights?

2.6. Do you usually carry out a risk assessment before certain operations especially in the specific category? If yes which Assessment tool, do you use and why is this the best for you?

2.7. What are some of the potential market and economic impact of drones on the transport and mobility sector?

2.8. Are your activities affected by atmospheric attenuations? What measures do you adopt in such scenarios?

2.9. Do you take into consideration privacy, security, the environment, in your business operations?

2.10. The drone industry is a rapidly growing one with great prospects and we see a lot of new industry players emerging. How do you cope with this intense competition that already exists? And do you foresee a possible collaboration or merger with another company in order to gain market strength and dominance in service provision?

2.11. How has COVID-19 impacted your business activities and what are your forecasts for the service provision industry by 2030 in Europe and globally?

3. Questions for government Agencies and regulators

3.1. What is the impact of U-Space regulations on other domains of air and space traffic management?

3.2. What are the impeding factors limiting the rapid implementation of the U-Space Concept?

3.3. What is the state of the current traffic management capabilities?

3.4. Is there a (Potential) collaboration with non-EU regulatory agencies like the Federal Aviation Agency (FAA) in the USA for knowledge and technology sharing for the safe integration of drones in the airspace?

3.5. We have had the national rules different across member states of the EU and then the EU rules came with minor differences and now the introduction of the U-Space framework. What will be the next evolution after U-Space?

3.6. What will be the next challenges? Will it be the share volume of drones managed by the U-Space or the collaboration between multiple countries for cross border flights?

3.7. What role will the governments have in the U-Space? Will they also host the central Common Information Service (CIS)?

4. Questions for Drone Insurance Providers

4.1. Drone liability insurance is very important for drone operators within the European U-Space airspace. What are the range of insurance policies you offer?

4.2. How are these policies determined? Are they a function of the type of drone to be insured, the functional capabilities of the drone, risk calculations, historical data, or there are other criteria?

4.3. Do your insurance policies cover medical expenses stemming from drone use?

4.4. Is there a possibility for an on-demand flight liability coverage especially for pilots who don't fly often? As this might be ideal rather than pay a huge amount of money when you will only fly a limited number of times within a month or year.

4.5. What do you anticipate for the future of drone liability insurance in Europe by 2030 especially after the introduction of the U-Space with the expectation that autonomous drones will take-off? This will normally reduce on the risk factors which is human errors, and so will this affect your insurance packages and business model?

APPENDIX B

INTERVIEW REQUEST LETTER

Dear ………….

My name is Elvis Ekane NGALLE, I am an MSc student in Transportation Sciences at Hasselt University, Belgium. The European Union adopted the U-Space Regulatory Framework in April 2021 which gave a formal green light for drone operations across the European airspace. According to the SESAR Joint Undertaking's Drone Outlook Study, an estimated fleet of more than 400,000 commercial and government drones are expected to be in use by 2050 (SESAR JU, 2016).

I am currently doing a research study on the potential impact of the European U-Space regulation, and the challenges hindering the smooth integration of drones in the European U-Space airspace.

I would like to invite you for a 30-minute interview on the subject. The interview will be recorded for data analysis purposes and will only be available to the interviewer and the direct supervisors of Hasselt University and will in no way be used other than the analysis of this research. In the resulting thesis, your participation will be anonymised by default, unless you specifically make mention that this is not necessary. In that case, permission may be requested to use one or more direct quotes.

I hope you are available for an interview at a time convenient for you. If you have any questions, please feel free to contact me directly. I will be available on phone: (+32465484632), and by email: (elvisekane.ngalle@student.uhasselt.be) in case of any query.

Thanks for your anticipated participation and I look forward to your reply.

Yours sincerely,

Elvis Ekane.