CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of Transportation Sciences
Department of Air Transport

Comparison of UTM Solutions in the World
Porovnání UTM řešení ve světě

Bachelors thesis

Study programme: Technology in Transportation and Telecommunications
Study field: Professional Pilot

Thesis supervisor: doc. Ing. Jakub Kraus, Ph.D.
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Yifeng Fu

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ZADÁNÍ BAKALÁŘSKÉ PRÁCE
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Název tématu (česky): **Porovnání UTM řešení ve světě**

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Zásady pro vypracování

Při zpracování bakalářské práce se řiďte následujícími pokyny:

- Cílem práce je analyzovat integraci služeb UTM do současných struktur ATM v různých státech světa a identifikovat nejlepší praxi.
- UTM koncepty ve světě
- Světové přístupy k integraci UAS do vzdušného prostoru
- Identifikace nejlepších elementů jednotlivých přístupů
- Doporučení a tvorba nejlepší praxe

Rozsah grafických prací: dle pokynů vedoucího práce

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Potvrzuji převzetí zadání bakalářské práce.

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BACHELOR'S THESIS ASSIGNMENT

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Guidelines for elaboration

During the elaboration of the bachelor's thesis follow the outline below:

- The main objective of the thesis is to analyze the integration of UTM services into the current air traffic management structure in different states in the world and identify best practices.
- UTM concepts in the world
- World's approaches to UAS integration into common airspace
- Identification of the best elements of specific approaches
- Recommendation of best practices

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Ing. Šárka Hulínská

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a) date of first anticipated submission of the thesis based on the standard study duration and the recommended study time schedule
b) in case of postponing the submission of the thesis, next submission date results from the recommended time schedule

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I confirm assumption of bachelor's thesis assignment.

Yifeng Fu
Student's name and signature

Prague .... December 2, 2021

Abstract

Unmanned aircraft (UA) has developed striding over centuries from flight trials in its early days to nowadays flourishing progress. It has experienced technological breakthroughs and achieved great success in its practical application. With the improvement and perfection of relevant scientific and technological levels, civilian UA technology has been widely applied in each field with this research looking into leisure and commercial areas in which UA has been applied. The purpose of this research was to compare unmanned traffic management in the world by evaluating six countries and six key areas and finding the best. The researcher used qualitative secondary research while using a comparative approach for comparison to achieve the above research goal. Some of the significant areas that the research looked into included the licensing of drone operators and drone registration while looking into the aspect of quality and safety in the aviation industry, the weight of the drones and safety distances, privacy, visual line-of-sight, flying time, and the number of drones to be flown at a time. The six key areas of comparison were to be evaluated based on six countries which include China, Australia, the United States, Brazil, South Africa, and the European Union.

Key words : Unmanned aircraft, Unmanned Traffic Management (UTM), UA, UAS, ICAO, Aviation safety, Regulation, VLOS.

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Declaration

I declare that I prepared the bachelor's thesis entitled Comparison of UTM solutions in the world independently and for this I used the complete list of citations of the sources used, which I present in the list attached to the bachelor's thesis.

I have no serious reason against the use of this school work in the sense of §60 of Act No. 121/2000 Coll., on copyright, on rights related to copyright and on the amendment of certain laws (Copyright Act).

In Prague 07. August 2022 ……………………………………………...

Signature

Content

List of Tables

List of Abbreviations

AGL	Above Ground Level
ANSPs	Air Navigation Service Providers
ATC	Air Traffic Control
ATM	Air Traffic Management
VLOS	Visual Line-Of-Sight
BVLOS	Beyond Visual Line-Of-Sight
CAA	Civil Aviation Authority
CASA	Civil Aviation and Safety Authority
DOD	Department of Defense
FAA	United States Federal Aviation Administration
EASA	European Aviation Safety Agency
GIS	Geographic Information System
GPS	Global Positioning Systems
ICAO	International Civil Aviation Organization
NAA	National Aviation Authority
NOTAM	Notice to Air Missions
RNP	Required Navigation Performance
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
RPL	Remote Pilot License
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System(s)
USS	UAS Service Supplier
UTM	Unmanned Aircraft System(s) Traffic Management
LAANC	Low Altitude Authorization and Notification Capability
NASA	National Aeronautics and Space Administration
SESAR	Single European Sky Air Traffic Management Research Program
CORUS	Concept of Operation for EuRopean UTM Systems
DECEA	Department of Airspace Control
SACAA	South African Civil Aviation Authority
GDPR	General Data Protection Regulation
ACAS	Airborne Collision Avoidance System
ROC	Remote Air Operator Certificate
VTOL	Vertical Take-off and Landing aircraft

Introduction

A drone represents an aircraft operating without a pilot on board also known as unmanned aircraft (UA). Their nature has resulted in research on unmanned aircraft systems (UAS) developed by the Department of Defense (DOD) and the United States Federal Aviation Administration (FAA). With the increasing improvement of intelligent control technology, the production cost of UA has begun to drop significantly, which has promoted the rapid development of civilian UA industries. Drones were first used in the military. UA has been increasingly used in the civilian field, such as flying activities in industry, agriculture, forestry, fishery, mining, disaster relief [1], meteorological detection, ocean monitoring, scientific experiments, and remote sensing mapping [2].

While civilian drones bring convenience to people, production, and life, the laws of some countries are not perfect in terms of organizing and managing the UA traffic, which can be widely called Unmanned Aircraft Systems traffic management (UTM) [2]. The safety hazards caused by UA flying in non-compliance with laws and imperfect laws have increased risks and challenges in navigation [3]. The presence of drones has also contributed to growth in air traffic, calling for traffic management systems. The quest to address the prevailing risks has resulted in participation from various organs, including UAS. The UAS operators and remote pilots ought to be certified to perform all relevant everyday and emergency running strategies by the specific classification of airspace in which UTM operations and services are performed [4]. The issuance of licenses for these operations also attempts to build a regulatory framework around drones. Similarly, considering the weight of the drones and the safety distances in which they fly is a significant aspect. Additionally, privacy and the use of visual line-of-sight (VLOS) regulations have been significant areas of development considered in the UAS.

Bodies such as NASA participate in the research and development of ideas surrounding air traffic management systems with the classification of the performance ranges [5]. NASA has executed flight demonstrations to examine UTM closely, leading to improvements in the existing architecture [6]. These operations remained within singular 3D volumes intended to encompass the flight course of the vehicle, which also required the aircraft to stay within VLOS during its flight. For instance, in the second level flight demonstration, the technical capabilities from the first level had been carried over, and the idea used to be prolonged to encompass a combination of VLOS and beyond visual-line-of-sight (BVLOS) operations. Additional enhancements help alert flights' airspace intrusion, indicators to contingency management, and segmented flight planning that allowed stratification of operational volumes and greater environment-friendly use of airspace throughout BVLOS operations [7]. Therefore, while different UTMs have been introduced in other countries to ensure that UA operates efficiently, there is a need to identify the best UTM that will ensure safety in the aviation industry.

1. The Idea of UTM

The concept of UTM was proposed by members of the State research organizations and industry in 2016 [8]. The reason for the proposal was that they wanted to support the near-real-time or real-time organization, its coordination, and the management of the operations of UA. Aside from the organization, coordination, and management, this proposal would enable the inclusion of the potential for several BVLOS functions. According to ICAO, the UTM would allow the civil aviation authorities (CAAs) and air navigation service providers (ANSPs) to provide near-real-time or real-time information concerning the intentions of aircraft available to UAS operators, their remote pilots through the UTM service provider (USP), and information about airspace constraints [9]. Once the information concerning these constraints is provided, the UAS operator would be in a better position to responsibly manage its operations safely without the ANSP providing air traffic control (ATC) services.

ICAO notes that the aim of UTM is to ensure safe, economical, and efficient management of the operations of UAS by providing facilities and seamless conventional services that ensure a collaborative integration of information, humans, technology, services, and facilities that are supported by the ground, air, and space-based communication, navigation, and surveillance [10]. Therefore, UTM systems are imagined to be consistent with the air traffic management (ATM) systems to ensure the facilitation of safe, efficient, and scalable operations. A common aspect of UTM is the national aviation authorities (NAAs) dependence on and collaboration with the private sector operators who obligingly separate their drones from other operators in uncontrolled airspace. UTM is, therefore, intended to majorly mitigate the risk of small UAS that fly below 400 ft in uncontrolled airspace from colliding.

1.1 Scientific Research on Unmanned Traffic Management (UTM)

The development of UAS regulations provides many opportunities for traffic management. The regulations have targeted areas including UAS and UTMs. However, the effective association between UAS and UTMs yields a positive impact on the consumers and the existing airspace capacity. However, some of the challenges involved include privacy, security, reliability, environmental safety, and ideal use of automation which are necessary for public acceptance [11]. UAS operators should show compliance with minimum protection requirements and be held legally accountable if daily operations are official to the public [12]. Each of these factors depends on the attainment of a balance between risks and performance-based legislation and control and the need to consider new technological solutions. According to Jiang et al., UTM is significant in ensuring safe and efficient operations for UAS [12]. This is important because UTM systems will borrow basic ideas from large-scale air-traffic control while integrating several key diverse changes, which will provide efficiency in operations while ensuring safety for UAS since they are different based on their functions and methods of control maneuverability and even range and operational challenges. This is an idea supported by ICAO, which argues that the main goal of having UTM systems is to ensure automatic, safe, and efficient management of the UAS operations [13]. This, however, should be attained by providing a continuous set of products, services, and infrastructure in collaboration with key stakeholders in the aviation environment to allow for the UTM systems to thrive. ICAO has a proposed framework for the significant parameters that should be in place to ensure UTM systems thrive. These parameters are inclusive of registration and identification methods, traditional air traffic control (ATC), air traffic management (ATM), communications compatibility between UTM, detect and avoid (DAA), and adaptability of the UTM infrastructure performance requirements [13].

There are few papers and articles focused on UTM and drone integration, but they are not focused on the comparison of regulations in different countries. Paper [69] named Unmanned Aircraft Systems Traffic Management: A comparison of the FAA UTM and the European CORUS ConOps based on U-space compares the general approach to UTM of two countries. Paper [68] about Unmanned Aircraft System traffic management: Concept of operation and system architecture describes how sUAS pilots would use a typical UTM system, who has authority over UTM, and determine what physical architecture is required in a UTM system that handles a large variety of sUAS. There can also be found more technical papers, e.g. [67] focused on Modelling and Simulation of Collaborative Surveillance for Unmanned Traffic Management covering general statistical simulation model covering message encoding, network capacity and access, sensors coverage and distribution, message transmission and decoding. Or an article [66] about Sensors and Communication Simulation for Unmanned Traffic Management proposes an agent-based simulation platform, implemented through a microservice architecture, which may simulate UTM information sources, such as flight plans, telemetry messages, or tracks from a surveillance network. There are also safety concerns described in paper [65] on NASA Technical Reports Server about operations such as general aviation, helicopters, and gliders that must be safely accommodated with UAS at lower altitudes. However, key infrastructure to enable and safely manage widespread use of low-altitude airspace and UAS operations therein does not exist. Therefore, NASA is exploring functional design, concept and technology development, and a prototype UAS Traffic Management (UTM) system.

1.2 UTM concepts in the world

Experience of States in the Asia/Pacific Region shows that traditional administrative tactics for registration of aircraft, pilot licensing, etc., as usually used by way of State aviation regulators, are not ample to control the variety of UA registrations that have to be processed or effectively interact the UAS community [13]. Delayed or complex registration processes may also contribute to full-size levels of non-compliance by using UA operators, in particular, recreational operators with little or no experience or information of aviation whose important goal is to really just buy and fly. Registration must consequently be done through a specific online, automated process and need to consist of the provision of educational material. Asia-Pacific (APAC) State ride additionally suggests that charging a nominal price for online registration, paid by using a valid deposit card, facilitates the validation of UA operator identification [14]. Noting that the majority of States do now not yet have a UA registration system or procedure in place and the pace of evolution of the UA industry, ICAO is knowledgeable about the DRONE ENABLE/2 Symposium on the future improvement of the Aircraft Registration Network, through which States might also be capable of managing their UA registrations [15]. For UA operations in airspace, such as managed airspace or in the neighborhood of aerodromes and any related instrument flight procedures, standards may also be established to decide whether or not an operation should be both excluded or require specific authorization from a neighborhood ATC facility or different applicable authority.

1.2.1. UTM concept in FAA

According to FAA, the design of UTM was intended to ensure that the expectations and the demand for a wide range of operators are met, considering the increased risk and complexity. UTM comprises all policies, infrastructure, procedures, personnel, and services that are necessary for supporting low-altitude UAS operations [16]. UTM needs the creation of regulatory frameworks, information architecture, and data exchange to provide shared situational awareness among members and the development of performance requirements and new operating rules that collaborate with the operational demands. UTM operators are accountable for meeting established requirements for the operation type and the associated airspace route that they are operating and conforming with the FAA rules [17].

The FAA makes sure that UTM is consistent with its goals and meets the requirements for efficient and safe operations, especially because FAA is the federal authority over operations in all airspace and also because FAA regulates and oversees commercial operations. A UAS regulatory and traffic management framework is being developed by FAA to establish UTM.

The infrastructure of the developed UTM will advance to ensure that using a mature UTM ecosystem can support the planned commercial operations [18]. For example, LAANC supports the recreation operations under 49 USC 44809, Subpart C, and commercial operations requirements under 14 CFR Part 107, and it is considered an original UTM competence [18]. Secondly, an authorized and access philosophy is being adopted by FAA to ensure that UTM meets the major demands of the industry. The operational use of UTM competence can be event-based, and it can be controlled by the changes in the nature of the allowed operations, density concerns, or other diverse external factors. Thirdly, the UTM technology is being evolved in a time-based manner by the FAA with a development plan which offers tested products that meet the FAA demands and also the demands of the community. This evolution is also intended to provide awareness and prospects in the industry as it matures. Considering these factors, the FAA has high expectations that the industry will advance standards and grasp opportunities necessary for the innovation and development of solutions that will be useful in managing the enhancing numbers of UAS operations in the present day and in the future.

From the operation limitations point of view, the remote pilot should fly the private drone below 120 meters (400 feet) and within a visual line of sight. The private drone should maintain a distance of 5 miles (8,047 meters) from the airport. The private drone should keep a distance from crowds, public events, stadiums, and emergency operations. Also, the remote pilot can not fly in Washington and New York City without permission. Private drones are at least 5.5 kilometers away from controlled airports.

1.2.2. UTM concept in China

The regulations for integrating UA in a country's airspace are often based on the distance specification from the ground, buildings, persons, airports, and airstrips which are mentioned in the Civil Aviation Administration of China (CAAC) CCAR-92 [19]. This will be used in defining the place in which UA can or cannot operate, in allowing a degree of segregation between regular aviation and UA, defining the people that are no longer related to the required operation, and defining the constructions and infrastructure involved [19]. This research, to be specific, is concerned with the values for the heights, distances, velocity, and weight of UA as drawn from the recent counsel for UA operations in the Asian region. The integration of UAS services in China has resulted in specifications including distance from the ground and height, buildings, aerodromes, and persons, in turn creating a platform for better operations. The knowledge of the differences, however, has resulted in some degree of segregation between the regulations for the UAS and those of the manned aircraft, which have enhanced the management of people, operations, and infrastructural needs. Regulatory considerations have included suggestions of UAS in terms of weight and velocity to control operations as those embraced in Asia/Pacific regions [20].

From the operation limitations point of view, the private drone shall be flown below 120 meters (400 feet) and within visual line of sight, while some states are able to fly 200ft above the ground. The remote pilot of the drone can fly up to 500 meters away from his location. Beijing is in a no-fly zone. The restrictions have brought issues in the standardization of regulations, although the authorities have to consider some elements. Drones are not allowed to fly on the 6th Ring Road. Before starting your drone, try to find out about temporary drone bans, for example, during celebrations or important events [21].

1.2.3. UTM concept in Australia

In Australia, it was revealed that UAS operations had been deployed based on the international and national factors as featured in CAS Part 101. Australia relies on the Civil Aviation and Safety Authority (CASA) with a focus on the control and establishment of a regulatory framework. However, efforts by CASA have focused on the deployment of a regulatory framework that supports the training of the personnel in addition to providing support for better judgment when flying drones [22]. The increase in activities around air traffic has enhanced management contributing to CASA approvals, law enforcement elements, commercial improvements, and security. CASA has also set a focus on developing material guidelines that enhance standardization as enforced in other countries. The extent of the operations has, however, played a key role in making this possible with the definition of standards focused on maintaining operations within the defined scope.

From the operation limitations point of view, the remote pilot flying below 120 meters (400 feet) and within a visual line of sight is necessary. Private drones shall fly at least 5.5 kilometers away from controlled airports, and the remote pilot should make sure don’t endanger manned aircraft when flying near uncontrolled airfields and heliports. Private drones should keep at least 30 meters away from other people and respect their privacy. Private drones flying over people and populous areas such as beaches, busy parks, or sports facilities are not allowed. The remote pilot should keep away from emergency operations, such as accidents or fires. The remote pilot should keep a safety distance of 300 meters from marine mammals such as whales and dolphins, also from birds of prey. Several popular attractions, such as Sydney Harbor Bridge, are “No Drone Zones” [23].

1.2.4. UTM concept by EU

The aviation sector in the EU has evolved to include UTM systems that have yielded structural improvements considered vital for positive outcomes. A Single European Sky Air Traffic Management Research Program (SESAR) has been initiated in the European Union to facilitate further structural improvements in air traffic [24]. In the same manner, embedded in Europe´s Research and Innovation Programme Horizon 2020, the SESAR project CORUS has published a U-space Concept of Operations (ConOps) characterizing the phased implementation of procedures and services to support safe, efficient, and secure operations of UAS in very low level (VLL) airspace applicable for the European Union [24]. Technical projects have been launched in regards to SESAR to ensure positive improvements in the field to generate a reliable traffic management system. The improvements in the air traffic management system have contributed to enhanced safety since monitoring of drones ensures safety measures are followed in operations. Transport markets have also emerged to reduce the level of controls in place and restrictions instituted on frequent drone routes within identified economic areas [25].

From the operation limitations point of view, the remote pilot shall fly the drone below 120 meters (400 feet) and within a visual line of sight. The remote pilot flying a drone in the vicinity of airports needs a permit for the Specific Category from the state aviation authority. This regulation applies at a lateral distance of one kilometer from the outer boundary of the airport and the centerline of the runway, and in such conditions, the private drone is controlled by the tower [26].

1.2.5. UTM concept in Brazil

In Brazil, the ICA 100-40 has established the guide leading to effective handling of UAS in the country [27]. The regulations have established better safety guidelines for remotely piloted aircraft (RPA) in Brazil, with technical and operational outcomes that have set the ground for managing manned and unmanned aircraft (UA) in the country. However, the effective integration of the above laws in the airspace activities has yielded from the educational demand associated with them. The education demand, which requires that operators are trained, has helped in the prevention of violations and strengthening of the safety awareness aspects key in air traffic management. Also, the regulation of activities associated with remotely piloted aircraft systems (RPAS) is easily implemented following the standards set by the Brazilian authorities. The controls instituted by ICA 100-40 have also yielded controls of access by UAS from other countries. Research by Fotouhi et al. [27] reveals that access to the Brazilian airspace occurs with authorization by the Department of Airspace Control (DECEA) regional unit carrying the responsibility of the area in which the flight will occur [27]. Such strict measures have ensured control of air traffic in the region, also equipping the regulatory authority with a supportive framework that yields positive outcomes in terms of safety. Some special occasions, however occur with the Special Use Airspace approvals also discussed under ICA 100-40 based on the technologies involved and definition of coordinates and volume [28].

From the operation limitations point of view, remote pilots are only allowed to fly their drone below 120 meters (400 feet) and within a visual line of sight. The remote pilot should keep a distance of 30 meters from bystanders unless they have given their consent. The remote pilot must not fly over crowds or critical infrastructure (e.g., power plants, prisons, military facilities). The remote pilot must be 30 meters away from buildings, again, except for the owner's consent. Also, keep away from security areas. For flights up to 30 meters, the remote pilot should keep a distance of 5.4 kilometers from airports. Between 30 and 120 meters, the distance should be 9 kilometers [29].

1.2.6. UTM concept in South Africa

South Africa is another country of comparison that has instituted significant controls on UAS. The country adopted Part 101 of the regulatory framework anticipating the expansion of the UAS operations due to civilian involvement [30]. The initiation has also become a key component in improvements in air traffic management targeted in other countries. However, the absence of reliable laws and standards has complicated this improvement in addition to little experience in operations of civil matters in South Africa [31]. The country has also struggled with risk management with poor mitigation approaches, further raising concerns about air traffic controls and the entire industry. Industry and Civil Aviation Safety Authority (CASA) workers have been tasked with performing risk assessments despite these not being adequately trained, further complicating the management efforts of the aviation sector in South Africa [32]. The regulations established have provided CASA with the basis for control while also establishing high-risk areas, including the inconsistencies in responses. CASA has resorted to considering each RPA request separately as part of addressing possible security and safety risks arising. The rising levels of activity by CASAhaves also become a factor to consider as this has mainly been in areas of permits for charitable, security, commercial activities, and law enforcement [33].

Private drones can not ascend higher than the highest obstacle within 300 meters. For private drone flights, your drone must not be farther than 500 meters away from the remote pilot. At airports, a distance of 10 kilometers must be observed. The remote pilot must keep at least 50 meters between the drone and crowds or public roads. The same applies to private land unless the remote pilot has permission from the owner [34].

1.3 Limitations of the Current State

UTM implementation has been adopted in different countries in the world, including the United States, the European Union, South Africa, Australia, China, and Brazil (European Union, with its harmonized regulation, is considered for this thesis as one country). However, the approach to implementation of UTM differs across these countries. One of the challenges is the fact that drone operations cannot expand across countries considering the differences in the certification of operators and registration of drones [38]. Secondly, another critical area is the evolving regulation in the area of VLOS operations, considering that there are countries that have implemented the use of BVLOS operations. In this area, the critical aspect is to consider the extent to which drones in different countries can be operated within VLOS and BVLOS. There are also differences in the aspect of societal worries about their privacy and safety from accidents caused by drones [38]. Therefore, this poses a barrier to the flying of drones in populated areas, which is a key aspect of safety distances and privacy and consent, which vary in different countries. In consideration of the limitations listed above, this research will compare the differences in UTM implementation in the United States, the European Union, South Africa, Australia, China, and Brazil from the perspective of six key areas, which include drone registration and operator accreditation, weight and safety distances, privacy and consent, VLOS/BVLOS, flying time, and the number of drones to be flown at a time. After the comparison, the researcher will propose the best UTM.

2. Methodology

The primary objective of the research is to assess the integration of UTM services into the current air traffic management structure in different states in the world, in addition to identifying the best practices. The traffic management and services are in this thesis used in the widest sense as the overall management of flying in the air, including the rules and services for the people involved. This section describes the methodology, including the ideal approaches to achieve the objective of the thesis through the comparison of different countries. The methodology section features the approach for comparison and the defined steps of comparison.

Approach for Comparison

The key to research handling is the approach selected by the researcher. In this study, the researcher chose to use the comparative research approach. A comparative approach is used by researchers to compare theoretical cases to each other to assess covariation. This is especially used in social research to compare the orientation or perspective of qualitative work. The researcher chose to use the comparative approach since he was dealing with qualitative work, which would lead to understanding different concepts about UTM in the aviation industry. By using a comparative approach, the researcher analyzes the qualitative work, puts the diverse works together, and finds the areas of similarity and differentiation [38]. With the comparative approach, a researcher can describe and explain the differences and similarities of diverse situations.

2.2 Defined Steps of methodology

The research relied on secondary data collection to meet the research objectives. The secondary data collection method featured already existing content with journals and other secondary materials used for examining the various UTM regulations based in different countries. The researcher embraced the following steps in comparison:

- The first step was case selection (countries to be compared). In a comparative research approach, case selection is a significant stage. Case selection aids the researcher in ensuring they cover areas that are specific to the objectives of their work helping the researcher to avoid taking for granted important aspects that will eventually impact the results of their work. A comparative researcher approach requires at least two or more items [38]. In this study, the researcher incorporated the countries as mentioned in chapter two that were significant in achieving the objective of the study appropriately aiding them to identify the key differences based on the UTM concept in the United States, China, Australia, Brazil, the EU, and South Africa. in the UTM integration in different countries hence identifying the best key area and the best UTM overall.

- The second step was the description and identification of the key areas of comparison. After case selection, the researcher has to evaluate the discursive contexts of the items to be compared. According to Miri [38], comparative items must be theoretical constructs and empirical units which can be identified as having differences or similarities in a wide range. In this research, the key areas were compared.
- The third step of comparison was juxtaposing the items to be compared. According to Miri [38], a researcher should employ a similar weight between the differences and similarities of the items to be compared. This can be done by ensuring a careful and balanced approach as this will ensure that emphasis lies in the researcher analyzing the differences and similarities based on the objective of their study. In this study, the researcher considered the six countries since they all have integrated UTM into the aviation industry. This identifies them as similar in this manner. However, the researcher went further to identify the different aspects considered by these countries by first acknowledging that they are different considering the landscape, and then secondly by identifying the different perspectives they have taken integrating UTM concepts in their aviation industry.
- Step four was to use the Analytic hierarchy process to calculate each key area and score each country. Criteria selected were: Drone registration and operator accreditation, weight and safety distances, privacy and consent, VLOS, flying time, and number of drones at a time. And the alternatives were: the United States, European Union, Australia, China, South Africa, Brazil
- Step five was to identify the best UTM overall. After identifying the differences and similarities between the countries selected in chapter two, and the features of comparison, the researcher went ahead to establish the best UTM overall. This is done by first identifying the country with the highest number of points after comparison, hence establishing it as the best UTM overall.
- Step six was focused on proposing the best UTM for the world. This is done based on Key areas comparison when the best key areas will be selected and, after analysis of their compatibility, marked as usable for the proposal of the best UTM for the world.

- Step seven was indicating the findings and analysis of the results. In this study, after identifying the key countries of comparison, which are the United States, Brazil, China, South Africa, Australia, and the EU, and the areas to be compared, the researcher went ahead to indicate the findings of the comparison in chapter four and to discuss the results in chapter five.

3. Results and Findings

This chapter is focused on evaluating the differences and similarities between six countries mentioned in chapter two, including the United States, Australia, Brazil, China, the EU, and South Africa. The researcher identifies these differences and similarities based on the aspects of operator licensing, drone registration, weight and safety distances, privacy, and VLOS/BVLOS regulations and how these features ensure that there is safety in flying drones in these countries. This comparison is made based on the methodology introduced in chapter three.

Key areas of comparison

This section of the research is used to discuss the six key areas that were used to compare and contrast the implementation of UTM in the key countries mentioned in chapter two.

3.1.1. Drone registration and operator accreditation

In Brazil, the National Civil Aviation Authority (ANAC) demands that drones weighing more than 250 grams be registered. The requirement in Brazil is that drones beyond 25 kg should be checked for airworthiness by ANAC to enhance safety which should be registered through an unmanned aircraft system (SISANT), and operators should have a valid proof of remote pilot license [40]. Therefore, airworthiness and a valid certificate of operation are deemed necessary. Similarly, China also requires that all drones weighing 250 grams be registered with the Civil Aviation Administration of China (CAAC). Commercial operations normally demand licensing. Besides a commercial drone license, the drone operator should be trained. However, this process involves the use of the Chinese language, which limits access to foreigners. Moreover, a legal business entity is deemed crucial for new operators in China who should be connected with individuals that have used drones before.

In the United States, the FAA's process of drone registration and operator licensing is accomplished under Part 107, which demands registration to be undertaken every three years [41]. The process entails operators creating their drone accounts and user inventory for those with remote pilot certificates. Based on its agency, European Union requires that drones be registered based on the National Aviation Authority rules of the nation they intend to fly. In South Africa, on the other hand, the registration is done through a website. If drones are used for commercial purposes, the operators should have proficiency in the English language, and their medical assessment should denote good health [42]. The drone license for commercial drones is acquired through academies in South Africa, and the licenses are usually subject to renewal every two years.

The countries stated above are different from Australia, and they limit the commercial operation of drones. In Australia, the registration and accreditation process of drones demands that drones are registered differently and operators' qualifications assessed separately. Brazil and China do not offer verification of operators' qualifications for the entertainment dromes separately, and this qualifies as an accreditation failure that threatens the safety of the whole sector. However, Australia is unique given that commercial pilots are expected to have RPA operator accreditation, which involves pursuing an official course and getting tested for competence to operate a drone that enhances safety [43]. There is also an application in Australia whose name is RPAS. It can search all of the restricted areas, and it helps the pilots not to fly into the dangerous area by accident. Aside from China and Brazil, the European Union also has a flexible drone registration and operation system considering the three categories of operation, which include the open, specific, and certified categories. The open category, which is considered for lower-risk drone operations, allows for drones and operators to fly without registration and certification, respectively. The specific category is for riskier drone operations; only the operator is certified, but the drone is not registered; and thirdly, the certified category for considerably high-risk drone operations is the only one that incorporates the registration of the drone and the certification of the operator [44]. The United States also has a website where operators enter their details and register themselves for accountability once they prove they have a license. Despite being commendable, the registration of the process in the US is limited as the competence of operators is not tested. South Africa also has strict laws on drone registration and operator requirements, but it never proactively regulates commercial use of drones, as verification of operators is the duty of academics. In Australia, the registration of drones used for commercial purposes is done through a registry at the myCASA portal, and all commercial drones are kept in the registry. This myCASA portal is where you can an individual obtain an aviation reference number. The qualification also involves doing drone activities for a business or an employer. The regulation is key as it helps generate income for the government due to license fees paid and improves safety by planning effectively for low-level airspace commercial activities on the part of the government. For instance, a registration levy of about 40 dollars per drone applies for those weighing beyond 500g, which is mandatory but can be refunded in exceptional circumstances through an application. This policy helps in increasing accountability, hence making Australia the best in drone registration and operator accreditation.

3.1.2. Weight of drones and safety distances

The second very important aspect that this research focused on was the laws and regulations about the weight of the drones and safety distances in various countries. In Brazil, certification is required for drones that weigh 150 kilograms and above. These drones are required to be registered in the Brazilian Aeronautical Registry, and the pilots flying them should have the operator's and drone license [45]. On the other hand, drones that weigh from 250 grams to 25 kilograms are only registered if they operate above 120 meters above ground level. Otherwise, there are no requirements in Brazil's regulation for drones weighing from 250 grams to 25 kilograms. In China, drones weighing 250 grams and more must be registered with CAAC, whether for commercial or recreational purposes. Similarly, in China, all drones are only allowed to fly up to 120 meters above the ground [46]. In the European Union, on the other hand, there is no clear distinction between recreational and commercial drones. Therefore, regulations on the weight of drones are quite flexible. This is because there are no strict regulations on the training of operators flying drones that weigh below 250 grams, while for drones weighing 250 grams and more, the operators must be trained. Drones weighing from 250 grams and beyond have trained operators because trained operators are essential to ensure safety is maintained. In South Africa, drones that weigh more than 7 kilograms are not allowed to be flown unless approved by the South African Civil Aviation Authority (SACAA) to ensure safety, considering that the more the weight of the drone, the higher the risk of safety for people [47]. No unmanned aircraft (UA) should be flown near manned aircraft, 10 kilometers or closer to an airport, airfield, or helipad. Similarly, no RPAs should be flown 50 meters or closer to a person or a group of people, a public road, or a private property. In the United States, all drones require registration except drones that weigh 250 grams or less. These drones are not registered because they are exclusively for recreational purposes. However, drones that are registered under part 107 can be flown for both recreational and commercial purposes. Drones that weigh more than 250 grams must be registered in Australia. The drones are only allowed to fly 120 meters above ground level to ensure safety in uncontrolled airspace. The drones should keep 30 meters away from people and 5.5 kilometers away from controlled airports, which have control towers for the safety of the manned aircraft. While countries like Australia emphasize registration for commercial drones weighing 250 grams and beyond, China emphasizes that whether for commercial or recreational purposes, all drones weighing more than 250 grams must be registered. Although the weight of drones is similar across the world, there is a brand of drones in China called DJI. It has a very detailed production of the division of the weight of the drone. In many countries, drones exceeding 250g need to be registered and tested for driver's licenses. China's DJI is working on many 249g drones, which greatly meet the needs of consumers and can occupy a favorable market. And DJI is trying to add a chip to the drone which can have a collision avoidance system like ACAS (Airborne Collision Avoidance System) and also can warn the pilot about non-fly zone detection. After installing this chip, if you want to fly to a restricted area or destroy the drone when flying, the drone itself will stop the pilot from doing that, which greatly increases the reliability of the safe distance. For this reason, China is the best in implementing weight and safety distances regulation.

3.1.3. Privacy and consent

The third aspect of consideration was privacy. In Australia, drones are restricted from recording or photographing people without their permission. This is necessary to ensure that the drones do not breach the privacy of individuals. In South Africa, on the other hand, it is required that drones keep at least 50 meters away from private land unless the operators have permission to fly their drones above private lands [48]. This ensures that privacy is maintained. In the EU, drones are ensured to maintain privacy by requesting permission to photograph or record private property and people. This regulation is strictly followed since, in the EU, privacy is regarded as a human right that every individual should enjoy, and therefore, it should be protected from any kind of intrusion, whether from the government or not. This is different from the United States, which considers that privacy should only be protected from government intrusion. Therefore, in the EU, every drone operator must comply with the privacy criteria outlined by the General Data Protection Regulation (GDPR), which requires that the privacy of every individual is protected. In Brazil, except in cases of civil defense operations or public security, drones are only allowed to record or photograph people and property with consent. In the United States, some areas, such as Florida, have passed laws that regulate the flying of drones over private property. However, no federal laws are available according to FAA regulating flying drones over the private property since the FAA is only responsible for regulating airspace in which drones cannot fly above 400 ft (120 meters) [49]. In China, there are no-fly zone rules that all operators must abide by. These rules indicate that airports, military installations, and sensitive areas such as Beijing are off bounds unless the operator seeks consent from CAAC. These rules of privacy across various countries are necessary to ensure that there is the protection of private data hence safety. Even though other countries have enforced the privacy and consent regulation, the EU comes out as the best considering their measure to ensure that individual privacy is protected from every kind of intrusion, whether from the government or not.

The EU was proposed to have the best UTM based on the regulation of privacy and consent. While many other countries compared have enforced this regulation, the EU has proved to be the best considering the fact that in the EU, privacy is regarded as a very important aspect that, as a human right, should be protected from any intrusion from the government and any other individual. Therefore, in this regard, the EU has ensured that every drone operator complies with the privacy criteria as outlined by GDPR, which requires that consent should be asked from individuals to either record or photograph them [60]. This has helped the EU in enhancing safety, especially since the protection of personal information is secure.

3.1.4. Visual line-of-sight

Many countries have regulations to use VLOS flights. However, using VLOS limits operators to see only a limited maximum distance. In this area, however, the researcher proposed South Africa to have the best UTM with regard to this key area. This is because, even though the EU and the United States have also implemented the use of BVLOS, South Africa has ensured that for safety, recreational drones are used within RVLOS, while commercial drones are used within BVLOS [61]. RVLOS ensure that the drone operators maintain unaided visual contact while BVLOS ensures that commercial drone operators can effectively apply the vertical take-off and land. This is unique for South Africa since BVLOS must be approved by SACAA and for approval to be made, only two crew members are allowed to fly the commercial drones, and the commercial drones must utilize the Iris Automation Casie onboard detect-and-avoid system which is essential in ensuring that the operators can efficiently make automated maneuvers during the flying of the commercial drones, hence avoiding collision with other drones [61]. This policy has already been implemented in commercial drones such as the United Drone Holding (UDH), and has allowed UDH to cover wide areas hence providing greater productivity and better economic value by ensuring that the drones fly efficiently since they can be tracked even if they are out of visual line-of-sight. On the same note, since South Africa has ensured that drone operations are conducted in VMC below 400ft above ground level and operators must have ROC, South Africa has emerged to have the best UTM, in this regard.

The fourth aspect of comparison is the visual line-of-sight aspect. In Australia, all operators are required to always keep their drones within the visual line-of-sight (VLOS). This implies that the drones should always be seen by the operators with their own eyes rather than using a screen or a device to see. This ensures the safety of people and property since the operator's eyes will be keen on the drones as they fly. This also happens in China since drones are required to have a VLOS for safety. In Brazil, the rules are also followed to the latter, and all drone pilots are required to maintain a VLOS with their drones at all times. In South Africa, drones flying for recreational purposes are required to fly within a restricted visual line-of-sight (RVLOS) in which an operator maintains unaided visual contact with the RPA at all times to manage its flight and avoid collision [50]. However, South Africa has approved BVLOS for commercial flights such as the United Drone Holding (UDH). However, this applies to vertical take-off and landing aircraft (VTOL). This is the case in the EU, in which there is a new predefined risk assessment (PDRA) devoted to BVLOS operations for direct inspections of infrastructure, for example, rail tracks and power lines [51]. In the United States, on the other hand, the FAA regulations indicate that an operator must keep their drone in VLOS at all times, with the exception of drones flown for recreational purposes. Commercial drones wanting to fly BVLOS can apply for a part 107 waiver. While other countries such as Australia and Brazil have implemented VLOS and others such as the United States and the EU have implemented BVLOS, South Africa is unique in enforcing this policy as the country has adopted RVLOS for recreational drones and BVLOS for commercial drones with approval from SACAA which demands that BVLOS flights must only be operated with two crew members. Permission to operate commercial drones in BVLOS is granted on the basis of the utilization of the Iris Automation Casia onboard detect-and-avoid system, which helps operators to make automated maneuvers while operating the drone, hence avoiding a collision. South Africa is also unique since BVLOS operations are only approved to be conducted in Visual Meteorological Conditions (VMC) below 400ft above ground level, and the operators must have a Remote Air Operator Certificate (ROC).

3.1.5. Flying time

In Australia, drones are not allowed to fly at night. Flying drones at night will pose a threat to safety, considering the fact that there is not enough light at night. Therefore, in Australia, drones are only allowed to fly during the day for optimal lighting that will enable the operators to keep the drones in sight. China, on the other hand, has regulations for drones not flying in controlled areas unless approval from CAAC and the regulation restricting the use of BVLOS. However, the country does not cover the aspect of flying time, whether night or daytime, for drones. This poses a threat to safety since operators can fly the drones even during the night in limited lighting. In Brazil, drones are not allowed to fly at night time. However, if the operator needs to fly the drone at night, then he or she must acquire a letter of authorization from the National Civil Aviation Agency [52], for operator to acquire approval, documents that show proof of drone insurance, remote pilot license, drone serial number, the operator's contact information, and the flight plan and risk assessment. These are measures used to ensure safety and accountability. However, in the EU, EASA has not enforced this regulation, and therefore, not much is considered based on the time drones should be flown in the EU. In the United States, on the other hand, flying drones at night are allowed. However, the operators need to have anti-collision lights on their drone, and they will be tested for an understanding of the unique challenges that flying their drone at night presents. This regulation is also observed in South Africa, where drones are only allowed to fly during daylight hours. Brazil proves to be the best in this regulation since the country has enforced measures that operators should acquire a letter of authorization and their documents need to be approved for them to fly their drones at night.

Identifying and having regulations for the appropriate time to fly a drone is significant to ensure that people and property are safe. This regulation has been enforced in various countries, with many of them enforcing that all drones should only be flown during the day, for example, in Australia. However, in Brazil, this regulation is flexible enough to accommodate flying drones at night hence identifying Brazil to have the best UTM with respect to this key area. This regulation is considered the best for Brazil because, in Brazil, even though drones are not allowed to fly at night, any operator who needs to fly at night can do so but with strict measures. The measures include ensuring that the operator acquires a letter of authorization from the National Civil Aviation Agency, which will require them to provide safety and accountability documents that show proof of remote pilot license, drone insurance, drone serial number, operator’s contact information, flight plan and risk assessment [62]. These documents are necessary to ensure that safety is guaranteed and the operator will be accountable.

3.1.6. Number of drones at a time

In Brazil, drone operators are not allowed to fly more than one drone at the same time. In South Africa, this regulation has been largely ignored. However, in the United States, only one drone can be flown by an operator. To ensure that there is safety for people and property, the United States allows one pilot or operator to be a visual operator for only one drone at a time. The major reason behind the prohibition of flying more than one drone at a time by the same operator is to avoid the overlapping of communication signals, especially if the drones are not designed to communicate with each other using a system powered by a strong WI-FI system [53]. This regulation is greatly observed in China, where one operator flies only one drone at a time. Australia also maintains that one pilot or operator should be a visual operator for only one drone at a time to avoid collision and to keep the drone in sight at all times [54]. This regulation has, however, not been enforced in the EU. Even though this regulation has been enforced in all the six countries discussed above, the United States is the best because it has provided a number of safety protocols which include making sure that if an operator flies more than one drone at the same time, he must acquire permission from FAA to fly more than one drone at a time, and the restriction to fly more than one drone is only waivable if the operator proves that the simultaneous operation of more than one drone can safely be undertaken under the terms of a certificate of a waiver since according to FAA, no technology has yet established the required level of reliability through civil aviation airworthiness certification. Therefore, the operator should prove that all the drones are within VLOS for them to receive the waiver.

The United States was proposed to be the best based on the fact that the country has ensured that drones avoid overlapping communication signals, especially if the drones are not powered by a strong WI-FI system with which they communicate with each other. If drones are powered by a strong WI-FI system, then they are required to be flown by licensed operators, and the drones must have a visible registration number since the drones must be registered [63]. This way, the operators can acquire permission to fly more than one drone at a time. Another safety protocol that enhances safety is that drones if more than one is flown, must not be flown over or close to many people. Therefore, this ensures safety since the operators and their drones must go through a stringent process for authorization.

3.2 Best UTM key areas

In table 3.1, the best key areas are shown in the countries of comparison based on the comparison done in chapter 3.1.

Table 3.1: Best UTM key areas

	Drone registration and operator accreditation	Weight of drones and safety distances	Visual line-of-sight	Privacy and consent	Flying time	Number of drones at a time
USA						✓
EU				✓		
AUS	✓					
CHN		✓				
SA			✓			
BRZ					✓	

3.3 Best UTM overall

In table 3.2, the score of each country was determined by comparing how the key areas were integrated into the aviation rules in each country. This helped the researcher to identify the best key areas. The researcher utilized the analytical hierarchy process to determine the score of each country.

3.3.1. Drones registration and operator accreditation

Table 3.2: Pairwise comparison matrix for drones registration:

Drones registration and operator accreditation	USA	EU	AUS	CHN	SA	BRZ
USA	1	0.333	0.111	0.167	0.143	0.2
EU	3	1	0.111	0.167	0.143	0.2
AUS	9	9	1	9	9	9
CHN	6	6	0.111	1	7	6
SA	7	7	0.111	0.143	1	7
BRZ	5	5	0.111	0.167	0.143	1
Sum	31	28.333	1.555	10.644	17.429	23.4

Table 3.3: Normalized pairwise comparison matrix for drones registration:

Drones registration and operator accreditation	USA	EU	AUS	CHN	SA	BRZ	Criteri on weight	Averag e weight
USA	0.032	0.012	0.071	0.016	0.008	0.009	0.148	0.025
EU	0.097	0.035	0.071	0.016	0.008	0.009	0.236	0.039
AUS	0.29	0.318	0.643	0.846	0.516	0.385	2.998	0.5
CHN	0.194	0.212	0.071	0.094	0.402	0.256	1.229	0.205
SA	0.226	0.247	0.071	0.013	0.057	0.299	0.913	0.152
BRZ	0.161	0.176	0.071	0.016	0.008	0.043	0.475	0.079

3.3.2. Weight of drones and safety distances

Table 3.4: Pairwise comparison matrix for weight of drones:

Weight of drones and safety distances	USA	EU	AUS	CHN	SA	BRZ	Criterion weight	Average weight
USA	1	3	0.143	0.111	0.143	0.2	0.148	0.025
EU	0.333	1	0.143	0.111	0.2	0.2	0.236	0.039
AUS	7	7	1	0.125	7	7	2.998	0.5
CHN	9	9	8	1	9	9	1.229	0.205
SA	7	5	0.143	0.111	1	6	0.913	0.152
BRZ	5	5	0.143	0.111	0.167	1	0.475	0.079

Table 3.5: Normalized pairwise comparison matrix for weight of drones:

Weight of drones and safety distances	USA	EU	AUS	CHN	SA	BRZ	Criterion weight	Average weight
USA	0.034	0.1	0.015	0.071	0.008	0.009	0.237	0.0395
EU	0.011	0.333	0.015	0.071	0.011	0.009	0.45	0.075
AUS	0.239	0.233	0.104	0.079	0.399	0.299	1.353	0.226
CHN	0.307	0.3	0.836	0.637	0.514	0.385	2.979	0.496
SA	0.239	0.167	0.015	0.071	0.057	0.256	0.805	0.134
BRZ	0.17	0.167	0.015	0.071	0.01	0.043	0.476	0.079

3.3.3. Privacy and consent

Table 3.6: Pairwise comparison matrix for privacy:

Privacy and consent	USA	EU	AUS	CHN	SA	BRZ
USA	1	0.111	0.125	0.143	0.2	0.25
EU	9	1	8	8	9	9
AUS	8	0.125	1	6	7	6
CHN	7	0.125	0.167	1	7	5
SA	5	0.111	0.143	0.143	1	6
BRZ	4	0.111	0.167	0.2	0.167	1

Table 3.7: Normalized pairwise comparison matrix for privacy:

Privacy and consent	USA	EU	AUS	CHN	SA	BRZ	Criterion weight	Average weight
USA	0.029	0.07	0.013	0.009	0.008	0.009	0.138	0.023
EU	0.265	0.632	0.833	0.517	0.369	0.38	2.996	0.499
AUS	0.235	0.079	0.104	0.387	0.287	0.22	1.312	0.218
CHN	0.206	0.079	0.017	0.065	0.287	0.183	0.837	0.139
SA	0.147	0.07	0.015	0.009	0.041	0.22	0.502	0.083
BRZ	0.118	0.07	0.017	0.013	0.007	0.037	0.262	0.043

3.3.4. Visual line-of-sight

Table 3.8: Pairwise comparison matrix for visual line of sight

Visual line-of-sight	USA	EU	AUS	CHN	SA	BRZ
USA	1	7	5	5	0.111	5
EU	0.143	1	3	5	0.111	6
AUS	0.2	0.333	1	5	0.125	5
CHN	0.2	0.2	0.2	1	0.143	5
SA	9	9	8	7	1	7
BRZ	0.2	0.167	0.2	0.2	0.143	1
Sum	10.743	17.7	17.4	23.2	1.633	29

Table 3.9: Normalized pairwise comparison matrix for visual line of sight:

Visual line-of-sight	USA	EU	AUS	CHN	SA	BRZ	Criterion weight	Averag e weight
USA	0.093	0.395	0.287	0.216	0.068	0.172	0.944	0.157
EU	0.013	0.056	0.172	0.216	0.068	0.207	0.732	0.122
AUS	0.019	0.019	0.057	0.216	0.077	0.172	0.56	0.093
CHN	0.019	0.011	0.011	0.043	0.088	0.172	0.344	0.057
SA	0.838	0.508	0.459	0.302	0.612	0.241	2.96	0.493
BRZ	0.019	0.009	0.011	0.009	0.088	0.034	0.17	0.028

3.3.5. Flying time

Table 3.10: Pairwise comparison matrix for flying time:

Flying time	USA	EU	AUS	CHN	SA	BRZ
USA	1	7	0.143	6	5	0.125
EU	0.143	1	0.167	0.333	0.2	0.125
AUS	7	6	1	6	5	0.125
CHN	0.167	3	0.167	1	0.2	0.125
SA	0.2	5	0.2	5	1	0.125
BRZ	8	8	8	8	8	1
Sum	16.51	30	9.677	26.333	19.4	1.625

Table 3.11: Normalized pairwise comparison matrix for flying time:

Flying time	USA	EU	AUS	CHN	SA	BRZ	Criteri on weight	Averag e weight
USA	0.061	0.233	0.015	0.228	0.256	0.077	0.87	0.145
EU	0.009	0.333	0.017	0.001	0.01	0.077	0.447	0.075
AUS	0.423	0.2	0.103	0.228	0.256	0.077	1.287	0.215
CHN	0.01	0.1	0.017	0.038	0.01	0.077	0.252	0.042
SA	0.012	0.167	0.021	0.189	0.051	0.077	0.517	0.086
BRZ	0.485	0.267	0.827	0.304	0.412	0.615	2.494	0.417

3.3.6. Number of drones at a time

Table 3.12: Pairwise comparison matrix for number of drone at a time:

Number of drones at a time	USA	EU	AUS	CHN	SA	BRZ
USA	1	8	7	8	8	7
EU	0.125	1	7	5	3	5
AUS	0.143	0.143	1	7	7	6
CHN	0.125	0.2	0.143	1	5	4
SA	0.125	0.333	0.143	0.2	1	0.2
BRZ	0.143	0.2	0.167	0.25	5	1
Sum	2.661	9.876	15.453	21.45	29	23.2

Table 3.13: Normalized pairwise comparison matrix for number of drone at a time:

Number of drones at atime	USA	EU	AUS	CHN	SA	BRZ	Criterion weigh	Average weight
USA	0.376	0.81	0.453	0.373	0.276	0.302	2.59	0.432
EU	0.047	0.101	0.453	0.233	0.103	0.216	1.153	0.192
AUS	0.054	0.014	0.065	0.326	0.241	0.259	0.959	0.159
CHN	0.047	0.02	0.009	0.047	0.172	0.172	0.467	0.078
SA	0.047	0.034	0.009	0.009	0.034	0.009	0.142	0.024
BRZ	0.054	0.02	0.011	0.012	0.172	0.043	0.312	0.052

3.3.7. Criteria vs reaching the goal

Table 3.14: Pairwise comparison matrix for key area:

	Drone registration and operator accreditation	Weight and safety distances	Privacy and consent	VLOS	Flying time	Number of drones at a time
Drone registration and operator accreditation	1	9	9	9	9	9
Weight and safety distances	0.111	1	7	0.143	5	0.2
Privacy and consent	0.111	0.143	1	0.143	0.2	0.143
VLOS	0.111	7	7	1	5	5
Flying time	0.111	0.2	5	0.2	1	0.143
Number of drones at a time	0.111	5	7	0.2	7	1
Sum	1.555	22.343	36	10.686	27.2	15.486

Table 3.15: Normalized pairwise comparison matrix for key area:

	Drone registration and operator accreditation	Weight and safety distances	Privacy and consent	VLOS	Flying time	Number of drones at a time	Criterion weight	Average weight
Drone registration and operator accreditation	0.643	0.403	0.25	0.842	0.331	0.581	3.05	0.508
Weight and safety distances	0.071	0.045	0.194	0.013	0.184	0.013	0.52	0.086
Privacy and consent	0.071	0.006	0.028	0.013	0.007	0.009	0.134	0.188
VLOS	0.071	0.313	0.194	0.094	0.184	0.325	1.181	0.196
Flying time	0.071	0.009	0.139	0.019	0.037	0.009	0.284	0.047
Number of drones at a time	0.071	0.223	0.194	0.019	0.257	0.065	0.829	0.138

The score for each country was determined by multiplying the average weights of the criteria vs goal and the average weights of the criteria vs alternative. This helped in attaining the weight of each country, and the average weight.

Table 3.16: Total score and average weight

Goal	Drone registration and operator accreditation	Weight and safety distances	Privacy and consent	VLOS	Flying time	Number of drones at a time	weight	Average weight
USA	0.013	0.003	0.004	0.031	0.007	0.059	0.117	0.02
EU	0.019	0.006	0.094	0.024	0.004	0.026	0.173	0.029
AUS	0.254	0.019	0.041	0.018	0.01	0.022	0.364	0.061
CHN	0.104	0.043	0.026	0.011	0.002	0.011	0.197	0.033
SA	0.077	0.012	0.016	0.097	0.004	0.003	0.209	0.035
BRZ	0.04	0.007	0.008	0.005	0.02	0.007	0.087	0.015

Table 3.17: Ranking of the key area for each country

	Drone registration and operator accreditation	Weight and safety distances	Privacy and consent	VLOS	Flying time	Number of drones at a time
USA	6	6	6	2	3	1
EU	5	4	1	3	4	2
AUS	1	2	2	4	2	3
CHN	2	1	3	5	6	4
SA	3	3	4	1	4	6
BRZ	4	5	5	6	1	5

Australia has charted recommendable developments in various key areas, making it unique and ahead of other countries, but from the calculation (Table 3.17) can be seen that it needs to be enhanced in some areas. Such as visual line of sight. In addition to this, it is first, second and third place in other key areas. This was proposed because drone registration is an essential regulation that is necessary to enhance safety through minimizing accidents and ensuring accountability is attained since the operator's liability can be tracked [57]. The same can be stated about the accreditation of operators of drones which is intended to eliminate unskilled people by ensuring only professionals are viable to operate the drones hence enhancing safety. Compared to most countries, Australia has progressive laws concerning drone registration and accreditation of operators that increase the safety of the low-level airspace and minimizes costs due to accidents. This has been made possible by, first of all, making this regulation strict, considering that all drones, despite the size, must be registered if used for commercial purposes. Commercial purposes in Australia include activities like videos or photos taken and sold through a drone, inspection of construction sites, surveillance, and research and development [57].

3.4 Proposal of the best UTM

After the comparison in chapter 3.3, the researcher identified the best country based on the best key areas. The researcher proposed that Australia qualifies to have the best UTM with respect to the policy of licensing operators and drone registration which was identified as the best key area in Australia. The next goal was to find the best UTM regulations for the world to use, so the best countries in each key area were picked out, and their highest scores in each area added up to get a total score. Australia was considered the highest scoring country in previous calculations with a score of 0.364, but the world's best regulation scored a whopping 0.567, and the average score of Australia is 0.061, but the world average is 0.0945.

Table 3.18: Selection of the best key area to proposal best UTM

Proposal of the best UTM	Drone registration and operator accreditation	Weight and safety distances	Privacy and consent	VLOS	Flying time	Number of drones at a time	Overall score	Average score
	AUS	CHN	EU	SA	BRZ	USA	0.567	0.0945
	0.254	0.043	0.094	0.097	0.02	0.059		

In the proposed UTM for the world are used:

- Australia's regulations for drone registration, because it processes each drone by registration number, so it's straightforward to find out who's flying where and when.

Drones over 250g require mandatory instruction and a $20 registration fee to obtain a drone license.

- China's regulation in terms of drone weight and safe distance, put drones below 250g into the chip for recreational drones, which can control lawbreakers to enter the no-fly area and cause harm.
- EU's regulations when it comes to drone privacy, General Data Protection regulation (GDPR), which requires that the privacy of every individual is protected.
- VLOS from South Africa, drones flying for recreational purposes are required to fly within a restricted visual line-of-sight (RVLOS) in which an operator maintains unaided visual contact with the RPA at all times to manage its flight and avoid collision. This greatly increases the safety of drone flights.
- Brazil's regulation for flying time, even though drones are not allowed to fly at night, any operator who needs to fly at night can do so but with strict measures. If you want to fly at night the operator acquires a letter of authorization from the National Civil Aviation Agency which will require them to provide safety and accountability documents that show proof of remote pilot license.
- USA's regulation in terms of number of drones at a same time. Even if the law of each country is that one drone pilot only can drive one drone at the same time, but in the United States, if you pass the FAA review, not only fly one drone at a same time.

Used key areas are compatible, even when they are used in different countries, so this type of UTM can be used in countries around the world. If all countries in the world apply this proposed UTM, the operational benefits of drones will be greatly improved.

4. Discussion

The researcher identified Australia as the country that has the best UTM overall. In comparison to the six countries compared in 3.2, Australia was identified as the only nation that qualifies for effective execution of drone regulations framework designed to enhance safety. The first aspect considered was Australia's capacity to put proactive measures that are strictly followed by drone operators. A key consideration of this system at the macro-level includes the myCASA portal designed to register all drones and operators, whether for commercial or recreational use, to enhance safety culture and accountability. However, compared to countries like Brazil and China, there is a strict concern for incorporating all airspace users as the focus is beyond commercial use. Moreover, the UTM system in Australia is the best overall due to its recognition of the role operators play to enhance safety in stating requirements for compliance compared to other countries. Australia requires operators to adhere to given conditions to safely operate drones in the airspace, including measures like who flies a drone, how they fly it, and where they carry out the process [55]. Although one may presume that all nations practice the same, Australia and European Union has gone beyond to enforce drone registration for commercial and recreational operators for increased accountability. Furthermore, tests are needed online to gauge the ability of an individual to operate a drone besides checking competence on the requirements like areas of operations and how to manage a drone appropriately. That ensures only the most competent can operate in the airspace, and they should have the right credentials. Therefore, effective airspace and traffic management regulation of drones make Australia have the best UTM overall.

When evaluating the best key areas, it was found that every key area is implemented best in a different country. Based on the use of the method of the Analytic hierarchy process pairwise comparison was made. The first key area is drone registration and operator accreditation; the researcher calculates that Australia is the best in this key area. In the second key area, the Weight of drones and safety distances, the researcher calculates that China is the best in this key area. In the third key area, Privacy and consent, the researcher calculated that the EU is the best in this key area. In the fourth key area, Visual line-of-sight, the researcher calculated that South Africa is the best in this key area. In the fifth key area, Flying time, the researcher calculated that Brazil is the best in this area. In the sixth key area, Number of drones at a time, the researcher calculated that the United States is the best in this key area. After that, the researcher summed up the ranking of each country in each key field and made a table to clearly see the ranking of each country in each key area. The differences in the various countries are evident that various countries are exerting different efforts in various key areas to improve Unmanned Aircraft. I think the countries and the world, in general, are undergoing technological and innovation revolution in the sector to ensure they meet the demands of the various departments. These differences are accommodative because they have shown that the various countries are using various models to develop the efficiency of various key areas for UA. The differences are significant because it is not normal for countries to have outstanding performance in all sectors. Some countries prioritize the development of UA over others hence the existing differences. Although all the countries are showing efforts in some key areas, their performance is not emphasized in all key areas hence the existing gaps. Each country has its outstanding policy in the key area; ICAO can allow each country to focus on what it is good at so that it can come up with a drone regulation that is most suitable for the world to be used by countries all over the world. And if the countries can learn from each other's strengths, we can get the best UTM. This will not only improve the safety of drone use but also help the world's cultural integration and then improve the harmony between countries.

Regarding the proposal of the best UTM for the world, the drone regulations of the countries are similar, so it can be concluded that the six countries are comparable to each other in drone regulation. Therefore, we can propose a unified drone regulation that is used by all countries in the world, and this regulation can greatly improve the safety and reliability of drones. Australia is very outstanding because it has noticeable standardized improvements, regulations, legislations, and frameworks in all key areas, although it was number four in one of the key areas. I think not that the other countries do not have operating guidelines, but the differences might be in their implementation. Countries like the USA are well known for being considered in many things but sowed reluctance in the key areas. The differences are especially due to the implementation of policies, regulations, and guidelines. The comparison based on key areas showed that Australia was also the best but was below the world’s best regulations. Australia is following possible applications of expanding new areas in Unmanned Aircraft's technologies advancement which are happening in fast spaces. Some countries are having issues or challenges like infrastructure, emergencies, and funding which are hindering the implementation of regulations; hence have to work to overcome the application of technologies for all interventions in the sector.

The reason why Australia has not adopted my proposal at present may be because some infrastructure equipment is limited or lacks powerful software support, but if it can use my proposal in the next few years, it will greatly improve the safety of drone flying. Another reason that restricts the proposal of the best UTM for the world is language and culture. As we mentioned before, remote pilots of Chinese are only allowed to use Chinese as one language when they take the driver's license test. However, in some European countries, not only the local language can be used, but also the English version of the exam has been added. This can greatly improve the usability of the best-proposed UTM. And the most important reason which limits the proposal of the best UTM is the airspace classification. Each country has its own method of dividing airspace, and if the method of dividing airspace can be unified in the future, this will further enable the use of the proposed UTM. For example, the United States divides airspace into six levels: A, B, C, D, E, and G.[65] Among them, A, B, C, D, and E airspace are controlled, and aircraft flying in G airspace is completely unrestricted. Class G airspace mainly refers to the ultra-low altitude from the ground to 700 or 1200 feet.[65] At this height, close to the ground, the radar cannot cover due to terrain reasons, so there is no control at all. As long as the weather permits, flying in Class G airspace is completely free, without the need for radios and transponders, and without the need to apply or contact any organization. Commercial aircraft, gliders, helicopters, balloons, etc., are not restricted in G airspace, and drones are just flying in G airspace, which undoubtedly greatly increases safety risks. However, China is developing new airspace between the ground and 400ft, which is an exclusive drone area. It would be a further improvement to the proposal best UTM for the world if this airspace were to be available worldwide.

The various countries are all working towards imposing the safety of the drones and people while ensuring they meet their aims and objectives. This research will be essential in examining UTM systems and provide a contribution to the research with the aim of improving air traffic management. The research also contributes to the theoretical development of a body of knowledge with the ability to improve the role of future researchers in interpreting UTM innovations and contributing toward service improvements. Therefore, the research increases the quest for further investigations in areas of UTM systems and air traffic management structures, with more students embracing research in this area.

5. Conclusion

The research focused on the comparison of different UTMs in different states in the world through the identification of the best key area and the best UTM overall. Briefly introduces the drone regulations used by countries and their limitations in the first chapter. In the second chapter, the method of comparison is introduced to facilitate the comparison of key areas, which is described in the third chapter. An Analytic hierarchy process comparison method is used in comparing key areas to find at the most applicable UTM regulations worldwide. Australia which was considered to have best UTM overall, has also provided regulations for safety, especially in consideration of the licensing of operators and the registration of commercial drones which is unique considering that commercial pilots are expected to have RPA operator accreditation, which involves pursuing an official course and getting tested for competence to operate a drone that enhances safety.

In this research, the researcher utilized secondary sources, which mainly focused on a qualitative approach to data analysis using the information that was already available with regard to the integration of UTM in different countries in the world. The use of secondary data limited the researcher considering the fact that it indirectly, rather than directly, answered the research question at hand. This was because the information used was on the basis of the evaluation of the primary data collected by the actual researchers. This research was also limited by the extent and availability of research materials that covered the integration of UTM services into the current air traffic management structure in different states in the world. This left the researcher with a small sample of the information available to work with, which, therefore, impacted the element of representation based on the integration of UTM in the six countries that were compared. Lastly, since the researcher drew a larger geographical scope looking at many countries in the world, there was an increased risk of less reliability and validity of the research conducted. And since the drone industry is still in a developing state, there is not a lot of relevant information that can be used in the paper. The aviation regulations of drones are similar in most countries, so there is some controversy in the scoring process of the researchers because they are collected from the specific portals of each country and then pass their improvement in related key areas. security and safety. In the comparison and scoring process, the third, fourth, fifth, and sixth countries may be legally the same, but the investigators can only judge their rank by the relevant reports of other authors. In some countries, drones have been used in the commercial industry and entertainment industry, but in some countries, there are not many drones in use due to technical limitations. For example, two companies such as Amazon and Google, in the United States are using drones to replace some humans, but South Africa has not put drones into commercial use, so this greatly limits the standard of country-to-country comparison.

This research which targets the integration of UTM services and air traffic management systems obtains knowledge and support for innovations that will have a positive impact in the field. The air traffic management industry struggles with limited research due to the complexity of the industry. However, the increasing number of unmanned drones in the world and other aircraft have created the need for innovation and improvement in the UTM systems. Therefore, this research is beneficial in this regard since it provides suggestions that would greatly impact the operations of unmanned aircraft and the regulatory framework. Secondly, this research provides a basis on which future scholars can further examine UTM. This is because it encourages positive action research and experimentation that will yield innovations to improve air traffic management. Thirdly, this research contributes to the theoretical development of a body of knowledge with the ability to improve the role of future research in interpreting UTM innovations and contributing toward service improvements in the industry.

In this research, Analytic hierarchy process methods were used. However, these methods did not provide an active assessment of the UTM systems in air traffic management structures. Therefore, it is recommended that future researchers should re-examine the research topic using quantitative research, which focuses on primary data collection with an experiment that would adequately reveal the ideal features of integrating UTM services into the current air traffic management structure in different states in the world. Additionally, future scholars should further examine the UTM regulatory framework in the air traffic structures since it has shown to have a continued need for improvement to meet the global outlook and threshold.

In the context of increasing labour costs and higher efficiency requirements, drones are becoming more and more important in all walks of life. However, in order to play a greater role, it is necessary to use software algorithms to turn the images captured by drones into practical data and analysis data. The application of the algorithm can include two aspects: one is to set the UAV flight parameters and camera parameters and let the computer automatically plan the flight trajectory and optimize it. Autonomous or semi-autonomous control of the flight, autonomous inspection, autonomous return, and landing, etc., according to instructions; the second is to perform video image analysis to achieve functions such as removing photos with substandard quality and autonomously labelling image information. In addition, there is still room for improvement in drones. For example, the flight control stability of UAVs and the operational level of operators still need to be improved. At the same time, the application of drones is still in the practical stage, and it is necessary to do a good job of safety control and process standardization. But I believe that in the next 10 to 20 years, through the continuous efforts of people, the drone industry will be perfect.

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