Drones for Safety and Security Surveillance Systems (D4S): The Case of Mega Sporting Events

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy (PhD)

By

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ABSTRACT

Unmanned aerial vehicle (UAV/drone) use is rapidly expanding across diverse civil applications, including real-time tracking, wireless coverage provision, sensing, search and rescue missions, goods delivery, safety and surveillance, security, and safety inspections of engineering structures. Smart UAVs herald the next technological advancement in UAV technology, offering new possibilities in numerous applications, particularly in reducing risks and costs for civil infrastructure. Civilians can readily purchase commercial UAVs from online platforms or retail stores. Drones hold significant potential in significantly improving safety and security operations across various sectors, including large-scale affairs like mega sporting events, provided there is a framework to govern their safe and effective deployment. The key to the success of these applications lies in equipping them with the necessary sensors and software to provide sufficient evidence of their contribution and enhance situational awareness (SitAW). However, drone deployment in Qatar is lagging for various reasons.

The aim of this work was to explore, through a comprehensive analysis, the potential for integrating drone technology into the civilian safety and security (S&S) sector, with an additional aim of identifying challenges faced in deploying drones in Qatar. In seeking to achieve this aim the study proposes a framework to address the operationalisation gap and serve as a roadmap for different stakeholders to enable the successful, safe, accountable, and sustainable development of drone applications. The framework, based on an analysis of data gathered from previous guidelines for unmanned aerial system operations and the identification of challenges facing drone deployment in Qatar, was evaluated using semi-structured interviews with key stakeholder participants (n=27) from a range of occupations that include firefighting, military aviation, interior security, the police, oil and gas, civil aviation, research and higher education, and the Qatar World Cup Security Committee.

The results of the study indicate that the proposed framework, which encompasses a SitAW model that can guide S&S professionals and other stakeholders in integrating drones as key contributors to their operations, is ready to be put into operation by policymakers. A further and unique contribution is the critical importance of recognising the role of drones in enhancing SitAw for dynamic decision-making (DD-M) in various sectors and operational contexts. Fundamentally, the proposed framework addresses the problem of low drone adoption in Qatar and elsewhere by guiding policymakers and other stakeholders in the safe and effective deployment of drones in shared airspaces.

DECLARATION

“I declare that the research in this thesis is the author’s work and submitted for the first time to the Post Graduate Research Office at Brunel University of London. The study was originated, composed and reviewed by the mentioned author in the Department of Electronic and Electrical Engineering, College of Engineering, Design and Physical Sciences, Brunel University of London, UK. All information derived from other works has been referenced and acknowledged.”

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To my family, whose unwavering love has supported my journey. I am immensely grateful to my parents and brothers for your steadfast belief in my potential and for instilling in me the values that have guided my endeavours. To my cherished wife, Lolwa, you are my heart and my source of inspiration. Your limitless love and support have anchored me, especially during the more challenging aspects of this journey. The joy you have brought into my life through our wonderful children—Nasser, Mariam, Shaikha, and Hamad—fills me with profound gratitude. Witnessing your nurturing spirit as you raise them has been a true blessing. Your strength and compassion illuminate our family life, and I am eternally thankful for the warmth and happiness you cultivate in our home. Together, we have forged a life rich in love, laughter, and treasured memories, and I feel truly fortunate to have shared this journey with you.

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Lastly, I extend my heartfelt gratitude to my homeland, Qatar. The values and traditions of my country are a guiding force in my life, and I am eager to give back to the community that has nurtured me. It is my sincere aspiration to contribute positively to Qatar’s development, to show my appreciation for the opportunities I have been afforded.

This thesis stands as a testament not only to my individual efforts, but also to the love, support, and encouragement that I have received from my family, mentors, and my country. Thank you all for being an integral part of this meaningful journey.

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LIST OF ABBREVIATIONS

A-D4S	Advanced Drone Safety and Security Surveillance System
AI	Artificial Intelligence
AI DSS	AI Decision Support Systems
ANOVA	Analysis of Variance
AR	Augmented Reality
ATM	Air Traffic Management
B-D4S	Basic Drone Safety and Security Surveillance System
BI2U	Behavioural Intention to Use
BIM	Building Information Modelling
BVLOS	Beyond Visual Line of Sight
C&CC	Command-and Control-Centre
CONOPS	Civilian Concept of Operation
D2D	Device-to-Device
D4S	Drone Safety and Security Surveillance System
DC	Drone Camera
DD-M	Dynamic Decision-Making
DFQ	Deployment Framework for Qatar
EAD	Electro-Aerodynamic Propulsion
EASA	European Union Aviation Safety Agency
EC	European Commission
FAA	Federal Aviation Administration
FC	Fixed Camera
GPS	Global Positioning System
GUI	Graphical User Interface
HL	Humanitarian Logistics
HMI	Human-Machine Interface
ICAO	International Civil Aviation Organization
IoT	Internet of Things
LIDAR	Light Detection and Ranging
LOS	Line of Sight
LTE	Long-Term Evolution
LUC	Light UAS Operator Certificate
MIR	Methodology for Interdisciplinary Research
MoTC	Ministry of Transport and Communications

MSE	Mega Sporting Event
MTOM	Maximum Take-off Mass
NASA	National Aeronautics and Space Administration
NCAs	National Competent Authorities
NFIPs	National Football Information Points
PDSA	Plan-Do-Study-Act
PEoU	Perceived Ease of Use
PESTLE	Political, Economic, Social, Technological, Legal, and Environmental
PU	Perceived Usefulness
R&D	Research and Development
RPA	Remotely Piloted Aircraft
RSUs	Roadside Units
S&R	Search and Rescue
S&S	Safety and Security
S&SPs	Safety and Security Professionals
ScenAn	Scenario Analysis
SD	Standard Deviation
SDLC	System Development Life Cycle
SID	Site Inspection Drone
SitAW	Situational Awareness
SitAwM	Situational Awareness Model
sUAS	Small Unmanned Aircraft Systems
TAM	Technology Acceptance Model
UAAS	Unmanned Aerial Assistance System
UAM	Urban Air Mobility
UAS	Unmanned Aerial System
UAVs	Unmanned Aerial Vehicles
UTM	Unmanned Aircraft System Traffic Management
VLOS	Visual Line of Sight
VR	Virtual Reality
VTOL	Vertical Take-off and Landing

CHAPTER 1
INTRODUCTION

1.1. Background

Drones, also referred to as unmanned aerial vehicles (UAVs), have gained significant popularity due to their diverse range of applications. Ranging from compact, lightweight devices to larger systems equipped with advanced technology, these aircraft are utilised across various industries and sectors (Hamid, Hussain and Aman, 2019). Their ability to access and navigate challenging or hazardous environments is one of their primary advantages.

The usefulness of drones can be seen across a range of dimensions. In search and rescue (S&R) missions, for example, drones play a crucial role in locating missing individuals in remote or dangerous areas, providing vital assistance to rescue teams. Equipped with thermal cameras and infrared sensors, they can detect heat signatures, making them invaluable tools in these and other such emergencies (Manrique, Müller and Mellado-Bataller, 2017). The agricultural sector has embraced the potential of drones – by employing sensors and imaging technology, they can monitor crops, assess crop health, and provide precise information on irrigation needs. This enables farmers to optimise crop yields, minimise resource usage, and improve overall crop management. Drones equipped with spraying systems can also be used for targeted pesticide application, reducing the need for manual labour, and minimising negative environmental impacts (Nandi, Zhang and Larcher, 2020).

In logistics, particularly in the delivery industry, drones have the potential to be used extensively. Companies like Amazon and UPS are actively exploring their use for package delivery, which would significantly reduce delivery times and costs. Drones have demonstrated their efficacy in infrastructure inspections, such as monitoring pipelines, power lines, and bridges. They can conduct visual inspections and collect data without requiring expensive equipment or posing risks to human lives (Soh, Ngo and Yang, 2020). They have revolutionised aerial cinematography in the media and entertainment industry – equipped with high-resolution cameras and stabilising technology, they have expanded creative possibilities for film makers and photographers by capturing stunning aerial footage and providing unique perspectives in film production, sports coverage, and event photography (Hamid, Hussain and Aman, 2019).

However, as the prevalence of drones increases, comprehensive research and regulatory frameworks are necessary to ensure their safe and efficient integration into global airspace. Such integration is complicated by the rapidly developing nature of UAVs and associated technologies, as well as by the diverse patchwork of established legislation and regulations governing aerial transport and other drone activities worldwide. Critical considerations, such as privacy, security, and airspace management, need to be addressed to prevent misuse and ensure public safety. The development of technical requirements and standards for drone design and operation is vital to minimise these as well as the risk of accidents and collisions with other aircraft (Tran and Shen, 2019).

Regulatory bodies and aviation authorities worldwide are actively working on implementing guidelines and regulations for drone operations. These regulations encompass drone registration, pilot certification, flight restrictions, and airspace coordination. The establishment of clear rules and standards enables effective mitigation of potential risks associated with drone operations while harnessing their benefits (Federal Aviation Administration [FAA], 2023). Ensuring their safe and efficient integration into the global airspace, however, requires further research to establish robust regulatory frameworks and technical requirements as each country and sector may benefit from them differently. Through such efforts, drones can be effectively integrated, unlocking their full potential for the betterment of society.

It can therefore be asserted that, contemporaneously with the continuing evolution of UAV technology, numerous challenges must be addressed to ensure the safe, secure, and effective deployment of drone applications (Citroni, Di Paolo and Livreri, 2019). These challenges include privacy and security concerns (Dalton, Wolff and Bekker, 2021), the energy restrictions of onboard batteries (Citroni, Di Paolo and Livreri, 2019), and the establishment of civilian UAV deployment frameworks in line with international efforts endorsed by the International Civil Aviation Organization (ICAO, 2022). Overcoming such challenges would mean that drones can be leveraged for surveillance and safety and security (S&S) applications, which would significantly enhance situational awareness (SitAW) and facilitate dynamic decision-making (DD-M).

Despite Qatar’s wealth and significant technological investments, UAV applications remain lacking compared to those in other countries. This research therefore seeks to develop a framework to address current challenges and improve UAV deployment in Qatar. Additionally, it proposes a SitAw model (SitAwM) to establish an S&S drone-based system for civil applications, using mega sporting events (MSEs) as an example.

1.2. Motivation

Having worked in civil defence for several years, I have witnessed first-hand the crucial role of technology in risk identification and crisis management. My involvement in developing strategies for the Qatar World Cup 2022 highlighted the importance of leveraging drones to enhance S&S measures and it was surprising to realise that, despite Qatar's wealth and significant investments in technology, our country lags in drone applications. This realisation prompted me to delve deeper into identifying challenges and establishing frameworks for drone deployment there. I was privileged to have the opportunity to pursue my studies in this field at Brunel University of London, a global leader in UAV-related technologies, and engineering in general, with world-renowned experts in various germane fields. Additionally, I recognised the need to contribute to the development of awareness models and system architectures for drones in various S&S applications. This study seeks to contribute to this important field, and particularly in facilitating the safe and effective deployment of drone applications in Qatar and beyond.

1.3. Aim

The principal aim of this research project was to undertake a comprehensive analysis to explore the potential for integrating drone technology into the civilian S&S sector as well as identifying the challenges faced in the deployment of drones in the state of Qatar with specific reference to MSE's.

1.4. Objectives

1. Conduct a review and comprehensive analysis of relevant literature about drone technology and its key applications in various civilian S&S domains.
2. Investigate and delineate the challenges encountered in the deployment of drones, specifically within the context of Qatar, including political, economic, social, technological, legal, and environmental (PESTLE) dimensions.
3. Develop and evaluate a framework aimed at facilitating the future adoption of civilian drone applications in Qatar, to overcome key challenges and lay the groundwork for addressing other obstacles facing UAV deployment in the country.
4. Conduct a study to establish an aligned SitAwM, termed the "Drone Surveillance SitAw Model", for DD-M.
5. Propose and assess the feasibility of implementing a novel "Drone Safety and Security Surveillance System" (D4S), aimed at standardising drone-based systems to enhance SitAw and support DD-M processes in civilian S&S operations.

1.5. Conceptual Research Design

Given the nature of this research project, which intersects with numerous engineering disciplines and engages stakeholders from different academic and professional backgrounds, a multidisciplinary research methodology design was deemed the most appropriate to accomplish the stipulated objectives (Dalton, Wolff, and Bekker, 2021). This approach allowed for the utilisation of different research methodologies together to achieve various objectives, ultimately serving the main aim of the research. Figure 1.1 displays the conceptual model of the research objectives, which were achieved through various methods adumbrated here, and detailed in subsequent chapters.

The first objective, of conducting a literature review, was accomplished through a narrative review methodology. A way of justifying this first objective is in terms of building blocks, bearing in mind that a purpose of literature reviews is to gain an understanding of the current state of knowledge for the topic in question by undertaking a wide review of literature in the whole field. For the second objective, of identifying the challenges, a PESTLE analysis was undertaken to explore the eponymous dimension, using a quantitative questionnaire This can be seen as being a further building block – it would be difficult to have confidence in seeking to address the challenges without first gaining a thorough understanding of what they are and their implications. Having identified these challenges the third objective could be addressed, which involved the development of the framework, based on the theory of change and the Plan-Do-Study-Act (PDSA) approach. With these three objectives in hand the researcher was then in a position to proceed with the research and, to align with the SitAwM, mixed methods were employed for this fourth objective, including quantitative content and scenario analyses (ScenAn) using a quantitative questionnaire. This led to the fifth and final objective, which was designing and evaluating a system prototype using the system development life cycle methodology, with live evaluation conducted using the technology acceptance model.

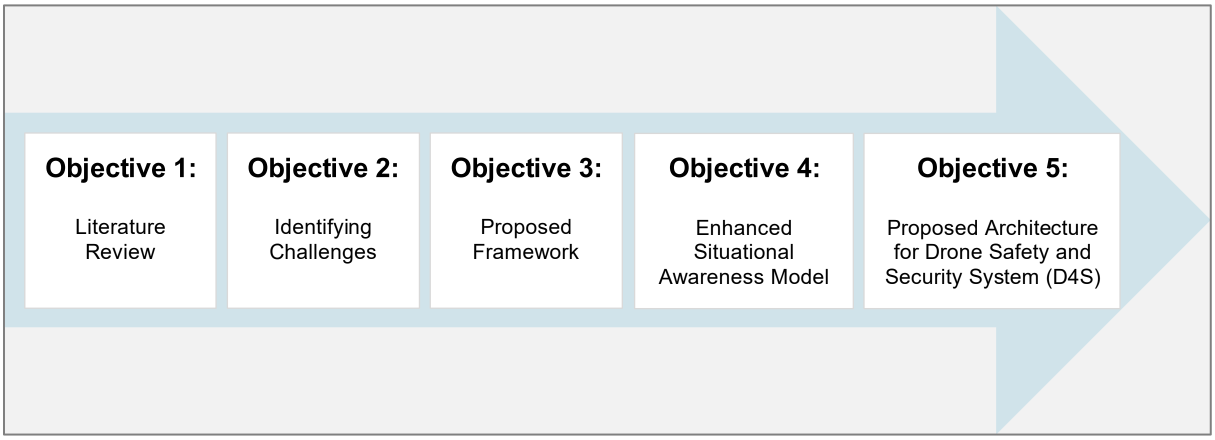

Figure 1.1: Conceptual model of research objectives
Source: Author

1.6. Contributions to Knowledge

This PhD project has contributed to knowledge in various ways, as summarised below:

- The literature review and the scoping systematic review conducted to identify civilian applications for S&S purposes across different sectors has been beneficial. It highlights potential applications and the work done so far in each sector. This information can be useful for other researchers and stakeholders to build upon.
- The findings regarding the challenges related to drone deployment in Qatar are valuable for researchers, policymakers, and other interested parties. Understanding these challenges is crucial for successfully deploying civilian drone applications. Additionally, the assessment methodology used can be applied to other countries.
- The proposed framework for deploying civilian drones in Qatar addresses the low adoption of drone applications and guides policymakers and stakeholders in deploying these safely and effectively in shared airspaces. It can also benefit other countries facing similar situations by providing a model that can be adapted to align with their needs.
- Enhancing the SitAwM by integrating drone surveillance elements supports decision-making in dynamic environments related to S&S. This enhanced model can serve as a foundation for researchers and stakeholders to develop specific applications.
- The proposed D4S architecture and the tested prototype provide practical insights into using drones for S&S applications. This can help set standards for future systems and promote the use of drone systems in civilian applications. Other researchers and stakeholders can build upon these findings.
- The outcomes of these contributions have been disseminated to the public through various publications, filling gaps in the literature in this area.

1.7. Thesis Structure

CHAPTER 1: **Introduction**

This chapter provides an introduction to the thesis that includes the motivation, aim, and objectives, research project design, contribution to knowledge, and the structure of the thesis.

CHAPTER 2: **Literature Review**

This chapter covers literature related to the use of civilian drones in S&S applications.

CHAPTER 3: **Challenges for Civilian Drone Applications in Qatar**

This chapter presents the study conducted to identify the challenges facing civilian drone deployment in the state of Qatar, with specific reference to PESTLE factors.

CHAPTER 4: **Civilian UAV Deployment Framework for Qatar**

This chapter presents the proposed framework designed to foster the deployment of future applications for civilian drones, along with a stakeholder evaluation.

CHAPTER 5: **Drones Surveillance SitAw Model for DD-M**

This chapter presents an aligned model for SitAw using drone surveillance to enhance DD-M in S&S applications, along with the outcome of the assessment of the aligned model by S&S personnel.

CHAPTER 6: **Drone S&S Surveillance System (D4S) Prototype**

This chapter presents two proposed architectures for D4S, along with an evaluation by end users based on the technology acceptance model.

CHAPTER 7: **Conclusions and Recommendations**

Presents the conclusions and recommendations for further work, including the limitations of the research.

CHAPTER 2
LITERATURE REVIEW

2.1. Chapter Overview

UAVs have emerged as powerful tools across diverse sectors, promising numerous benefits alongside inherent risks to civilian S&S. Amidst their rising popularity, notably amplified during the COVID-19 pandemic, important challenges have been highlighted that exist across multiple dimensions. This chapter delves into these challenges by dissecting the intricacies of drone deployment. The efficacy, for instance, of drone operations is impeded by delayed responses, sensor malfunctions, and vulnerabilities to malicious attacks, underscoring the imperative for robust design and technical solutions. Public apprehension surrounding surveillance, privacy infringements, and the imperative for education on drone regulations and benefits necessitates nuanced approaches to address privacy, ethical, and cultural concerns. The susceptibility of drones to cyber-attacks, including hijacking, poses grave threats to control and safety, demanding rigorous security measures and protocols. Collisions, operator errors, and susceptibility to physical damage or theft pose significant safety risks, necessitating comprehensive safety protocols and mitigation strategies.

Drones are used for many purposes, ranging from finding people trapped under debris or avalanches, to collecting data for scientists, and to delivering groceries. Drones are commonly used for dangerous tasks and were created for the aerospace industries, as well as the military, to aid in their more difficult tasks (Enemark, 2013). They are commonly used for safety applications, such as reconnaissance, to see if an area is safe for ground troops to advance into, or to see if someone is buried under rubble before rescue teams go in. In some cases, drones are even used in place of soldiers and are fitted with weapons, such as bombs (Enemark, 2013).

Drone technology has become increasingly mainstream over the years and, due to its efficiency and effective safety, is slowly being used for civilian purposes. Civilian drones can, as noted, be used to carry groceries to one's doorstep or to photograph any view a person wants from different angles or heights (Kardasz *et al.,* 2016). This chapter presents a review of publications concerning research into the use of civilian drones, particularly in safety applications. The reviewed publications are classified under four main headings: *engineering*, *environment and urban*, *public*, and *healthcare*. Each of these sections includes a number of drone application examples.

2.2. Chapter Research Methodology

The method used was the narrative literature review, also known as narrative analysis (Ferrari, 2015). This method allows for the gathering of broad, comprehensive, and critical information related to the subject, enabling the identification of any gaps in knowledge (Rother, 2007). The first stage was to identify studies germane to the domain of drone applications in S&S published in the last 10 years (2014 to 2024), with the resultant outcomes then being refined to select studies directly related to the topic. The studies were then sorted into four identified themes (*engineering*, *environment and urban*, *public*, and *healthcare*). The process is presented in Figure 2.1.

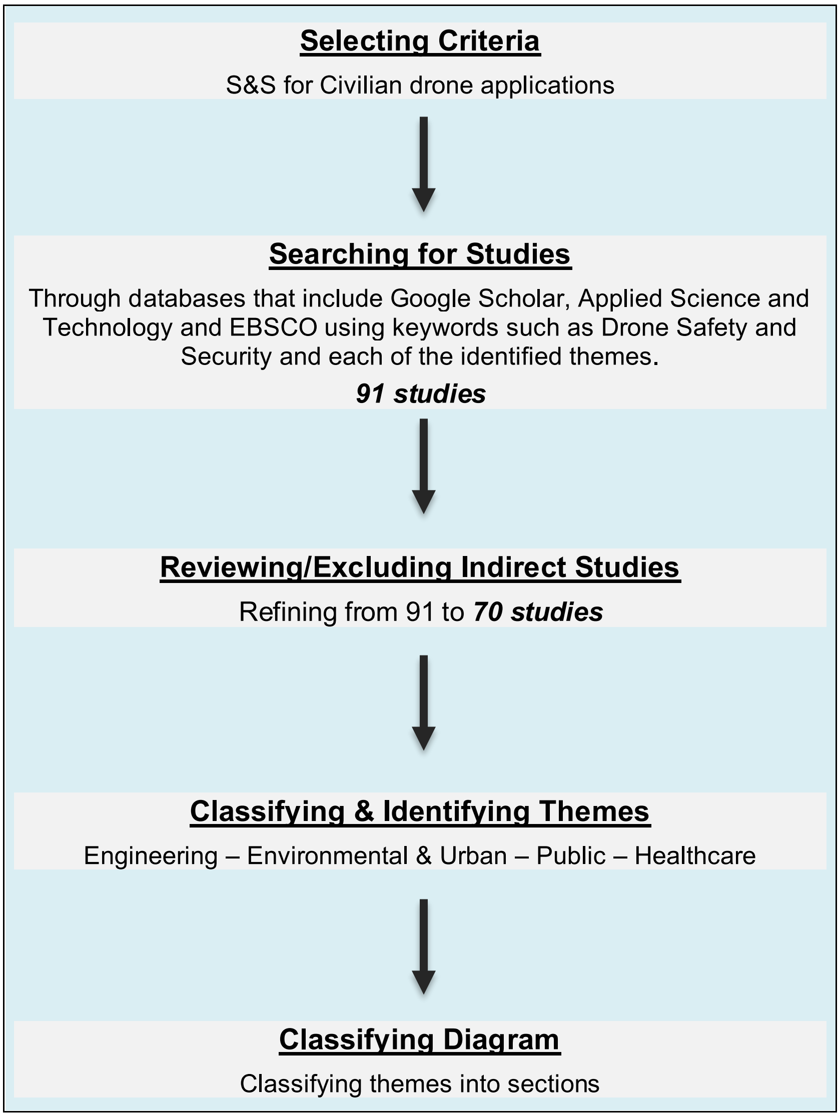

Figure 2.1: Literature review flow chart
Source: Author

The following sections review the key publications concerning drone applications as per the identified classification system.

2.3. Classification of Drone Applications for S&S in Engineering

2.3.1. Construction

Two central themes can be identified with regard to the construction industry. One is its importance in terms of its contribution to an economy and a second is safety. On one hand, for example, it contributed 3.45% to the economy of the US in 2010 while on the other 751 fatalities occurred on construction sites in that country in the same year, a rate of 9.5 per 100,000 workers (Irizarry, Gheisari and Walker, 2012). Despite this, argue Irizarry *et al*. (2012), the industry lags behind other sectors in terms of technology when this could be a crucial element in addressing the considerable safety concerns that are always likely to exist. Using an experimental research design that included expert analysis and user participation these researchers set out to test the efficacy of a quadricopter drone in being of benefit to safety managers within the confines of a construction site. The results lead to the optimistic claim by the researchers that this tool, with an interface, has the potential to be "as accurate as having the safety manager with plain view of the jobsite" (Irizarry *et al*., 2012, p. 194). Several cautionary points are, however, made, and one refers directly to S&S and is the potential for drones to be hazardous if there is a risk of them striking workers and a second, more social, aspect is that workers would have less opportunities for interacting with managers as they would be less likely to walk around a site.

While this potentially negative aspect of using drones on construction sites was noted by Irizarry *et al*. (2012), other writers seem to only see positive ones in terms of communication. In their review of drone use in civil engineering Tkáč and Mésároš (2019), for example, cite higher levels of communication between those working on construction sites, along with photography, topographical measurement and overall enhanced safety, as being some of the benefits the use of drones can bring. These writers also suggest a reluctance in the construction industry to adopt new technology, particularly with regard to established practices, but seem to contradict this by stating that the sector has, in recent years, "seen an almost 240% increase in drone usage, higher than any other commercial sector" (Tkáč and Mésároš, 2019, p. 28). An important aspect, overlooked in some of the literature, is discussed and evaluated by Tkáč and Mésároš (2019) and this is the type of drone used. Each seems to have advantages and disadvantages, with some designs better suited for specific purposes than others. At a very basic level, a fixed wing drone only uses energy when moving forward, meaning they can cover greater distances at higher altitudes and are therefore particularly useful for mapping and surveying large areas. However, they are unable to remain in a fixed position and need space (or a catapult) to take off and land. Conversely, multi-rotor drones are limited in terms of speed and time in the air but can hover in one position.

This last advantage (of being able to hover in one position) is perhaps why multi-rotor drones are most commonly used in the construction industry. Although not discussed in any detail, this was the model used for a site inspection drone (SID) in the work of Ashour, Taha, Mohamed, Hableel and Kheil *et al*. (2016). The model was developed for entry into a competition called 'Drones for Good' that was held in Dubai and certain claims are made about it and its potential. The main problems identified regarding construction sites in the United Arab Emirates are stated as being "preventing labour force abuse, monitoring health and safety standards of construction sites, and stopping unlicensed constructions" (Ashour *et al*., 2016, p. 1) and the drone in question was specifically designed for the latter issue, namely inspections to detect violations. It is claimed that this drone will enhance health and safety standards as well as efficiency, with the process of site inspections being "a cheap solution that vastly increases efficiency, safety and practicality of the inspection process" (Ashour *et al*., p. 4). Questions can be raised about the accuracy of these claims bearing in mind that the article is mainly concerned with the contents of the drone (including an on-board processor and sensors, an autopilot and hardware as well as batteries) and that it has a maximum flight time of 20 minutes. Nevertheless, and despite the overly optimistic claims made, the fact that the drone was specifically designed for the purpose and that attention was paid in this respect to its contents suggests that this work has some value.

While the accident and fatality rate for the whole construction industry, as noted, is high, it is considerably higher when it comes to those who work on towers. The challenges these workers have to face include electrical problems, structural failure, extreme weather, and falling objects, and it is therefore of great importance that the potential of drones to moderate these dangers is explored. That was the purpose of work by Leasher (2017), who employed an experimental method that involved flying a drone in a building where there were no obstacles that could pose danger to it. A pre-flight inspection took place, including making sure the batteries were full. The results showed that the UAV could be used to inspect towers and capture clear pictures and videos. All parts of the building were visible in these pictures and videos, which were taken at different heights and angles to inspect for damage. It is, however, important that the potential demonstrated is adequately contextualised – the experiment was undertaken in ideal conditions; therefore, the robustness of the drone, its ability to produce the same level of quality, and the extent to which S&S could be compromised when such conditions do not prevail, remains to be seen. As Leasher (2017) further notes, the extent to which tower workers would believe in the capabilities of drones for close-up inspections that can also be undertaken through climbing also remains to be seen.

This issue, of considering those who would actually use the drones in practice, is included in a minority of works undertaken in the construction industry and one of them is Irizarry *et al*. (2012) (see above, this section). Another is the work of Gheisari, Irizarry and Walker (2014), which sought to explore the benefits of the use of an unmanned aerial system (UAS – drones) for safety managers on a construction job site, using augmented reality (AR). Safety managers are required to perform walk-throughs of the job site and check the current safety situation of workers, materials and equipment while having direct interactions with workers. The authors state a belief that providing safety managers with a safety inspection assistant drone would be beneficial and could enable them to achieve the goals of the safety inspection. To test this the authors carried out experiments with three possible conditions: plain view, using an iPad, and using an iPhone, and it is of interest to note that when given the choice of conditions participants chose the plain view. Based on this and other study outcomes Gheisari *et al*. (2014) recommend an 'ideal' unmanned aerial system that would include autonomous navigation, high resolution cameras and voice interaction. They also note, however, that the maximum flight time was just 13 minutes on a single charge, which begs the question of how much the already low flight time would be reduced to accommodate these 'ideals.' It also begs the question of how safe such a system would be when used in real life scenarios.

How UAVs are used regarding construction hazards and the potential threats to workers, and how safeguarding is the responsibility of a safe work environment, is included in a review article by Howard, Murashov and Branche (2018). Positive aspects are noted, such as using video footage to create a 3D view of the site while comparing it to a computer-generated architectural plan but, as Howard *et al*. (2018) further point out, there have been approximately 30 incidents of near-misses or crashes that have resulted in injuries suffered by people using recreational UAVs. However, there is insufficient data and literature concerned with industrial application, which leads these authors to a recommendation that research be undertaken to consider the potential hazards as well as benefits in the practical use of UAVs. This may be of greater benefit than hypothesising about the benefits of UAVs (for example Dastgheibifard and Asnafi, 2018) without also acknowledging safety hazards, which indicates the need for research that not only identifies the challenges faced and evaluates various prototypes but also seeks to develop a framework for the use of drones in specific contexts.

An example of research that could be usefully undertaken involves a framework, set out by Alizadehsalehi, Asnafi, Yitmen and Celik (2017) and which has four processes, that aims to create and then monitor safety procedures for construction projects over their whole course.

The four processes are a building information modelling (BIM) system, safety regulations, the collection of safety inspection data by drones, and analysis of project safety procedures. In addition to collecting dynamic safety data with a UAS, safety inspection data can be analysed based on the model created by BIM and construction accident prevention can be enhanced by safety managers, designers, and workers using the system. By using 3D software and BIM, this system identifies potential hazards throughout the design process. The framework can be used in pre-construction and during the design stage to identify and eliminate potential hazards by using the safety-rule-checking system during the pre-construction phase. By integrating BIM and UAS, this novel method lets safety managers obtain and analyse data from construction sites, allowing safety specialists (e.g., supervisors, agents, and inspectors) to identify risks at different phases, and design mitigation strategies accordingly. By incorporating 4D BIM-based models and UAS technology, construction site safety can be improved in identification, implementation, and monitoring, increasing the safety of project stakeholders.

While the importance and relevance of addressing safety concerns is (rightly) emphasised in the work of Alizadehsalehi *et al*. (2017) and in other studies reviewed, it is important that the potential benefits from drone technology are appropriately itemised and shown to function in the real world. Research by Sreeram, Nisha and Jayakrishnan (2018) at least partly tests models proposed by researchers such as Alizadehsalehi *et al*. (2017) but also includes AR. The scenario is a drone with AR that can fly over a proposed construction site before any building has taken place because it interacts with software that includes a 3D model created by BIM. A smartphone was placed on a drone which was controlled by a person standing in a remote location. This smartphone could communicate with other smartphones, laptops, or other devices (subject to standard configuration and settings). The team viewer application was used to operate the smartphone from another device. The video of the location was sent to the device at the other end from the smartphone mounted on the drone and this device could be a smartphone, laptop, or tablet. The model could be placed with the help of an AR-based Android application. One of the main outcomes of the experiment was to modify and perform different operations on the models (e.g., to resize, relocate, or rotate the model, depending on what was suitable for the project or clients) before undertaking any construction work (thereby avoiding waste and minimising costs). Furthermore, using this system of AR and drones provides safety for workers spared from difficult and dangerous access tasks.

The potential usefulness of frameworks as set out, for example, by Alizadehsalehi *et al*. (2017), has been noted and a further dimension that also seeks a broader perspective comes from Hatoum and Nassereddine (2022), who summarise the extent of drone adoption in the construction industry across all stages of project lifecycles, including the benefits they bring, challenges that need to be met and the costs incurred. The point is made that drones can be used across all of the stages, from pre-planning to design, to construction, and then in asset management and operations. Uses in the pre-construction phase include providing designers with an overview of the project environment, and a broader scope of that environment to assist in the bidding stage (detailing any potential risks and hazards). In the construction phase they can assist safety managers, including the monitoring of air quality, they can assist with logistics in terms of measuring and tracking the volume and movement of materials, and can provide frequent visual updates to stakeholders of progress being made. In the post-construction phase drones can be used for mapping and monitoring, particularly in areas that are difficult to access and potentially hazardous for humans, and they can assist in marketing by providing photos and videos from various angles and perspectives that would otherwise be impossible to create. A further benefit cited by Hatoum and Nassereddine (2022) is overall cost-effectiveness but they also note challenges. These are flight times, weather conditions and limitations when using drones in indoor conditions.

It could be proposed that the work of Hatoum and Nassereddine (2022) is just a summary of individual factors that are the subject of more detailed studies, as identified in other parts of this section. On the other hand, it can be posited that such a holistic view is necessary, and something that is often lacking in this field of study. As Hatoum and Nassereddine (2022, p. 547) note, such an approach can "set a baseline for both construction academicians and practitioners for the state of drones in the industry." Such a perspective finds agreement from some other authors, for example Mahajan (2021), who looks forward to a future where drone technology in the construction industry will embrace artificial intelligence as well as the Internet of Things (IoT) and augmented and virtual reality and Choi, Kim, Kim and Na (2023, p. 1), who propose that regardless of challenges, drones will increasingly make "transformative advancements across all phases of construction projects."

Alongside a tranche of the literature reviewed in this section that seems to be mainly interested in showcasing the capabilities of UAVs in ideal conditions without taking full account of S&S and real-life challenges, are some studies that do seek to acknowledge and address, or at least partially address, the challenges that exist. These are the development of a framework through the lenses of key workers that can inform drone deployment in each sector, the development of a suitable prototype that includes specific sensors, and the testing of such a system in real life situations. A key aspect, along with safety, and emphasised by these and other authors referenced in this section, is that drones are able to navigate in places where it is difficult for humans to reach. Another industry that has challenges concerning human access is mining.

2.3.2. Mining industry

Before turning attention to the subject area indicated in its title (UAVs and mining) a review article by Lee and Choi (2016) considers types of drones, their relative advantages and disadvantages, the types of technology they can be equipped with and some of the sectors they have been used in, or may in the future be used in. Some points concerning multi-rotor versus fixed wing issues have been previously discussed (above – Section 2.3.1) but an additional point made by Lee and Choi (2016) concerns limitations with regard to weight and therefore the type of camera and other equipment that can be carried in multi-rotor drones compared with those that are fixed wing. Nevertheless, the writers highlight the potential use of infrared cameras and laser scanners – as well as being able to film at night the former can observe that which cannot be seen by the human eye, while the latter can produce accurate data regardless of any topographical irregularities, something that cannot be done if the scanner is based at ground level. With specific reference to the mining industry Lee and Choi (2016) first note some of the challenges the industry faces before suggesting how these may be met by the use of UAVs. The challenges include mining operations, in lieu of a precise topography, being undertaken based solely on experience, and climatic difficulties being experienced when aeroplanes and satellites are used. Examples of the use of drones to overcome these are cited, including the use of infrared cameras to identify the self-ignition point in a coal mine, investigating the precise location of abandoned mines, and their usefulness in topographical surveying.

While Lee and Choi (2016) provide some useful background information on the general use of drones, the review by these writers of their use in mining is somewhat limited. Such is not the case with the work of Shahmoradi, Talebi, Roghanchi and Hassanalian (2020), whose review is focused solely on the mining sector. Challenges faced in this industry and how these may be overcome by the use of drones are detailed. One is accessing data from regions that are very difficult to access alongside mapping discontinuity when using ground-based technology. As well as being able to access such areas, drones can be equipped to apply overlapping photos and take accurate measurements. Another is blasting, which carries inherent risks that are traditionally difficult to avoid due to a lack of detailed information. Drones can at least moderate these by analysing relevant issues such as the type of rock and the geology and topography of the area. Through constant monitoring of mine moisture and the materials left after the valuable product has been removed (mine tailings), drones can also contribute towards sustainability and reductions in environmental harm. Although this suggests a positive outlook for the use of drones, much of this is concerned with surface mining, while some considerable difficulties remain for that which is underground. This can be highlighted by noting the ideal drone proposed by Shahmoradi *et al*. (2020). This device needs, at the very least, to be able to navigate fully autonomously in a place that has no GPS, has no lighting, the drone must be robust enough to tolerate collisions, be able to identify and avoid obstacles; it would have to be dustproof, waterproof and resistant to changes in temperature, humidity and pressure. Because of these requirements, and despite significant advancements in drone technology, the application of drones in underground mines remains, note Shahmoradi *et al*. (2020), limited.

Regardless of such misgivings it is still relevant to consider how beneficial the use of drones can be, bearing in mind that coal fires can occur in surface as well as underground mines. Given the typically remote locations of coal fires, furthermore, it can be posited that any safety concerns arising from the use of drones in assessing the existence and/or likelihood of underground coal fires would be outweighed by the benefits they bring. This is emphasised by Dunnington and Nakagawa (2017, p. 139), who point out that as well as destroying a valuable source of fuel, "burning coal seams emit carbon dioxide, carbon monoxide, sulphur oxide and methane, and is a leading cause of smog, acid rain, global warming, and air toxins." Overall, these fires create as much as 3% of global carbon dioxide emissions, destroy as much as 5% of usable coal, and the cost of remediation in just the US is estimated to have been $5 billion since 2009.

Coal rank refers to the extent to which the substance has 'coalified' and this ranking in turn is an indication of coal fires. Coal rank can be determined by the use of gas ratios and Dunnington and Nakagawa (2017) propose a model that can be attached to a drone. This model is lightweight and has a low effect on the flight time of the drone it is attached to, which can achieve up to 15 minutes in the air. The model can be used with a miniature infrared carbon dioxide detector to add up to 100% of by-volume carbon dioxide to its low carbon dioxide range, while the additional airflow from the drone does not affect the instrument's ability to measure gas. Tests conducted by these researchers found that the proposed method is reliable for estimating coal rank based on proportional gas analysis, with drone flights providing data quickly and safely. The further point is made that traditional ground-based methods of detection mean field scientists can be in danger of inhaling too much gas and being directly harmed, which leads to a conclusion that in this case "drone collected gas concentration data provides a safe alternative for evaluating the rank of a burning coal seam" (Dunnington and Nakagawa, 2017, p. 139).

The use of drones in underground mines, including in detecting coal fires, may be less challenging when it is noted that the view expressed by Shahmoradi *et al*. (2020) is counterbalanced with more optimistic ones, for example Minh and Dung (2023). A scoping review by these authors lead them to a conclusion that "UAVs are an excellent tool for multitasking at any stage of a mining project and in any type of mine" (Minh and Dung, 2023, p. 128). Eight main applications of drones used in mining are presented and two of these refer to mines below the surface – underground and abandoned mines. The articles reviewed for these mining dimensions indicated that drones can be used in such environments but this appears to be limited to monitoring and mapping. Although their use in other spheres has some additional uses, such as the identification of hazards and the identification of coal fires, the main uses were found to be in surveying, mapping and monitoring. In a similar vein Said, Onifade, Githiria, Abdulsalam and Bodunrin *et al*. (2021) cite the mitigation of real time dangers, the gathering of data in locations that pose risks to humans and the ability to map as beneficial drone employment scenarios in mining.

Even if such challenges are overcome and the ideal model drone proposed by Shahmoradi *et al*. (2020) were created, a further important issue remains, one that was identified in Section 2.3.1 (above), and one that re-occurs across this review. It is the extent to which workers in real world situations would be willing to enthusiastically adopt and use drone technology. That is the subject of a research article by Stroud and Weinel (2020), who conducted group interviews with 5 groups of 12 workers and 4 groups of 12 workers respectively in two European steel plants located in Italy and Germany. Although only indirectly concerned with mining (the research covered coal as well as steel), the study has relevance in terms of attitudes towards drones in associated sectors. The opportunity was taken by these researchers to explore aspects of drones and their impact in some depth. One aspect was the potential for the use of UAVs to lead to a loss of jobs but participants were, overall, unconcerned about such a threat. Instead, they felt that the use of drones would save time and make the work teams more efficient. Even those likely to be most affected, scaffolders, were perceived as being unlikely to be made redundant. Benefits, such as more detailed inspection and analysis, were articulated, as well as improved safety for workers, but concerns about having drones flying about the place were also expressed. Further points raised include losing the 'human touch,' situations where something does not feel right, as well as the need for more training. The overall conclusion drawn by Stroud and Weinel (2020) is that workers saw the use of drones as being beneficial. A conclusion that may also be drawn is that while this study may be of some interest to the steel, and even some associated industries, it cannot be claimed to have much relevance beyond that – the research was among a specific group of workers in a specific industry and within a particular cultural context.

In summary of this section it is clear that there are differences across the literature in the extent to which drones can be of particular benefit in the mining industry. Generally speaking, the outlook for surface mining is much more positive than for that which is underground, but it is in this scenario (underground) where drones could, perhaps, be of most benefit, at least with regard to safety. The context of mining is an industry with quite specific demands and hazards and, in the main, concerns one group of workers. It is also a context where S&S concerns favour drone use because the sector is naturally hazardous and usually very sparsely populated. A much wider and global context, and one where the population concerned is much larger, and where society and its dynamics exist in a condensed area, is smart cities, a concept of increasing and growing importance in terms of economic as well as social growth and development.

2.3.3. Smart cities

As well as being under-researched in relation to its importance and potential, the use of drones in smart city contexts is portrayed in the literature as having a very positive outlook but with one very important caveat and that is safety. With regard to the positives, for example, Khan, Alvi, Safi and Khan (2018) make the point that the increasingly widespread use of drones in warfare, and the images resulting from this use, has presented a negative perception, but a different and emerging perspective is that they can be a very beneficial tool for good. Dung and Rohacs (2018) identify a range of dimensions in which such goodness can become apparent in smart city environments, for instance in medicine, transportation, sustainability and the environment.

There are numerous definitions of smart cities but fundamentally it is an urban area that has embraced and integrated digital technology as a means of improving the living standards and quality of life of its citizens. The use of drones within this context can become a very useful enhancement of such aims and Khan *et al*. (2018) in particular itemise aspects where they can be used. These include the monitoring of traffic, policing and crime prevention, pollution control, firefighting, rescue, disaster management and, more futuristically, ambulance drones. In terms of safety, Khan *et al*. (2018) focus on potential damage and harm caused by crashing drones due to malfunction, collisions, misuse, as well as bad weather conditions and, perhaps most concerning, collisions with passenger aircraft. Two other areas of concern are also highlighted by Khan *et al*. (2018) and these are security and privacy – the technology carried by UAVs could be accessed or destroyed, resulting in severe disruption of any services being delivered and cameras and other equipment carried by drones could be misused in terms of personal lives and personal data. A recommendation made by Khan *et al*. (2018, p. 6) is that enhanced FAA regulations could make it easier for drone technology to best serve cities and protect citizens by “embracing innovation while considering safety, security and privacy issues.”

The focus of a systematic review by Gohari, Ahmad, Rahim, Supa’at and Razak *et al*. (2022) was on the use of surveillance drones in smart cities. The study identified six areas of use, namely infrastructure, the detection of objects and people, disaster management, collecting data, transport and the environment, with monitoring air pollution and traffic flows being the most common use of drones. The authors conclude that whether used singly or in multiples, whether the technology is stand-alone or integrated with other systems (such as AI, IoT, cloud computing, machine learning etc.), drones “can offer efficient and sustainable solutions compared to conventional surveillance methods” (Gohari *et al*., 2022, p. 11). With specific reference to the use of AI and drones in smart cities, Shah, Jhanjhi and Brohi (2024) contend that AI is particularly useful in smart city environments and highlight several areas where they can be of particular benefit, such as healthcare, precision farming, identity management, and smart grid management. In contrast with some other studies reviewed, however, and along similar lines proposed by Khan *et al*. (2018), these authors make clear that there must be a holistic approach in terms of safety and security, one that combines “technology, legislation, and public awareness” to ensure “that the advantages of drone technology are achieved while reducing associated risks” Shat *et al*., 2024, p. 27).

This balance between safety and the undoubted potential for drone use in smart cities is also the subject of work by Dung and Rohacs (2018), who concentrate more extensively on the need for them to be safe, stable, resilient, and sustainable, and in this regard attention is paid to two drone-following models in traffic flows. One of these ensures a safe distance based on relative velocity while the other utilises the stochastic diffusion process of speed decisions. The fact that the latter produced better simulation results than the former is perhaps less important than the finding that both ensured safe distance, which leads to a recommendation by the authors that future work should incorporate drone states into these models. It can be proposed that it is the need for safety that should be the priority in terms of research and application because the literature strongly indicates that the technology exists to move forward but S&S lag behind such progress. In this respect Foina, Sengupta, Lerchi, Liu and Krainer (2015) note that a very important step forward in terms of the economy of a smart city is the ability of drones to deliver goods and information. While this is very feasible, however, it means drones flying at very low altitudes within densely populated areas, and this “cannot happen without a new generation of air traffic control and management services” (Foina *et al*., 2015, p. 351).

This notion (of a new generation of air traffic control and management) is one of several proposals to mitigate for the dangers posed by low flying drones. Another comes from the work of Rathee, Kumar, Kerrache and Iqbal (2022) and is that the problem could be solved through a ‘trust establishment scheme’ whereby “malicious devices can be traced and blocked by analysing and evaluating their historical interactions within the system and calculating their trust values” (Rathee *et al*., 2022, p. 255). It is difficult to understand how such a system could work effectively because it assumes that only malicious drones used previously would pose a threat.

One thing that emerges from the literature reviewed to this point is that while it is focused almost solely on potential on one hand and S&S on the other, relatively less attention is paid to the beliefs and attitudes of those who would be most affected by these positives and negatives, which is the citizens of smart cities. Such is the topic in the work of Tan, Lim, Park, Low and Yeo (2021), who carried out quantitative research in Singapore. The study found levels of acceptance depending on the environment in which drones are used – industrial areas had the highest acceptance levels, followed by recreational, commercial, and then residential areas, where there were the lowest levels. The study also found that citizens were able to understand and consider the potential benefits against the potential pitfalls.

An impression that can be gained from this very important and relevant section of this study is that while S&S is acknowledged, and while the challenges posed are identified, relatively few studies seek to find realistic solutions. Engagement with the citizens of smart cities is an important aspect but so too is engagement with experts in the field, who would be the users of drones. Such engagement would allow for the development of a framework for use, alongside the development of specific prototypes with properly evaluated sensor capabilities, to be used in specific smart city situations, such as traffic control. Such research should exist and stand alongside the potential uses and safety concerns that are most prominent across the relevant literature if meaningful progress is to be made.

While the use of drones in smart cities is of specific interest, it is important that their use in broader urban and environmental contexts is also reviewed.

2.4. Classification of Drone Applications for S&S in Environmental and Urban Contexts

2.4.1. Environmental monitoring

As the preceding section has identified, the potential use of drones across various sectors is an exciting prospect; however, whether it be flight times, the amount of equipment that can be carried, the attitudes of workers using them, insufficient regulation or, perhaps most importantly, safety issues, there are always caveats that lead towards relatively less use than that potential implies. Literature concerned with environmental monitoring continues along these lines, with exciting prospects entwined with cautionary notes. A pertinent example of this comes from Gallacher (2016), who notes that to be viable a drone-based service must offer comparable value to ground-based methods, which they potentially do. However, the substantial security, privacy and safety threats tend to be underestimated in the development and deployment of drones, which can lead to restrictions being placed on them, and this can undermine their value.

Seen in this light the trade-off goes beyond potential financial and data quality benefits and moves towards risks compared with ground-based (or satellite) alternatives but, as Gallacher (2016) suggests, this can only be properly evaluated once UAVs are more widely used. A way, perhaps, of breaking out of this cycle (where necessary restrictions are placed, which limits use, and which in turn makes proper evaluation impossible) may come through the introduction and application of local as well as national regulations. In his review article Gallacher (2016) first describes the potential uses of drones for environmental monitoring in urban places before considering reasons why this potential may not be fully realised. With regard to air quality management the possibilities include pollution monitoring, sound sensing for species detection, liquid/gas gathering for sampling, and the dispersal of gasses and liquids. The collection of water samples can be undertaken to monitor nitrate run-off in areas where intensive farming is taking place, as well as on or in-water sampling of lakes and rivers, with models either hovering above or landing on the surface. They can be used to monitor volcanic activity and may be used as an enhancement of existing sensor capabilities in smart cities, which are placed around such urban areas to monitor air quality. Drones can be used to inspect wind turbines as well (as noted above) as to inspect construction sites.

As Gallacher (2016) points out, distinctions can be made between near ground and much higher use as well as between the use of drones in urban compared with less densely populated areas. In terms of the former, “urban settings have a range of possibilities, but there is little, if anything, that has moved beyond the experimental stage to routine application" (Gallacher, 2016, p. 4). There are numerous reasons for this that are mainly concerned with safety, privacy and security. In terms of cost/benefit and manned aircraft Gallacher (2016) calculates that a 10-minute delay in take-off or landing costs more than the price of the drone that caused such a delay and that the closure of a runway for one hour would cost, at the time of writing, approximately $100,000. This is apart from the potential financial and human cost involved if there was a collision between a UAV and a manned aircraft. Conversely, if legislation is introduced that is not really needed, important conservation and other work may not be undertaken. Aside from safety concerns surrounding the use of drones at near ground level in urban areas is the potential for security breaches, such as the use of drones for unlawful purposes, and them being hacked or diverted. While higher altitude drones may be less of a threat to privacy, those nearer to the ground can be used in ways that make them "akin to paparazzi" (Gallacher, 2016, p. 9).

In concluding his work Gallacher (2016) emphasises the point that safety and other concerns are likely to severely limit the use of drones in urban contexts, regardless of developments that could extend those uses in numerous ways. Such a caveat could be applied to the work of Sharma, Muley, Singh and Gehlot (2016), which proposes a UAV that could be used to survey the environment but does not consider safety, privacy, security or regulatory implications. The proposed model is a quadrotor multi-rotor system which, aside from sending real-time data, can also transmit a video feed. Data is captured and displayed via a laptop, video pictures are received and recorded using surveillance cameras, and a graphical user interface (GUI), based on lab-view software, controls the multi-rotor. During the flight, sensors on the aircraft detect levels of flammable gases, CO2, and smoke. By detecting these, fires can be identified and prevented from spreading out of control. The quadrotor can also provide live video feeds of search and rescue (S&R) missions, or disaster relief.

As the preceding discussions imply, the extent to which drones may be used for environmental monitoring in urban compared with less densely populated areas is limited. A further limiting issue, in urban as well as other areas, is that drones, due to their relatively low size and weight in comparison with larger aircraft, are particularly vulnerable to atmospheric conditions (Watkins, Burry, Mohamed, Marino and Prudden *et al.*, 2020). Woo, Jin, Woo, Su and Hu (2021) also note limitations imposed by meteorological conditions, which can restrict the accuracy and functionality of sensor technology. Another salient point, raised in previous sections of this chapter, is societal acceptance of their use when undertaking environmental monitoring (Watkins *et al.*, 2020).

The work of Gallacher (2016) in particular highlights the quandary being faced in the use of drones, especially in urban areas. It explains why their potential is so lauded but in reality only a fraction of this is realised. Any cost-benefit analysis in urban areas is heavily weighted against UAVs because of S&S and privacy concerns, which suggests there should be a focus on holistic solutions, but such is generally missing from the literature. This represents a significant gap in current knowledge but it is one that can be addressed through the creation of a framework, informed by key stakeholders, and the development of prototypes with appropriately designed sensors that are directed at specific uses. This, as noted, is of particular relevance in urban areas and therefore to the management of such places.

2.4.2. Urban management

The theme of advancements in drone technology and use versus constraints based around safety, security, privacy and regulation continues in this sub-section through the work of Portas, Campaña, Bergesio and Barbolla (2022). These writers outline the possibilities for drones in urban environments, including air taxis, package deliveries, surveillance, gas sensing systems, roof inspections, construction management etc. before pointing out that a safe environment is assumed; therefore, there is a tendency "not to consider the flight safety constraints" (Portas *et al.*, 2022, p. 924). The purpose of the paper is to seek to at least partly address this tendency by describing the requirements for a flight planning tool that can be used to collaboratively plan flights, while considering traffic constraints and limitations using an unmanned traffic management system. To demonstrate examples of flight planning, a prototype tool is used. A set of possible flight planning use cases are defined, with interfaces and requirements that integrate existing flight planning processes with unmanned aircraft system traffic management (UTM) processes.

The fundamental aim of the work of Portas *et al*. (2022) is to show that there is a need for the integration of planning into traffic management in order that drone flights can be shown to safely take place. The work of Kim (2020) can also be associated with traffic management in urban environments, in this case with cyclists and pedestrians. Rather than safety, security and privacy these writers identify the main issue with their proposed model as being battery life, suggesting that technological advances are likely to overcome this in the future. There are descriptions of how a drone can be used to count pedestrians and bicycles, with the feasibility of creating two active transportation datasets that utilise drone technology being explored. These datasets include counts of active vehicles and measures of their volumes, as well as accurate quantification of pedestrian and bicycle activity. Five areas that were heavy with bicycle and pedestrian traffic on a university campus were selected for data collection. A systemic approach in which video footage acquired from a drone was converted into pedestrian and bicycle counts and spatial-temporal datasets of their volumes were created. These data, suggests Kim (2020), can be useful in a variety of ways in terms of planning and gaining a better understanding of pedestrian and cyclist behaviour, their volumes and density in specific urban places. The video footage, furthermore, confirmed that pedestrians and cyclists travelling on the streets were not disrupted or affected by the drone operation.

Using video footage to suggest that pedestrians and cyclists were not affected by the use of drones does not go far enough – a minimum requirement would surely be to ask them how they felt about it. Even firmer reassurance might come if there was a robust UAS UTM in place, in the same way that people are reassured by the knowledge that such a system is in place for manned aircraft. As Ali (2019) points out, while ATM (air traffic management) is clearly designed for manned flights, the increasing demand for and use of drones has led to calls for the adaption of this system to include a UTM. Proposals from commercial companies, including Amazon, have been put forward. As this is a company that wants to extensively exploit drone opportunities in urban areas, they are of interest. The company has proposed a number of classifications and one is based on 'equipage,' which is the technology and equipment carried. A second is four types of safe operation (basic, good, better and best), with all but 'best' requiring visual line of sight (VLOS) by an operator and limited to daytime use. The 'best' category would be allowed to fly beyond visual line of sight (BVLOS) in the night as well as during the day. Lower levels of Class G airspace (the uncontrolled space from ground up to 14,500 feet MSL (mean sea level)) is divided into three, which is up to 200 feet (low speed and for local traffic), 200 - 400 feet (for higher speed and transiting craft) and a 'no-fly' zone at 400-500 feet (Ali, 2019).

A number of other proposals for the urban management of UAVs are discussed by Tran and Nguyen (2022) and one is the concept of lanes and tunnels – routes above a city that follow, for example, specific highways and water channels, with categories of drones at various heights within Class G airspace. In terms of altitude layers this has similarities with the Amazon plan, as does the notion of altitude-based levels, with the addition of latitude and longitude to direct flight paths. As Tran and Nguyen (2022) point out, however, there are very significant legislative barriers that would have to be overcome before any of the systems became functional.

Overcoming such legislative barriers comes within the four stated aims of an article by Jiang, Geller and Collura (2016), which are to define a UTM system, consider industry practices from industry partners, describe how a UTM system would be used and the authority it comes under, and to set out the physical requirements for a UTM system handling a variety of drones. Although they may appear detailed, the majority of these objectives can be summarised from the work in a couple of sentences – a UTM system "consists of its own airspace and manager(s)" (Jiang *et al*., 2016, p. 128); a UTM system comes under the authority (in the US) of the FAA; the 'industry partners' are Amazon and Google, who have set out plans for the use of UAVs and "the physical architecture for UTM consists of four classes: sUAS (small unmanned aircraft systems) pilots, control centres, vehicles (sUAS), and airspace infrastructure" (Jiang *et al*., 2016, p. 129). If there is one potential item of interest from this work it is a summary of FAA proposed requirements as they were at the time of writing. This highlights the constraints being faced as the requirements include weighing less than 55lbs, line of sight only, no operations during the night, an altitude maximum of 500 ft, must give way to any other aircraft (including drones), the operator must be certified (or be supervised by such a person) and must take and pass a test of knowledge every two years. There are, surely, further constraints and one is the density of drone traffic if it were to be used as companies such as Amazon and Google desire. Another is whether the additional necessary costs would make economic sense and a third is concerned with security as well as safety.

A question that remains is the extent to which the proposed use of drones in an urban setting substantially advances existing methods of monitoring traffic flows. This is addressed by Outay, Mengash and Adnan (2020) in terms of intelligent transport systems, which are identified by these authors as being a main building block for smart cities. Emerging aspects such as autonomous and connected vehicles are creating pathways towards improved transport dimensions for citizens but automation is needed to go alongside these innovations if the potential of the technology is to be fully realised. The authors specify certain areas where this need exists and they are in the management of road infrastructure, the monitoring and management of traffic and the safety of highways. UAVs, contend Outay *et al*. (2020), can meet many if not all of these needs and this is supported in their review article by a consideration of the available technology in each of these areas. There are, however, constraints as well as solutions and these are also reviewed.

With regard to road safety, and citing the work of Mehmood *et al*. (2018), comparisons using multi-criteria decision analysis were made across four systems for incident management and these were a vehicle used by an incident commander, a helicopter, a manned drone and a UAV. The findings are that a UAV is less costly than a helicopter and a manned drone and can reach an incident site faster than an incident commander; therefore, in terms of response time, cost and availability, a UAV is the best option. These findings extend to the investigation of incidents using photogrammetry and to progress that has been made from initial focus on positioning to a more recent focus on software capabilities concerned with image processing and scene reconstruction. A similar position (where considerable progress has been made but with limited practical application) is found with regard to risk assessment, including the risk of collision in unusual traffic situations, analysing driving behaviour, and the production of terrain and 3D object models. Some of these models can be applied for traffic management as well as for risk assessment but in addition Outay *et al*. (2020) cite applications of drones in models that include the way vehicles behave on differing road sizes and composition, car following, gap analysis, critical points in a vehicle trajectory, lane changing behaviour and congestion causes (such as buses and delivery vehicles). The use of UAVs and progress made in the sub-field of the physical infrastructure of roads are also reviewed, including bridges and pavement distress.

Regulations and regulatory bodies are given attention by Outay *et al*. (2020) and a pertinent point made is that addressing safety concerns often requires additional equipment, which reduces flight times and therefore the capabilities of the model. The majority of jurisdictions allow the use of drones but with certain restrictions, the main one being a requirement that they remain within the VLOS of the person operating them. The FAA of the US, as well as authorities in other nations, do have waiver schemes and this may include BVLOS in certain circumstances, such as having detect-and-avoid capacity. In terms of technological constraints, a consistent theme that has emerged across this chapter is limited flight times due to battery technology, and this is also cited as a main constraint by Outay *et al*. (2020). These writers optimistically predict that flight times may be increased by as much as several hours in the future, for instance with the use of solar power, but also note that the increased costs of such drones may compromise the advantage they have over other approaches to traffic management.

A reason for dwelling on the work of Outay *et al*. (2020) is that it provided a comprehensive overview of the existing situation, including technical details, constraints and possible future directions. Work by Jiang *et al*. (2016) is more specific and detailed in terms of existing regulations on one hand, while considering the perspective of industry partners on the other. The article describes a sort of evolutionary process in the attitude of the FAA towards UTM, to a point where, with certain provisos, sUAS operations could “shift from being a science-fiction gimmick to an element of daily life” (Jiang *et al*., 2016, p. 123).

The need to integrate UAVs into existing systems and infrastructure is a theme that runs through the work of Jiang *et al*. (2016) and this is at the forefront of an article by Saputro, Akkaya, Algin and Uluagac (2018). Their work is concerned with the use of a swarm of drones to be used by mobile roadside units (RSUs) as part of an intelligent transportation system and one issue with regard to existing systems is long term evolution (LTE), which is the primary communications method between a drone and control centres. In instances where poor connectivity does not allow this system to operate a hybrid mesh is proposed. A further challenge is in terms of security and interoperability, whereby multiple agencies may, in certain circumstances, have access to drones and could override the autonomy of them. Alongside this are hierarchy issues in situations where multiple parties have drone access. This issue, argue Saputro *et al*. (2018), can be addressed within their proposed hybrid communication network through the integration of an authentication framework built on top of the newly released OAuth 2.0 standard, which ensures that only authorised users can control mobile RSUs.

The fundamental aim of the work by Saputro *et al*. (2018) was to propose a hybrid architecture to achieve smooth end-to-end communications by addressing interoperability issues between different standards. The performance of the proposed communication architecture was evaluated using a NS-3 network simulator under multimedia traffic (e.g., still images and video streaming) and it was found to be good, given that it was able to provide clear video streaming. Several specific aspects are noted, such as background traffic not having a significant impact on the LTE system and only a minor amount of frame loss due to blank spots, despite substantial end-to-end delays for multimedia traffic. However, the results showed that the manoeuvrability of a drone may result in significant frame losses when IEEE 802.11s and LTE are used simultaneously.

As found in previous sections, there is also the issue of technological capabilities and potential on one hand and safety/societal concerns on the other. A point made by Gallacher (2016a) is that weighing the safety benefits of drones in terms of managing traffic against any dangers they may pose could show their net worth. This may be true within a prevailing context where there is acknowledgement of S&S issues and fragmented suggestions in how they may be addressed. An alternative is to develop frameworks tailored to specific contexts, such as traffic control, and subsequently develop a suitable prototype with appropriate sensors and then do a benefits analysis.

The net worth of drones will, surely, be higher when they are used in emergencies and in the management of disasters.

2.5. Classification of Drone Applications for S&S in Public

2.5.1. Security organisations/First responders

The potential purposes that drones can be used for represent, in much of the literature concerned with them, positive steps in a range of dimensions such as providing safety in places (for example construction sites, mining operations, natural disasters and on roads) that may otherwise be dangerous for workers and rescuers, increasing the productivity of work and workers, protecting the environment, assisting in sustainability targets, and a host of other potentially beneficial uses. Specific areas where they can be of benefit in terms of S&S have been considered and more literature related to these aspects is reviewed in this sub-section. Across the perspectives on drone use there is, however, one that suggests their use has a more sinister, even insidious, purpose, and this is put forward in the work of Wall (2013).

Military technologies have been used in the controlling and pacifying of forces and territories that are external to the US and at the centre of these uses are drones, having been described by one defence official as being “the only game in town” when it comes to fighting terrorism (Wall, 2013, p. 33). Such technology has, according to Wall (2013), been imported and used by the police in the US and other countries as a means of extending this notion of controlling and pacifying from outside to within the nation. The writer cites the views of Marx and Foucault in terms of power and its use as a means of controlling through the inevitability and ‘malleability’ of insecurity, which requires constant attention on security, for instance through the ‘war on crime’,’ the ‘war on drugs,’ alongside the ‘war on terrorism.’ Various examples of drone use are cited, mainly manhunts, but it is important to contextualise the work of Wall (2013) – it does not see drones *per se* as being agents for control but as one of a range of tools that are increasingly being used for that purpose; the work comes from a particular ideological stance and does not suggest alternatives to tracking down and apprehending criminals if we are to live in relatively peaceful ways. The work of Wall (2013) may, nevertheless, have some use in terms of drawing attention to surveillance in the guise of security and protection.

Even Wall (2013) acknowledges the beneficial use of drones in some situations and highlights the fighting of forest fires as being one of these. It is also the subject of work by Roldán-Gómez, González-Gironda and Barrientos (2021), who note the challenges being faced in fighting forest fires before proposing a system of drone swarms to overcome these. The challenges are in three main areas, which are prevention, surveillance and extinguishing the fires, with various vehicles and machines (as well as humans) being the tools currently used (at the time of writing) to seek to overcome them. Two surveys were conducted among firefighting professionals in Spain, as well as interviews with key respondents. Based on the results of these a system was devised that used drone swarms that are able to assist in searching, surveillance, reconnaissance, mapping, supporting, tracking, monitoring and supporting. The system proposed three human roles, which are the mission leader, team leaders and team members, with a fundamental benefit of the system being the efficiency and timeliness in which tasks could be carried out in comparison with the current situation (drones have rarely been used to date). Two additional and important points that emerged from the surveys and interviews are that drones could have a role in assisting with post-fire investigations and that firefighters were found to be supportive of the use of drones in their work. It is proposed that the main important theme that emerges from the work of Roldán-Gómez *et al.* (2013) is engagement with professionals within the sector before designing an appropriate system.

In contrast with Wall (2013) Daniel and Wietfeld (2011) highlight the positive aspects of using drones in terms of homeland security, highlighting areas such as uncontrolled emissions of dangerous substances, natural disasters, fires and terrorist attacks as well as surveillance and their use in police operations. However, they also highlight the issue of frequencies used for civilian purposes and the fact that the pool of these is, in the US, close to being exhausted. The article therefore discusses the civilian concept of operation (CONOPS) for UAVs, especially small models. Based on existing constraints and user requirements, they propose viable concepts at the system level for leveraging public wireless communication networks for UAV-based sensor networks. Coverage, existing infrastructure, and frequencies can be beneficial in overcoming delays and reliability constraints. Even with relatively small investments in communication awareness and autonomous UAVs, CONOPS can, posit Daniel and Wietfeld (2011), significantly improve rescue workflow.

2.5.2. Public security

The potential for using UAVs to support and enhance wireless communications, particularly in emergency situations, is also the subject of work by He, Chan and Guizani (2017). However, while a main concern of Daniel and Wietfeld (2011) was with coverage, infrastructure and frequencies, He *et al*. (2017) focus on cyber security. Incorporating drones into public safety networks can reduce network congestion and coverage gaps and, due to the controllable mobility of low-altitude versions, these systems are generally cheaper to operate and faster to activate than conventional solutions. In addition, drones can be used to observe and analyse situations involving disasters since they can reach areas that first responders cannot. As He *et al*. (2017) point out, however, networks are, in general, becoming more complex, which gives rise to more opportunities for security attacks.

There is a need for data safety on drones because sensitive information may have to be sent between network participants. The study by He *et al*. (2017) examined cybersecurity issues involving such networks and found causes for concern, with the minimum necessities being security features for confidentiality, privacy preservation, etc. A first step in having such preventive tools is the creation of cryptographic keys for use in a drone-supported public safety network, with more research, according to He *et al*. (2017), being needed. Coverage rather than cybersecurity was the main issue covered in work by Li, Guo, Yin and Wei (2015), with this being achievable through a nationwide system in the US. This wireless broadband network would be able to cover areas where land-based relays were not easily deployable through the use of drones. A drone and Rayleigh fading model were proposed, with the data rate of each hop increasing in the time allocated following a concave pattern. The study proposed that the multi-hop device-to-device (D2D) drone's communication be extended to the wireless coverage of the public safety network. With transmission power being fixed, the drone is needed only if the distance between the terminal divide and the base station exceeds a threshold. The rate of data collection was found to increase when the drone was deployed and when the transmission power and distance were beyond its threshold. The work concludes with a recommendation that D2D drone communication with different types of drones be studied.

A further issue related to public security, and one that was given some attention in the preceding sub-section, is crime and the potential for drones as a tool for reducing crime rates. Following the identification of system architecture that helped identify the required characteristics Kwon, Yoon, Kim and Kwon (2017) introduced a quadcopter-based auto-patrol drone that had an Arduino platform-based (APM) on board, a GPS module, and a camera that worked together with a smartphone application to track a person's location and view images installed in real time. The system was tested and there were concerns about the drone's infrared sensor, which were overcome by upgrading the buzzer and LED sensor module as an alternative. Flight testing used the autopilot mode and this worked well, with images being seen and heard in real time. The biggest potential impact implied by the outcomes was, according to Kwon *et al*. (2017), the replacement of unnecessary manpower with drones, although the latter's actual efficiency needs to be evaluated for future projects.

One motivation for the testing of drones for shark detection by Butcher, Piddocke, Colefax, Hoade and Peddemors *et al.* (2019) was a number of unprovoked attacks by such creatures on beaches in New South Wales in the period 2013 – 2015 while another was concerns about the environmentally harmful effects of techniques being typically used for the capture and/or detection of sharks. The authors used a multi-rotor drone (DJI Inspire 1) to detect shark analogues over a period of three weeks, with the 27 flights covering a wide range of environmental conditions, including diverse profiles of wind speed, turbidity, cloud cover, glare, and sea level. The results found that detection rates were significantly higher for an independent observer undertaking video analysis following the flight than for in-flight observation and that very few observations were made at depths of more than 2 metres. Main conclusions reached by Butcher *et al*. (2019) are that drones can operate in various environmental conditions, that they are most effective in observation over shallow water and when there are light winds, and that they may be a useful means of protecting bathers (given that sharks are often near the surface).

Drones themselves can also be a threat in civilian as well as military spheres, posing in the former (civilian) dimension “serious security threats to public privacy” (Jamil, Rahman, Ullah, Badnava and Forsat *et al*., 2020, p. 3923). The detection of such ‘malicious’ drones has therefore been the subject of a tranche of work that includes the creation of a framework by Jamil *et al*. (2020). Using machine learning techniques, the study detected airborne UAVs with high precision by using acoustics and image processing. Two models are cited for the experiments undertaken and these are Mel Frequency Cepstral Coefficients (MFCC) for audio extraction and AlexNet for extracting image features. Both models performed, according to Jamil *et al*. (2020), very well, with a combined accuracy of 98.5%. The authors claim that the model is relatively inexpensive due to the small number of datasets used, that it has the capacity for wireless communications to be incorporated into future versions and that it could be adopted quickly and accurately by national security agencies to locate malicious UAVs. The authors seek to support their claims by citing other related work where the results indicated less accuracy and where there are disadvantages in these proposed other systems. The related works cited are, however, relatively small in number, and no criteria are given to suggest objective selection criteria, which indicates the possibility that more favourable examples could have been cited.

The purpose of a research study by Nguyen, Nguyen, Manley and Saidi (2020) was to gain an understanding of ways in which drones were being used in public safety operations and, further to this, to find how they may be more widely used in the future. Data was collected through a survey administered to first responders (n=183), which found that there was still a need to maximise the flight time of the drones. As a result, it was able to identify the most critical drone requirements for public safety when they are used to supplement or provide wireless communication infrastructure, which effectively revealed perceived limitations. These included flight times, where a majority of respondents cited 120 minutes as being necessary for maximum effectiveness, a preference for a mix of both tethered and untethered drones, 94% wanted cellular broadband for their operations, and 70.5% indicated they would need to fly their drones at a certain altitude, with 200-400 feet being the most preferred range. Further limitations included operational efficiency, incident response times and having sufficient expertise but the authors nevertheless state that “the results of this survey lay an important foundation for future research and testing of resilient systems for first responders" (Nguyen *et al.*, 2020, p. 21).

One benefit of the study by Nguyen *et al*. (2020), in some contrast with many works cited in this chapter, is a realistic appraisal of the drawbacks, rather than extolling only potential benefits. However, while the recommendations made for future research have validity, it is possible that this and many of the studies reviewed in this chapter may be limited by a sole focus on the US and the US regulatory regime. It may have been beneficial, for instance, if there were such studies that included first responders from other countries, from other cultural contexts, who operate within different regulatory regimes and who may have experience in events, including emergencies and disasters, that US professionals have not had. Such points are given emphasis by Yaacoub, Noura, Salman and Chehab (2020) who note that the whole world has seen great and continuing increases in the use of drones due to their potential in addressing the needs of people across many domains as well as across the globe. As is pointed out by Yaacoub *et al*. (2020, p. 1), however, the usefulness and utility of drones has not just been recognised in terms of being beneficial as "drones are not being used exclusively by 'good guys'; 'bad guys' are (also) leveraging drones to achieve their malicious objectives."

The motivation for the review study by Yaacoub *et al*. (2020) is stated as being an understanding that relying on wireless communications inevitably makes UAVs an easy target for hackers with malicious intent. Two main aspects were reviewed before some recommendations are made by the authors for countering the threats posed. To these ends successful experiments to detect, intercept, and hijack a drone through de-authentication or jamming were presented. It is stated that these were undertaken based on realistic scenarios that followed the established hacking cycle, verifying the ease with which drones can be intercepted, particularly regarding their communication channels. The recommended counter measures include the licencing of drones, tracking them across their purchase history, stronger laws, enhanced detection methods, stronger authentication schemes, and only allowing their flight over "certain confined and designated areas" (Yaacoub *et al*., 2020, p. 8).

The validity of their work and relevance of the recommendations made by Yaacoub *et al*. (2020) to at least moderate the effects of those with bad intentions is not denied. They do, however, suggest the imposition of further restrictions on drone use when other work has shown that the regulatory regime around safety already places strict limitations on their use. This trade-off (between use and regulation), it can be argued, adds to the dichotomy between technological progress and regulations. The term 'trade-off' is also used by Azari, Sallouha, Chiumento, Rajendran and Vinogradov *et al*. (2018) in the title of their work, which is concerned with systems that can be used in the detection of amateur drones, and which are not allowed to fly at certain heights or in certain areas for obvious reasons. Two detection methods are cited, with one being described as active and the other as passive. The former uses ground-based infrastructure (radar) to locate amateur drones while the latter (also requiring ground infrastructure) detects the source of any transmissions from the drones in question. The disadvantage (of requiring ground infrastructure) is enhanced in urban areas because more of it will, according to Azari *et al*. (2018), be required.

Based on these disadvantages Azari *et al*. (2018) propose the use of surveillance drones as an alternative. These would be equipped with (passive) sensing equipment and would be particularly effective when flying at a higher altitude than any amateur drones. A range of technical details are covered in the study and these may indicate the theoretical feasibility of such a system, which leads the authors to a final conclusion that "we expect that academic and industrial research and development activities can use the proposed framework to address the drone surveillance challenges introduced in the paper" (Azari *et al*., 2018, p. 8). Bearing in mind the expectations placed on their surveillance drones there is, it is posited, one drawback that may make their expectations seem somewhat optimistic. This is the fact, noted under a sub-heading titled 'network lifetime,' that the lifetime of the surveillance drone is less than one hour.

A main theme that emerges from this section is the importance of designing drone models for specific scenarios and roles. What is somewhat lacking is the development of an informed framework for such situations and scenarios. This is also one of many challenges that will inevitably be present when organising and presenting mega and sporting events.

2.5.3. Mega and sporting events

As Nadobnik (2016) points out, the use of technology now permeates human life and many, if not most, human activities. For good or bad, it also features highly in large scale sporting events and one increasingly used item of technology is drones, which were used quite extensively at the 2016 Olympic Games in Rio de Janeiro. Such an event encompasses many of the dimensions of drone use covered in various sections of this current literature review, with one example being in the early phases when they are used to survey the land where the proposed Olympic Games infrastructure is to be built, extending from that point to actual construction. As well as being used in the construction and preparation phases, drones were employed over the course of the event itself. With regard to policing, monitoring and general security, organisers at the Rio games used a US-Israeli produced Hermes 90010 drone to take photos and videos; with 17 onboard cameras and a system for monitoring pedestrians and vehicles, this UAV could detect potential dangers on foot and on the road over an area of

100 square kilometres. It was equipped with advanced sensors that could identify faces and licence plates above the ground in an observation area covering several square kilometres. Also used was the Skunk12 (drone), which is specifically designed to suppress protests, operating according to similar principles to those of riot police. Stroboscopes and blinding lasers were also included in the drone.

Drones were used as substitutes for the much more expensive manned helicopters by journalists and TV companies and were also used to hot-spot internet capabilities in areas where it was otherwise lacking. The popularity of local beaches, as well as their use for some events, created a strong need for enhanced safety measures and to this end drones with emergency equipment, including the Dragan Flyer X4-ES16, were used. This UAV can guide rescue teams when boats sink, with drone-mounted cameras several dozen metres above the water or beach observing the surface. The devices are controlled by pilots on fast boats which have professional rescue equipment, and the pilots coordinate with rescue teams. A further noteworthy factor, and one that has arisen in literature previously reviewed in the chapter (for example Yaacoub *et al*., 2020; Azari *et al*., 2018 – see previous sub-section), is that the Brazilian government introduced much stricter legislation concerned with the private use of drones prior to the event, including much stronger penalties for breaches of that legislation (Nadobnik, 2016).

While Nadobnik (2016) proposes an overall positive perspective on the use drones at the Rio Olympics, a more sinister one is set out by Ferrari (2023) concerning preparations for the Olympic Games in Paris for 2024. The argument is made that what would otherwise be seen as being 'exceptional' security and surveillance methods became normalised because of the event. The term "surveillance capitalism" is used to depict the "total information awareness" that governments can gain when there is "strict cooperation" with private companies (Ferrari, 2023, p. 77). It is not the technology, in this instance the deployment of drones, that is the problem, it is the fact that 'exceptions,' defined as necessities during mega supporting events such as the Paris Olympics of 2024, become the grounds for turning these exceptions into norms. This is something that is done in conjunction between the state and private companies without any reference to the consent of the population.

The work of Nadobnik (2016) in providing an overview of drone use at a mega sporting event is useful and informative, while that of Ferrari (2023) provides an insight into why their use is a concern in some quarters, a concern that goes beyond safety fears. Another perspective is one that focuses on one specific and very important aspect of such an event and that is the use of drones for emergency medical and other support, for instance if a fire breaks out. As Kumar and Jeeva (2017) point out, the extremes that even fit and healthy athletes place on themselves when competing can lead to very serious health problems, including fatigue, dehydration, and cardiac arrest. There have been instances when fires have unexpectedly broken out, for instance during football matches, and these have caused considerable numbers of casualties and injuries to spectators. The prompt provision of first aid kits and fire extinguishing capabilities are therefore very important requirements and to this end Kumar and Jeeva (2017) designed an unmanned aerial assistance system (UAAS) that can help athletes when geography and distance prevent timely assistance from the ground. The system can control specific geographical areas to prevent fires through elide fire extinguisher balls, with the further capacity to provide airborne first aid to dehydrated and injured athletes. To test how the proposed solution reacted to emergencies, the researchers attached electronic devices to players and the drone and it was determined to be effective at improving patient safety. There was also an alarm button, whereby players could summon medical assistance (for themselves or others) by clicking on an SOS button. The system sent their location and vital signs to a drone that carried a first aid kit to them.

There are some questions that can be asked of the work by Kumar and Jeeva (2017). Two possibilities are cited, which are when the drone is already in the air when an emergency is called and when it is static. In the former instance it will be very limited by battery life and if it is the latter, it is effectively describing the functions of an air ambulance. With regard to the use of elide fire extinguisher balls, their effectiveness may be questioned, particularly as fires once started to a detectable level tend to spread very quickly.

One thing that can be said of this area of drone use is the relative lack of research undertaken when it is emerging as a very important aspect of international interaction and cooperation, and one where drone use can be central to maintaining cross border relationships and ensuring successful and harmonious outcomes. This clearly represents a gap in existing knowledge. Such a gap is less obvious in more traditional and longstanding sectors, such as healthcare.

2.6. Classification of Drone Applications for S&S in Healthcare

2.6.1. COVID-19

On one level an article by Skorup and Haaland (2020) is about the ways in which a crisis such as COVID-19 can open new dimensions for the use of drones but on another it is about regulation and how this can dampen or even prevent any meaningful progress. The US had the capability to use drone deliveries across a whole range of areas related to COVID-19 when the imperative was that lives should be saved by reducing or eliminating human-to-human contact. Examples of this capacity are cited by Skorup and Haaland (2020) with regard to the use of drones by US companies to deliver to rural hospitals in parts of Africa. That such technology was used by the Chinese government during the COVID crisis is also cited, whereby drones were used not only to bring medical supplies for patients in hospitals but also to collect and deliver samples to testing laboratories in a timely fashion so that quarantining of individuals and communities could be instigated as early as possible. Such services, argue Skorup and Haaland (2020), could have been adopted in the US and expanded to include, for instance, the delivery of groceries and other services in urban areas. That this potential was not realised was institutional, not technical. To support their arguments Skorup and Haaland (2020, p. 2) cite the CEO of Zipline, who stated that "We're essentially waiting for the U.S. government to catch up to a country like Rwanda, in terms of using [drone] technology."

Based on an assumption that COVID-19 (excluding, apparently, the US) "has forced the world to present new implementing measures which will also widen the use of drones in civil and commercial and social applications" (Euchi, 2021, p. 1), the question, according to Euchi, 2021), is how that use can be optimised? In concurrence with Skorup and Haaland (2020) Euchi (2021) also notes the ways in which drones have been used in delivering aid in Africa when the terrain and remoteness of some settlements limits other choices. Ways of optimising drone use in COVID-19 are set out by this author but, again in agreement with other writers, limitations imposed by laws and regulations are found to be a major impediment. Rather than being over-critical of this, however, Euchi (2021) makes recommendations that include the development of "a continental regulatory framework for the use of UAVs worldwide" and the fostering of "collaborations, partnerships, networks and knowledge exchanges" that will "facilitate the generalization and use of drone technology" (Euchi, 2021, p. 8).

Another way of optimising the use of drones during a pandemic is proposed by Kunovjanek and Wankmüller (2021) and is through a capacity to transport and deliver COVID-19 test kits to people who may be infected with the ailment. The idea is not to create a new system or type of drone but to change the use, when necessary, of existing fleets of them. This is supported by the author, who notes that drones have already been used to deliver medical supplies in some developing nations where there are issues with infrastructure as well as across terrains that are both remote and challenging. Such a model (where existing drone capabilities are transferred to test kit delivery) is created by the author, who claims it can function with little or even no additional investment. A major hindrance is, however, identified by Kunovjanek and Wankmüller (2021), and it is the same issue identified by other writers, for example Skorup and Haaland (2020); Euchi (2021). This is existing legal and regulatory frameworks and the recommendation by these authors is that future policies and regulation will "have to look different" (Kunovjanek and Wankmüller, 2021, p. 149). This difference should be within a new and targeted legal framework that includes and encourages public-private partnerships.

A relevant point with regard to the Covid-19 pandemic is made by Javid, Haleem, Khan, Singh and Suman et al (2022) and it is that the event revealed the extent of disparities in healthcare across the world. The extent to which drones may be a significant factor in addressing these disparities is an important issue.

2.6.2. Healthcare and medicine

A dominant theme from the preceding section, and one that permeates this chapter, namely legal and regulatory hindrances, is also highlighted by Balasingam (2017, p. 1), who identifies a legislative lag that is "slowing the proliferation of drone use." Despite this the author contends that drones have the potential to transform medicine and healthcare in future years and decades. To support this current application and future potential are explored, with the former including the delivery of testing kits for HIV, tuberculosis samples, aid packages, medicines, vaccines, blood, and other medical supplies to remote areas. With regard to potential, drones will be able to assist elderly populations with mobility issues through robot-like technology and can augment telemedicine with diagnostic imaging capabilities to enable remote community health assessment. Further potential includes the delivery of defibrillators to heart attack victims, with direct links to emergency personnel who can instruct people assisting the patient, and the delivery of other life-saving supplies when a disaster occurs. As well as the legal and regulatory hindrances previously cited, however, drone use in the medical field is also hampered by legacy regulatory restrictions (e.g., mandating that certain products be handled by authorised personnel, whereby they cannot be transported by drone), which need to be addressed and updated.

Despite these regulatory concerns, Balasingam (2017) suggests an optimistic future concerning the use of drones in the field of medicine and healthcare. An optimistic future is also suggested by Ullah, Nair, Moore, Nugent and Muschamp et al (2019) with regard to 5G and, within this, to the use of drones. These authors suggest that 5G will pave the way for smart technologies and the IoT through continuous and ubiquitous internet communication that connects everyone to everything, anywhere, anytime, and through any device, service, or network, regardless of geographical location. With a high density of base stations and devices, 5G will also mean a paradigm shift with high carriers' frequencies and immense bandwidths. Current drone limitations are discussed, for example altitude ceilings and interference, as well as complexities around the use of multiple UAVs, and how these will be considerably improved with the introduction of 5G. Implications for drones include online consultation, online health monitoring, remote diagnosis, and mobile robotic surgery.

COVID-19 was not the only health emergency of recent years and one that was of considerable concern at the time was the outbreak of Ebola in West Africa in the period 2013-2016. As Amukele, Street, Carroll, Miller and Zhang (2016) point out, the epidemic was worsened by badly maintained roads as this delayed the transportation of biological samples. Along with the other regulatory hindrances discussed in this section, another is brought to attention by Amukele *et al.* (2016) and it is that specific validation of biological specimens is a medical requirement. The aim of the study was therefore to test whether microbiological specimens could be transported by UAVs without compromising them. UAVs were flown for 30 seconds after being seeded with pathogens, and were then flown for a further 30 seconds to examine their impact on microbiological specimens. Approximately half of the samples were then flown in the UAV for 30 minutes each and it was found that the drone transportation system tested in this study had no negative effects on the growth times of sample types or microbes.

Again in an African context, the results from a review article by Nyaaba and Ayamga (2021) make some additional and noteworthy points about the benefits as well as challenges that come from the use of drones in healthcare. Along with the collection and delivery of samples, vaccines and drugs, the benefits include drastically reducing response times and environmental friendliness (drones use less power than conventional delivery means such as cars and trucks). Apart from regulations, potential misuse and cost, additional challenges include psychological impacts on people who have previously experienced bombing by military drones. There may also be issues concerning the ability of others to use the medical equipment being delivered, with an example being automated external defibrillators (AEDs). If such challenges are overcome, drones can, in an African context, be a very good example of 'leapfrogging,' whereby developing nations are able to skip past incremental technological development and therefore arrive quickly at an equal point with advanced countries (Nyaaba and Ayamga, 2021).

With a few exceptions the works reviewed in this and the previous section have been concerned with the outbreak of a pandemic (COVID-19) and an epidemic (Ebola). An observation that can be made is that the deployment of drones in these situations was influenced by them being potential disaster situations. Such situations can be further reviewed.

2.6.3. Disaster relief

Rejeb, Rejeb, Simske and Treiblmaier (2021, p. 1) state the purpose of their systematic literature review as being to “synthesize prior research on drones and cumulatively identify current knowledge gaps which require further investigation” and three research questions are set. These are to find out the current state of research regarding the use of drones in humanitarian logistics, to find out what the barriers and capabilities of drones in this capacity are and to identify any existing research gaps in this domain. Following a long and detailed outlining of the review process the results are presented and these are that drones are useful in transportation and delivery in humanitarian logistics, they have been widely used in surveying, monitoring and assessing disaster scenarios, and they can be used to provide communication networks in such situations. Further findings are that drones can be flexible and responsive in disaster situations, for example by being able to fly over blocked roads and other infrastructure, they are cost effective and they can foster environmental sustainability. Attention then turns to issues related to technology and privacy, where we are informed that the performance of drones can be affected by adverse weather, that they are limited in payload weights and flight duration and that a reliance on connectivity could be compromised in disaster situations. We are then told that there are privacy issues with the use of drones. Rejeb *et al*. (2021) then move to other barriers and the finding that organisations may have cost and expertise barriers and hindrances that come from regulatory requirements.

It is somewhat difficult to agree with some of the claims made by Rajeb *et al*. (2021) concerning the value of their work, for example that it “fills an important knowledge gap,” given that no new knowledge is presented. These authors state a desire that under-researched areas concerning the use of drones for humanitarian purposes are researched; given that it is unlikely that new studies will investigate over-researched aspects, this will include most new work undertaken and this includes that by Tanzi, Chandra, Isnard, Camara and Sébastien *et al*. (2016). Their work is primarily about the future potential of drones in disaster management, whereby a new generation of UAVs may improve SitAw and information assessment. This could result in significant advantages, such as improved efficiency and reduced risk as disaster rescue teams may be relieved of the burden of tedious data collection tasks as well as enabling more accurate guidance for research operations. Sensors, including optical ones, can be readily installed on UAVs, depending on the requirements of their possible missions and this means being able to see underneath clouds because of their altitude, which produces better images.

UAVs, posit Tanzi *et al*. (2016), could be deployed based on specific needs identified by search and rescue teams, with one example being the finding of paths for victims who are stranded in flooded areas. The possibility of finding people who are buried following a disaster is set out in a scenario involving the detection of devices such as smart phones belonging to victims. Such a detective capability could also be used to direct operations based on the density of signals detected at given locations. In contrast with some authors, Tanzi *et al*. (2016) do not make any exaggerated claims and appropriately contextualise the future potential they outline. One 'indispensable' condition, for instance, is that the drones must be autonomous because without that capability "it would be not possible to correctly integrate these new tools within the activities flow of rescue teams" (Tanzi *et al*., 2016, p. 188). They also acknowledge that in lieu of field experiments it is not possible to validate certain claims and assumptions, for example mobile phones are set up to search for available networks, which uses full power; it is therefore possible that batteries would drain quickly, thereby lessening the effectiveness of the drone detection ability described.

Despite this potential drawback the issue of victim identification following a disaster, and the development of this aspect of drone usage, is strongly recommended by Daud, Yusof, Heo, Khoo and Singh *et al*. (2022) following a scoping review study. The study also found that drones can be of great benefit in the training of emergency medical services personnel and cite a simulation study to support this contention. The study, by Fernandez-Pacheco, Rodriguez, Price, Perez and Alonso (2017), involved 40 students who were provided with a mass casualty incident simulation. The findings show that the use of drones enhanced the self-perceptions of the incident by the participants and "allowed the students to remember events or situations that were forgotten or ignored" (Fernandez-Pacheco *et al*., 2017, p. 3). The fact that a majority (80%) of the participants self-assessed improvement as a result of the employment of drones may be of importance in terms of accepting and being willing to work with this technology.

The rationale for their experimental research is explained by Maher and Inoue (2016) – many people die in the immediate aftermath of disasters, particularly earthquakes, because of unplanned evacuation routes. It would be of great benefit, therefore, if the status of evacuation and evacuation routes could be tracked immediately in a real-time alert system after an incident occurs. Drones have the potential to be used to do this for a variety of reasons; they can be flown at high speeds, they can assess the status of a route, the conditions of buildings, or the movement of survivors. The study by Maher and Inoue (2016) utilised a machine-to-machine (M2M) system, which was integrated into a drone. The drone was used as a third-party robot, or endpoint of the M2M architecture, to track survivors and build routes after a disaster, as well as to provide visual data of damage. Using a Parrot Drone 2.0's camera, a video was fed to the device to verify the accuracy of the tracking and three tracking experiments were subsequently conducted. The researchers found that multicolour tracking and upper-body tracking performed better than full-body tracking, although the tracking method depends on the target's appearance, the environmental characteristics, and the tracking approach.

Even though it would have been useful if Maher and Inoue (2016) had commented on the potential to assess route status and surrounding conditions in more detail, theirs is a useful study that may assist in ongoing research. Something similar may be said of an experimental study undertaken by Abrahamsen (2015). In providing the background and justification for the work Abrahamsen (2015, p. 1) points out that major incidents are "complex, dynamic and bewildering task environments characterised by simultaneous, rapidly changing events, uncertainty and ill-structured problems." Such an environment makes the management and allocation of vital but limited medical equipment challenging as there will often be a reliance on "sparse information and data." As this indicates, communication and the sharing of information is critical but is usually undertaken through voice-to-voice methods, typically using phones or radios. This indicates that important and abundant visual images are, at best, difficult to communicate.

An experimental feasibility study was undertaken by Abrahamsen (2015) to see if this problem could be overcome, or at least moderated, by the use of UAVs. A remotely controlled, multi-rotor UAV with vertical take-off and landing (VTOL) was equipped with colour and thermal imaging cameras, a laser beam, a mechanical gripper arm, and an avalanche transceiver and the following four simulated exercises were conducted: (1) mass casualty traffic accident, (2) mountain rescue, (3) avalanche with buried victims, and (4) search for casualties in the dark. Following these experiments a number of limitations are noted and these include payload restrictions, tolerance to weather conditions and some electromagnetic interference. The author nevertheless concludes that the UAV could be used as a tool carrier within its payload limitations and it "can be used to support situation assessment and information exchange at a major incident scene" (Abrahamsen, 2015, p. 8).

An impression from this section of the review is that the provision of healthcare by drones, including during the COVID-19 emergency, could be very beneficial but similar issues as emerged in previous sections are notable, for instance frustration at the lack of sufficient regulatory regimes, potential that exists but which is largely unrealised, and experiments conducted in ideal rather than real-life situations. What is largely missing are proposals for comprehensive solutions, for example in the development of frameworks for each situation along with appropriately designed models and sensors. Such challenges may be moderated in disaster scenarios because the S&S costs are outweighed by the benefits that can be gained. Even here, however, there is a significant issue regarding power limitations.

2.7. Power Limitations

The issue of the power limitations of UAVs is one that has been a feature of this review thus far. It is clearly of great importance but is often put to one side in studies seeking to promote the benefits of drone use in one sphere or another, or to highlight the advantages of one particular model. Even though it is not one of the identified and classified themes (see Fig. 2.2), it has relevance to this work and is therefore considered as being important enough to warrant a section of this review. Hopes are expressed in the literature that the issue of power limitations will in the future be resolved as battery and other technologies make further advances but despite this optimism it remains a significant barrier.

The use of the internal combustion engine for drones is a potentially appealing one due to its power and energy density. It is, however, discarded in favour of electric power as this brings the advantages of less noise, better control, reliability and reduced thermal signatures. The hybridisation of both engine types is a possibility that is also discarded due to increasing environmental concerns in the aviation industry (Boukoberine, Zhou and Benbouzid (2019). There are more options for fixed-wing drones, for example in the ability to carry solar panels. However, batteries are currently the only feasible option for multi-rotor drones and the option of carrying more of these is not practical because of constraints around weight and space.

Electro-aerodynamic propulsion (EAD) “relies on the transport of electrically charged particles in the air” (Grosse, Moreau and Binder, 2024, p. 2). Advancements have been made in EAD thrusters and to the possibility of them being viable in enhancing the power capacities of drones. A test case was conducted using a commercial drone with EAD thrusters but it was found that a significant increase in flight times given a 10 kg load and a maximum height of 30m would need the EAD thrust capacity to be doubled. Significant developments would be required to achieve a target of 2 hours 20 mins at 30m altitude, which leads Grosse *et al.* (2024, p. 25) to conclude that “tremendous work is required to achieve these targets.”

Another potential source is microwave power transmission and an experiment was conducted by Moro, Keicho, Motozuka, Matsukura and Shimamura *et al.* (2021) in an anechoic chamber with a drone and indoor GPS. The drone, flying at 800mm, and with two rectannas attached to receive from two horn antennas, was “able to continuously receive power for about 20 seconds, and the maximum overall efficiency was 0.044 %” (Moro et al., 2021, p. 1). As with

EAD, microwave power transmission may have potential for the future but, as with EAD, some serious obstacles need to be overcome before it can be used in practice.

Although laser charging was first demonstrated as workable by NASA in a large building in 2003 (NASA, 2004), it is still categorised as being futuristic, even “novel technology” (Lahmeri, Kishk and Alouini, 2023, p. 518). The way such a system operates is that a laser on the ground sends a beam of light to a receiver located on a drone. The receiver acts in a similar way to a solar panel, transforming the energy received into electricity. As with other systems, however, it is one thing to show that laser charging works in principle, and even in ideal indoor conditions, but another to show it works in realistic and practical environments. To this end Lahmeri *et al.* (2023) modelled the system’s communication capabilities in a number of environments and at various charging levels. It was found that coverage decreased when weather conditions were less than ideal, for example by 12% when they were moderate to strong, and that when the range was short the connection rate decreased by a significant amount. This leads to a conclusion that drones powered by lasers are, at best, an “interesting alternative” when used “in low-to-moderate optical turbulence, and at reasonable ranges from the charging stations” (Lahmeri et al., 2023, p. 518).

A further possibility is swapping, which fundamentally means either swapping the drones or changing the batteries for the same drone at a docking station. Attempts have been made to make such systems more efficient and an example is an ‘inverted docking station’ whereby positioning systems and gripping mechanisms make it possible for the batteries of a drone to be changed without the necessity of unloading (de Silva, Phlernjai, Rianmora and Ratsamee, 2022). It can be proposed that if a docking station is autonomous and if it is conveniently located it may have some potential but limitations in terms of range and time lost having to revisit it will still exist. A way of ensuring a continuous supply of power is through tethering, where the drone is attached by a line to a ground-based supply of power. While this clearly resolves the issue of power, it will limit the sphere of operations, although this could be partly resolved by having a mobile source of power (Boukoberine *et al.*, 2019).

2.8. Chapter Summary

The development and use of drones in a military capacity has shown that in this sphere they can be very effective, albeit in often brutal and devastating ways. This effectiveness, however, is in many respects because a range of factors can be disregarded which cannot be overlooked when it comes to civilian uses. This fact produces a sort of undercurrent that runs through the literature, an undercurrent that is sometimes ignored or at least underplayed. On one hand are experiments (typically conducted under ideal conditions that do not often exist in the real world) demonstrating the potential for drones to be used in a wide range of very beneficial ways and across a swathe of industries and sectors, while on the other are reasons why this demonstrated potential is not put into practice.

Many examples of the positive uses of drones have been found across this chapter. In construction they can strongly assist in providing site safety and security, they can enhance the role of the site manager, they can conduct inspections in places that would otherwise pose dangers to workers, they can survey terrain and they can be tools that survey land and build accurate 3D models of proposed structures. In mining they can allow access to places that are otherwise inaccessible, they can detect toxic substances, substantially reduce the dangers inherent in blasting, and can contribute to the environment and sustainability, for example through the detection of potential coal fires and mine moisture. The potential of drones in smart cities and urban areas generally is huge, ranging across many of the challenges faced by city authorities, including traffic monitoring and control, policing, crime prevention, gas sensing, water management, roof inspections and the delivery of packages as well as air quality and pollution monitoring. Drones undoubtedly have the potential to contribute towards the saving of human lives across a range of domains, including natural and other disasters, where they can become the ‘eyes’ of first responders in coordinating relief efforts, in finding safe exit routes for survivors, in delivering emergency medical supplies and even in detecting people who are buried. They have been demonstrated as being capable of delivering testing kits and necessary supplies during pandemics and endemics, which is of particular benefit when human contact is to be avoided.

Even when the overly optimistic claims made by some researchers are taken account of, the potentially beneficial uses of drones are more than clear. Although not given sufficient attention in some of the work reviewed, there are important reasons why this potential has not been fully realised and some of these are technical and include battery and payload limitations. As the previous section identified, it is unlikely that the issue of powering drones to their full potential can be realised in the near future. Another under-explored reason is the extent to which workers and managers will be willing adopters of drone technology, while another is security and privacy with regard to surveillance, alongside cybersecurity and hacking challenges. Perhaps most significant of all are the interconnected factors of safety, security and regulations. As envisioned by several writers, there are numerous scenarios where safety can be compromised by drones, particularly in urban areas. They can malfunction, they can collide with each other or with another airborne device, such as a manned aeroplane, and they can be misused with malicious intent.

With regard to regulations, an impression that comes through in the literature is that while necessary these are generally quite draconian and there is a reluctance to change them. One writer suggested that if FAA regulations were enhanced it could be made easier for drone technology to be implemented for the benefit of cities and their citizens. Based on the apparent attitudes to regulations, however, the reverse may be nearer to the truth – enhanced regulations may lead to less progress and less implementation. This lack of progress and implementation was particularly notable in the literature related to the COVID-19 pandemic and the benefits that could have been gained in the US but were not due to FAA regulations. The interesting contrast was made between the non-use of drones in the US compared with their use in Rwanda by an American company and it is perhaps worth reiterating some of the limitations imposed by the FAA – UAVs must weigh less than 55 lbs, can only be used in VLOS, cannot operate at night time, must not fly above 500 ft, must always give way, the operator must be certified (or be supervised by such a person) and must take and pass a test of knowledge every two years.

It would have been of interest if the responses of nations other than Rwanda to the pandemic had been considered but none of the literature reviewed contained this; indeed, the FAA was the main regulatory body discussed or mentioned across these works. This reflects a subject area that is US-centric, at least with regard to regulations, which suggests a knowledge gap, particularly when it is borne in mind that the use of drones is a global phenomenon.

One area of particular interest for this current work and for this researcher concerned the 2016 Rio de Janeiro Olympic Games and the quite extensive use of drones within a context where the government of Brazil showed a willingness to change its laws and regulations to help accommodate this mega event. There were, of course, other challenges to be overcome, as there were for Qatar in hosting the 2022 World Cup, and many of these still exist as the nation moves forward in its development of technology, including the use of drones. Based on an understanding of how progress can be made as set out in the aim and objectives of this study, and within the context of a subject area that lacks some attention beyond the US, it is held that this is a significant gap in existing knowledge that this study sought to address.

Of particular importance in terms of this study are a number of clearly identified gaps in existing knowledge that have emerged from this review. One is the lack of research attention paid to smart cities and mega sporting events within a context where drones have increasingly been used for S&S across sectors. Reasons for this can be speculated about – neither can be classed as a traditional sector of interest and the research attention given to them can be unfavourably contrasted with industries such as construction, mining and healthcare. Another reason may be extent of the challenges posed in urban and densely crowded situations, which may be seen as being beyond the scope of anything more than fragmented approaches. Whatever the reason, it is posited that there is an urgent need for a holistic approach, one that takes account of a number of challenges at the same time. Understanding these challenges through the value and beliefs of key stakeholders can inform a framework for drone use in specific contexts, which in turn can enable the development of a comprehensively evaluated prototype. Alongside, or prior, to the development of this prototype it will be beneficial to research the specific sensors to be integrated into it.

CHAPTER 3
CHALLENGES FACING DRONE APPLICATION DEPLOYMENT IN QATAR

3.1. Chapter Overview

UAVs have emerged as powerful tools across diverse sectors, promising numerous benefits alongside inherent risks to civilian S&S. Amidst their rising popularity, notably amplified during the COVID-19 pandemic, important challenges have been highlighted that exist across multiple dimensions, challenges that have yet to be resolved or even sufficiently researched, as found in Chapter 2. This chapter delves into these challenges by dissecting the intricacies of drone deployment in Qatar. The efficacy, for instance, of drone operations is impeded by delayed responses, sensor malfunctions, and vulnerabilities to malicious attacks, underscoring the imperative for robust design and technical solutions. Public apprehension surrounding surveillance, privacy infringements, and the imperative for education on drone regulations and benefits necessitates nuanced approaches to address privacy, ethical, and cultural concerns. The susceptibility of drones to cyber-attacks, including hijacking, poses grave threats to control and safety, demanding rigorous security measures and protocols. Collisions, operator errors, and susceptibility to physical damage or theft pose significant safety risks, necessitating comprehensive safety protocols and mitigation strategies.

The study as a whole adopted an interdisciplinary research approach, navigating through the labyrinth of challenges and opportunities in drone application deployment in Qatar. Methodologies such as structured interviews, questionnaires, and PESTLE analysis were harnessed to glean insights across the PESTLE spectrum with a research instrument that demonstrated high reliability across the dimensions, unveiling a landscape where awareness of drone applications coexists with perceived inadequacies in adoption efforts. Notably, participants cited prevalent challenges encompassing policy gaps, funding constraints, societal anxieties, technological barriers, legal ambiguities, and environmental considerations. This chapter provides a holistic analysis of the opportunities and hurdles surrounding drone deployment in Qatar, laying a robust foundation for future inquiry and potential solutions in this burgeoning domain.

3.2. Key Challenges for Civilian Drone S&S

This early section of the chapter builds upon the review undertaken in Chapter 2 by summarising and providing focus on the main challenges being faced in the use of drones for civilian purposes, providing a context for the remainder of it.

3.2.1. Design and technical challenges

Delayed responses to instructions can cause technical issues in drone use. The control of civilian drones depends on control signals sent from a ground control centre, or a flight or remote controller. Sometimes delays can occur during this process, exacerbated by climate factors that affect communication signals, as well as physical barriers, and drone distance from the main control signal. Any delay in information communication between the controller and the drone can result in unsafe behaviour by the drone. For example, an operator might instruct the drone to swerve to avoid an obstacle, but a delay in communication can result in a collision that could damage people, property, and/or the drone itself (Hobbs, 2010).

Related to drone deployment and interactions with the physical environments in which they operate, their sensors (e.g., altitude and collision avoidance radar sensors) might malfunction, which would result in unsafe behaviour. Aside from such latent challenges are possibilities of malicious attacks on drones in operation, with one method being the injection of falsified sensor data. This can create technical issues for drones, resulting in improper behaviour or destabilisation (i.e., artificially causing de facto sensor malfunction). This is achieved by inserting false readings into the sensors, thus misinforming the flight controllers and undermining their control. A further outcome of this method of malicious attack is that it makes the drone accessible to unauthorised personnel (i.e., prone to being hijacked) and it is the design of civilian drones that can make it easier for unauthorised personnel to manipulate their operations (military drones have built-in safeguards against such threats) (Salamh *et al.*, 2021).

Similarly, malevolent and malicious hardware and software can create issues for drones, with the flight controller in civilian use being particularly vulnerable to software or hardware trojans (viruses designed to disrupt or steal data and inflict damage to either data or networks). A case study can be cited of a trojan attack in 2011 concerning a ground control unit at the Creech Air Force Base being infected with viruses and malware (Hartmann and Steup 2013), where traces of malware were found in the hardware of drones that flew over Iraq and Afghanistan. There was no consequence in this case, but it is clear that such attacks could happen to civilian drones if they lack sufficient protection.

Malware and/or virus developers are already creating drone-specific attack capabilities, such as Maldrone software, which enables unauthorised personnel to control drones (Altawy and Youssef, 2016). The software opens a back door connection and then acts as a proxy for the flight control, sensors, and all communications. Overall, this malware can grant unauthorised personnel the opportunity to control the drone and land it wherever they want (Altawy and Youssef, 2016).

The design of a drone can hinder deployment, particularly through its potentially intimidating presence for civilians on the ground. Drones can come in any size, from tiny to extremely large, with larger models in particular causing negative reactions due to perceived threats, which in turn exacerbates latent concerns about security and privacy, particularly regarding the perception that drones are filming. Despite being seen by some as being innocuous, people may also react negatively and suspiciously toward smaller drones, associating them with stealth and covert surveillance, and may even worry that they could access private spaces such as homes and commercial properties for spying. Fundamentally, areas that are not accessible to humans can be easily and covertly accessed by smaller drones but a study of human perceptions nevertheless found that people generally prefer drones to be smaller, mainly because of their innocuous appearance and the reduced risk that they might injure people (Chang, Chundury and Chetty, 2017).

3.2.2. Privacy, ethical, and cultural challenges

Based on the preceding discussion it is clear that overall the public does not feel safe with the idea of having civilian drones flying indiscriminately across the sky due to concerns about surveillance, the violation of privacy, and intrusion into private spaces. Drones are capable of extensive surveillance, including the use of advanced imaging techniques and (to a lesser extent) sound recording, key parts of the functionality of many applications, but which frightens the general public. It has proven to be difficult to get the public to understand and accept the presence of drones, even when the ethical and legal frameworks being developed for drone application are included in the conversation. Drones have multiple functions that can assist people and understanding the benefits of drones could, and perhaps should, put people at ease regarding their general presence, as well as increasing their awareness of the legislation and regulations governing responsible drone use and liability. However, while legislation is clear about data protection issues drone owners can hide their actions and violate privacy rights covertly, despite the fact that images or videos obtained from drones should not be used without the consent of subjects, and general data protection laws apply to data from drones (Pauner, Kamara and Viguri, 2015).

The increase in drone use is thus laden with the possibility of inappropriate or illegal deployments, with similar freedoms and restrictions to those governing other forms of data capture, such as video and sound capture using mobile phones. Responsible use depends on drone owners and operators, which means that civilians may be left at the mercy of irresponsible or malicious users. A main way in which the drone industry seeks to reassure the public about such concerns is through systems of registration and the application of conventional legislation for drone data, but as drones become increasingly commercially available, it may not be feasible to expect all drone owners to be registered with government authorities; therefore, it becomes increasingly difficult to monitor and identify drone operators as their number increases. If conventional data protection and privacy laws and regulations prove to be insufficient to effectively regulate drone use and guarantee public rights, this could result in an explosion of malicious and illegal activities by drone users, including unauthorised tracking and surveillance, and even terrorist attacks or targeted assassinations (Altawy and Youssef, 2016).

3.2.3. Drone security

The main challenges to drone security are cyber threats, particularly cyber-attacks perpetrated via wireless links. Drones can be operated by computers or remote control, and their onboard sensor and actuator networks provide feedback or communicate with operators via a wireless link (Altawy and Youssef, 2016). These connections are vulnerable to cyber-attacks and in one such military case a drone was hijacked by attackers employing a mix of cyber-attacks to shut off all communications from the authorised ground control centre to the drone (by jamming both the ground control signals and the satellite link). Subsequently, a GPS spoofing attachment was launched by the attackers, feeding the drone with modified GPS data, which steered it to a new destination, this despite the protections the military had installed. Civilian drones have less sophisticated protections and monitoring and thus are even more vulnerable to cyber-attacks (Yaacoub *et al.*, 2020).

Any attack (whether physical or cyber) on a drone or on ground control centres causes the machine to become unmanned, creating malfunctions whereby it is rudderless, meaning it can crash, potentially harming people and infrastructure. This is because the drone is dependent on the information being fed to it from the flight controller or the ground control centre via a data link and a sensor feeding back information about the surrounding environment. If unauthorised personnel are able to manipulate the internal communication system or the data link, they can falsify data and make the operator think they are in control, or make the drone think it has not been hijacked, meaning it will not apply any defensive safety measures (e.g., an automatic safe-landing and shutdown procedure) to counter the attack (Krishna and Murphy, 2017).

3.2.4. Drone safety

Physical damage to the drone or its surroundings is the most critical safety issue. Collision is one of the main risks that threatens drones, their surroundings, and the objects with which they might collide (including humans and animals). A lack of operator skill (due to novice status or complicated deployments) can easily result in collisions, including with other drones in the air, as well as with objects on the ground. If the drone loses connectivity with the flight controller that is in the hands of the operator, accidents can occur, and, in urban deployments, it is inevitable that a rudderless drone will ultimately collide with infrastructure (e.g., buildings, roads or pavements) and, potentially, people (Chang, Chundury and Chetty, 2017).

A successful and safe drone flight requires constant and clear vision of what the drone sees by the operator, which enables instructions on evasion if obstacles emerge. Video footage is essential for collision avoidance and navigation; while radar systems may enable automated obstacle avoidance, objects with low mass can only be effectively avoided by human operators (e.g., tree branches). Operators need live video footage from the kernel of the operating system via a computer, which is elicited by issuing a system call. Unauthorised personnel or an attacker who has knowledge of the system and its parameters can gain access to the flight controller and intercept the system call that the operator issues to the kernel; thus, they can fabricate the footage that the operator sees.

In the GPS spoofing attack previously described, the authorised military users were aware that the drone had been seized (Yaacoub *et al.*, 2020), but civilian drones may be more vulnerable to hijacking if it is not perceived by the authorised operator. The latter may consequently think that they are controlling the drone and that nothing is amiss when, in reality, the attacker has complete control, being able to then land the drone with no interference from the operator. Such attacks can be used to vandalise or steal drones, and they are particularly enabled when drones fly close to the ground, or at a distance that can easily be seen by people, which makes the drones more attractive prizes for thieves and vandals.

Vandals can easily damage or destroy drones, for example by using simple dart guns, physically grabbing low-flying drones, or using rifles. There are even specialist anti-drone rifles used by police to bring down drones suspected of being engaged in criminal activities. These rifles are designed and created to disable drones immediately without damaging them, using radio pulses to disrupt the data link communication in the drone and forcing it to activate fail safe protocols, making it hover close to the ground in preparation for a safe landing. As mentioned above concerning security challenges, the use of malware and software can be used to bring a drone down, including Maldrone-type viruses. Immobilising a drone can enable thieves to seize drones in an area of their choice (Altawy and Youssef, 2016).

This section has outlined the general challenges to drone deployment worldwide. This study undertook a case analysis of specific opportunities and challenges facing drone application deployment in Qatar, the methodology of which is explained below.

3.3. Chapter Methodology

3.3.1. Chapter research design

This chapter is based on the methodology for interdisciplinary research (MIR) approach, as displayed in Figure 3.1 (Tobi and Kampen, 2017). MIR was selected as it was specifically developed to support cross-disciplinary research projects, especially those concerning both natural and social sciences. Moreover, the MIR is appropriate for research projects with different levels of complexity and sizes, which enables the complementary use of different methods (e.g., experimental, and mixed methods, etc.), as used in this chapter.

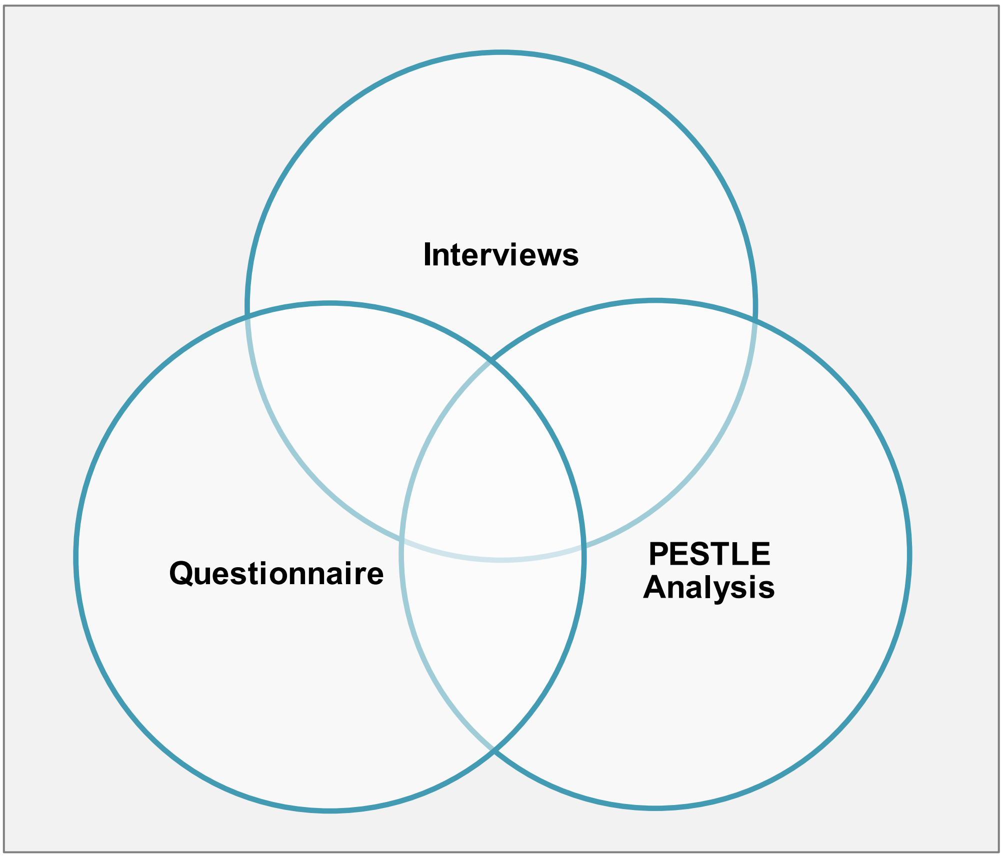

Figure 3.1: Chapter research design
Source: Author

To identify opportunities and different challenges facing drone application deployment in Qatar, the main chapter questions are:

- What are the opportunities for drone applications in Qatar?
- What types of challenges face drone deployment in Qatar?
- What are the most significant challenges facing drone deployment in Qatar?

Numerous stakeholders with different levels of knowledge and particular perspectives are involved in drone approval and operation and for this reason interviews were selected as the best way to understand these potentially divergent opinions. Interviews involve social interactions and are useful in helping a researcher understand more about a certain topic through the thoughts and attitudes of people. Unstructured interviews with open-ended questions can be used to explore subjects about which very little background knowledge exists, requiring in-depth inductive analysis (Stuckey, 2013). Also known as informal interviews, this format is beneficial as it allows one to understand a person's opinions, thoughts or understanding of the topic in depth. However, it is time-consuming and the outcomes are of very limited generalisability for practical purposes (Taylor, 2005).

Focus group interviews are another qualitative approach whereby a group of participants discuss their perceptions and experiences of phenomena of interest. This can generate a considerable amount of rich data from certain target groups (purposively selected to be members of such groups), but the logistic practicalities of organising such interviews can be problematic (Taylor, 2005). Another method is structured (formal) interviews, which in this case can be used to capture the special professional insights of key stakeholders., This research therefore conducted structured (formal) interviews with key stakeholder groups concerned with drone application in Qatar.

The most expedient form of structured interview is one that uses questionnaires as these generate quantitative data that can be used to support conclusions for general application. While lacking the depth of qualitative insights, this is the most efficient way to generate data about issues of practical concern. Consequently, a quantitative questionnaire was used in this study, developed based on the reviewed literature (Wilkinson, 2015).

The structured interview and questionnaire methods used in this study are described in the following sections, followed by an explanation of the PESTLE analysis used to conceptualise them with regard to the data collected.

3.3.2. Structured interviews

Structured (formal) interviews have a rigid structure and follow a standardised interview schedule. They are a quantitative research method whereby the interview is prepared with multiple closed questions beforehand. During the interview the interviewee reads the questions word for word, with no major deviations other than to clarify a question and its meaning and the questions are read in the same order to each interviewee. This type of interview is commonly used for a number of reasons. It is easy to replicate due to the same multiple fixed questions being used, responses are easy to quantify, which means that testing for reliability is straight forward, and the coding processes or analytical framework for it are facilitated by its quantitative nature. However, it does have disadvantages, including inflexibility and being impervious to potentially unexplored areas of the participants' expertise and experience. Impromptu and spontaneous questions are excluded, potentially making it harder for researchers or interviewers to understand why participants believe or answer as they do (Creswell and Creswell, 2018).

3.3.3. Questionnaires

To get a wide sample in a short space of time, structured quantitative questionnaires, using Likert-type scales (Albaum, 1997), are the most efficient way to gather data in research concerning human opinions (Creswell and Creswell, 2018; Sudman and Bradburn, 1982). These data can easily be converted for data analysis via software packages such as SPSS (Babbie, Wagner and Zaino, 2018). A 3-point Likert scale was used in this research.

3.3.4. PESTLE analysis to form structured interviews and questionnaires

Different coding processes or analysis tools can be used to interpret the data. This chapter adopted the PESTLE analysis framework (sometimes rendered "PESTEL") (Figure 3.2, Figure 3.3). It can be used to analyse theories, methodologies, and organisations, and is amenable to modification for particular contexts, offering a high degree of flexibility for researchers. It offers in-depth insights into multiple external factors that are influencing or impacting human and organisational behaviours. This framework has a variety of uses and some are as follows (Chartered Institute of Personnel and Development [CIPD], 2020):

- Strategic planning: a PESTLE analysis can provide an organisation with information regarding which direction the organisation is going, the risks that may occur, a decline in productivity, etc.
- Workforce planning: the analysis can be used to identify changes with negative or positive impacts on the organisation, such as employee conditions, etc.

Figure 3.2: PESTLE analysis
Source: Ibis World (2020)

P	E	S	T	L	E
Governmental policy	Economic growth	Population growth rate	Technology incentives	Weather	Discrimination laws
Political stability	Exchange rates	Age distribution	Level of innovation	Climate	Antitrust laws
Corruption	Interest rates	Career attitudes	Automation	Environmental policies	Employment laws
Foreign trade policy	Inflation rates	Safety emphasis	R&D activity	Climate change	Consumer protection laws
Tax policy	Disposable income	Health consciousness	Technological change	Pressure from NGO's	Copyright and patent laws
Labour law	Labour law	Lifestyle attitudes	Technological awareness		Health and safety laws
Trade restrictions	Unemployment rates	Cultural barriers			

Figure 3.3: Example of PESTLE analysis application
Source: Statius Management Services Limited (2022)

The constituent dimensions of a PESTLE analysis encompass the six external influences that affect the researched phenomenon and data:

- *Political:* This may include fiscal and environmental regulations, political stability, and policy directions.
- *Economic:* This looks at economic decline or growth, including unemployment rates and cost of living, etc.
- *Sociological:* Cultural expectations and assumptions about human perceptions and quality of life, population growth rates, age, ethnicity, etc.
- *Technological:* The type and quality of technological devices pertinent to the phenomenon of interest, such as organisational technology resources, the growth rate of technological advancements, their benefits, or limitations, etc.
- *Legal:* Existing and likely developments in legislation that can be anticipated to affect stakeholders.
- *Environmental:* Issues concerning local and global environmental impacts, such as pollution and climate issues, sustainability, energy, raw materials, and other resources.

A PESTLE analysis is an effective and simple framework used to facilitate a wider understanding of diverse stakeholder concerns and impacts (CIPD, 2020), but it can be prone to over-simplification of the research problems and the generation of a surfeit of superfluous data that can overwhelm the analyst (Perera, 2017). The most important step for applying PESTLE effectively is to proceed from a conceptualised research topic. In this case such an approach determined the focus of the interviews and questionnaires, with the resultant data being analysed according to the six identified PESTLE dimensions (Dudovskiy, 2022) (Appendix 3).

3.3.5. Ethical observance

This study adhered to all pertinent ethical requirements of the Brunel University of London, subject to the Declaration of Helsinki and UK data protection laws. The participants were assured of the voluntary nature of their participation, and their right to refuse or withdraw from the study. All data were stored anonymously in password-protected files, and no personally identifiable data were reported in this research (Creswell and Creswell, 2018) (Appendix 4).

3.4. Data Analysis

3.4.1. Reliability

A reliable questionnaire requires a Cronbach's alpha coefficient value of at least 0.6, which indicates that the questions measure the intended variables and that the instrument is consistent and dependable (Sekaran and Bougie, 2016). As shown in Table 3.1, all of the questionnaire dimensions (into which the items were grouped) achieved Cronbach's alpha coefficients that exceed the 0.6 threshold, which indicates the stability of the study instrument.

Table 3.1: Reliability scores for the research instrument

Challenge dimension	Cronbach's alpha
Legal	0.88
Environmental	0.80
Social	0.85
Political	0.87
Technological	0.80
Economic	0.81
Total	0.89

Source: Author

3.4.2. Descriptive analysis

General information and the demographic characteristics of the participants are shown in Table 3.2 and Figure 3.4. In terms of the participants' occupation, the largest cohort of respondents were from the military aviation sector (18.41%, n=102), followed by firefighting (14.44%, n=80), government innovation (14.26%, n=79), the Qatar World Cup Security Community (11.7%, n=65), civil aviation (11%, n=61), interior security (9%, n=50), the Ministry of Transport and Communications (MoTC) (8.3%, n=46), the environmental sector (6.1%, n=34), the police (5.6%, n=31), research and higher education (5.4%, n=30%), oil and gas (3.97%, n=22), and Qatar RC Club (3.79%, n=21).

Table 3.2: Participants' socio-demographic characteristics

Variable	Response	N	%
Occupational sector	Military aviation	102	18.41
	Firefighting	80	14.44
	Government innovation	79	14.26
	Qatar World Cup Security Community	65	11.73
	Civil aviation	61	11.01
	Interior Security	50	9.03
	MoTC	46	8.3
	Environmental	34	6.14
	Police	31	5.6
	Research and higher education	30	5.42
	Oil and gas	22	3.97
	Qatar RC Club	21	3.79
Are you aware of any drone applications in your sector?	No	151	27.3
	Yes	385	69.5
	Not sure	18	3.2
Do you think drone applications are useful to your sector?	No	10	1.8
	Yes	528	95.3
	Not sure	16	2.9
Do you think there is enough effort to adopt drone applications in your sector?	No	473	85.4
	Yes	53	9.6
	Not sure	28	5.1
Total		554	100

Source: Author

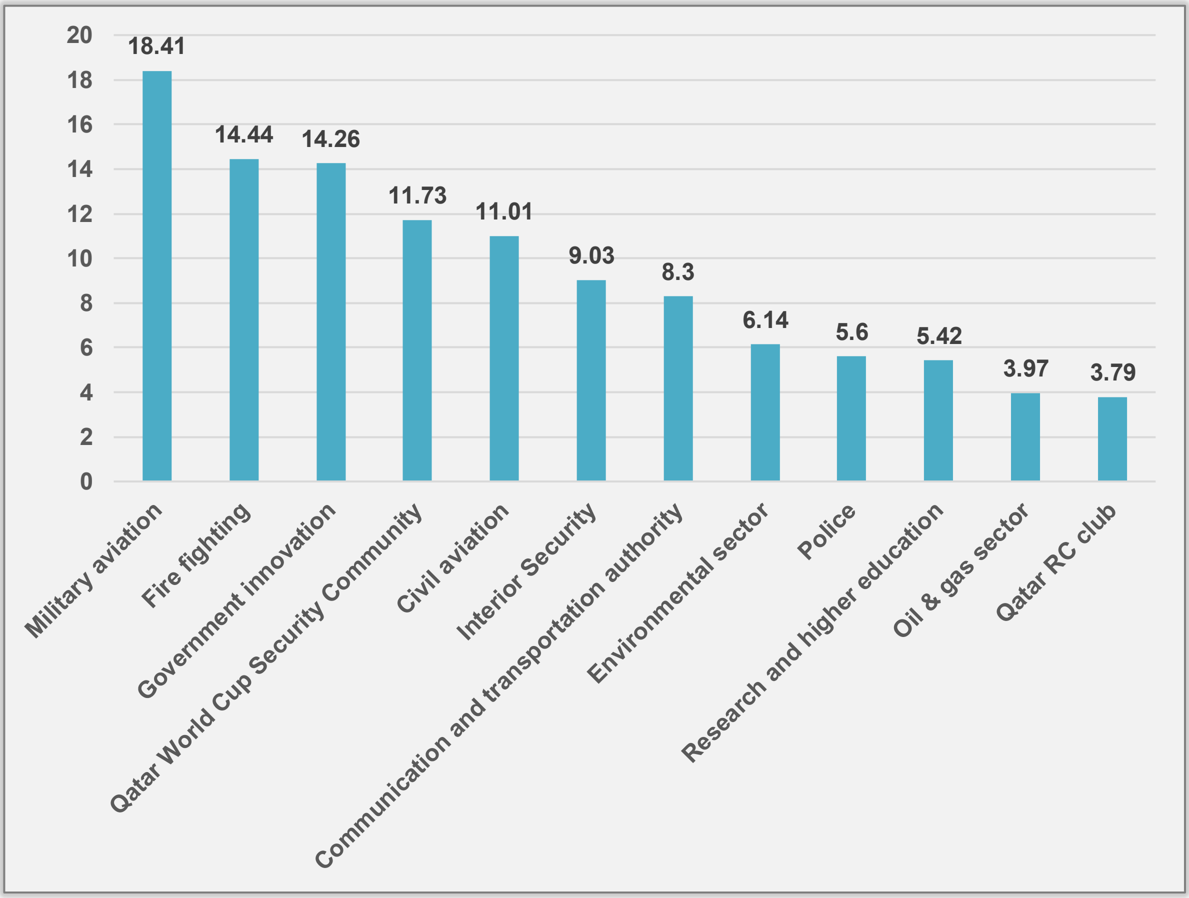

Figure 3.4: Participants' socio-demographic data

Source: Author

3.5. Findings

3.5.1. Potential drone applications in Qatar

The majority (69.5%, n=385) of respondents were aware of drone applications in their sectors, while only 3.3% (n=18) were unsure. Almost all (95.3%, n=6528) declared that they considered drone applications to be useful for their sectors, and 85.4% (n=473) felt insufficient effort was being made for drone adoption (Figure 3.5).

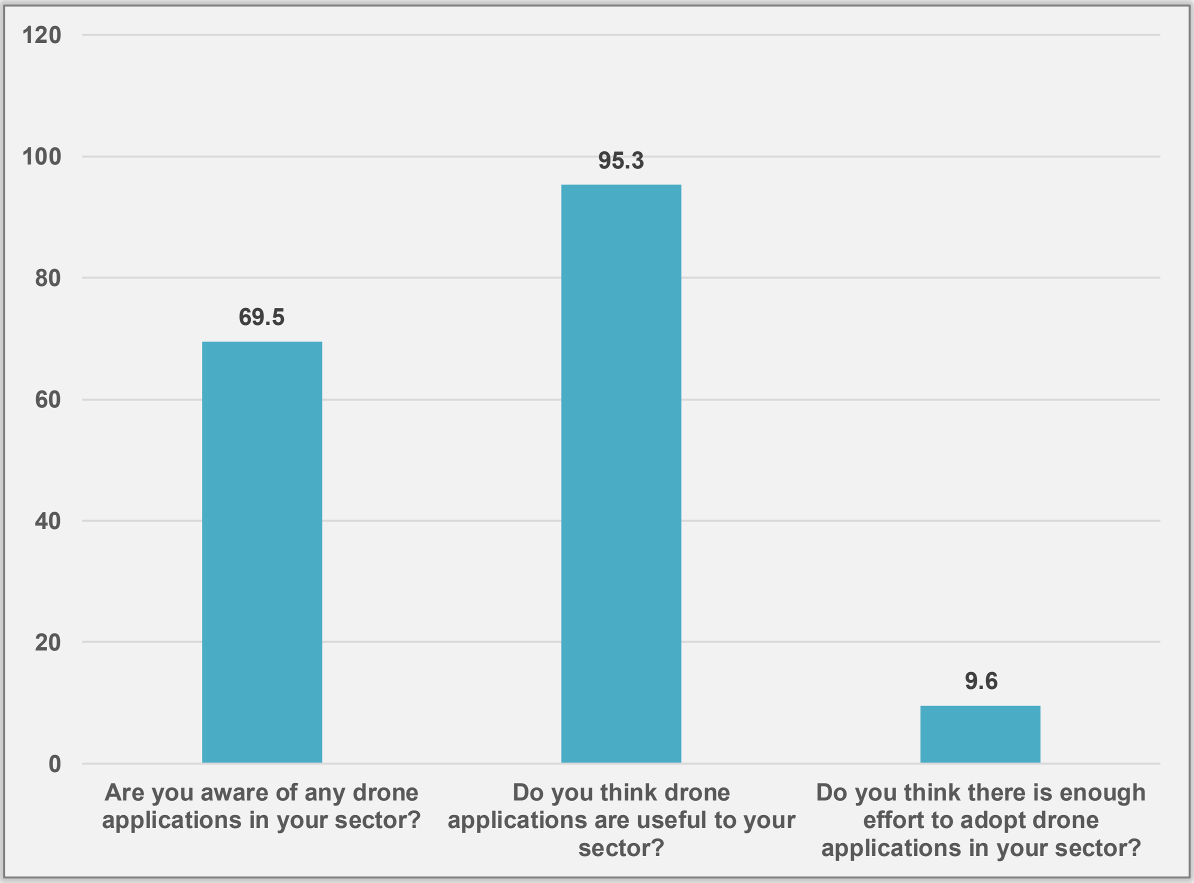

Figure 3.5: Potential drone applications in Qatar

Source: Author

3.5.2. Challenges affecting drone operations

Table 3.3 and Figure 3.6 display the main factors identified as affecting drone operations. The most commonly cited dimensions, all with similar scores, were legal (94.66%), environmental (94.55%), social (94.51%), political (93.47%), and technological challenges (93.46%). Economic challenges were only cited by 5.29% of participants. The average "challenge" perception score was 79.32%. Particular challenge dimensions are discussed below.

Table 3.3: Main challenges to drone operations

Challenge dimension	Mean	Standard deviation
Legal	94.6622	18.60206
Environmental	94.5487	17.30156
Social	94.5075	16.84739
Political	93.4717	20.27045
Technological	93.4567	20.96908
Economic	5.29	1.76396
Average	79.32	12.41

Source: Author

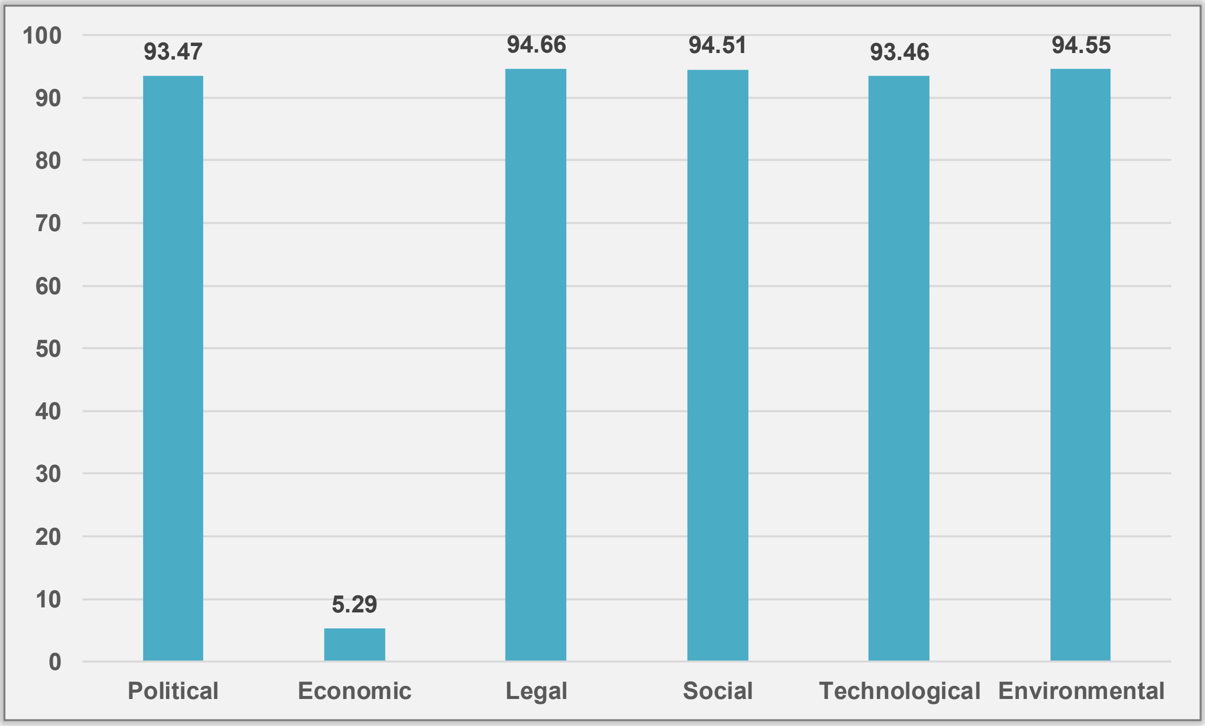

Figure 3.6: Drone deployment challenges
Source: Author

3.5.2.1. Political

Similar numbers of participants considered the greatest political challenges to be a lack of organisational policy to adopt drone applications (94.2%), lack of policy collaboration between different government departments concerned with drones (94.2%), lack of clear government policy (93.3%), lack of safety policy (93.3%), political concerns with neighbouring countries (concerning flying zones and borders) (93.3%), and lack of security policy (92.4%) (Table 3.4).

Table 3.4: Political challenges to drone operations

Challenge dimension	No	Yes	Not sure
Lack of organisational policy to adopt drone applications	4(0.7%)	522(94.2%)	28(5.1%)
Lack of policy collaboration between different government departments concerned with drones	6(1.1%)	522(94.2%)	26(4.7%)
Lack of clear government policy	15(2.7%)	517(93.3%)	22(4%)
Lack of safety policy	18(3.2%)	517(93.3%)	19(3.4%)
Political concerns with neighbouring countries (flying zones and borders)	11(2%)	517(93.3%)	26(4.7%)
Lack of security policy	18(3.2%)	512(92.4%)	24(4.3%)

Source: Author

3.5.2.2. Economic

While few participants cited economic challenges, as discussed previously, those who did considered the greatest economic challenge to be a lack of funding in organisations to finance drone projects (5.6%), a lack of government funding (5.4%), and a lack of funding for individuals to finance drone projects (4.9%) (Table 3.5).

Table 3.5: Economic challenges to drone operations

Challenge dimension	No	Yes	Not sure
Lack of funding in organisations to finance drone projects	499(90.1%)	31(5.6%)	24(4.3%)
Lack of government funding	506(91.3%)	30(5.4%)	18(3.2%)
Lack of funding for individuals to finance drone projects	500(90.3%)	27(4.9%)	27(4.9%)

Source: Author

3.5.2.3. Social

Similar numbers cited all of the mentioned social challenges, including privacy emphasis (96.6%), a lack of trained people (96.6%), lack of awareness related to drones' benefits (95.5%), safety emphasis (94.6%), fear of taking responsibility (93%), cultural barriers (93%), and resistance to change (92.4%) (Table 3.6).

Table 3.6: Social challenges to drone operations

Challenge dimension	No	Yes	Not sure
Privacy emphasis	3(0.5%)	535(96.6%)	16(2.9%)
Lack of trained people	7(1.3%)	535(96.6%)	12(2.2%)
Lack of awareness related to drones' benefits	8(1.4%)	529(95.5%)	17(3.1%)
Safety emphasis	12(2.2%)	524(94.6%)	18(3.2%)
Fear of taking responsibility	10(1.8%)	515(93%)	29(5.2%)
Cultural barriers	26(4.7%)	515(93%)	13(2.3%)
Resistance to change	15(2.7%)	512(92.4%)	27(4.9%)

Source: Author

3.5.2.4. Technological

The greatest technological challenge was a lack of technical support (94.8%), followed by a lack of technological awareness (93.7%), technological changes (93.1%), and a lack of R&D (92.2%) (Table 3.7).

Table 3.7: Technological challenges to drone operations

Challenge dimension	No	Yes	Not sure
Lack of technical support	12(2.2%)	525(94.8%)	17(3.1%)
Lack of technological awareness	15(2.7%)	519(93.7%)	20(3.6%)
Technological changes	17(3.1%)	516(93.1%)	21(3.8%)
Lack of R&D	6(1.1%)	511(92.2%)	37(6.7%)

Source: Author

3.5.2.5. Legal

The greatest legal challenge was a lack of laws to cover drone incidents (95.7%), followed by a lack of drone ownership laws (95.3%), lack of laws on who can operate/fly drones (95.1%), lack of laws to cover drones and their application (95.1%), lack of laws related to flying drones (94.4%), lack of a legal framework for drone operations and neighbouring countries (94%), and lack of laws to cover drone insurance (93%) (Table 3.8).

Table 3.8: Legal challenges to drone operations

Challenge dimension	No	Yes	Not sure
Lack of laws to cover drone incidents	6(1.1%)	530(95.7%)	18(3.2%)
Lack of drone ownership laws	7(1.3%)	528(95.3%)	19(3.4%)
Lack of laws on who can operate/fly drones	9(1.6%)	527(95.1%)	18(3.2%)
Lack of laws to cover drones and their application	10(1.8%)	527(95.1%)	17(3.1%)
Lack of laws related to flying	18(3.2%)	523(94.4%)	13(2.3%)
Lack of a legal framework for drone operations and neighbouring countries	4(.7%)	521(94%)	29(5.2%)
Lack of laws to cover drone insurance	7(1.3%)	515(93%)	32(5.8%)

Source: Author

3.5.2.6. Environmental

The greatest environmental challenges were military and sensitive restricted zones/areas (97.8%), followed by civil aviation airspace zones (97.1%), S&S of drones in certain areas for certain people (to bring drones down) (94.2%), high rise buildings (92.2%), and the weather (91.3%) (Table 3.9).

Table 3.9: Environmental challenges to drone operations

Challenge dimension	No	Yes	Not sure
Military and sensitive restricted zones/areas	3(0.5%)	542(97.8%)	9(1.6%)
Civil aviation airspace zones	10(1.8%)	538(97.1%)	6(1.1%)
S&S of drones in certain areas for certain people (to bring drones down)	11(2%)	522(94.2%)	21(3.8%)
High rise buildings	29(5.2%)	511(92.2%)	14(2.5%)
Weather	40(7.2%)	506(91.3%)	8(1.4%)

Source: Author

3.6. Chapter Summary

The utilisation of drones presents both promising opportunities and daunting challenges in Qatar. While they offer numerous benefits across various sectors, and while there is potential for enhanced efficiency and safety, they also pose significant S&S risks. As well as privacy concerns and security vulnerabilities, and despite the increasing popularity of drones, other issues remain, with technical issues being prominent among them. The COVID-19 pandemic underscored the potential of drones in overcoming established barriers and ensuring public safety; however, delayed responses and technical malfunctions continue to jeopardise their safe deployment. Moreover, the threat of malicious attacks and the susceptibility to tampering raise serious concerns about drone security.

Public apprehension regarding surveillance and privacy infringement fundamentally hinders their widespread acceptance and deployment. Regulatory frameworks struggle to keep pace with the rapid evolution of drone technologies, exacerbating these challenges. Cyber threats, such as hijacking and spoofing, pose additional risks to drone operations and public safety.

Structured interviews and quantitative questionnaires were employed to gather data, revealing a high awareness of drone applications but inadequate efforts for adoption. The PESTLE analysis framework highlighted the significant influence of political, social, technological, legal, and environmental factors on drone deployment in Qatar.

Despite the absence of a comprehensive economic dimension in the analysis, there is a clear need for a comprehensive framework to address the identified challenges and promote safe and effective drone adoption in Qatar. This chapter is a necessary first step along a path that seeks to address the clear gaps in existing knowledge that have been identified. It not only shows that strategies must be developed to mitigate risks, enhance regulatory frameworks, and foster public trust to realise the full potential of drones but also how these strategies can best be developed in that nation.

CHAPTER 4
CIVILIAN UAV DEPLOYMENT FRAMEWORK FOR QATAR

4.1. Chapter Overview

Recent years have seen an exponential rise in the use of drones, especially UASs. Most civil UAS operations currently occur in low-level uncontrolled areas, or separate controlled airspace, due to safety concerns; however, by the end of the decade it is anticipated that both the operational and technological capabilities of UASs will be mature to the point where they can access both controlled and uncontrolled airspace (Zhaoxuan *et al.*, 2021). There have been numerous conventions addressing issues and concerns associated with civil aviation regulation since the 1920s and more than 50 states attended the most notable of such meetings, held in Chicago in 1944, just after the end of World War II. It paved the way for aviation safety and international collaboration in creating legislation, regulations, and procedures that are still in use today (Outay, Mengash and Adnan, 2020).

An ‘unmanned aircraft’ is any aircraft that can be operated or controlled remotely, without requiring a pilot to be on board; an ‘aircraft’ is any machine that may receive support from atmospheric reactions other than those originating from the earth’s surface. Any UAS operating in the same airspace as human-operated aircraft, no matter where it is, must meet the same safety and operational requirements as manned aircraft in the same national domain (e.g., any UAS operating in the UK must do so following UK legislation governing conventional human-piloted aircraft). Due to this, UAS activities must not pose or generate a greater risk to people, property, vehicles, or boats than manned aircraft of the same class or category.

Despite the wealth and keen technological investment in the state of Qatar, its UAS advancements remain lacking compared to other countries. Having identified the challenges to improved UAS deployment, this research seeks to develop a framework to facilitate and foster their deployment in Qatar, something which may also be useful to other countries.

4.2. Chapter Research Design

The research design for this chapter encompassed five steps, as illustrated in Figure 4.1. The framework purpose and data collection procedures are briefly described below.

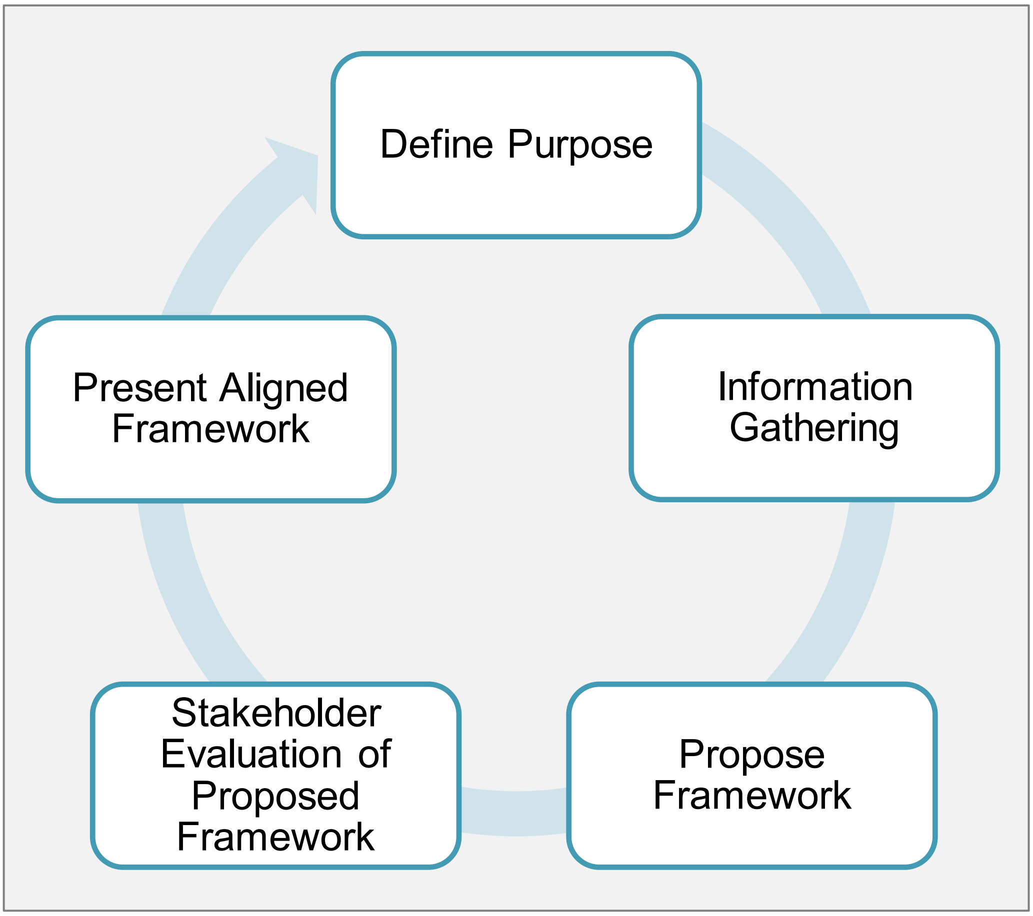

Figure 4.1: Research design for framework development
Source: Author

4.2.1. Framework purpose

The key purpose of the framework is to establish a roadmap for UASs in Qatar that can be easily understood by different stakeholders and may enable the future deployment of civilian UASs. It seeks to address the main existing challenges by learning from the experiences of the UK and EU in joining ICAO efforts for the integration of UASs into a safe and efficient manner in the global airspace.

4.2.2. Data collection

Data collection was undertaken in two phases. The first phase was to study UK guidance for UAS operations, as published by the Civil Aviation Authority (CAA, 2020) in "*CAP 722: Unmanned Aircraft System Operations in UK Airspace – Guidance & Policy*", and by the European Union Aviation Safety Agency (EASA) in "*Civil Drones (Unmanned Aircraft) EU Regulations*" (Bassi, 2020). The second phase was to study the challenges facing UAS deployment in Qatar.

4.3. UK and EU UAS Frameworks

4.3.1. Guidance for unmanned aircraft system (UAS) operations in UK airspace

In the UK, the CAA is responsible for regulating civil aviation, according to the amended Civil Aviation Act 1982. Following government legislation, the CAA regulates aviation under the supervision of the Department for Transport (CAA, 2020). It is responsible for aircraft registration, air navigation, aircraft safety (including airworthiness), air traffic control, certification of aircraft operators, and airport licensing. As per Article 18 of the UAS Implementing Regulation, other responsibilities include executing the duties of the responsible authorities. Furthermore, policies and guidelines, operational authorisations and safety notifications and instructions have been developed by the CAA., It also grants public approvals and exemptions and oversees the operations of organisations and individuals with permission and licences and enforcement activities (CAA, 2020).

The most crucial aspect of unmanned aviation is the operation being undertaken rather than who or what is performing it or why it is being done. Because an onboard human operator is lacking in UASs, the established aviation paradigm based on manned aircraft faces several gaps when encountering this new and rapidly growing industry. Currently, in the case of adverse events or accidents, liability is contextualised mainly in terms of the incident or accident location (CAA, 2020). The CAA is concerned with the risk that the UAS operation causes to third parties, which means that when the risk is more significant, more effort or proof is required to prove innocence.

The CAA is now debating a proposal to amend the Air Navigation Order. This proposal aims to safeguard the public by placing operating limits on UAVs weighing less than 7 kg, which are deemed to comprise a category of devices whose operation poses a palpable risk of harm to the public (CAA, 2020). Operators of UASs with a UAV component weighing less than 7 kg would be required to get CAA permission under this proposal, comparable to the requirement for UAVs weighing 7-20 kg (EASA, 2020).

VLOS is one of the most important rules to follow when flying in UK airspace. The remote pilot must always observe both the aircraft and the surrounding airspace when the unmanned aircraft is in the air. VLOS operation allows the pilot to watch the aircraft’s flight path and guide it clear of obstructions, which is essential to avoid crashes. Correctional lenses are permitted, but binoculars, telescopes, and other image-enhancing equipment are not. The aircraft cannot fly out of sight of the remote pilot when running VLOS (CAA, 2020). Some small planes can operate at a range of 500 m, maintaining adequate visual contact if the aircraft remains within proximity to the pilot.

There are no particular restrictions on VLOS operations during the night, and the basic VLOS principles still apply (i.e., the remote pilot must be able to view the aircraft and the surrounding region). Any applications for operational authorisations that incorporate VLOS flying at night must include a “night operations” section in the operations manual that outlines the operating procedures to be followed. For example, site safety assessment and daylight reconnaissance must be undertaken for the area where the drone will be launched. Any dangers, limits, or impediments should be identified and recorded, along with the launch site’s Radiance (CAA, 2020).

According to UK law, one must be of sufficient intellectual, physical, and mental maturity to acquire, retain, and demonstrate the essential theoretical knowledge and practical ability to operate UAVs, as with manned aircraft. A drone pilot must learn and maintain the requisite useful talents to accomplish their tasks using the drone and obtain and maintain a level of expertise adequate for the responsibilities required and commensurate with the risks inherent in the drone’s activity. Topics such as air legislation, technical concerns relevant to the drone’s category, human perception, and limits must all be covered. Continuous evaluation during training and, if necessary, exams are required to show the acquisition and retention of theoretical information. Maintaining a high level of theoretical knowledge competency is required (Legislation.gov.uk, 2018).

Regular assessments, exams, tests, or inspections are necessary to demonstrate conformity. Exams, tests, and checks must be conducted frequently to the level of risk associated with the activity. Activities such as aircraft performance, mass and balance determination, aircraft inspection and servicing, fuel/energy planning, weather appreciation, route planning, airspace restrictions and runway availability or aerodrome and traffic-pattern operations, and so on, must be proportionate to the risks associated with the type of activity (Legislation.gov.uk, 2018).

4.3.2. Operating authorisations issued by the CAA mandate UAV insurance

Regulation (EC) 785/2004, which went into effect on April 30, 2005, requires most aircraft operators to carry adequate insurance to meet their duties in an accident, regardless of the aims for which they fly. Based on their maximum take-off mass (MTOM), this regulation provides minimum levels of third-party accident and war risk insurance for aircraft flying into, over, or inside the EU (including UASs). The CAA website states the insurance requirements under “Mandatory Insurance Requirements”. In the UK, the Civil Aviation (Insurance)

Regulations 2005 establish the insurance requirements. According to Article 2(b) of EC 785/2004, the legislation does not apply to “model aircraft with a MTOM of less than 20kg”, although the term “model aircraft” is not defined in the regulation. As a result, to interpret the insurance legislation, the word “model aircraft” should be construed as “an unmanned aircraft used only for sport or recreational purposes” (CAA, 2020).

4.3.3. UAS deployment EASA regulatory framework

The European Commission establishes aviation standards throughout the EU by implementing appropriate regulations, but only if a group of state representatives agree on such regulations (through a vote if required). UASs are becoming more common in European airspace, posing safety, security, and integration concerns. A comprehensive legal framework is necessary to ensure safe UAS traffic management while facilitating the safe operation of unmanned aircraft in the existing air traffic environment in a harmonised way across European airspace. In response to requests from the European Commission (EC), member states and stakeholders submitted proposals for EASA, an operation-centric, proportional, risk-and-performance-based regulatory framework for all unmanned aircraft, with national competent authorities (NCAs) chosen by each EU member state, being collectively responsible for overseeing and enforcing air law in the EU (Huttunen, 2019). Article 15 of Regulation (EC) No. 300/2008 requires the Commission to review some airport and operator security aspects. However, the agency and NCAs have a more significant role. Even though EU statutes allow the latter two agencies to outsource specific duties to other parties by certifying them as permitted organisations, supervision is centralised (Huttunen, 2019).

EASA and NCAs oversee all manned and unmanned operators and pilots, aircraft, related equipment, and other things covered, according to the Basic Regulation. In the instance of an airspace violation, they must undertake an investigation and inspections and take all necessary enforcement steps to stop the infringement. This authority to supervise and investigate is usually expanded to specific requirements outlined in supplementary rules based on the Basic Regulation. In manned aircraft, organisations having their principal place of business in a EU member state are typically monitored by the state’s NCA, while EASA is responsible for EU-level oversight of operators based in non-EU countries (Huttunen, 2019).

Opinion 01/2020 (a proposal to the EU Commission for adoption) is a high-level regulatory framework for the U-space, comprising rules and regulations on the use and control of UAVs in urban areas, provided by EASA (2020). Establishing the U-space airspace and facilities for U-space services is seen as critical in responding to the anticipated expansion of unmanned aircraft operations, particularly in low-level airspace, which is expected to outnumber the current volume of traffic observed with manned aircraft. The current ATM system is already overburdened, and the unmanned aircraft's expected UAS traffic and flying characteristics (without onboard pilot and a higher level of automation) differ fundamentally from conventional manned aircraft. Thus, it cannot be considered viable for legacy ATMs to simply take over the management of UAS traffic safely and efficiently.

As a result, and to augment the existing European Regulations for UAS operations in the "open" and "specific" categories, a European legislative framework allows for harmonised U-space implementation and is focused on ensuring safe control of UAS traffic. Indeed, U-space enables the management of increasingly complicated and long-distance operations and ensures that activities such as beyond visual line of sight (BVLOS) or urban air mobility (UAM) are supported by services that improve safety, security, privacy, and efficiency. The requirement for U-space airspace and U-space services is predicted to grow as UAS traffic and complexity grows, potentially covering the whole area where BVLOS and operations of UASs with increasing levels of autonomy are undertaken.

Based on the "Advance Notice of Suggested Amendment", a basic idea was proposed, namely that humans should be able to operate UASs in three categories (*open*, *specific*, and *certified*), each of which has varying safety criteria commensurate with its risks. The following are the three primary types of UAS operations:

- UAS operations in the "open" category do not require prior approval by the competent authority or a declaration by the operator before the operation occurs.
- A "specific" category of UAS operation is one that, because of the risks involved, requires authorisation by the competent authority before taking place, based on the mitigation measures identified in an operational risk assessment. A declaration by the operator is sufficient in some standard scenarios, or the operator holds a light UAS operator certificate (LUC) that gives access to the operation. The "certified" category of UAS operations is one that, because of the hazards involved, necessitates certification of the UAS, a licenced remote pilot, and a competent authority-approved operator to assure a sufficient degree of safety (Clothier and Walker, 2015).
- Currently, most national space monitoring agencies, such as the FAA in the US and EASA in Europe, allow drones to be operated with some restrictions. Aside from weight and sensors (such as cameras), there are restrictions on altitude, professional training and certification, drone registration, and prior permission for using controlled airspace (FAA, 2022). The most important limitation is that drones must operate within their operators' VLOS.

4.4. Reported Challenges Facing UAS Deployment in Qatar

In a previous study to identify the challenges facing the deployment of drones in Qatar using a PESTLE analysis as a platform to identify different challenges as perceived by different stakeholders (Perera, 2017), and a review of civilian drones' systems, applications, benefits, safety, and security challenges (AL-Dosari, Hunaiti and Balachandran, 2023), five key challenges to UAS deployment in Qatar were identified, as shown in Figure 4.2. These challenges justify the need for a framework to enable a roadmap for fostering further UAS deployment.

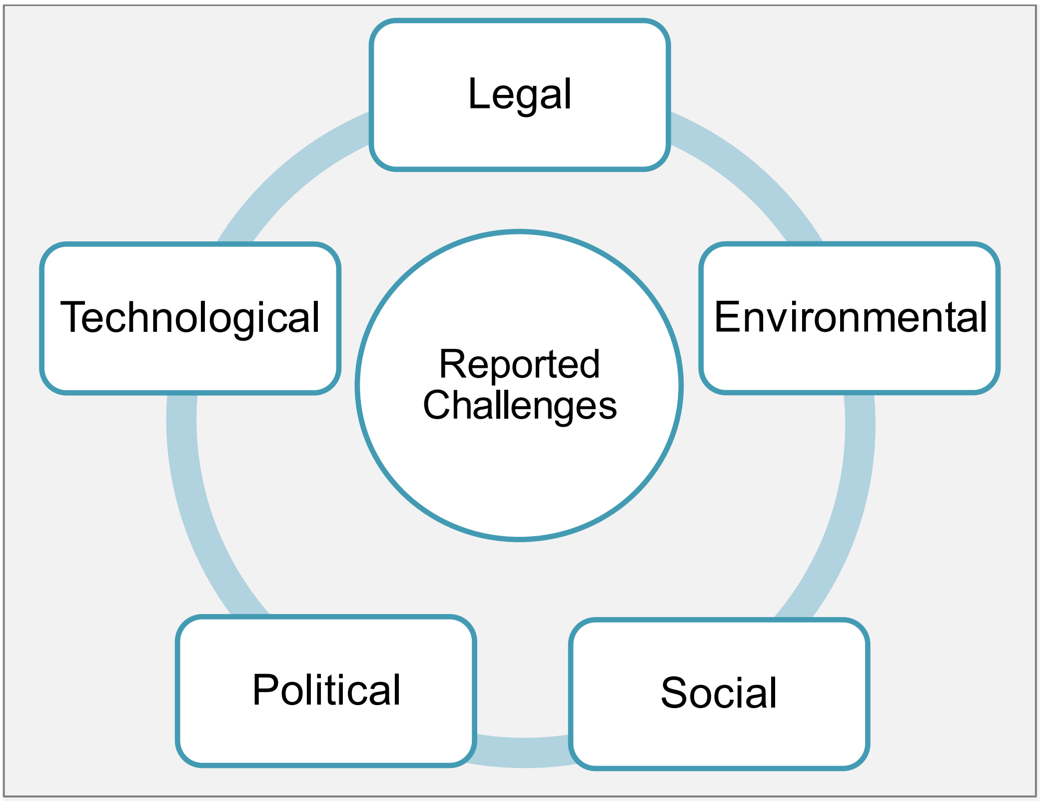

Figure 4.2: Top five challenges to UAS deployment In Qatar
Source: Author

As legal challenges have been reported as the most insurmountable, the framework must begin with the primary aim of providing a legal foundation for drones in the state of Qatar, which will lead to the rest of the challenges to be overcome. Other stages in the framework have been modelled on the UK CAA's (2020) "*Unmanned Aircraft System Operations in UK Airspace – Guidance & Policy*," and the EU EASA's "*Civil Drones (Unmanned Aircraft) EU Regulations*" (Bassi, 2020).

4.5. Overview of the Proposed Framework

The proposed framework has been divided into four key stages, as shown in Figure 4.3 and discussed below. This facilitates task allocation among different stakeholders and enables collaborative working within a comprehensive full cycle of deployment and future improvement.

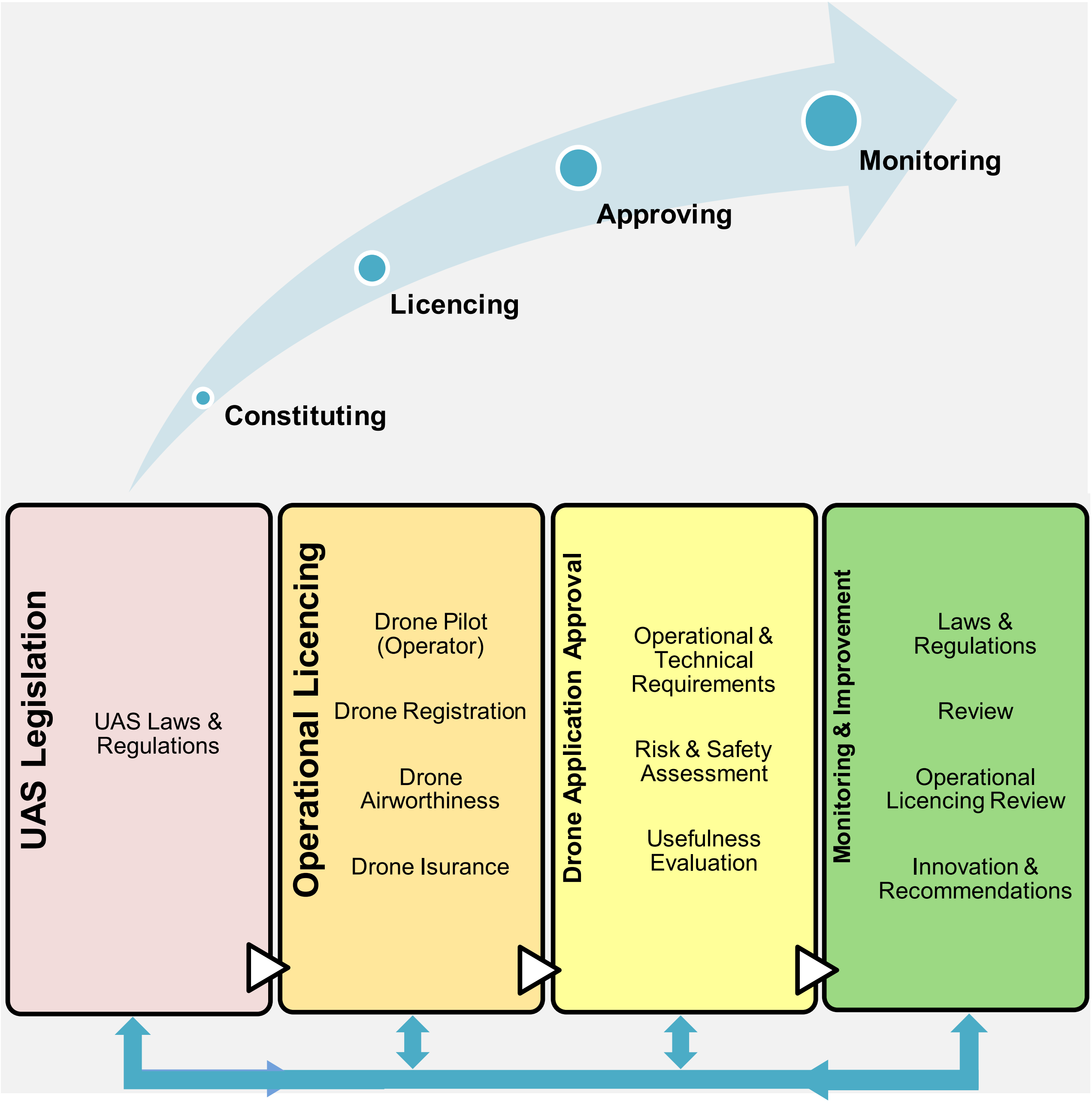

Figure 4.3: Proposed framework
Source: Author

4.5.1. Stage 1: Constituting

The UAS industry is a rapidly developing economic sector that is producing increasingly effective and affordable devices for diverse applications, including in the scientific and commercial domains. The UAS market is forecast to be worth EUR 10 billion per annum in Europe by 2035, and it could exceed EUR 15 billion by 2050 (Kramar, 2019). Various UAS applications include (but are not limited to) mapping, surveillance, construction, maintenance, inspection, and firefighting. The UAS is essentially a vehicle that can serve as a platform for different kinds of sensors required by different application types, including cameras, laser devices, radar, heat sensors, etc.

Safe UAS navigation is a fundamental challenge, necessitated by the need to minimise risks to different airspace users, people, and properties on the ground, as well as to the UAS itself. Therefore, each country should have clear UAS legal frameworks to regulate UAS planning and operation (Alamouri, Lampert and Gerke, 2021). Moreover, developing effective UAS regulation in Qatar is an essential first step to addressing the global efforts initiated by the ICAO (2022) to enable the integration of UASs safely and efficiently in global airspace.

Therefore, enabling the establishment of all laws and regulations that can govern UAS use in the country, with a view to impacts on neighbouring countries and the global UAS picture, is an important and difficult theoretical and legal stage. Other lessons and mistakes from other countries must be effectively used to establish such laws and regulations. To this end, this study adopts positive regulatory examples from EASA (Bassi, 2020) and the CAA (2020).

4.5.2. Stage 2: Licensing

The second stage related to licensing pertains to the actual enforcement related to the operational licences of humans and systems involved in UAS operations, including:

- **UAS pilots**

Pilots operate UASs remotely to perform tasks such as surveying, film making, and aerial photography. Airborne surveys can be conducted, digital images and data can be gathered, or maps can be created using flight data. To get a pilot ID, pilots must complete a theoretical exam; operators of UASs and model aircraft must obtain an operator ID (CAA, 2020).

- **UAS registration**

In the UK, most UASs and model aircraft must be registered before they can be flown in the open (CAA, 2020).

- **UAS airworthiness**

An aircraft's airworthiness is a measure of its suitability for safe flight. Certificates of airworthiness are issued by the CAA of the state where the aircraft is registered. Maintaining airworthiness is achieved by performing the required maintenance actions. The airworthiness of a plane or plane part refers to its possession of the requirements to fly safely within allowable limits. There should be a particular emphasis on three essential elements: safe conditions, compliance with required criteria, and acceptable limits (Ghasri and Maghrebi, 2021).

- **UAS insurance**

UAS insurance protects people against damage to their UASs and claims filed by other parties whose property may be harmed by a UAS; it is akin to conventional motor insurance. If one were to lose control of their UAS and it crashed into someone's car, they would be covered for both the UAS damage and the driver's claim. This is necessary if one wants to fly a UAS in UK airspace (CAA, 2020).

As explained previously, UASs have a wide range of applications, including but not limited to surveillance, inspection, monitoring, mapping, mining, construction, agriculture, energy, firefighting, healthcare, and logistics. Different challenges, including weather conditions and human factors, may undermine the optimum performance of the unmanned aircraft and impair its S&S. Therefore, having the right level of pilot competency, registration system, airworthiness mechanism, and insurance are necessary safeguards for this new revolution (Kramar, 2019).

4.5.3. Stage 3: Application approval

The third stage of approving UAV applications is an advanced one which requires that applications be designed according to the best standards to enable effective deployment, without imposing any risk to the safety of the public or people involved in device operation. It is important to fully follow a systematic approach to investigate the effectiveness of drone applications to serve the intended purpose, which can be facilitated by different developed approaches, such as the well-known system development life cycle (SDLC) (Usman and Nonyelum, 2018), which comprises five stages: inception to define user requirements, design that can serve the intended goal, implementation to establish the real solution prototype and test it, maintenance, and audit or disposal to continue to refine and improve the solution, with high consideration of risk analysis. A similar five-point framework based on the design-thinking methodology was proposed by Mollá *et al.* (2018): 'empathise', to better understand user needs; ‘define’, to state user needs and problems; ‘ideate’, to test assumptions and generate ideas; ‘prototyping’, to present real examples, and ‘testing’ performance in real trials.

Application approval ensures the right procedure and best-intended outcomes from the different stages of design prototyping and evaluation. The most important aspect is the UAS operational risk assessment, which indicates the safety level associated with UAS application under real circumstances. Hence, the assessment of UAS operational risk is the first significant step towards establishing safe flight missions for specific applications, with consideration of sensible and acceptable levels of risk, as UAS operation involves different agencies or organisations (Alamouri, Lampert and Gerke, 2021). Moreover, it is essential to have the right balance between different complex factors and data collected from public, technological, political, and commercial perspectives (Clothier and Walker, 2015). For this stage, the framework proposed in this study splits the process into three phases: defining technical requirements, risk and safety assessment, and evaluation of new application usefulness. These procedures help both operators and regulators.

4.5.4. Stage 4: Monitoring

As UAS technology is rapidly changing, monitoring is essential to dynamically learn lessons from real experiences as quickly and efficiently as possible, to make sure that regulations are fit for purpose, and to revisit all aspects related to device technology deployments and operation. All stakeholders involved in the preceding three stages must actively follow up the monitoring and evaluations stage for comprehensive troubleshooting to maximise the efficiency of UAS deployment, and to ensure that guidelines are being followed. A good example to build on in this regard is the EASA regulatory framework for drone service delivery. This framework enables the identification of technological problems and potential disruptions, ensures timely alignment of business models, and allows the incorporation of new UAS technologies and the integration of state-of-the-art technologies with existing systems, to sustain competitive advantage (Choi-Fitzpatrick, 2014). In the context of Qatar, this will enable commercial parties to become more competitive and productive.

4.5.5. Framework evaluation

To evaluate the framework, this study chose interviews as the most effective method to gather feedback from key stakeholders who had participated in a grievance study to identify challenges related to the deployment of drone applications in Qatar. The interviews were conducted using a mixed method approach, where both quantitative and qualitative data was collected. Such an approach can have several advantages and one of them is that greater depth and understanding of quantitative results can be gained by also using a qualitative data collection method (Saunders, Lewis and Thornhill, 2023). The well-known qualitative data collection method of semi-structured interviews is highly advantageous for both interviewers/researchers and participants, allowing the interviews to remain focused on phenomena of concern while allowing participants to disclose contextually rich data (Wengraf, 2001), based on their in-depth knowledge and perspectives (DiCiccoBloom and Crabtree, 2006; Galletta, 2012). This was the qualitative approach taken in this research, with the interview form used in this study (Appendix 5) being adopted from Al-Yafei (2018), who successfully proposed a previous framework for use in another context. Thus, the interview sheet included several questions with closed answers and three with open answers to allow each participant to provide their opinion concerning questions related to the elements of the framework and to provide their suggestions, from their professional perspectives, concerning the drone industry.

Following the construction and the validation of the interview by three professionals to make sure it was correct and could be understood by stakeholders from different professional backgrounds (Sargent, 2013), interviews were conducted with the stakeholders and quantitative answers were directly digitised, to enable better data analysis. The quantitative analysis method was conducted using SPSS (Abu-Bader, 2021), with the qualitative responses from the semi-structured interviews being recorded and subsequently transcribed. As the total number of participants was 27 the researcher decided not to use a software package to analyse the data but did follow recommended steps (de Casterle, Gastmans, Bryon and Denier, 2012), whereby the data was coded, arranged into themes and then categorised. Quantitative analysis began with the reliability of responses, followed by providing descriptive and comparative analysis between the responses from different stakeholders. Finally, the qualitative results provided by the participants were collated and reported.

4.6. Findings from the Evaluation

4.6.1. Statistical analysis

The statistical analysis includes descriptive analysis with mean, standard deviation (SD), frequency, percentage, and degree values, with length of period scores calculated based on the following formula:

$$\text{Length of period} = \frac{\text{Upper bound - lower bound}}{\text{Number of levels}} = \frac{5-1}{3} = 1.33$$

Where the number of period levels was low (1-2.33), medium (2.34-3.67), and high (3.68-5). Cronbach's alpha test was used to determine the stability of the study instrument, and one-way analysis of variance (ANOVA) testing was used to compare between results from different groups (Abu-Bader, 2021).

4.6.2. Sample reliability

For responses to be reliable, they had to have a Cronbach's alpha coefficient of at least (0.6), indicating that the question from the questionnaire measured the variable it was supposed to, which is indicative of a consistent and dependable instrument. The value of the Cronbach alpha coefficient in this study reached (0.87), indicating that the study instrument was valid for study purposes (Sekaran and Bougie, 2016).

4.6.3. Demographic characteristics

The results shown in Table 4.1 show that the participants worked in diverse sectors. The largest cohort worked in firefighting (n=4, 14.8%), followed by research and higher education, and military aviation (n=3, 11.1% each). The remaining participants were from other sectors in equal proportions, with two each (7.4%), except for one participant (3.7%) employed in the civil aviation sector.

Table 4.1: Participants by work sector

Work sector	N	%
Firefighting	4	14.8
Research and higher education	3	11.1
Military aviation	3	11.1
Interior Security	2	7.4
Police	2	7.4
Government innovation and authorities, public services, and business development	2	7.4
Oil and gas sector	2	7.4
MoTC	2	7.4
Environmental sector	2	7.4
Qatar RC Club	2	7.4
Qatar World Cup Security Community	2	7.4
Civil aviation	1	3.7
Total	27	100.0

Source: Author

4.6.4. Satisfaction with the current civilian UAS deployment framework for Qatar

Satisfaction with the current civilian UAS deployment framework for Qatar (DFQ) was answered by participant agreement with various aspects of satisfaction, as shown in Table 4.2, which shows the mean scores of all the paragraphs representing participants' degree of satisfaction. It can be seen that all the items got a high degree of agreement, ranging from 4.04 to 4.63. "The framework is clear and easy to understand" got the highest degree of agreement, while "The framework is comprehensive (includes all essential aspects)" got the lowest. The average indicated a high degree of satisfaction with the DFQ (4.39).

Table 4.2: Degree of satisfaction with the DFQ

Satisfaction indicator	Mean	SD	%	Degree
The framework is clear and easy to understand	4.63	.688	92.6	High
The framework is efficient	4.59	.888	91.9	High
The framework is practical	4.41	.888	88.1	High
The framework is applicable	4.41	.844	88.1	High
The framework is systematic and well-structured	4.41	.888	88.1	High
The framework is appropriate for Qatar	4.37	.884	87.4	High
The framework is easy to implement	4.33	.784	86.7	High
The framework helps stakeholders understand civilian UAS deployment needs	4.30	.993	85.9	High
The framework is comprehensive (includes all essential aspects)	4.04	.940	80.7	High
Average	4.39	0.866	87.7	High

Source: Author

Table 4.3 shows the degree of satisfaction with the DFQ depending on the work sector. One-way ANOVA was conducted to determine whether the work section affects the degree of satisfaction with the DFQ. The results are shown in Table 4.4, indicating that the (F) value is not statistically significant at ($\alpha \leq 0.05$), so we can conclude that the work section does not significantly affect the degree of satisfaction with the DFQ. In summary, the study found that the degree of satisfaction with the DFQ was high, with no difference due to the work section.

Table 4.3: Degree of satisfaction with DFQ by “work sector” variable

	Sector																							
	A		B		C		D		E		F		G		H		I		J		K		L	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
I	4.00	1.732	5.00		5.00	0.000	5.00	0.000	4.00	0.000	4.75	.500	4.50	.707	5.00	0.000	4.50	.707	4.50	.707	4.50	.707	5.00	.000
II	3.33	2.082	4.00		4.67	.577	4.50	.707	4.50	.707	4.75	.500	4.50	.707	5.00	0.000	4.50	.707	4.00	1.414	4.50	.707	4.50	.707
III	3.33	2.082	5.00		4.00	0.000	4.50	.707	3.50	.707	4.50	.577	4.50	.707	4.50	.707	4.00	0.000	3.00	1.414	4.50	.707	3.50	.707
IV	3.33	2.082	5.00		4.67	.577	4.50	.707	5.00	0.000	4.50	.577	4.50	.707	4.50	.707	5.00	0.000	4.00	0.000	4.50	.707	4.00	0.000
V	3.67	2.309	5.00		4.67	.577	5.00	0.000	4.50	.707	5.00	0.000	5.00	0.000	4.50	.707	5.00	0.000	4.50	.707	4.50	.707	4.00	1.414
VI	3.67	2.309	5.00		4.33	.577	4.00	0.000	4.00	1.414	4.75	.500	4.50	.707	5.00	0.000	4.50	.707	4.50	.707	5.00	0.000	4.00	0.000
VII	3.33	2.082	4.00		4.00	0.000	5.00	0.000	3.50	.707	4.75	.500	5.00	0.000	4.50	.707	4.50	.707	4.50	.707	5.00	0.000	4.50	.707
VIII	3.33	2.082	4.00		4.33	.577	4.50	.707	4.00	1.414	4.75	.500	4.00	0.000	4.50	.707	5.00	0.000	3.50	2.121	4.50	.707	5.00	0.000
IX	3.33	1.528	5.00		4.67	.577	5.00	0.000	4.50	.707	4.50	.577	4.00	0.000	4.50	.707	4.00	1.414	4.50	.707	4.50	.707	4.00	0.000
Av.	3.48	1.957	4.67		4.48	.339	4.67	.157	4.17	.236	4.69	.229	4.50	.236	4.67	.000	4.56	.314	4.11	.943	4.61	.079	4.28	.393

Key:

I. Clear, easy to understand
II. Systematic, well-structured
III. Comprehensive
IV. Applicable
V. Efficient
VI. Practical
VII. Appropriate for Qatar
VIII. Helps stakeholders understand needs
IX. Easy to implement
M: Mean
SD: Standard deviation

A. Research and higher education
B. Civil aviation
C. Military aviation
D. Interior Security
E. Police
F. Firefighting
G. Gov. innovation, business development, public services, and gov. authorities
H. Oil and gas sector
I. MoTC
J. Environmental sector
K. Qatar RC Club
L. Qatar World Cup Security Community

Source: Author

Table 4.4: One-way ANOVA testing for work section–degree of satisfaction with DFQ

Work sector	N	Mean	SD	df	Mean square	F	Sig.
Research and higher education	3	3.48	1.957				
Civil aviation	1	4.67					
Military aviation	3	4.48	0.339				
Interior security	2	4.67	0.157				
Police	2	4.17	0.236				
Firefighting	4	4.69	0.229				
Government innovation and authorities, public services, and business development	2	4.50	0.236	11	.337	.542	.845
Oil and gas sector	2	4.67	0.000				
MoTC	2	4.56	0.314				
Environmental sector	2	4.11	0.943				
Qatar RC Club	2	4.61	0.079				
Qatar World Cup Security Community	2	4.28	0.393				
Total	27	4.39	0.708				

Source: Author

4.7. Stakeholder Suggestions (Recommendations and Limitations)

Tables 4.5 and 4.6 show the suggestions made and limitations identified by different stakeholders for the framework, along with actions taken to address them (respectively).

Table 4.5: Stakeholder suggestions

Stakeholder Suggestion	Comment
'Focus more on the regulations part since there are no regulations in Qatar for drones so far."	Addressed in Stage 1
'The aim of fostering the capabilities of UAS drones can most easily be accomplished by removing the technical and regulatory barriers to civilian drone flights. This means Qatar must endeavour to develop technologies from its low technology readiness levels to ones that can be readily developed in the commercial sense; then, the cost will have a lower impact on market development. It also means developing technology and policies that facilitate flight in the national air space of Qatar. When these occur, innovation and entrepreneurship will drive down the cost of UAS drones and drive up the safety, reliability, and operability of drones.'	Addressed in Stages 1, 3 4
'Some technical modifications will improve the framework.'	Not clear
'Drones offer numerous benefits and vast potential in the academic community, both for deploying new programmes of study and for augmenting research in existing fields. However, the proposed framework should ensure the accommodation of challenges and management of UAS use on computers.'	Addressed in Stage 3
'Low flying time. It should be enhanced in terms of time through this framework.'	Outside the scope of the research
'Area of study should be elaborated.'	Addressed in all stages
'Show the internal structure of the UAS drones.'	Outside the scope of the research
'Show conceptual sketch of UAS drones.'	Outside the scope of the research
'It is very generic; you have to create a more detailed framework.	Not clear
'This framework has many flaws; this is a generic model without experimental design. It should be made based on an experimental design that will ultimately prove the existence of UAS drones. I am currently working for the Stadium Security Office, and I don't think this framework will help me to design the security measures.'	Addressed in Stage 3
'Improve drone flight timing.'	Outside the scope of the research
'Reformat the shape to be more professional regarding graphics.'	Addressed in all stages
'Should be engaged in stadium security measures.'	Addressed in Stage 3
'Vehicles you will get some useful information.'	Not clear

Source: Author

Table 4.6: Limitations of the proposed framework

Weaknesses/limitations	Comment
'The terminologies are weak and should be more accurate and professional to be implemented.'	Addressed in all stages
'The process of handling it; practical implications are weak.'	Not clear
'It is useless in mortal combat.'	Not clear
'How are the systematic procedures to enhance battery timing? I think it is under-researched.'	Outside the scope of the research
'Time frame.'	Addressed in all stages
'It is limited to technical and operational skills; the human resources and the influence of stakeholders need to be addressed.'	Addressed in all stages
'Area should be specified in that country.'	Not clear
'Lack of practical and experimental design.'	Addressed in Stage 3
'Need more battery timing duration.'	Addressed in all stages

Source: Author

4.8. Aligned Framework

The aligned framework is shown in Figure 4.4, including the suggested cosmetic improvements by the participants, and the inclusion of a time frame for each stage. It should be noted that these time frames are just estimations to provide some guidance. However, policymakers should be able to identify realistic time frames for each stage to be accomplished.

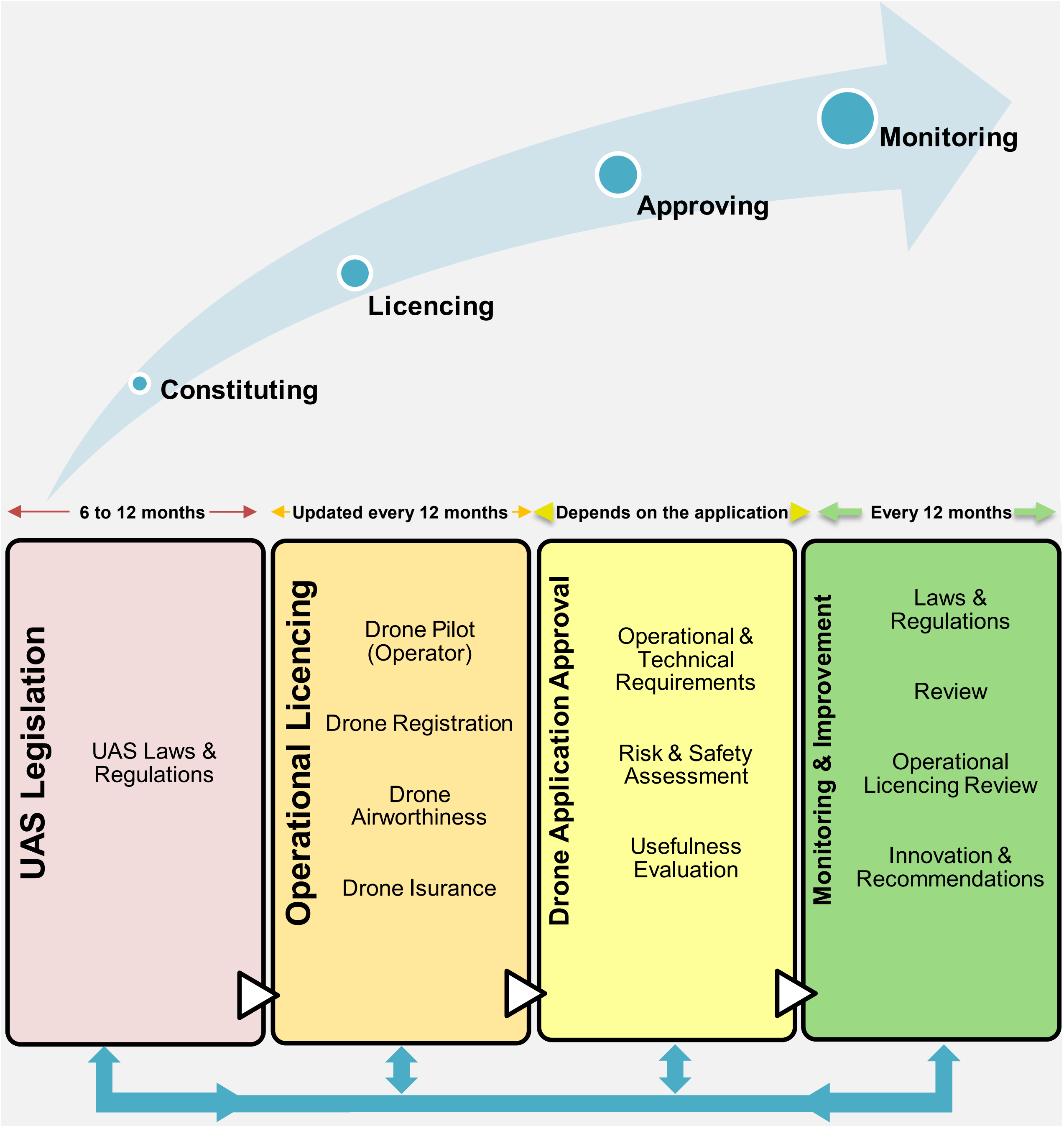

Figure 4.4: Aligned framework
Source: Author

4.9. Chapter Summary

The proposed framework has been evaluated by a wide range of stakeholders and it is clear from the analysis that this framework obtained a high degree of acceptance among them, with no statistical difference between any of the groups. The results from the first part of the questionnaire (with structured, closed-ended questions) demonstrated high confidence in each part of the framework to satisfy the mission of fostering the deployment of drone applications in Qatar, enabling the country to catch up with other countries that have made significant progress in UAS technology and infrastructure. The second part of the interview elicited insightful suggestions and also highlighted some shortcomings of the framework, which were addressed in the subsequent aligned version.

Nevertheless, there were some suggestions and weaknesses that were either unclear or beyond the scope of the purpose of this framework, which was drawn up to initiate and establish drone applications and operations in Qatar. However, these suggestions will be very useful for future research agendas. In conclusion, this framework offers a road map to enable different stakeholders to contribute to developing the UAS industry and supporting facilities in Qatar, enabling the country to develop an international presence in efforts to make civil drones more globally effective and safe. The next stage will be to put this framework into practice, regularly conduct validation and assessment, and continuously monitor and improve it relative to emerging data and stakeholder requirements, thereby continuing to provide sustainable support for the UAS industry in Qatar.

CHAPTER 5
MEGA SPORTING EVENT SCENARIO ANALYSIS AND DRONE CAMERA SURVEILLANCE IMPACTS ON COMMAND-AND-CONTROL CENTRE SitAw FOR DD-M

5.1. Chapter Overview

This chapter delves into the critical intersection of MSEs, risk management, and ScenAn, with a particular focus on the Champions League Final held in France in 2022. It begins by elucidating the concept of ScenAn and its historical evolution, emphasising its role in strategic planning, risk management, and decision-making. The chapter underscores the importance of ScenAn in the context of MSEs, especially in light of unprecedented challenges such as those posed by the COVID-19 pandemic. The methodology section outlines the research design, employing a mixed methods approach involving quantitative content analysis and a questionnaire administered to S&S professionals (S&SPs) in Qatar. This methodological approach allows for a comprehensive understanding of the France ’22 incident and the perceptions and attitudes of relevant stakeholders regarding risk management strategies and the role of drone surveillance in enhancing SitAw for DD-M.

Furthermore, the chapter discusses the implications of ScenAn for risk management in MSEs, highlighting the multifaceted nature of S&S concerns, including overcrowding, disorderly behaviour, and potential terrorist threats. It emphasises the need for proactive planning and preparedness to mitigate risks and ensure the safety of participants and spectators. The study also introduces a model of SitAw and DD-M adapted for the context of MSEs, aiming to enhance command and control centre (C&CC) operations and response capabilities. This model integrates AI and dynamic data-driven application systems to facilitate adaptive measurement and resource allocation based on changing situational dynamics. This is a comprehensive examination of the S&S challenges associated with MSEs, offering insights into effective risk management strategies and the potential of drone surveillance technology to enhance SitAw and decision-making processes.

5.1.1. ScenAn: History and role

ScenAn is a strategic planning technique used by organisations to anticipate and prepare for future challenges. It involves creating and analysing multiple plausible future scenarios to understand potential outcomes and their implications. ScenAn helps organisations enhance their readiness, resilience, and responsiveness by providing insights into different possible futures. By exploring a range of scenarios, organisations can identify potential risks, opportunities, and uncertainties. This enables them to develop robust strategies, adapt their operations, and allocate resources effectively to address both expected and unexpected challenges. ScenAn also plays a vital role in risk management by identifying vulnerabilities and enabling organisations to develop contingency plans tailored to different scenarios. It enhances organisational preparedness, ensuring proactive measures are in place to mitigate risks and seize opportunities (Postma and Liebl, 2005).

Designing scenarios in the context of strategic military planning was already common practice by the 1950s (Blood and Postma, 1997) and, by the end of the 1960s, private corporations like General Electric and Royal Dutch Shell were employing ScenAn to explore SitAw for the first time, generating the first energy scenarios. Scenarios are used in several contexts, with some of their significant applications including strategic corporate planning, municipal and land-use planning, political consultancy, and global scenarios addressing the future of energy or the environment. Numerous scenario strategies have been created for diverse sectors and strategists claim that scenarios help them make strategic decisions, particularly regarding contextual uncertainty. Long-term forecasts are often useless in the face of dynamic or unexpected changes in the external environment, and ambiguous trends are often hard to detect. Increasingly, managers have replaced forecasting techniques with scenario (and similar) methods to mitigate this problem.

ScenAn is fundamentally defined and distinguished from other forms of strategic analysis by predicting what might happen in the future, assuming that a phenomenon or trend will continue. It has become a common strategic tool to ensure organisational resilience and responsiveness in extraordinary or new contexts, seeking to minimise damage, recover operations, and reorient processes (where necessary) (Postma and Liebl, 2005). The use of scenarios to deal with uncertainty is effective. Rather than obtaining forecasts, ScenAn proposes alternative images of the external environment's future development. By highlighting essential tensions, scenarios affect the strategic decisions managers have to make.

Since its introduction, the scenario approach has undergone significant changes, although the forecasting substitution argument remains (Postma and Liebl, 2005). Multiple-ScenAn is becoming increasingly attractive to managers due to newly developed functions (Blood and Postma, 1997). It is now claimed that ScenAn supports the entire strategic management process, including elements such as the generation of options, the building of consensus, and even the implementation of strategies. As noted, the term "scenario" describes a possible future situation, including the path that led to it. Many people describe a scenario as a depiction of a possible future condition (conceptual future), and the routes of development that may lead to that future circumstance (Kosow and Gaßner, 2008).

Unlike an abstract future, which shows a possible future condition of events, a scenario describes the changes, dynamics, and moving factors that result in a given abstract future. The purpose of scenarios is not to define the future entirely but rather to identify the key factors that will influence future developments and highlight critical elements of possible events. The goal of scenarios is to generate orientation for future results by observing certain crucial critical aspects. Scenarios may also be used to develop communication and enlighten subjects and priorities, broadening awareness of topic areas, thereby shedding light on problem situations and enhancing discourse on these issues, ideally with the inclusion of diverse internal and external stakeholders' perspectives (Blood and Postma, 1997). Hence, three points should be considered while undertaking the ScenAn process or evaluating the outcomes of such an analysis:

- A scenario is not a whole picture of the future; instead, its real job is to bring attention to one or more specific and clearly defined portions of reality.
- Scenarios are hypothetical sequences of events designed to draw attention to causal processes and decision points (Kosow and Gaßner, 2008).
- Various selected aspects and events are consciously incorporated into certain interrelated clusters during the analytical process (Kosow and Gaßner, 2008).

5.1.2. ScenAn in risk management

Many scenario analysts emphasise that scenarios are hypothetical constructs that do not claim to represent reality *per se*. To begin with, scenarios help generate knowledge about the present and the future, as well as identify their limitations. Second, scenario production is frequently based on exchanging ideas between persons with various viewpoints, so that ScenAn can serve a communicative purpose. Scenarios may also be used to attract attention to specific concerns through public communication. Third, scenarios can help decision-makers develop goals. Finally, they may be used to assess the prospective efficacy of organisational tactics. Scenarios can be evaluated based on their plausibility, internal coherence, comprehensibility and traceability, distinctness, and transparency. The appropriate scenario technique is defined by the goals of the research endeavour and the context in which the study is done (Kosow and Gaßner, 2008).

Scenarios are used to attain diverse goals and meet the need for various services. These functions may be classified into four categories: explorative and scientific processes, communicative functions, target concretisation and production duties, and decision-making and strategy formulation functions (Kosow and Gaßner, 2008). They also focus on potential development paths, differentiating characteristics, crucial factor interactions, and the range of possible outcomes. A transformation effect may be achieved with the help of scenarios, whereby an initially unknown future environment characterised by a spectrum of possible developments (i.e., a range of potential futures) can be transformed into a future climate in which products are assembled into scenarios, allowing for the identification of different alternative or alternate futures (Kosow and Gaßner, 2008). Furthermore, scenarios can broaden the breadth of our reflections and increase their correctness in terms of options outside the boundaries of standard paradigms.

Scenarios are also employed in decision-making and strategic planning procedures since they give points of guidance for those who carry out the planning (Kosow and Gaßner, 2008) and alternatives and actionable indicators might be established based on circumstances. They also assess decision-making processes, proposed actions, and strategies. This work is frequently done with a variety of scenarios which are then contrasted to highlight probable future developments and allow the ramifications of various actions and decision-making processes to play out against a virtual backdrop. Scenarios may, therefore, be used to assess policy dependability, robustness, and efficacy. Aside from the several objectives of scenarios, it is wise to understand the limitations of what can be performed with them (Kosow and Gaßner, 2008).

When applied effectively, ScenAn can help organisations maintain their readiness, resilience, and responsiveness to meet unexpected (and expected) future challenges. For example, the scenario of a company facing bankruptcy should be used to devise a plan for such a contingency, which would be appropriate risk management for this potential future. Consequently, if this risk arises in reality, the company is prepared to tackle the problem and find a solution in a calm manner (de Ávila Costa *et al.*, 2022). This would be possible due to the ScenAn that the company had undertaken, preparing itself for bankruptcy before the problem or scenario was an actuality. This is why such analyses are crucial for risk management. They prepare a person or corporation for future possibilities and provide them with time to develop a strategy to tackle the problem if the scenario turns out to be true.

5.1.3. ScenAn for MSEs

The unprecedented global lockdowns following the spread of COVID-19 revealed the potential for public health diktats to close whole economies, signalling a major threat to mega sports and clubs. They cannot function based on the same conditions as they did previously, and national and international competitions may be cancelled or postponed at a moment's notice by erratic and unpredictable political decisions. Sponsorship contracts may be re-evaluated, and cash flow may be affected by particular macroeconomic fallout from the unprecedented economic shocks reverberating around the global economy (*Le Monde*, 2022).

There is always the potential for successive waves of infectious diseases but even under conditions of relative normalcy, when large crowds are permitted back into stadiums for mega events, sports and event managers need to prioritise the S&S of players, as well as customers. Therefore, sports organisations must prepare for many scenarios and eventualities. The short and long-term planning of sports organisations is essential even without pandemics or lockdowns (Child Protection in Sport Unit, 2021). For example, a sports manager will make assumptions about the transfer market and the current team before making any moves. Upon the opening of the transfer window, he must revise his assumptions in response to dynamic changes caused by other players on the market (Sky Sports, 2022). As a result, every transfer decision directly affects the team's performance, and therefore the club's internal context.

For planning purposes, the coaching team also must assume plausible outcomes. It may be possible to plan training cycles on a seasonal basis, on a six-week basis, or even every week. The coaching staff will conduct the training session based on their projections for the forthcoming season. Coaches can rely on their alternative planning, based on predicted situations, to react as rapidly as possible if internal or external circumstances change. Short-term scenario planning may be employed in the 'match plan' for upcoming games, with such a plan being essentially a set of 'if-then' scenarios that predefine reactions on the field. In this context, the coaching staff can foresee certain scenarios, such as key players being injured unexpectedly, red cards being issued, overtime in close games, and so on, and then take appropriate action based on these forecasts. Anticipating significant scenarios is vital since unanticipated changes in game parameters can impact dynamics in seconds (Child Protection in Sport Unit, 2021).

At the outset, organisations should set a time frame for their scenario planning; for example, for the next match, three months, six months, or a year ahead of time. After selecting an appropriate time frame, they can identify important trends and driving forces that will have an impact on their organisation (i.e. team) within that period. Workshops, brainstorming, and polling can be used in this process, along with the analysis of historical background data (Ringland, 1998). MSEs are attended by many thousands of spectators, and hundreds of thousands can potentially be associated with such events in surrounding hinterlands (e.g.

people watching football games in city pubs in addition to those attending the match in a stadium in the same city) (Guddat *et al.*, 2021).

For mega sports, ScenAn may encompass a wide variety of risk management issues, such as overcrowding factors, drunk and disorderly behaviour, assaults, missing or kidnapped children, sexual harassment, or exhibitionists running onto the field to disrupt play (Otto, Pawlowski and Utz, 2021). Risk management plans typically include surveillance, with established fixed cameras (FCs) installed in key locations, and drone cameras (DCs) on standby, or deployed, as necessary. Institutional security and law enforcement agencies must also be on standby during MSEs and heightened readiness and responsiveness is expected of emergency services, such as standby paramedic units and ambulances, to deal with emergencies, including medical injuries to players and spectators. It is also necessary to protect the privacy of players and high-profile spectators during MSEs who may be vulnerable to harassment, violent attacks, even assassination or kidnapping attempts. Risk management for MSEs entails making every effort possible, including many tiers of backup and emergency planning, to provide the optimum S&S for those attending and playing in events and the surrounding general public.

5.1.4. ScenAn methodology

Different organisations use ScenAn methodologies in different ways or actively seek to imitate the successful practices of others. This can be seen in the active imitation of Shell's ScenAn system in various organisations and institutions over the decades (Postma and Liebl, 2005). This methodology, which has also been adopted by the EC, applied the Pierre Wack Intuitive Logics method for ScenAn (Ringland, 1998). This 'wind tunnel' approach was developed by the eponymous Pierre Wack, a Shell Group planner during the 1960s and 1970s, to test business plans or projects, prompt public debate, and increase coherence (Postma and Liebl, 2005). It aims to help managers anticipate and prepare for various futures by working on their mindsets (Jungermann and Thüring, 1987).

The organisation develops estimates about how different scenarios would affect various business elements, such as borrowing rates and raw material costs. In general, a variety of possibilities are analysed, ranging from best-case to worst-case scenarios (e.g. ranging from significant revenue being generated from the sale of a new product released into the market to a fire accident leading to operations being shut down for months, allowing insurgent competitors to commandeer market share) (Kosow and Gaßner, 2008). Such scenarios have to include almost every possible contingency to ensure that the organisation is fully prepared when such scenarios materialise. Hypothetical scenarios are explored concerning input variables to calculate the business effect of each potential outcome. ScenAn may take into account a wide range of variables such as rent, labour, taxes, utilities, and other costs that may be included in an analysis of the prospective financial effect of developing a new facility.

Although there are many distinct types of ScenAn tools, the scenario process is fundamentally similar across these approaches. The first step of the scenario process involves identifying the scenario field, which refers to the range of potential future situations or conditions that an organisation considers during the scenario development process. It represents the space of possibilities within which the scenarios can be created. This step also includes defining the specific issues to be addressed and determining the scope of the study (Kosow and Gaßner, 2008). In the second step, the essential elements are determined. These elements encompass critical uncertainties or key factors that have a significant impact on how the future unfolds. By exploring different combinations or variations of these essential elements, a set of distinct scenarios can be developed. These scenarios capture different plausible futures within the defined scenario field, enabling organisations to gain a better understanding of the range of possibilities and make informed decisions accordingly. During this step, researchers identify the essential elements that will have significant impacts on the future and examine their effects.

The third step then investigates the spectrum of outcomes that these major elements may cause. This is followed by a fourth phase in which the list of primary factors is condensed, or essential factor values are bundled together, to form a reasonably small number of meaningfully identifiable scenarios. The last stage of the scenario process is known as scenario transfer, and it entails using the completed scenarios for objectives such as strategy evaluation (Kosow and Gaßner, 2008).

5.1.5. Adopted model: SitAw and DD-M (DD-M)

The S&S of MSEs requires a comprehensive approach to establish appropriate levels of SitAw, indicating sensitivity and responsiveness to changing environments. The model of SitAw shown in Figure 5.1 was adapted from the version originally developed in the 1990s by Jungermann and Thüring (1987), later developed by Endsley (1999), and subsequently improved. It covers three successive and interrelated core elements: perception, comprehension, and projection. The first stage is the most crucial one in the model, whereby human beings should establish a strong understanding of the environment by applying the available sensing method, to translate that into an informative understanding of the situation at that given time, and to establish options for correct actions (Endsley, 1995, 2017).

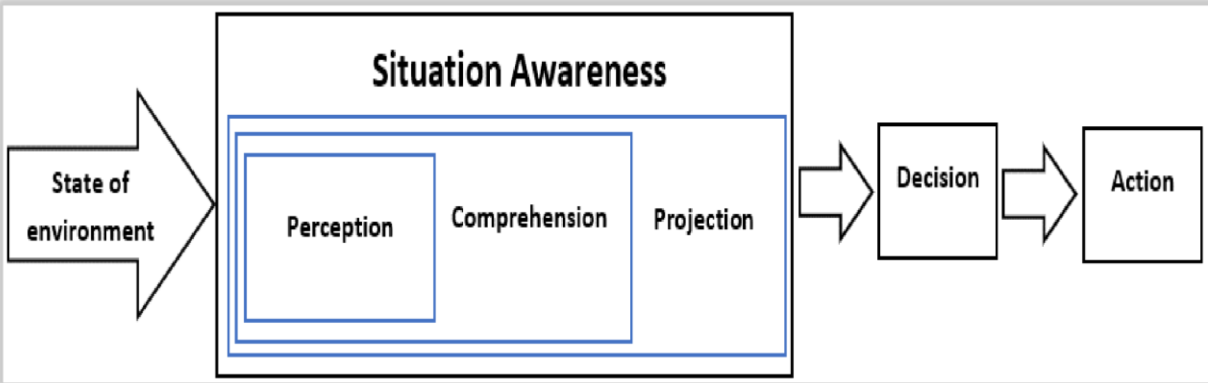

Figure 5.1: Model of SitAw in a dynamic system
Source: adapted from Endsley (2017), based on Jungermann and Thüring (1987)

The term ‘reception state’ is not commonly used in the context of decision-making. However, in the context of communication or information processing, it could refer to the state of receiving or perceiving information. The reception state is crucial in decision-making as it affects the availability and quality of information on which decisions are based. It involves being aware of and understanding the presented information, including its relevance, accuracy, and reliability. The reception state influences decision-making by shaping the inputs and knowledge that decision-makers rely on when evaluating options and making choices (Ensley, 1995).

Effective decision-making requires a clear and accurate reception state, where decision-makers actively seek, process, and comprehend relevant information. Maintaining a robust reception state is essential for making informed judgements and decisions, leading to more effective outcomes (Jungermann and Thüring, 1987).

It is important to note that any impairment or lack of information during the reception state can result in a lack of understanding of the current situation and, potentially, lead to incorrect or less effective decisions, especially in dynamic environments. Regular sensing and monitoring are necessary to sustain a comprehensive awareness mechanism that facilitates appropriate decision-making. This concept is evident in scenarios such as military aeroplane operations, where pilots must establish a high level of SitAw in rapidly changing and unpredictable environments. To address such contexts, an aligned model to fit this scenario was recently presented by Munir, Aved, and Blasch (2022).

The model integrates artificial intelligence and dynamic data-driven application systems to facilitate adaptive measurement and resource allocation based on the changing situations perceived and projected by the SitAw core. The model revolves around the SitAw core, with sensing and decision-making elements designed around it. Various sensors are deployed to perceive the environment and collect data on its state. The gathered data from these sensors is fused to remove redundancies, such as similar views captured by different cameras or multiple quantities sensed by nearby sensors. This fusion process also addresses the limitations of data obtained from a single source, such as occlusions, changes in lighting conditions, or environmental unpredictability (Munir, Aved and Blasch, 2022).

Applying the same concept may be appropriate for MSEs, which can be very dynamic and volatile, requiring swift and decisive courses of action. It is important to devise an aligned model for SitAw to accommodate MSE requirements, facilitate decision-making to ensure the S&S of major events and avoid any negative consequences. This chapter specifically aims to utilise ScenAn to extract insights from the recent Champions League Final held in France in 2022. The objective is to increase the awareness of S&SPs in Qatar regarding the repercussions of major sporting incidents and to establish a SitAwM for DD-M in the context of MSEs.

5.2. Chapter Research Methodology

A mixed methods research methodology was selected in this chapter to achieve the study objectives. The first phase comprised a quantitative content analysis to extract information related to France ’22 to analyse the identified scenario and establish a ScenAn based on the previous incident, to mitigate risks associated with similar incidents in the future. The second phase was a quantitative questionnaire administered to S&SPs in Qatar to explore their opinions about the possible consequences of such events, assess their level of SitAw regarding given examples, and investigate their attitudes towards the role of drone surveillance in improving SitAw for DD-M. The outcomes from the first phase led to the establishment of the second phase of the method: to enable data collection from those concerned with C&CC operations.

As France ’22 was very recent, at least at the time of this study’s fieldwork (June–July 2022), most of the information related to this incident was based on the availability of emerging news articles, videos, and investigative reports. Hence, the most suitable method to extract information related to the event causation, consequences, and investigation outcomes was content analysis (Drisko and Maschi, 2016). Content analysis enables a full understanding of incidents and helps to identify pertinent videos of sufficient quality to be used to establish the ScenAn (Van Teijlingen *et al.*, 2001).

A pilot study was conducted with three participants to make sure the study instruments were easily understood before starting the formal data collection. Data analysis from the content analysis phase was undertaken using the thematic approach (Liebl, 2002) to identify possible consequences when incidents occurred. The data collected by the questionnaire was analysed using SPSS (Cronk, 2017) and the SitAw mathematical formula, as described below (Munir, Aved and Blasch, 2022).

Figure 5.2. illustrates the chapter research design. It begins by identifying the case of the France '22 Champions League finals incident for content analysis. This involves investigating the impact of the incident and selecting informative videos and documentation to construct a comprehensive understanding of the event. The second phase focuses on establishing the ScenAn through a questionnaire. This questionnaire includes assumptions about the potential consequences of the incident, both through Lego legal simulation and real-life imagery. It also involves gathering the opinions of S&SPs in Qatar. The final phase involves conducting the study itself. This phase includes a pilot study to refine the chapter research approach, followed by data collection and analysis using the finalised methodology.

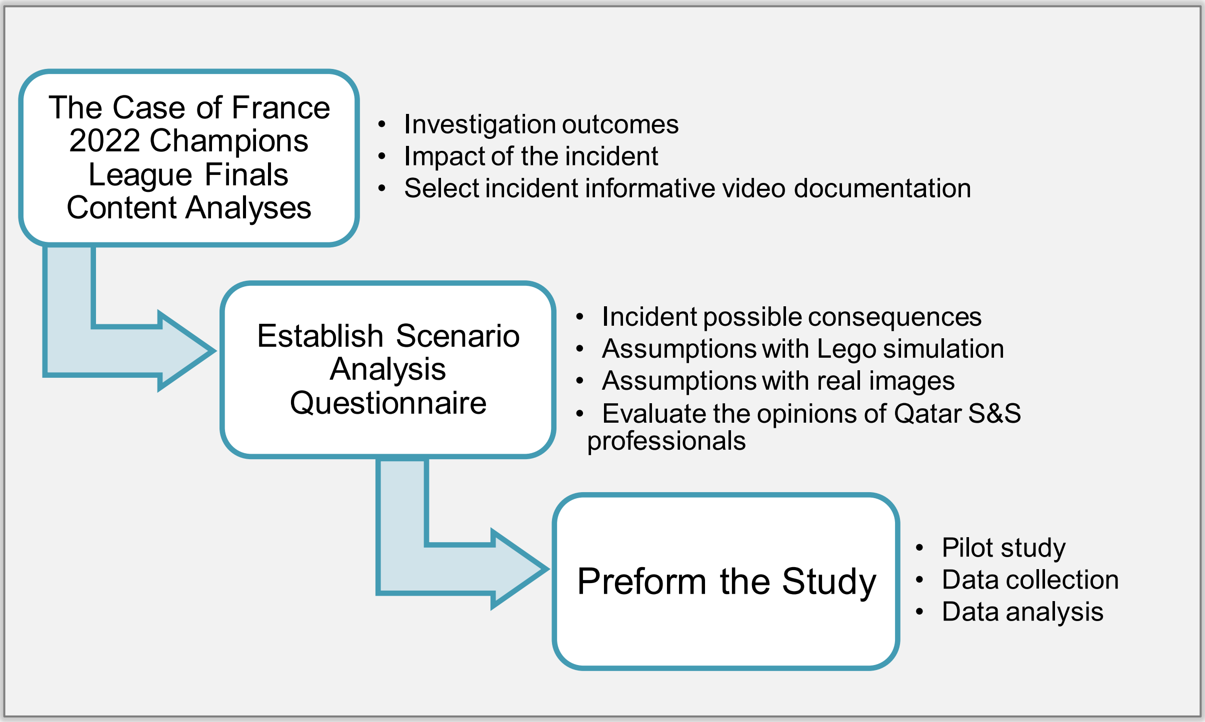

Figure 5.2: Chapter research methodology
Source: Author

$$\text{SitAw} = \frac{\text{Number of identified pieces of evidence}}{\text{Total number of pieces of evidence}}$$

This formula provides a quantitative measure of SitAw based on the ratio of identified evidence to the total evidence, providing insights into the extent to which the available information has been effectively perceived and processed. In this context, ‘evidence’ refers to relevant information or cues that contribute to understanding the given situation. The formula suggests that SitAw is determined by the ratio of identified evidence to the total available evidence. A higher value for SitAw indicates a greater level of SitAw, implying that a larger proportion of the available evidence has been successfully identified and taken into account. On the other hand, a lower value suggests a lower level of SitAw, indicating that a significant portion of the evidence has not been recognised or considered.

5.3. Content Analysis of 2022 Champions League Finals (France ’22)

5.3.1. Context

The case of France ’22 showed why ScenAn is so vital for sporting events by ensuring the safety of all those involved in such events, avoiding negative incidents, or minimising their impacts when they do occur. The Champions League Final at the Stade de France on 28 May 2022, between Liverpool and Real Madrid, resulted in major complications. Hazardous crushes and risks to human life arose as a result of access restrictions, and many supporters were indiscriminately tear-gassed or pepper-sprayed by the police. The debacle was catastrophic for France’s reputation, damaging it severely to the point that many questioned whether it was capable of delivering safe sporting events in the future, including the 2023 Rugby World Cup and the 2024 Olympics. The core problems encountered in France ’22 related to people flow and crowd issues, which ultimately deteriorated into mayhem (Chrisafis, 2022).

Tens of thousands of Liverpool fans had travelled to the city, leading to growing restlessness due to massive congestion in the stadium’s surroundings (Willsher, 2022). As a result of these congestion issues, the game started 35 minutes late. In an attempt to control the flow of people, the French police opted to use police buses (Neuendorf, 2018). However, this approach had adverse effects in terms of public perception and legal implications. The use of police buses to restrict individuals’ movement was viewed as heavy-handed, impeding the freedom of innocent spectators and potentially escalating tensions in the crowd. Images and videos capturing these actions were widely circulated, further tarnishing the image of the police and fuelling public discontent (Hunter, 2022). The police actions faced criticism for potentially infringing upon individuals’ rights, including the right to freedom of movement and peaceful assembly. Such actions could result in legal challenges and negative repercussions for the involved police force (Willsher, 2022).

At this point, the French authorities were embarrassed by the failure to control the people flowing in and around the stadium (Chrisafis, 2022). The authorities increasingly blamed the fans as the incidents escalated, accusing them of entering with counterfeit tickets, which the authorities claimed was the cause of the overcrowding (Chrisafis, 2022). This was built on previous police reports that a handful of fans had procured false tickets and disrupted entrance to the stadium, causing a delay (Willsher, 2022). The organisers, after initially attributing the delays to security difficulties, blamed fans for arriving late. The entrance to the Liverpool end of the stadium was jammed with supporters who had bought bogus tickets that did not work at the turnstiles, resulting in crowds building behind them.

The French police launched unprovoked tear gas and pepper spray attacks on spectators as a large crowd gathered outside the stadium in the hours leading up to kick-off at 21:00 CET, with scores of arrests and hundreds of injuries. Many Liverpool fans who had purchased tickets could not enter the stadium until half time, and fans were also attacked as they exited the Stade de France following the game. UEFA and several French politicians backed the repressive measures adopted by the security services, and Liverpool fans were smeared with accusations of unruly behaviour, and unlawfully entering the stadium with counterfeit tickets. There were 68 arrests associated with the Champions League Final, according to Paris police, and firemen treated 238 minor injuries, according to local media (Willsher, 2022).

In the aftermath, UEFA acknowledged that the police used tear gas to disperse supporters and announced it would quickly evaluate these problems in collaboration with the French police and authorities, as well as the French Football Federation. In the meantime, Liverpool requested a formal investigation into the origins of these unacceptable occurrences. The French authorities were under increasing pressure for seven days to investigate what the press had dubbed a failure (Chrisafis, 2022). Gérald Darmanin, France’s Interior Minister, reiterated his claim that Liverpool fans had attempted to use 40,000 fake tickets, provoking outrage both at home and abroad. Many fans with legal tickets found that the scanners would not accept them as real, so even the figures were undoubtedly exaggerated. Early reports indicated that fewer than 3000 counterfeit tickets had been detected at the turnstiles (Henley and Walker, 2022). An investigation was ordered by UEFA to find out what went wrong and what happened so it could never happen again (Chrisafis, 2022).

Laurent Lafon, a co-chair of the inquiry, told reporters at a press conference that these dysfunctions had occurred at every level, not just during the implementation (during the game) but also during the preparations for it (Willsher, 2022). Due to a transport strike, the stadium was not anticipating how and when supporters would arrive, and inadequate instructions were provided. Police checkpoints became pressure points, constraining the flow of people and exacerbating congestion.

The infamous event emphasised the importance of ScenAn and planning for any future events to avoid unnecessary damage to people, property, or the reputation and image of an organisation and country holding a MSE.

5.3.2. Investigation outcomes

The French Senate's Commission of Culture and Education (2022) issued a report on France '22 in which they dubbed the debacle as "an inevitable fiasco." Laurent Lafon, Co-President of the Commission, highlighted a sequence of shortcomings occurring before the match, stating that the authorities had implemented their plans with little collaboration and that there had been "failures" both "in the execution" and "planning" of the event. The French Senate questioned several key figures in the aftermath of the event regarding the initial official narrative that essentially sought to blame the Liverpool fans (Commission of Culture and Education, 2022). These included the Interior Minister, Gérald Darmanin, and the Sports Minister, Amélie Oueda-Castéra, alongside officials from the French Football Federation, the Parisian public transportation agencies, and Liverpool West Derby MP Ian Byrne, who attended the final. The report unequivocally denounced the initial attempts to blame fans, and acknowledged the systemic failure that had led to the events (i.e., poor S&S planning and responsiveness):

> It is unfair to have sought to blame Liverpool fans for the disturbances, as the Interior Minister did, to divert attention from the inability of the state to manage the crowds present adequately and to curb the action of several hundred violent and coordinated offenders. (Commission of Culture and Education, 2022)

Laurent Lafon, President of the Panel for Culture, and Francois Francois-Nol Buffet, President of the Commission for Legislation, apologised to the English supporters and suggested that further hearings would be held soon. Lafon went into detail about the events, lamenting the "unusual severity" of the organisational flaws and the repercussions that "might have been tragic." They noted that neither the French nor the English authorities could uncover the truth of the ticket fraud issues as well as that the prevalence of petty crimes and antisocial behaviour increased in the neighbourhood that day from 2 p.m. (Chrisafis, 2022).

According to Buffet, “the organisation of this event was the source of the major occurrences”; namely, the way the movement of spectators into and out of the stadium was handled. He also chastised police chief Didier Lallement for focusing on spectator management rather than the minor criminality that began outside the stadium at about midday: as noted, the prevalence of petty crimes and antisocial behaviour increased in the neighbourhood that day from 2 p.m. The destruction of security footage from the Stade de France was also cited as a “serious error”, according to Lafont, who concluded that there was a sense that no one was taking responsibility for what happened and that everyone involved in the operation had failed. All of the actors were linked to the state (Aljazeera, 2022).

The public was subjected to dangerous crowd control measures, tear gas, and baton charges from police. They later took legal action against the authorities. The senators stated that they would like to speak with UEFA about the usage of paper tickets. They issued a request but were still waiting for a response from the governing body of European football. Despite this, it was clear that the French government had to apologise comprehensively to Liverpool and Real Madrid fans (Chrisafis, 2022).

The outcome of the investigation showed that not only were the police unable to deal with large crowds but they had overreacted instead of trying to calm the situation, which led to a disproportionate and brutal response. It also led, as noted, to the entire world questioning the ability of France to host major international events, with grave implications for the 2023 Rugby World Cup and the 2024 Olympics.

5.3.3. Recommendations for MSEs

The official report investigating the incident included 15 recommendations to avoid such problems in the future, including mandating event organisers to keep video surveillance photos for one month after the event and making forgery-proof tickets mandatory (Commission of Culture and Education, 2022). Some particularly egregious breaches that occurred during France ’22 were adumbrated, as described below.

Many supporters arrived at the stadium with plenty of time to spare to pick up their credentials and get inside. People noticed the Police Nationale guiding people in any direction as they neared the stadium’s perimeter, and there did not appear to be any strategy. Four stewards were verifying tickets at the bottom of the ramp that hundreds of fans were using to enter the stadium’s main concourse. Soon after, cries could be heard. To escape the crowd, young children were hastily lifted onto shoulders to ensure their safety. This unpreparedness by the organisers put a lot of children at risk of harm by being trampled. The four stewards in charge of checking the tickets eventually became disrespectful and then antagonistic towards the fans. As one recalled:

> They'd been forced to scan hundreds of tickets between the four of them, and it was evident that they'd had enough. They just yelled 'ticket', and if you didn't have one for them to scan—or, like me, got an email from UEFA stating to get my accreditation—they were simply uninterested, even physically shoving individuals back into the mob. (Chrisafis, 2022)

After the police arrived they erected barricades that hemmed in the crowds, and they then tear-gassed them (Chrisafis, 2022). The Police Nationale did not discriminate when it came to their targets, and men, women, and children were indiscriminately gassed (Hunter, 2022). The police brutality against the fans caused outrage, prompting the Liverpool coach to demand a thorough investigation into the incident. France's reputation as a signatory of the Saint-Denis Convention in 2016 was blemished (Connolly, 2020). The Convention represents the long development of MSE principles which had begun with the Heysel Stadium Spectator Violence Convention of 1985, in the aftermath of the Heysel Stadium disaster, although, as the title implies, that was excessively focused on security rather than the entire administration of a large sporting event.

By 2011–2012, the Monitoring Committee had accepted 28 specific ideas to improve safety, security, and service at major sporting events. The Secretary of the Saint-Denis Convention, Paulo Gomes, discussed some of the key elements, including the need to coordinate processes and address all required standards in terms of safety, security, and service within athletic venues, with the three key concerns being pyrotechnics, any violent or other prohibited behaviour, and racist or other discriminatory behaviour. A separate article dealt with these issues outside of sports arenas, and the need to cover the entire journey of the fans from their homes to the city and stadium and back again was emphasised. This included fan zones, as well as everything going on in the city centre and around the stadium (Connolly, 2020).

For the first time, this Convention stated the need for dialogue and trust between public authorities, namely the police, supporters' organisations, and local communities and companies. An article on police operations and strategy set out best practices for policing football events, such as the importance of intelligence gathering, dynamic risk assessment, risk-based police officer deployment, and, perhaps most significantly, proportionate police intervention to address any escalation of danger or disruption. It is necessary to intervene proportionately, which did not occur in France '22. As a final step, it was emphasised that evidence should be collected and shared with the appropriate authorities for prosecutions (Connolly, 2020).

MSE S&S concerns worldwide collaboration for international matches, and it is critical that sports authorities and police exchange experiences and information. There is a European network of National Football Information Points (NFIPs), one in each member state, which allows the exchange of police information. Spanish and British counterparts in the NFIPs must have provided essential police information to the French police in Saint-Denis so they could plan and prepare for the policing of this event. During the weeks before the final, the "Spirit of Shankly" fans organisation collaborated extensively with Liverpool, Football Supporters Europe, and Merseyside police on fan safety, which is particularly poignant given the tragic history of Liverpool Football Club in this regard. However, UEFA and the French authorities ignored their collaboration efforts (Connolly, 2020).

This incident had a major global impact, and the Council of Europe officially contacted the French authorities to consider the lessons learned at its next meeting. More impacts could be seen through the trauma this inflicted on people (Connolly, 2020). The police action could not only have harmed people but also the event and property, with the potential for massive insurance claims and financial losses. Macroeconomic impacts could be experienced by France, which could see its tourism industry declining due to potential tourists looking at videos about the chaos or reading or watching media covering the event detailing how brutal the police were to the fans. Certain police officers could lose their jobs due to their malpractice and attempted cover-up. The most important impact could be the damage to international relations, especially in terms of the humiliation and disgrace suffered by France (and, by extension, Europe in general) due to such demeaning treatment of innocent football fans at a MSE of global importance and interest.

5.4. ScenAn Questionnaire

The questionnaire was developed based on related literature to target S&SP in Qatar. It comprised four parts, as described below (see Appendix 6).

5.4.1. Part 1: Opinions of S&SPs in France '22

This part assessed the opinions of S&SPs on the possible consequences of MSE incidents such as the case of France '22, covering aspects listed in Table 5.2. This preliminary section primed the participants with the increased awareness and familiarity needed to engage with the themes of the other parts of the instrument.

5.4.2. Part 2: Overcrowded football stadium simulation analysis

In this part, participants were presented with the scenario of people starting to overcrowd a football stadium in front of one security guard, considering two hypotheses:

H1. *Fixed camera (FC) surveillance information provides adequate SitAw for DD-M by the C&CC.*

H2. *Drone camera (DC) surveillance information provides adequate SitAw for DD-M by the C&CC.*

The scenarios related to H1 and H2 were simulated using Lego figures, as illustrated in Figures 5.3 and 5.4, respectively.

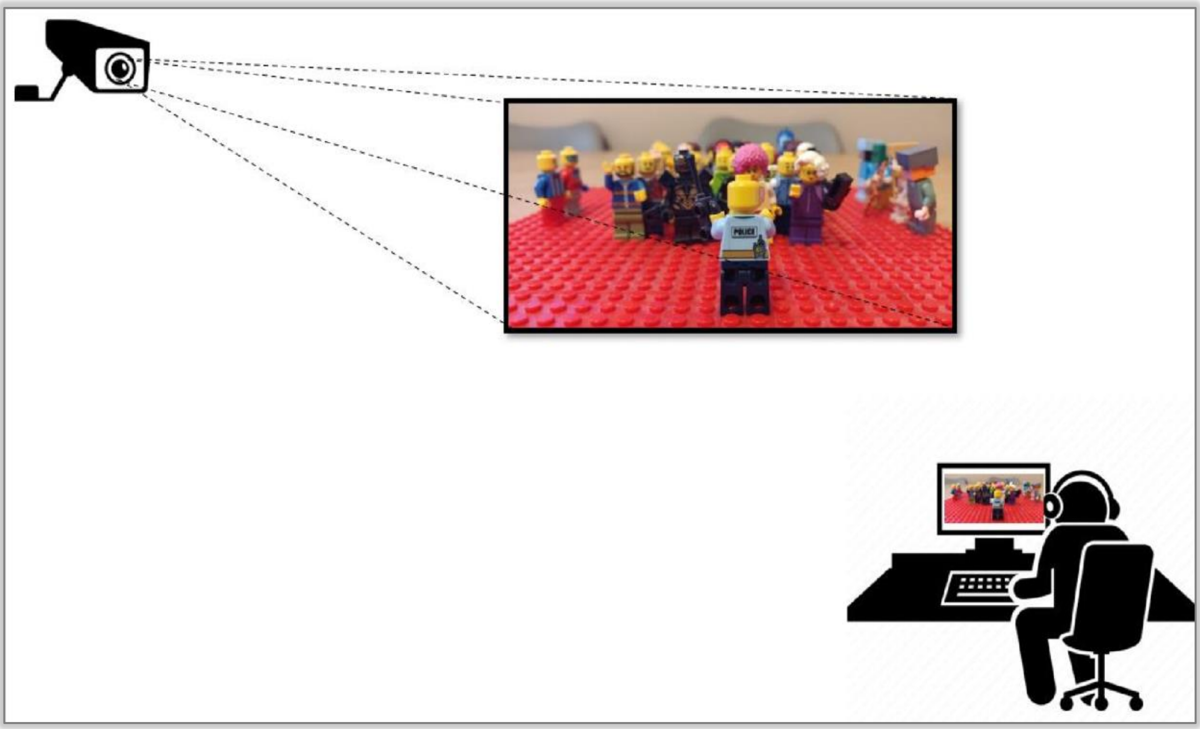

Figure 5.3: Simulated FC surveillance feed using Lego
Source: Author

Figure 5.4: Simulated DC surveillance feed using Lego
Source: Author

5.4.3. Part 3: Overcrowded football stadium video analysis

For this part of the study, a scenario was presented of people starting to overcrowd the football stadium, using video film captured from France ’22, considering H1 and H2, as displayed in Figures 5.5 and 5.6, respectively. Figure 5.6 was extracted from a video that was filmed from the top of the bridge, similar to a video captured by a drone.

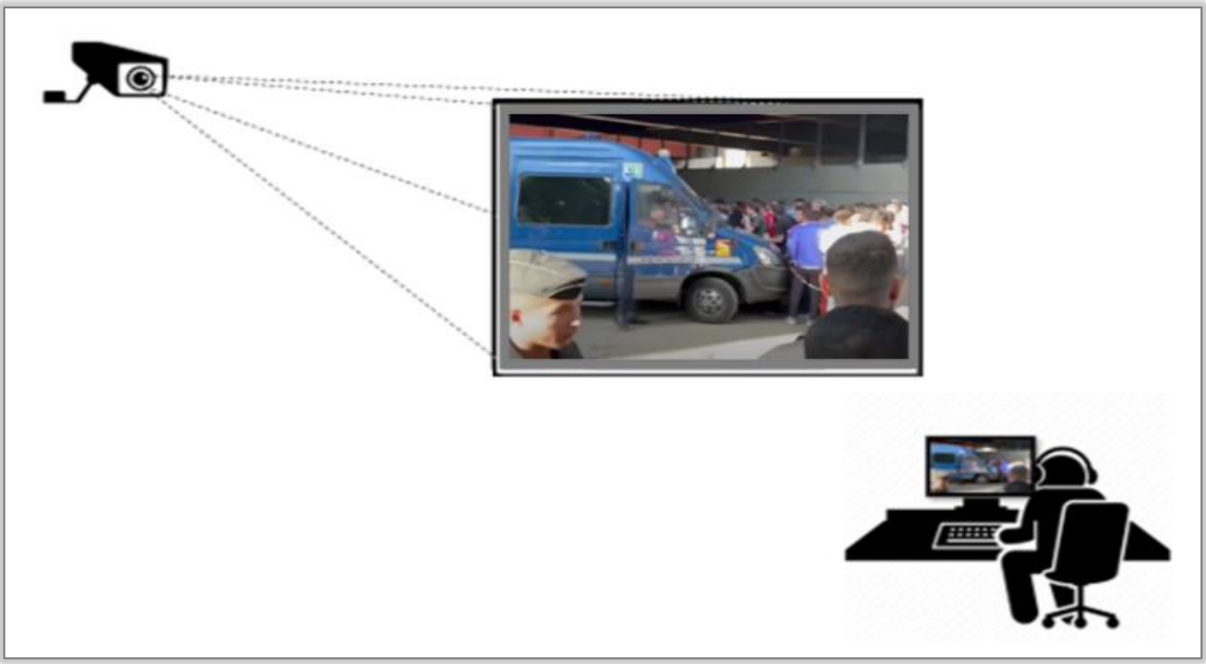

Figure 5.5: FC surveillance feed from France ’22
Source: Author

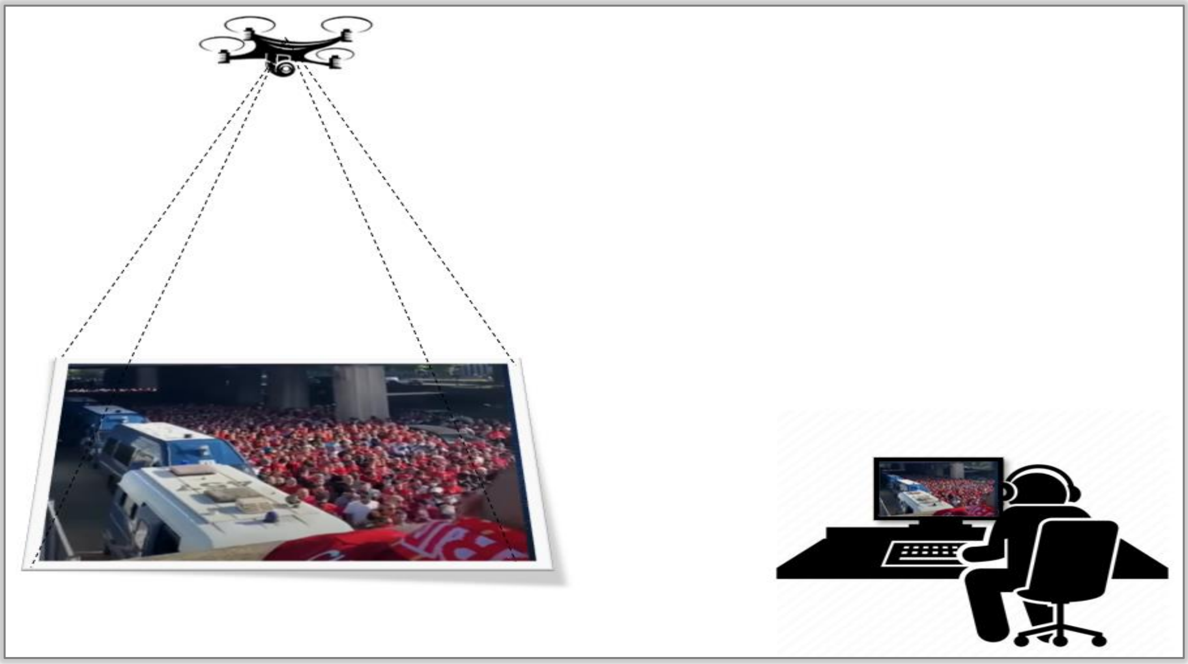

Figure 5.6: DC surveillance feed from France '22
Source: Author

5.4.4. Part 4: Opinions of S&SPs on ScenAn for DD-M

This part evaluated the opinions of Qatari S&SPs on the impact of DC surveillance enhancing C&C SitAw for DD-M.

5.5. Chapter Analysis and Findings

5.5.1. Statistical testing

The mean, SD, frequency, percentage, and degree values were calculated from scores based on the following:

$$\text{Length of period} = \frac{\text{Upper boundary - lower boundary}}{\text{Number of levels}} = \frac{5-1}{3} = 1.33$$

The number of levels was categorised as follows: low (1–2.33), medium (2.34–3.67), high (3.68–5). Cronbach's alpha coefficient was used to test the stability of the study instrument, alongside independent and paired sample t-tests. Questionnaire reliability is indicated by a Cronbach's alpha of at least (0.6), which indicates that the questionnaire items measure the variables they are supposed to effectively, thereby demonstrating the consistency and dependability of the instrument (Cronk, 2017). The questionnaire achieved a Cronbach's alpha coefficient of (0.77), indicating that it was valid for study purposes (Sekaran and Bougie, 2016).

5.5.2. Demographic characteristics

Table 5.1 shows that the majority of the participants were from the safety sector (62.5%, n=25), while over a third were from the security sector (37.5%, n=15).

Table 5.1: Occupational sector

Variable		N	%
Work sector	Safety	25	62.5
	Security	15	37.5
	Total	40	100

Source: Author

5.5.3. Consequences of MSE

Table 5.2 shows the mean scores for participants' opinions on the possible consequences of MSE incidents based on France '22. All items were measured using a five-point Likert scale, and all the statements received high scores, ranging between 4.9 and 4.98. The overall average was high: 4.94.

Table 5.2: S&SPs' rating of possible consequences of MSE

	Mean	SD	%	Degree
Possible negative reputation of the country	4.98	0.158	99.5	High
Possibility of putting people at risk	4.98	0.158	99.5	High
Possible damage to the event itself	4.95	0.221	99	High
Possible financial loss	4.95	0.221	99	High
Possible damage due to media coverage	4.95	0.221	99	High
Possible damage to property and infrastructure	4.93	0.267	98.5	High
Possible traumas to people involved	4.93	0.267	98.5	High
Possibility of facing challenges to host future events	4.93	0.267	98.5	High
Possible damage to international relation	4.90	0.304	98	High
Possibility of damage to the future career of S&SP	4.90	0.304	98	High
Average	4.94		98.75	High

Source: Author

Table 5.3 shows that the t-value was not statistically significant at (α ≤ 0.05), so we concluded that there was no significant difference in S&SPs' opinions on the possible consequences of MSE ScenAn according to work sector, based on the case of France '22.

Table 5.3: Independent sample t-test to test the effect of work sector

Sector	N	Mean	SD	T-value	P-value
Safety 0.200	25	4.93	0.090	0. 717	15
Security	15	4.95	0.083		

Source: Author

5.5.4. Results from Lego simulation of fixed camera and drone camera (DC) surveillance images

To determine the achieved SitAw for each image, a formula employed in military and air force analysis was utilised (Munir, Aved and Blasch, 2022). This formula calculates precision, which is a measure of the proportion of correct detections or predictions made by the SitAw system regarding the total number of activities detected. Precision is typically expressed as a ratio or percentage, reflecting the accuracy of the system's outputs compared to the total activities detected. Figure 5.7 compares the calculated SitAw from the two scenarios of FC and DC images, using Lego figures to simulate the number of people facing security guards. The difference between the two calculated SitAw values is significant; the FC provides an average SitAw of 49%, while the DC achieves an average of 98%. Table 5.4 shows that the t-value is statistically significant at (α≤ 0.05), thus it can be concluded that there is a difference between the quality of SitAw between the FC image in Figure 5.3 and the DC image in Figure 5.4, with better awareness being recorded for the latter. This means that DC surveillance can improve SitAw and DD-M.

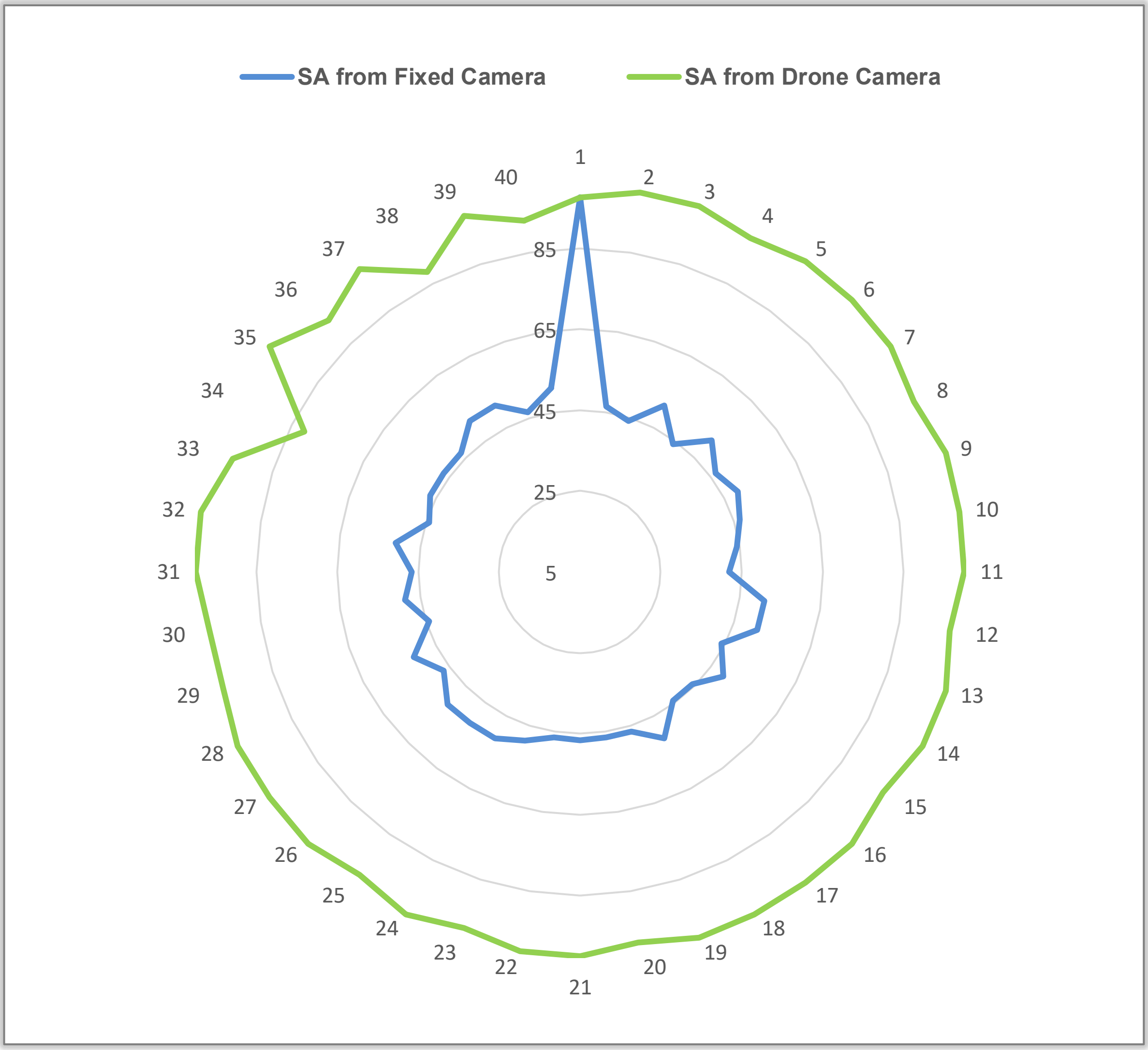

Figure 5.7: Lego simulation calculation of SitAw

Source: Author

Table 5.4: Paired sample t-test to test the difference between SitAw for FC camera image and SitAw for DC image

	N	Mean	SD	T-value	P-value
SitAW for image 4 FC	40	0.477	0.0284	65.37300	0.000
SitAW for image 5 DC	40	0.981	0.0364		

Source: Author

5.5.5. Evaluation of FC and DC surveillance impact on C&C SitAw for DD-M

Figure 5.8 shows the analysis of the SitAw results from the real FC and the DC images obtained from France ’22 (Figures 5.5 and 5.6) which shows that the FC images did not provide a high level of SitAw. This was identified as a major contributing factor to the negative incident. Meanwhile, drone surveillance (represented by the second image, Figure 5.6) provided a high level of SitAw. Table 5.5 shows that the SitAw from the DC surveillance feed was superior to that from the FC feed.

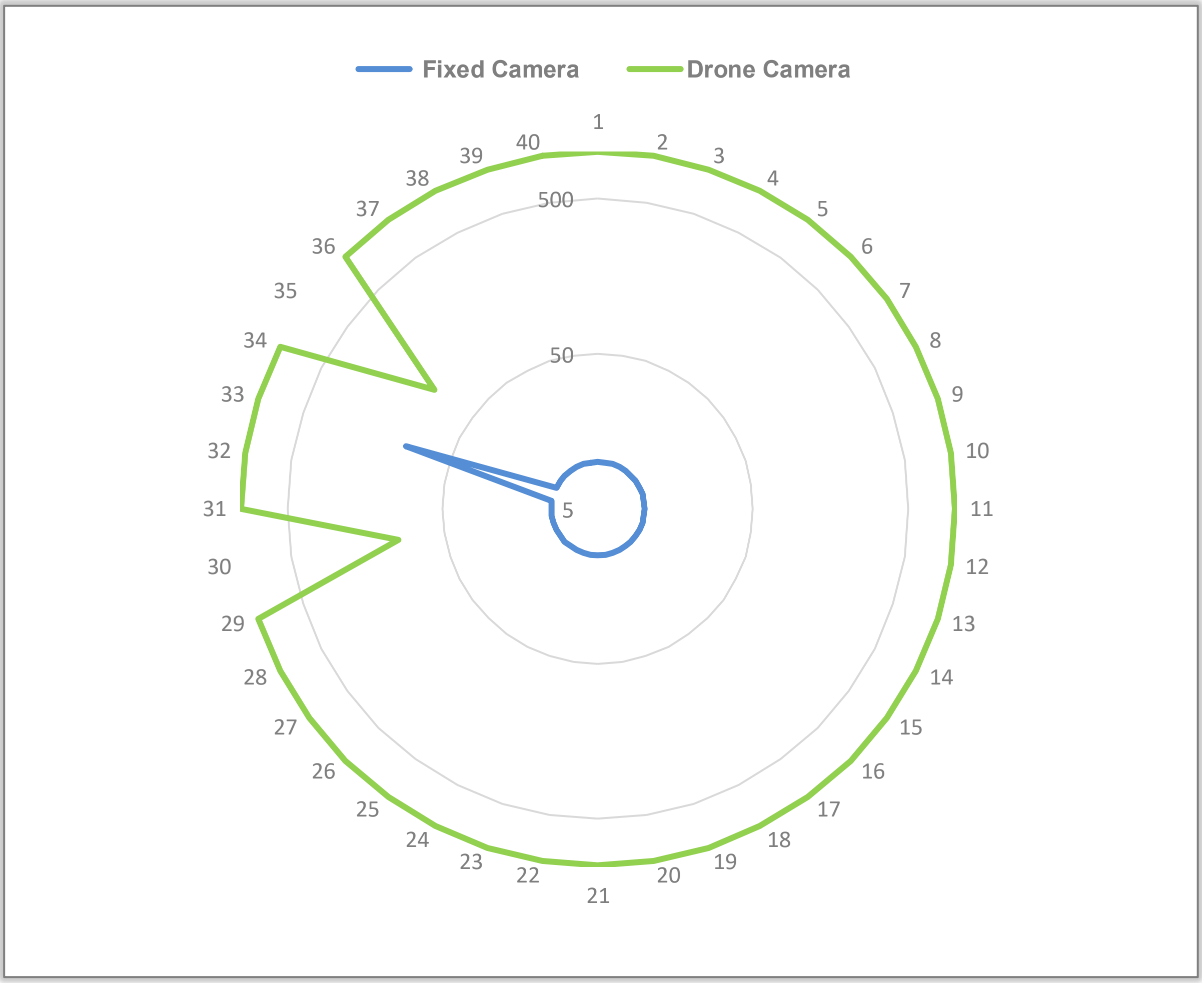

Figure 5.8: Estimated SitAw using real images from France ’22
Source: Author

Table 5.5: Evaluation of FC and DC

			N	%
From the FC surveillance feed (picture 6), I can see the crowd in:	100 rds	Low-level SitAw	1	2.5
	10 ns	Very low-level SitAw	39	97.5
From the DC surveillance feed (picture 7), I can see the crowd in:	1000 nds	High-level SitAw	38	95.0
	100 rds	Low-level SitAw	2	5.0
Total			40	100.0

Source: Author

5.5.6. Opinions on the use of DC surveillance

Figure 5.9 shows that S&SPs had very positive opinions about using DC surveillance in enhancing SitAw for DD-M. The findings demonstrated that they perceived that the DC could be a major contributing factor in enabling the C&C officer to establish better SitAw, which leads to improved DD-M. Table 5.6 shows that the t-value was not statistically significant (at $\alpha \leq 0.05$), so we concluded that there was no difference due to the work sector on opinions on DC surveillance enhancing C&C SitAw for DD-M. Consequently, this means S&SPs overall agree on the positive contribution of DC surveillance in improving SitAw and DD-M.

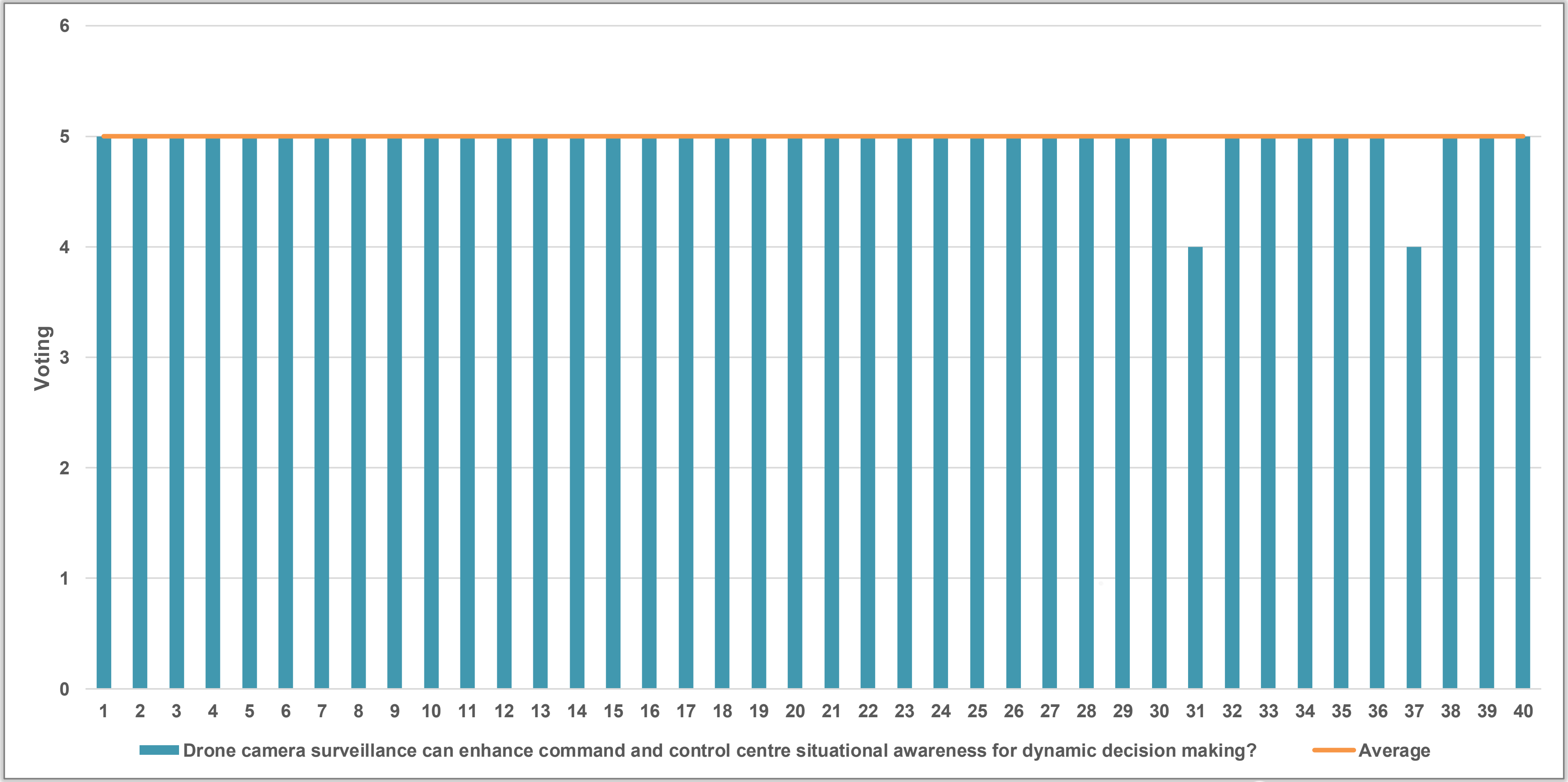

Figure 5.9: S&SPs' opinions on DC surveillance in enhancing SitAw for DD-M
Source: Author

Table 5.6: Independent sample t-test to test the effect of work sector

Can DC Surveillance Enhance C&C SitAw for DD-M?					
Sector	**N**	**Mean**	**SD**	**T-value**	**P-value**
Safety	25	4.96	0.200	0.366	0.717
Security	15	4.93	0.258		

Source: Author

5.5.7. Drone surveillance ScenAn model for DD-M

Based on the findings of this chapter, it is evident that the use of drones significantly contributes to enhancing SitAw, as demonstrated through both Lego simulations of crowd scenarios and real images from the France '22 case study. Therefore, integrating drone surveillance as a source of environmental sensing aligns with the SitAwM and serves as a key component of the first level of the Endsley model, which involves the reception of elements in the environment. This enhancement in environmental sensing leads to better inputs for the other two levels: comprehension of the current situation and the projection of future status. This integration enables more effective DD-M. Figure 5.10 illustrates that FCs can provide approximately 50% effective coverage in the best SitAw scenarios, while DCs can enable nearly 100% SitAw coverage.

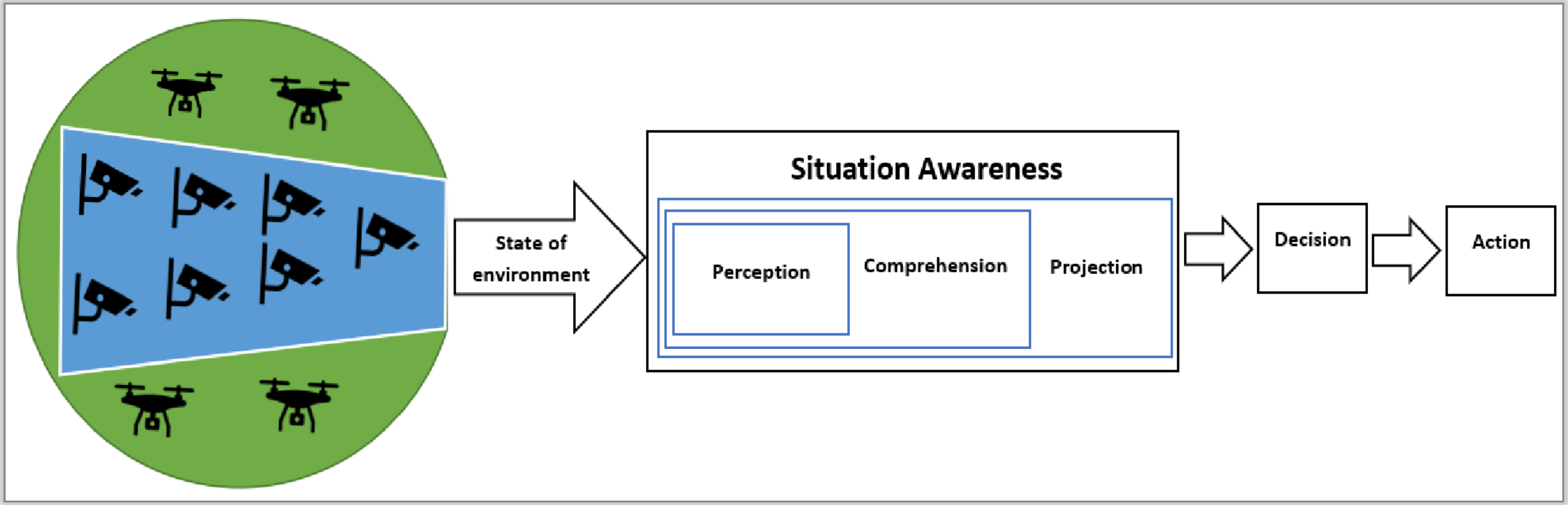

Figure 5.10: Drone surveillance SitAwM for DD-M
Source: Author

It is worth noting that while MSEs comprise the case of concern in this study, other events or situations involving large groups of people that require S&S measures can benefit from this model (e.g., music festivals, pilgrimages, or political rallies), to achieve a more robust strategy for effective risk management.

5.6. Chapter Summary

The study investigates the complexities of ensuring S&S during large-scale sports events, focusing specifically on the Champions League Final in France in 2022. It highlights the challenges such events face, including overcrowding, disorderly behaviour, and security breaches, using an incident from the mentioned final as an example. The study employs ScenAn to enhance SitAw and improve risk management strategies. By comparing the effectiveness of fixed and drone cameras in surveillance imaging, the research aims to identify ways to enhance situational analysis for improved risk management. The findings reveal that S&SPs demonstrated higher SitAw when using drone surveillance, indicating positive attitudes towards its adoption.

Additionally, the study introduces a model for drone surveillance: ScenAn, designed for DD-M, aligning with the Endsley model of SitAw. Through Lego simulations and real images from the France ’22 incident, it is evident that drone surveillance significantly enhances SitAw compared to FCs. The study emphasises the importance of advanced risk management strategies for hosting major sporting events. It presents recommendations for integrating drone surveillance as a key component of SitAw and DD-M processes during such events, highlighting its potential impact on effective risk management. However, it acknowledges the need for further studies and that technical and operational challenges should be addressed before the full implementation of drone camera surveillance systems in real-life scenarios.

CHAPTER 6

DRONE S&S SURVEILLANCE SYSTEM (D4S) PROTOTYPE

6.1. Chapter Overview

The advanced drone safety and security surveillance system (A-D4S) embodies an innovative approach to drone deployment, elevating S&S surveillance to new levels. This chapter provides a detailed exploration of the operational framework and capabilities of the A-D4S system, showcasing its potential for advanced SitAw and decision support. A-D4S operates on a strategic deployment model, with drone vehicles stationed at the base or mobile petrol reserves. Upon receiving operational clearance, drones are dispatched to commence surveillance activities. Notably, A-D4S offers flexibility in operational conditions, enabling drones to operate in line of sight (LOS) or BLOS scenarios. This adaptability significantly extends surveillance range and coverage, enhancing overall effectiveness. Once in flight, drones initiate surveillance operations, capturing real-time video streams of the monitored area.

Concurrently, the C&CC meticulously monitors the drone's location and altitude, ensuring precise operational control. Leveraging sophisticated AI algorithms, A-D4S analyses incoming data and suggestions, augmenting situational and environmental awareness during monitoring. This AI-driven analysis empowers decision-makers with comprehensive insights, enabling proactive response strategies. Members of the C&CC closely observe the received video streams and AI-generated insights, facilitating informed decision-making in response to observed events or anomalies. This approach enhances response efficacy and situational understanding. Upon the completion of surveillance tasks, drones are recalled for re-evaluation and potential redeployment for subsequent operations. This iterative process ensures continuous monitoring and maintains readiness for rapid response.

6.2. Chapter Materials and Methods

6.2.1. System development lifecycle (SDLC)

To achieve the goal of establishing a D4S prototype, the system development lifecycle (SDLC) methodology was used (Figure 6.1). SDLC is commonly used in academia and industry in different fields of systems engineering software development and other business activities. It enables a simple and well-known step-by-step process, from the basic identification of project requirements, through the design and deployment, to the evaluation phases (Kramer, 2018).

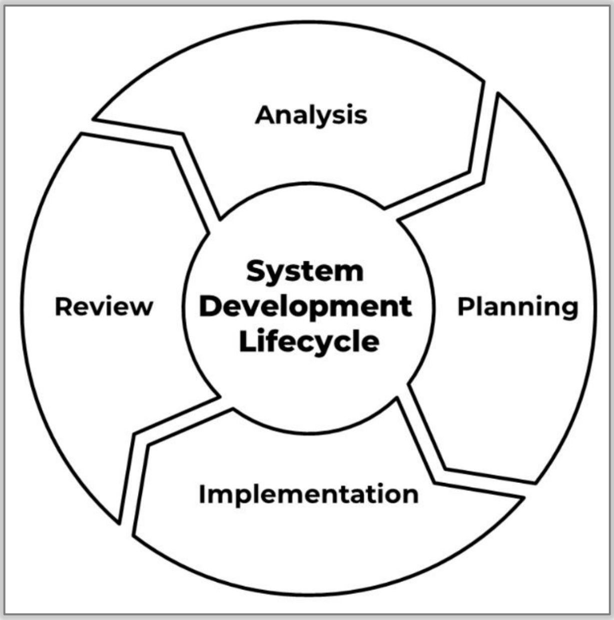

Figure 6.1: System development lifecycle (SDLC)
Source: Kramer (2018)

6.2.2. System prototype

6.2.2.1. Design method

Since the system prototype is only for use in this chapter and is not intended to be deployed and tested fully in real life, the iterative SDLC method was determined to be the most suitable to follow to establish the system (Figure 6.2). It expedites the creation of the first system version at a very low cost to perform testing and evaluation, and thereby identify required improvements (Alshamrani and Bahattab, 2015).

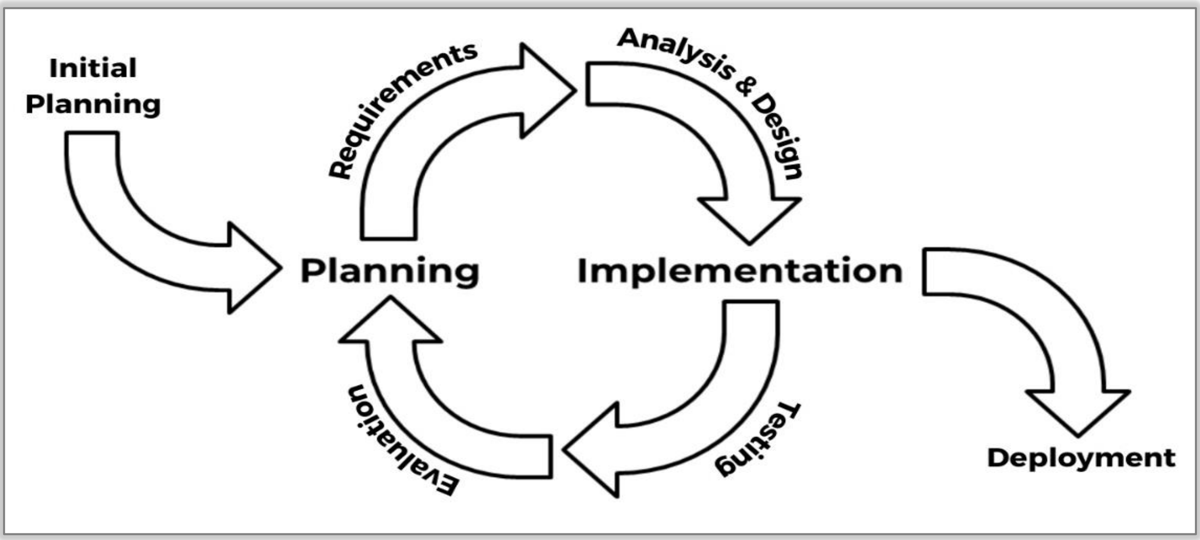

Figure 6.2: Iterative SDLC method
Source: Alshamrani and Bahattab (2015)

6.2.2.2. Evaluation method

For the evaluation of the prototype by key stakeholders, the technology acceptance model (TAM) (Marangunić and Granić, 2015) was used, as shown in Figure 6.3. It shows the factors that influence individuals' acceptance of computer technology (Davis, 1993). It is a widely accepted framework that can be applied to a variety of end-user computing technologies and user populations. The core concept of TAM includes perceived usefulness (PU), which refers to a user's belief that a technology will improve their job performance; and perceived ease of use (PEoU), which refers to a user's perception of how easy or difficult it is to use a technology. These concepts are closely related, with PEoU having an indirect effect on a user's acceptance of technology based on the impact of PU (Appendix 7).

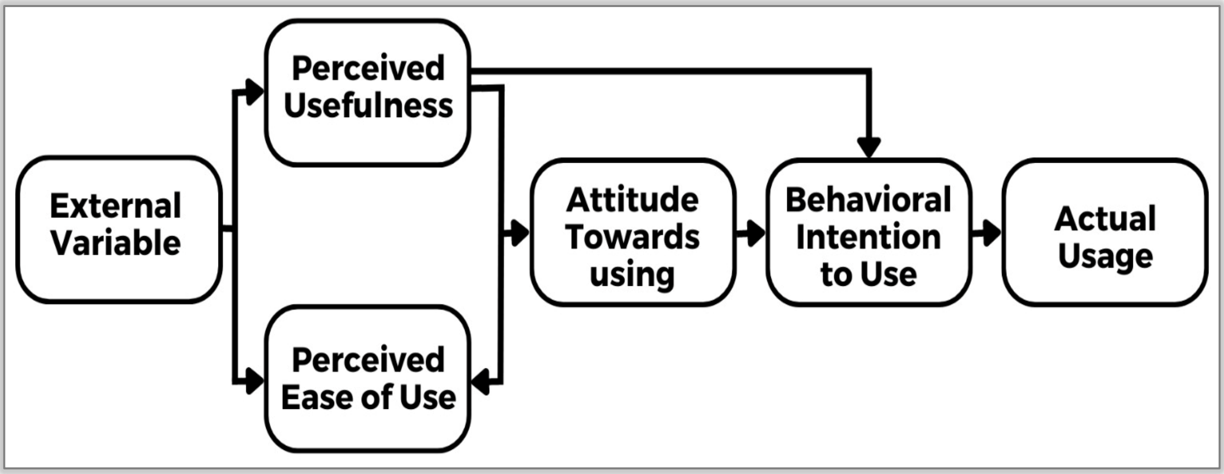

Figure 6.3: Technology acceptance model
Source: Davis (1993)

To provide a correlation between the two approaches for concrete evaluation outcomes, TAM was used to evaluate the four domains of PU, PEoU, behavioural intention to use (BI2U), and usage with construct items (as listed in Table 6.1). This was followed by further analyses according to the aligned model, based on the decision support system evaluation methodology (Rigopoulos, Psarras and Askounis, 2008). This revised TAM model (Figure 6.4), which was initially presented by Money and Turner (2004) and then subsequently extended by Rigopoulos, Psarras and Askounis (2008), measures users' attitudes towards the adoption of decision-support systems to enhance the decision-making process. The key objective was to study end users' attitudes towards the usage of the new D4S through testing the identified study hypotheses listed in Table 6.2. The Rigopoulos, Psarras and Askounis (2008) model was used to identify the relationship between PU and PEoU and users' BI2U and usage of the new system.

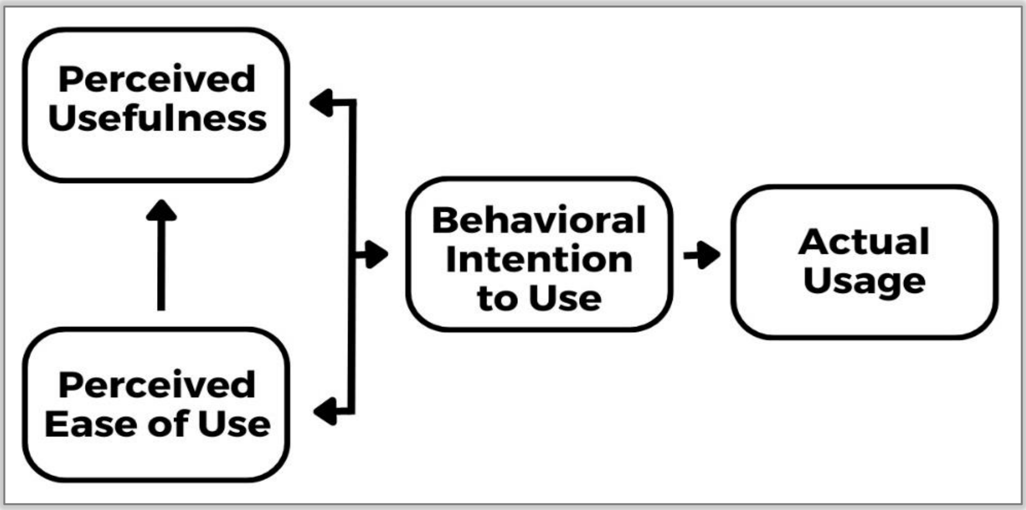

Figure 6.4: Adopted research model

Source: Money and Turner (2004)

Table 6.1: Construct items

Construct items	
Perceived usefulness (PU)	1. With the new D4S, decisions are easier. 2. With the new D4S, decisions are more accurate. 3. With the new D4S, decisions are quicker.
Perceived ease of use (PEoU)	1. The new D4S is easy to use. 2. The new D4S and methodology are easy to understand.
Behavioural intention to use (BI2U)	1. I think that using the new D4S is a good idea. 2. I think that using the new D4S is beneficial. 3. I have a positive attitude to using the new D4S.
Usage	1. I intend to use the new D4S. 2. I intend to use the D4S instead of the established procedure.

Source: Author

Table 6.2: Adopted hypotheses

No.	Hypothesis
H1	PU positively affects BI2U.
H2	PEoU has a strong indirect positive relationship with BI2U.
H3	PEoU has a weaker direct positive relationship with BI2U.
H4	BI2U has a strong positive impact on system usage.
H5	PU and PEoU have a strong positive impact on BI2U.

Source: Rigopoulos, Psarras and Askounis (2008)

6.2.2.3. Identifying requirements and functional architecture

In system development, a scoping systematic review can help identify the key requirements for a new system by gathering and analysing existing research, user feedback, and other relevant data. After completing a scoping systematic review, the findings can be used to develop a list of requirements for the system being developed (Pressman, 2014). These requirements should be specific, measurable, and aligned with the goals of the project. This list of requirements informs the rest of the SDLC methodology.

The requirements-gathering phase is critical to the success of the entire system development process. By using a scoping systematic review to inform this phase, one can ensure that the requirements are based on sound evidence and are aligned with the needs of users and stakeholders. Therefore, a comprehensive scoping systematic review study was conducted by AL-Dosari, Hunaiti and Balachandran (2023), which included 45 publications presenting previous efforts on using civilian drones in S&S applications. The full results of this scoping systematic review are shown in Appendix 1 and are summarised in relation to this chapter in Appendix 2.

The review's findings revealed that drones with basic sensors (for GPS and cameras), advanced sensors, and advanced software, were commonly used. As shown in Figure 6.5, 71% of the reviewed studies used basic sensors for GPS, and 64% used basic camera sensors, while over half used advanced sensors (51%) and advanced software (56%). Based on these insights from existing deployment, two versions of the D4S were proposed: the basic and advanced D4S (B-D4S and A-D4S, respectively).

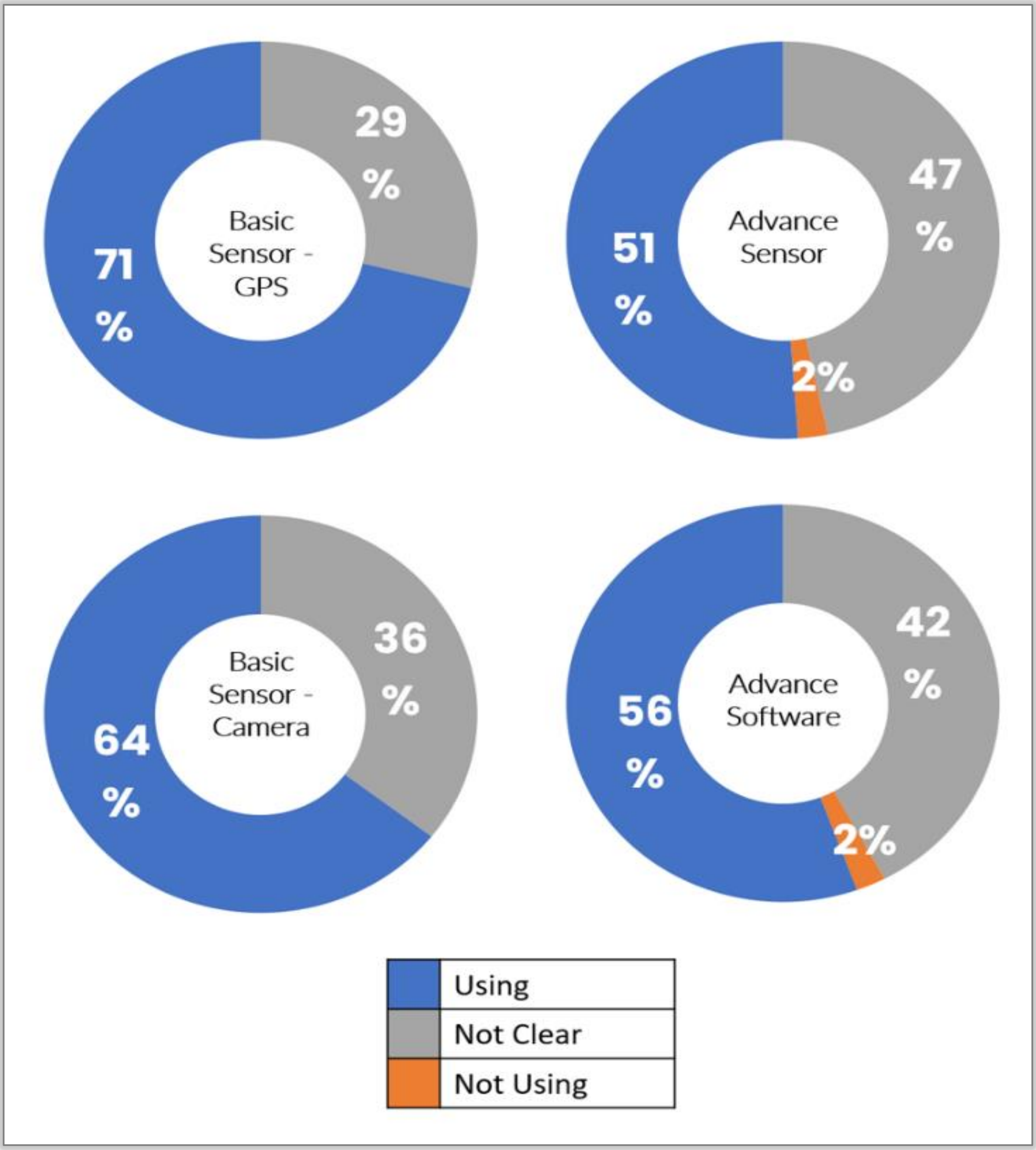

Figure 6.5: Percentage of papers using advanced/basic sensors and software
Source: Author

The basic version of the system was designed to enable quick deployment with minimal approval required for S&S personnel to utilise in their operations, while the other system, which requires advanced facilities and more approvals, is intended for advanced missions. This approach allows S&SPs to undergo digital transformation and begin adopting drones in their operation. Therefore, the functional architecture for the D4S can be illustrated as shown in Figure 6.6, which includes four primary components: the drone or UAV part, wireless communication channel, ground control, and remote C&CC.

Such functional architecture enables enhancement of SitAw for DD-M for S&S personnel by transmitting captured video images, location data, and other telematic data from sensors in real-time to the ground control centre in the B-D4S version of the system, and the C&CC in the A-D4S version. The received video image and telematic data, along with the location data, will be plotted on the GIS map. For the C&CC, which is mainly part of the A-D4S version of the system, specialised databases specific to each type of operation and AI decision support systems (AI DSS) can provide S&S personnel with extra assistance, enabling better SitAw and DD-M involving both human and machine elements.

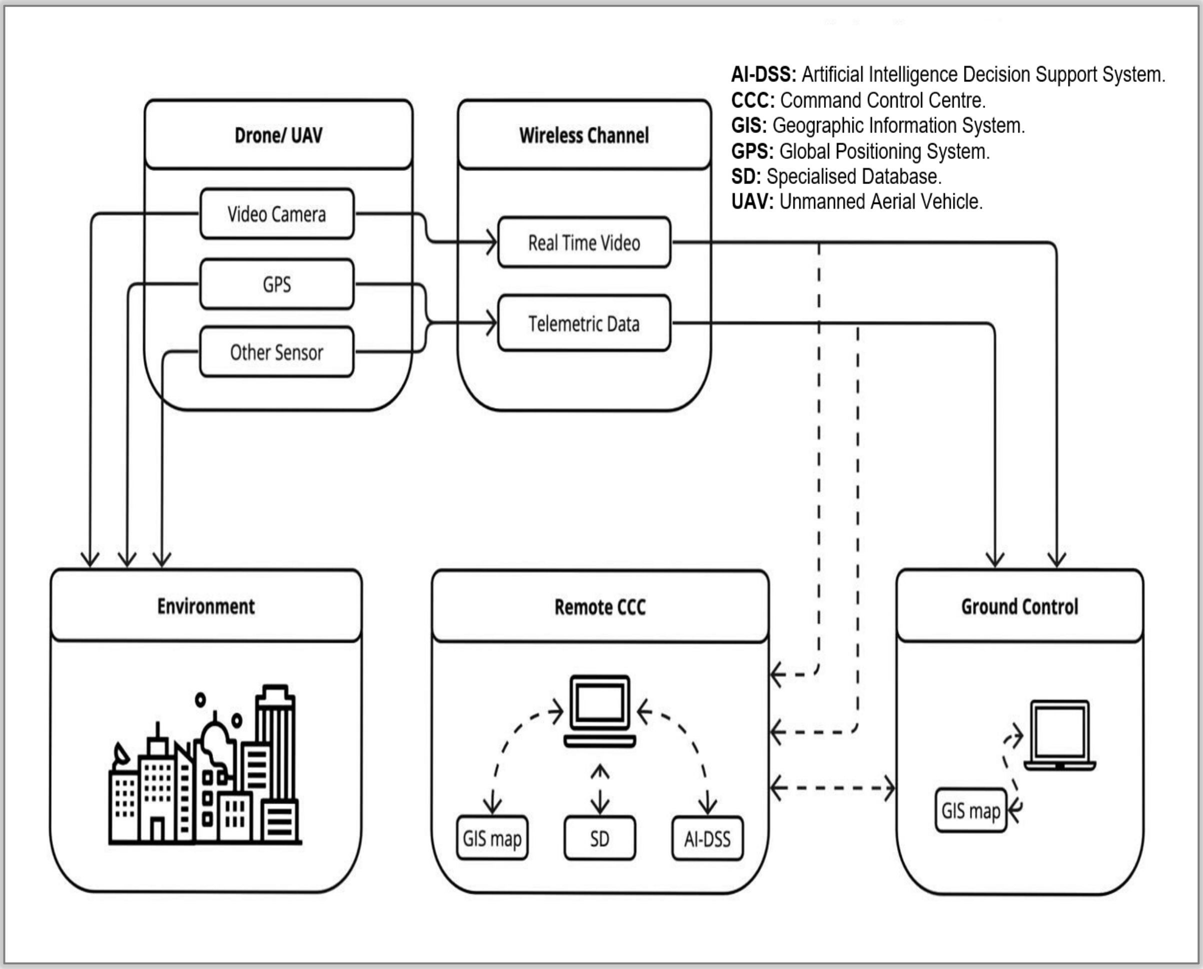

Figure 6.6: D4S functional architecture
Source: Author

6.2.3. Basic-D4S

6.2.3.1. B-D4S architecture

As can be seen from Figure 6.7. and Table 6.3, the B-D4S adopts a simple format to foster and facilitate the adoption of drone/UAV by S&S organisations with minimal costs, non-compacted training, and minimum levels of internal and external approval for use and operation in real-life deployments. The organisational management might only need to have an intuitive knowledge of how to modernise, digitally transform and integrate a new system in service within the applicable national UAV regulatory framework.

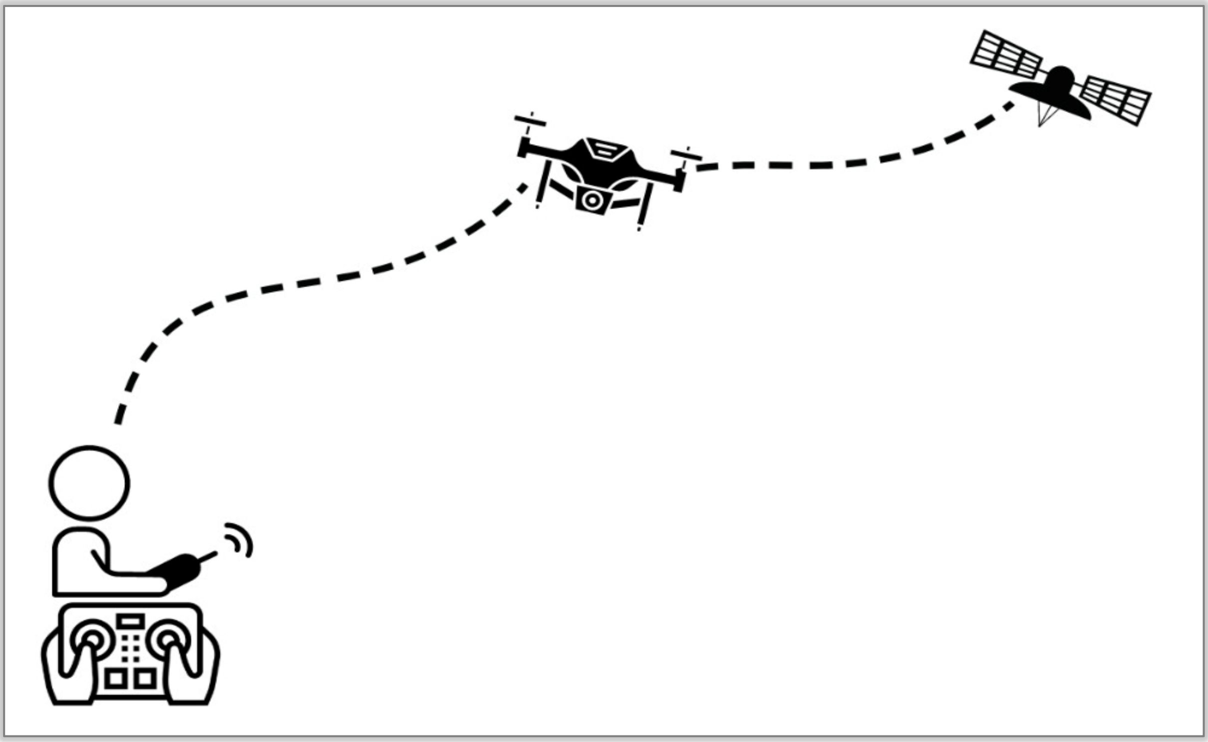

Figure 6.7: B-D4S architecture
Source: Author

Table 6.3: Basic-D4S requirements

Item	Specification	Justification
Drone vehicle	Portable	To support LOS civilian security and safety applications in normal patrolling missions (Bello *et al.*, 2022)
	Easy to operate and deploy	
	Can handle mild weather conditions	
	Good life cycle and is easy to maintain	
Communication link	Short-range, secure and reliable	For safe and effective operations (Javaid *et al.*, 2012)
Ground control unit	Portable	Easy to carry, operate and navigate using video displayed feed (Haque, Kormokar and Zaman, 2017)
	With HD Display	
GPS	Accuracy for urban and open space navigation	For navigation and location tagging (Mohsan *et al.*, 2022)
Surveillance camera	HD with night vision	For better awareness and investigation outcomes, navigation, and night operation (Ali *et al.*, 2021)
Video recording facility	Based on the nature and duration of operations	For later retrieval, decumulations, data collection, investigation, training, etc. (Dilshad *et al.*, 2020)
High battery life	The longer the better	To avoid operation interruption and risk of losing the drone vehicle (Mohsan *et al.*, 2022)
Onboard charging facility	Wired/wireless charging or other technology	To sustain longer missions (Lahmeri, Kishk and Alouini, 2022)
Light	LED	Navigation, searching, investigation, etc.

Source: Author

6.2.3.2. B-D4S operation concept

S&SPs with appropriate training can operate registered drones, and they can do so with appropriate SitAw, risk assessment, and observance of operation regulations. The drone can take off to start surveillance operations while the pilot maintains operational safety within LOS conditions. The received video stream can be used to support DD-M. Once the task is accomplished, the drone can be called back and further procedures can be followed.

6.2.4. A-D4S

6.2.4.1. A-D4S architecture

This version of the system supports much more advanced and sophisticated operations. As can be seen from Figure 6.8 and Table 6.4, it can be operated according to LOS and non-LOS conditions to extend the range of potential operations. To achieve this, the system needs to include special vehicle equipment with sensors, long-range communication links, a C&CC with database access, and an AI algorithm to support human and machine decision-making.

Therefore, before introducing the system into service, the right regulatory framework must be in place as well as a high level of collaboration between different authorities to make sure that the system can share airspace safely and effectively to achieve the intended purpose of use. In addition, the right level of training is needed to achieve the appropriate execution of all professional roles during the system's operation.

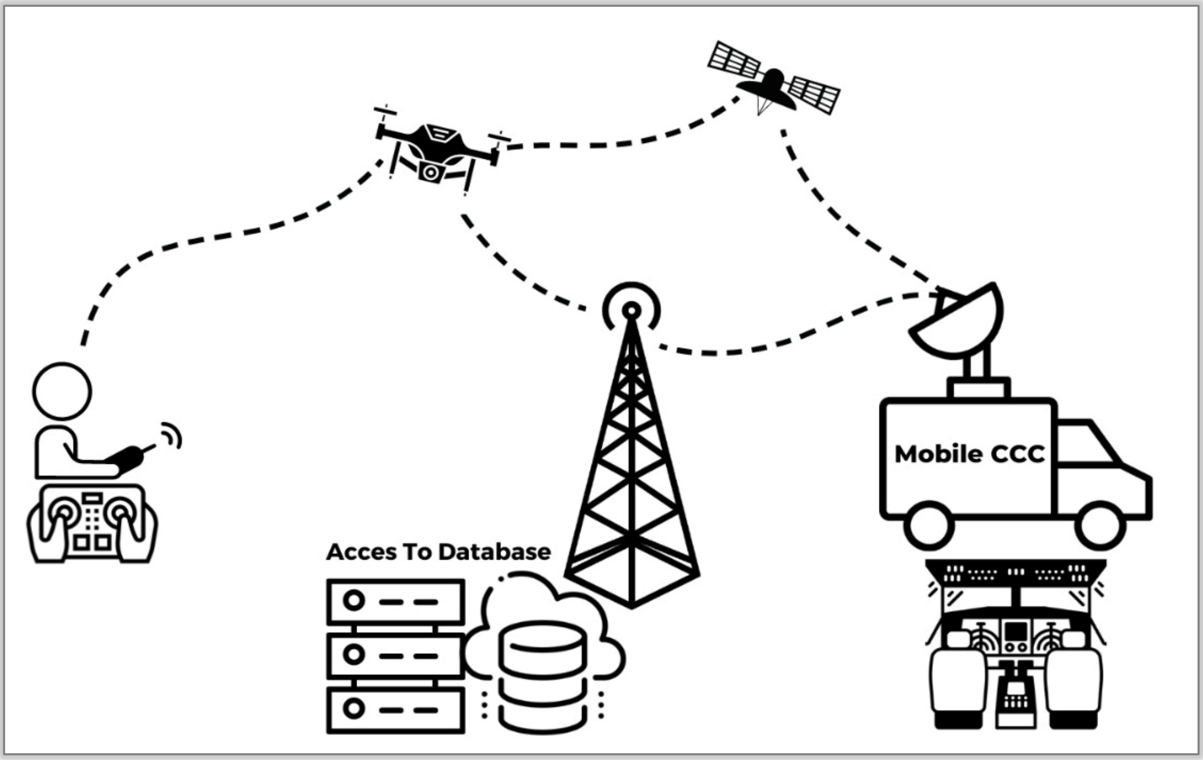

Figure 6.8: A-D4S architecture
Source: Author

Table 6.4: A-D4S suggested requirements

GPS	High accuracy for urban operations (based on application needed)	For navigation and location data (Mohsan *et al.*, 2022)
Surveillance camera	HD	For better awareness and investigation outcomes, navigation and night operations (Ali *et al.*, 2021)
	Night vision	
	Multi-angles	
Video recording facility	HD and high-capacity	For later retrieval, decumulations, investigation, training, etc. (Dilshad *et al.*, 2020)
High battery life	Hours	To sustain longer missions (Mohsan *et al.*, 2022)
Onboard charging facility	Wired and/or other options	To sustain long operations and avoid losing the drone vehicle (Lahmeri, Kishk and Alouini, 2022)
Light	LED	Navigation, searching, investigation, etc. (Burke *et al.*, 2019)
GIS mapping dataset	Regional or national level	Navigation, tracking, investigation and tagging (Wang *et al.*, 2019)
Access to specialised databases (e.g., offenders database)	Based on customisable operational needs	To support better decision-making (Eckstrom, 2020)
AI prediction algorithms (e.g., crowd detection, abnormal behaviour, facial recognition)	Suitable for operation in crowded and urban environments	To support better decision-making (Rigano, 2019; Pranav, Dubey and Singh, 2020)
Sensors array (e.g., fire, noise, and thermal detectors, anti-collision sensor)	Based on application requirements	Environmental sensing, risk assessment data gathering and safe operations (Burke *et al.*, 2019)

Source: Author

6.2.4.2. A-D4S operation concept

Drone vehicles are typically kept at the base or with mobile petrol reserves. Once approval for operation is given, a drone can take off within LOS and/or BLOS conditions and start surveillance, while the C&CC can maintain high levels of vigilance concerning the drone's location and altitude, issuing appropriate commands related to the operation. While other members of the C&CC observe the received video stream, data and suggestions from AI can establish better situational or environmental awareness during monitoring to establish and facilitate decisions. Once the event is finished, the drone can be called back to be rechecked for the next operation.

6.3. Results

6.3.1. Prototype

An off-the-shelf drone was used for the prototype to benchmark the system requirements with the specification datasheet as shown in Table 6.5 to make sure it satisfied the pertinent requirements.

Table 6.5: Benchmarking the system prototype requirements

Item	Requirement	Data Sheet Justification	Matching
Drone vehicle	Portable	595 g	✓
	Easy to operate and deploy	Yes	✓
	Can handle mild weather conditions	Stabilisation, 3-axis (tilt, roll, pan)	✓
	Good life cycle and is easy to maintain		✓
Communication link	Short-range, secure and reliable	O3 2.4 GHz/5.8 GHz Auto-Switching (compatible with OcuSync 2.0) 4-antenna 2T4R	✓
Ground control unit	Portable	5472×3078 @ 24/25/30 fps	✓
	With HD display		
GPS	Accuracy for urban and open space navigation	GPS+GLONASS+GALILEO	✓
Surveillance camera	HD with night vision	5.4K	✓
Video recording facility	Based on the nature and duration of operational use	Supports a microSD card with a capacity of up to 256 G	✓
High battery life	The longer the better	Approx. 4 hours	✓
Onboard charging facility	Wired/wireless charging or other technology	No	✗
Light	LED	Single LED	✓

Source: Author

The B-D4S prototype (Figure 6.9) was established, successfully deployed, and tested with Qatar Traffic Police. The prototype included an off-the-shelf drone, DJI Air 2S (Hopper, 2021), with GPS and surveillance cameras of 5.4K resolution, a take-off/landing pad on the roof of the traffic police patrol car, and a control joystick with a video stream displayed on the monitor fixed on the car's dashboard.

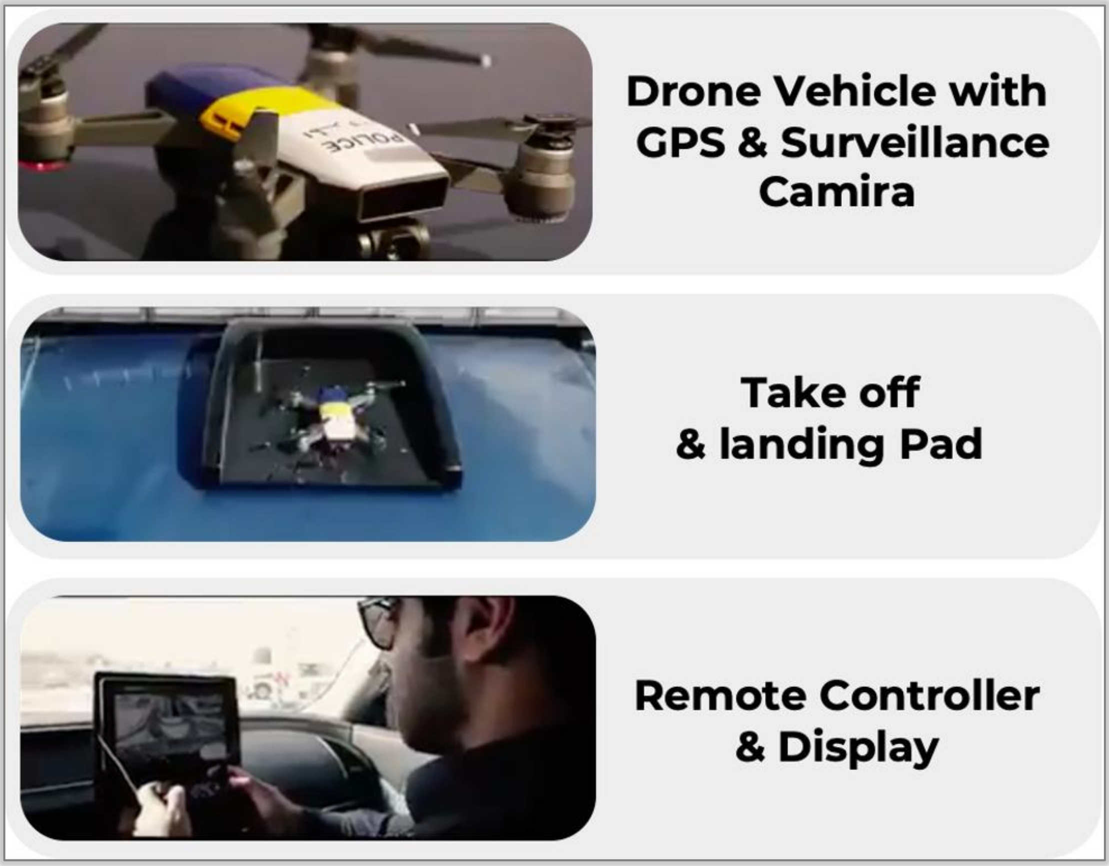

Figure 6.9: B-D4S prototype

Source: Author

6.3.2. Test mission

To test the effectiveness of the system in a real-life operation, the mission of emulating helicopter surveillance was used to monitor a traffic situation, as shown in Figure 6.10. This shows a police officer on the ground requesting a drone to establish better SitAw of the current traffic from a mobile patrol, which is equipped with a drone surveillance system. Approval and dispatch of the drone to the requested area were obtained, and the current video stream of the monitored environment was displayed on the car patrol monitor. Information about the environment was relayed back to the officer on the ground to facilitate decisions about necessary actions. After the mission was accomplished, the drone was recalled to the traffic police car patrol.

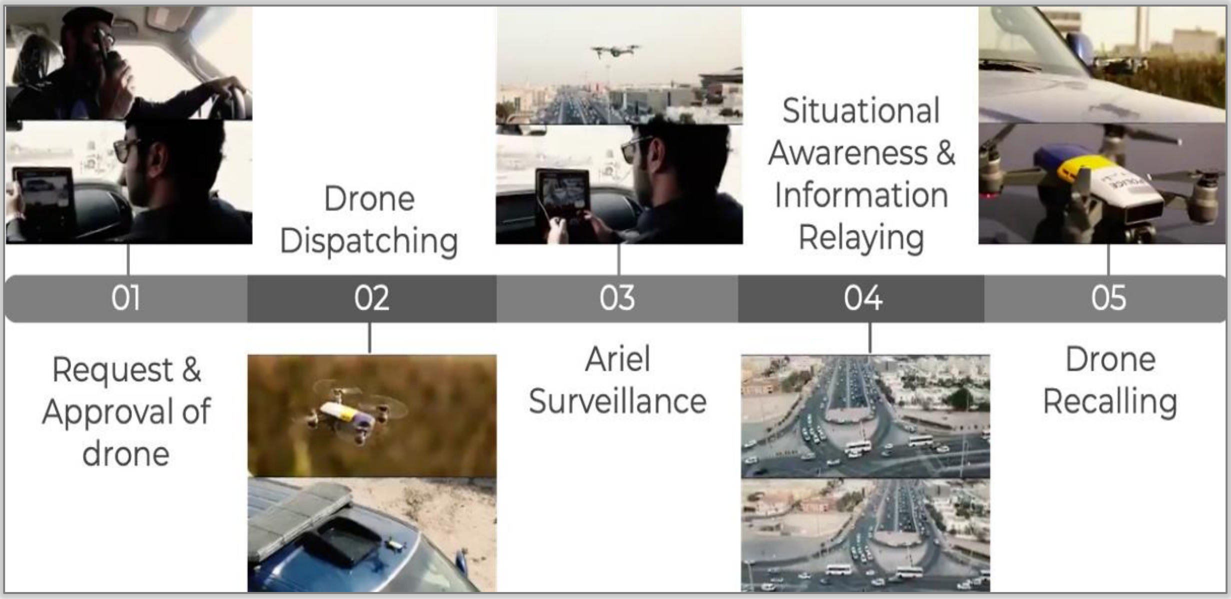

Figure 6.10: B-D4S evaluation test
Source: Author

Evaluation of the operational framework and system architecture was conducted by key stakeholders to obtain their feedback on the proposed framework and to make sure that it would tackle most of the issues required for the deployment of drone applications in Qatar, which does not currently have a framework for this kind of technology. The second evaluation was conducted by a consortium of experts to assess whether the proposed architecture can be deployed in Qatar in particular, and other countries in general, who are considering drone use for S&S applications. Such evaluation extends beyond technical performance issues to include consideration of end-user safety, to facilitate real-life deployment, and acceptability among users and the general public.

6.3.3. Protype evaluation analysis

This section presents the deployment of TAM to evaluate end users' attitudes towards D4S prototype adoption. Table 6.6 shows the construct items defined to test the study hypotheses.

Table 6.6: Construct items defined to test hypotheses

Construct Items
PU
1. With the new D4S, decisions are easier.
2. With the new D4S, decisions are more accurate.
3. With the new D4S, decisions are quicker.
PeoU
1. The new D4S is easy to use PeoU.
2. The new D4S and methodology are easy to understand.
BI2U
1. I think that using the new D4S is a good idea. BI2U.
2. I think that using the new D4S is beneficial.
3. I have a positive attitude to using the new D4S.
Usage
1. I intend to use the new D4S.
2. I intend to use the D4S instead of the established procedure.

Source: Author

To ensure the stability of the study tool, Cronbach's alpha coefficients were calculated for each construct, as shown in Table 6.7. All the values were higher than 0.7, which indicates that the study tool is valid for research purposes.

Table 6.7: Cronbach's alpha coefficients

Construct	Cronbach's Alpha
PU	0.93
PeoU	0.88
BI2U	0.98
Usage	0.91

Source: Author

Pearson correlation coefficients were identified to test the study hypotheses, as shown in Table 6.8. Figure 6.11 also shows the results, and the values of significance levels based on the study model. Table 6.9 summarises the results for each of the five hypotheses of the study, showing that all five hypotheses were supported.

Table 6.8: Correlation of constructs

Construct	1	2	3	4
PU	1	.763**	.751**	.551**
PEoU	.763**	1	.744**	.510**
BI2U	.751**	.744**	1	.345**
Usage	.551**	.510**	.345**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Author

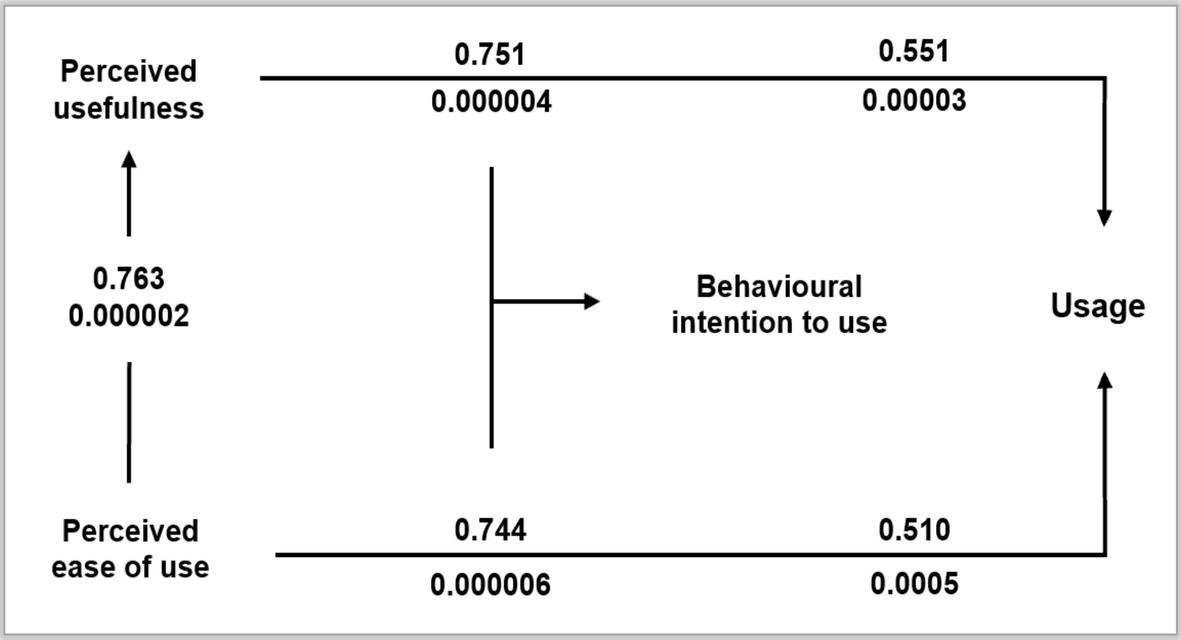

Figure 6.11: Research model with correlations

Source: Author

Table 6.9: Hypotheses testing results

No.	Hypothesis	Support
H1	PU positively affects BI2U.	Yes
H2	PEoU has a strong indirect positive relationship with BI2U.	Yes
H3	PEoU will have a weaker direct positive relationship with BI2U.	Yes
H4	BI2U has a strong positive impact on system usage.	Yes
H5	PU and PEoU have a strong positive impact on BI2U.	Yes

Source: Author

6.4. Discussion

The primary aim of this chapter has been to enhance SitAw and enable DD-M or decision support systems in the S&S sector through the utilisation of a proposed drone surveillance system. However, the potential applications of the proposed D4S extend beyond this specific field, also offering advantages for similar sectors. Two robust system architectures utilising different sets of sensors have been proposed, and the feasibility of a system prototype has been assessed by involving S&SPs who have used commercially available drones in Qatar and evaluated the acceptability of the technology (as per the identified dimensions of the TAM).

The outcomes of the evaluation strongly favoured the proposed systems, confirming their significant value for various stakeholders interested in deploying this innovative technology in real-life scenarios (e.g., traffic management). The D4S represents a crucial step towards revolutionising S&S practices, elevating SitAw to new heights, and empowering decision-makers with more informed and timely responses in critical situations.

Despite the promising results, it should be acknowledged that this research is not without limitations. The prototype evaluation was exclusively conducted in the S&S sector, prompting the need to further assess the system's benefits across different settings to fully explore its potential for various S&S applications. By addressing these limitations and conducting more comprehensive evaluations, the D4S has the potential to make substantial contributions to enhancing S&S measures, paving the way for advancements in the field of drone-based systems.

6.5. Chapter Summary

The chapter delved into the development and assessment of the D4S, targeting improved SitAw and decision-making in S&S operations. It provided an overview of drone applications across sectors, emphasising their adaptability and advantages, alongside the necessity for robust regulatory frameworks. A scoping systematic review informed the identification of key requirements, leading to the creation of the basic and advanced D4S versions (B-D4S and A-D4S, respectively), tailored to distinct operational demands. Operational concepts for both versions were delineated, outlining architectures, deployment protocols, and potential uses.

Notably, the A-D4S was highlighted for its advanced features, including BLOS operations and integration with AI for heightened SitAw. Successful development and testing of the B-D4S prototype with the Qatar Traffic Police validated its efficacy in real-world scenarios. Stakeholder and expert evaluations confirmed its feasibility and acceptability for deployment.

Additionally, the TAM gauged end users' attitudes towards the D4S prototype, revealing strong support across sectors. The D4S marks a substantial leap in S&S surveillance, offering enhanced SitAw and decision support. While further refinement and assessment are warranted, the D4S holds considerable potential to transform S&S practices, heralding advancements in drone-based systems.

CHAPTER 7
CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

The main aim of this research project was to conduct a comprehensive analysis to investigate the potential integration of drone technology in civilian S&S sectors, particularly its application in MSEs. Additionally, the study aimed to identify challenges encountered in deploying drones in the state of Qatar. To establish a framework for facilitating future drone deployments in Qatar, the study incorporated a SitAwM and proposed a system design for utilising drones in real civilian S&S applications.

The literature reviewed revealed a growing demand for the use of drones in various sectors for S&S purposes. Consequently, drones' sensors have evolved beyond GPS and camera surveillance systems to become more advanced, as has the software, enabling critical and efficient S&S applications. Therefore, the need for research to establish standardised guidelines for drone systems in S&S applications has become essential. Furthermore, having the right deployment framework is crucial to enable stakeholders to collaborate effectively for the safe and efficient deployment of drones in shared aerospace and support the efforts of the ICAO.

Another critical aspect of providing credible results for stakeholders interested in using drones for S&S applications is aligning the SitAwM with the integration of drone surveillance systems. This alignment enables better DD-M, as demonstrated by the positive reception of the aligned model by S&S personnel. It can serve as a reference for developing future systems that integrate with current static means of security and safety surveillance, thus enhancing efforts and avoiding disasters, such as those seen during the Champions League Final held in France in 2022, which served as a comparison for this research.

The two proposed system architectures for drone-based S&S systems, along with practical evaluations for real-life applications using system prototypes, provided supportive evidence for stakeholders. This evidence demonstrates how such systems can enhance the daily tasks of S&S specialists on the ground. Moreover, it provides options for decision-makers to choose between deploying an autonomous system as a new tool for security personnel or opting for a more advanced system for strategic operations at events requiring high-level S&S support systems.

7.2. Key Contributions and Implications

Although this work consists of a number of separate research studies, each is connected with the other; indeed, each is a building block towards a holistic destination. The justification for this approach can be found in the aim and objectives of the work, in the gaps in existing knowledge identified in Chapter 2, and in the scoping systematic review associated with Chapter 6. These reviews showed that two specific areas, smart cities and mega sporting events, each of which have so much to potentially gain from the use of drones in S & S, have not been the subject of sufficient research, despite their importance. It was also found from the reviews that while much attention has been paid to the possibilities for drone use, and to experiments in ideal conditions, a holistic approach, one that seeks to address the challenges realistically, is lacking.

The first building block, the stated second objective of this work, was to identify the challenges being confronted in a Qatari context and this was undertaken in Chapter 3. In some contrast with other works, the approach taken was to find out the challenges being faced from those most likely to have an understanding of them, namely key professionals. A quantitative methodology was chosen, using structured interviews and a survey instrument, and guided by PESTLE analysis. Having established the key challenges, the next task (Objective 3) was to develop a framework for drone use and this was the content of Chapter 4. The purpose of this framework is to be a roadmap for the deployment of UASs in Qatar, one that is easy for different stakeholders to understand, and which may enable the future deployment of civilian UASs in Qatar. The research had two strands and one was to study guidance provided by UK and EU authorities, while the other was to develop a framework based on this guidance and the challenges facing drone use in Qatar that had been previously identified. The framework was subsequently evaluated by key stakeholders through research with a mixed methods design.

Chapter 5, which sought to address Objective 4 (situational awareness), justified and used scenario analysis to consider drone use at a mega sporting event, which was the Champions League Final held in France in 2022. There were two phases and the first was a quantitative content analysis of documents related to the event and the second was a quantitative questionnaire administered to safety and security professionals in Qatar. They were provided with scenario examples based on the events in France ’22 and asked to give opinions concerning drone use in surveillance and whether it improved situation awareness for dynamic decision-making. Objective 5 (proposing an architecture for drone safety and security (D4S)) was the subject of Chapter 6. It utilised several evaluation models, as well as the results of a scoping systematic review that had previously been undertaken and published by the author, to produce the requirements and architecture for a prototype. This prototype was then tested in a real-life scenario with the Qatar Traffic Police and subsequently evaluated using statistical analysis.

This research contributes to the field of study in a number of potentially important ways. It identifies and seeks to address important gaps in existing knowledge. This knowledge is lacking in several areas and one is the lack of attention given to dimensions where drones have great potential for use in S&S, and these, as noted, are smart cities and mega sporting events. In doing this it addresses a further gap in existing knowledge and this is the lack of holistic approaches that not only identify the challenges but also seek to address them in a constructive manner. In this work each aspect is covered and builds upon the preceding step, rather than the fragmented approaches identifiable in the literature. The fact, furthermore, that the work is undertaken away from countries and regions that tend to dominate the research agenda is also an important contribution.

The outcomes of the study have implications that are both academic and practical. With regard to the former, it can inform and encourage further research. It is contended, for example, that the framework is robust and flexible enough to be used across the dimensions of drone application and to significantly influence future regulatory paths taken. This, however, should be researched in such varying contexts. In terms of practical application, and particularly because it is grounded in the values and opinions of professionals in the field, it may be more widely adopted in Qatar and even beyond the borders of that country. This is a particularly important implication for Qatar because drone use is currently low there despite the level of development and technical abilities that exist.

As an overall conclusion, drones can significantly contribute to enhancing S&S across a wide range of sectors. They offer the potential to improve S&S at an affordable cost and with a short deployment time. However, realising these benefits requires an understanding of the potential challenges and the establishment of a suitable framework that enables all stakeholders to collaborate effectively in deploying drones in shared airspace safely and efficiently. Additionally, it is crucial to recognise the role of drones in enhancing SitAw for DD-M in various sectors and operational contexts. This necessitates the use of drone systems equipped with the appropriate sensors to support such operations.

7.3. Recommendations for Further Work

This research project provided an initial list of contributions in Chapter 1; these areas of contribution are expanded with the following suggested work activities:

- **Conducting more specific systemic review studies on each application of drones for S&S purposes across different sectors**

This would provide stakeholders with comprehensive and detailed references. Such studies could more fully investigate the specific requirements, challenges, and best practices associated with deploying drones in various industries, thus offering invaluable insights for decision-makers and practitioners.

- **Implementing the proposed UAS deployment framework in practice and conducting further evaluations, particularly as drone applications become a reality in Qatar**

This is essential, as practical implementation will allow for real-world testing of the framework's effectiveness, identify any shortcomings or areas for improvement, and ensure its alignment with the local context and regulatory requirements.

- **Testing the aligned SitAwM with other scenarios beyond the initial scope to enable the gathering of additional data for comparison and validation**

By exploring diverse scenarios, such as emergency response situations or infrastructure monitoring, researchers can assess the model's adaptability, robustness, and reliability across various contexts, thereby enhancing its utility and credibility.

- **Experimenting with different scenarios for civilian S&S applications to further evaluate the D4S system is crucial for its refinement and optimisation**

By simulating various scenarios, such as crowd management, perimeter surveillance, or disaster response, researchers can assess the system's performance under different conditions, identify areas for enhancement, and tailor its functionalities to meet specific operational requirements. These experiments will contribute to the continuous improvement and advancement of drone-based security solutions, ultimately enhancing their effectiveness and usability in safeguarding public S&S.

References

Abrahamsen, H. B. (2015) ‘A remotely piloted aircraft system in major incident management: Concept and pilot, feasibility study’, BMC Emergency Medicine, 15, p. 12. Available at: https://doi.org/10.1186/s12873-015-0036-3

Abro, G. E. M., Zulkifli, S. A. B. M., Masood, R. J., Asirvadam, V. S. and Laouti, A. (2022) ‘Comprehensive review of UAV detection, security, and communication advancements to prevent threats’, Drones, 6(10), p. 284. Available at: https://doi.org/10.3390/drones6100284

Abu-Bader, S. H. (2021) Using statistical methods in social science research: With a complete SPSS guide. Oxford: OUP.

Alamouri, A., Lampert, A. and Gerke, M. (2021) ‘An exploratory investigation of UAS regulations in Europe and the impact on effective use and economic potential’, Drones, 5(3), p. 63. http://dx.doi.org/10.3390/drones5030063

Albaum, G. (1997) ‘The Likert scale revisited’, Market Research Society Journal, 39(2), pp. 1-21. Available at: https://doi.org/10.1177/147078539703900202

AL-Dosari, K., Hunaiti, Z. and Balachandran, W. (2023a) ‘A review of civilian drones’ systems, applications, benefits, safety, and security challenges’, in M. Alshurideh, B. Al Kurdi, R. Masa’deh and S. A. Salloum (eds.) The effect of information technology on business and marketing intelligence systems. Studies in Computational Intelligence, vol. 1056. Springer, Cham: Springer International Publishing, pp. 793-812. Available at: https://doi.org/10.1007/978-3-031-12382-5_43

AL-Dosari, K., Hunaiti, Z. and Balachandran, W. (2023b) ‘Civilian UAV deployment framework in Qatar’, Drones, 7(1), p. 46. http://dx.doi.org/10.3390/drones7010046

AL-Dosari, K., Hunaiti, Z. and Balachandran, W. (2023c) ‘Systematic review on civilian drones in safety and security applications’, Drones, 7, 210. Available at: https://doi.org/10.3390/drones7030210

Ali, B. (2019). ‘Traffic management for drones flying in the city,’ International Journal of Critical Infrastructure Protection, 26,100310. https://doi.org/10.1016/j.ijcip.2019.100310

Ali, H., Hang, L. Y., Suan, T. Y., Polaiah, V. R., Aluwi, M. I. F., Zabidi, A. M. and Elshaikh, M. (2021) ‘Development of surveillance drone-based internet of things (IoT) for industrial security applications’, Journal of Physics Conference Series, 2107(1), p. 012018. Available at: https://doi.org/10.1088/1742-6596/2107/1/012018

Alizadehsalehi, S., Asnafi, M., Yitmen, I. and Celik, T. (2017) ‘UAS-BIM based real-time hazard identification and safety monitoring of construction projects’, in Proceedings of the 9th Nordic Conference on Construction Economics and Organization, Göteborg, Sweden, 13-14 June 2017, vol. 13, p. 22. Available at: https://www.researchgate.net/publication/318707931_UAS-BIM_based_Real-time_Hazard_Identification_and_Safety_Monitoring_of_Construction_Projects (Accessed: 14 March 2024).

Aljazeera (2022) ‘Paris police chief admits “failure” at Champions League final’, Aljazeera, 9 June. Available at: https://www.aljazeera.com/news/2022/6/9/paris-police-chief-admits-failure-at-champions-league-final (Accessed: 14 March 2024).

Alshamrani, A. and Bahattab, A. (2015) ‘A comparison between three SDLC models: Waterfall model, spiral model, and incremental/iterative model’, International Journal of Computer Science Issues, 12(1), pp. 106-111. Available at: https://www.ijcsi.org/papers/IJCSI-12-1-1-106-111.pdf (Accessed: 14 March 2024).

Altawy, R. and Youssef, A. M. (2016) ‘Security, privacy, and safety aspects of civilian drones: A survey’, ACM Transactions on Cyber-Physical Systems, 1(2), pp. 1-25. http://dx.doi.org/10.1145/3001836

Al-Yafei, E. F. (2018) Sustainable design for offshore oil and gas platforms: A conceptual framework for topside facilities projects [Doctoral dissertation, Heriot-Watt University], ROS Theses Repository. http://hdl.handle.net/10399/3513

Amukele, T. K., Street, J., Carroll, K., Miller, H. and Zhang, S. X. (2016) ‘Drone transport of microbes in blood and sputum laboratory specimens’, Journal of Clinical Microbiology, 54(10), 2622-2625. Available at: https://doi.org/10.1128/jcm.01204-16

Anderson, K. and Gaston, K. J. (2013) ‘Lightweight unmanned aerial vehicles will revolutionize spatial ecology’, Frontiers in Ecology and the Environment, 11(3), pp. 138-146. Available at: https://doi.org/10.1890/120150

Ashour, R., Taha, T., Mohamed, F., Hableel, E., Kheil, Y. A., Elsalamouny, M., Kadadha, M., Rangan, K., Dias, J., Seneviratne, L. and Cai, G. (2016) ‘Site inspection drone: A solution for inspecting and regulating construction sites’, in Proceedings of the 2016 IEEE 59th International Midwest Symposium on Circuits and Systems (MWSCAS), Abu Dhabi, United Arab Emirates, 16-19 October 2016, pp. 1-4. http://dx.doi.org/10.1109/MWSCAS.2016.7870116

Azari, M. M., Sallouha, H., Chiumento, A., Rajendran, S., Vinogradov, E. and Pollin, S. (2018) ‘Key technologies and system trade-offs for detection and localization of amateur drones’, IEEE Communication Magazine, 56(1), pp. 51-57. http://dx.doi.org/10.1109/MCOM.2017.1700442

Babbie, E. R., Wagner, W. E. and Zaino, J. S. (2018) Adventures in social research: Data analysis using IBM SPSS Statistics. 10th edn. Thousand Oaks: SAGE Publications Inc.

Balasingam, M. (2017) ‘Drones in medicine: The rise of the machines’, International Journal of Clinical Practice, 71(9), p. e12989. Available at: https://doi.org/10.1111/ijcp.12989

Bassi, E. (2020) ‘From here to 2023: Civil drones operations and the setting of new legal rules for the European single sky’, Journal of Intelligent & Robotic Systems, 100(2), pp. 493-503. Available at: https://doi.org/10.1007/s10846-020-01185-1

Bello, A. B., Navarro, F., Raposo, J., Miranda, M., Zazo, A. and Álvarez, M. (2022) 'Fixed-wing UAV flight operation under harsh weather conditions: A case study in Livingston Island Glaciers, Antarctica', Drones, 6(12), pp. 384. Available at: https://doi.org/10.3390/drones6120384

Blood, R. and Postma, T. (1997) 'Strategic learning with scenarios', European Management Journal, 15(6), pp. 633-647. Available at: https://doi.org/10.1016/S0263-2373(97)00047-9

Boukoberine, M., Zhou, Z. and Benbouzid, M. (2019). 'Power Supply Architectures for Drones - A Review,' 45th Annual Conference of the IEEE Industrial Electronics Society, Lisbon, Portugal, pp. 5826-5831. doi: 10.1109/IECON.2019.8927702

Burke, C., McWhirter, P. R., Veitch-Michaelis, J., McAree, O., Pointon, H. A., Wich, S. and Longmore, S. (2019) 'Requirements and limitations of thermal drones for effective search and rescue in marine and coastal areas', Drones, 3(4), p. 78. Available at: https://dx.doi.org/10.3390/drones3040078

Butcher, P. A., Piddocke, T. P., Colefax, A. P., Hoade, B., Peddemors, V. M., Borg, L. and Cullis, B. R. (2019) 'Beach safety: Can drones provide a platform for sighting sharks?', Wildlife Research, 46(8), pp. 701-712. http://dx.doi.org/10.1071/WR18119

Cezar, P. O. P. A. and Mitulețu, I. (2021) 'State-of-the-art technologies to be used in command and control systems', Bulletin of Carol I National Defence University, 10(2), pp. 54-63. Available at: http://dx.doi.org/10.53477/2284-9378-21-06

Chang, V., Chundury, P. and Chetty. M. (2017) 'Spiders in the sky: User perceptions of drones, privacy, and security', in CHI '17: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, pp. 6765-6776. Available at: https://doi.org/10.1145/3025453.3025632

Chartered Institute of Personnel and Development (2022) PESTLE analysis. Available at: https://www.cipd.co.uk/knowledge/strategy/organisational-development/PESTLE-analysis-factsheet#gref (Accessed: 14 March 2024).

Child Protection in Sport Unit (2021) Online safety scenarios for sport organisations. Available at: https://www.clearinghouseforsport.gov.au/ (Accessed: 24 March 2024).

Choi, H. Kim, H., Kim, S. and Na, W. (2023). 'An Overview of Drone Applications in the Construction Industry,' Drones 7, pp. 1-21. https://doi.org/10.3390/ drones7080515

Choi-Fitzpatrick, A. (2014) 'Drones for good: Technological innovations, social movements, and the state'. Journal of International Affairs, 68(1), pp. 19-36.

Chrisafis, A. (2022) 'Liverpool fans unfairly blamed for Champions League chaos, French senate report finds', The Guardian, 13 July. Available at: https://www.theguardian.com/football/2022/jul/13/liverpool-fans-unfairly-blamed-for-champions-league-final-chaos-paris-french-senate-report (Accessed: 14 March 2024).

Citroni, R., Di Paolo, F. and Livreri, P. (2019) 'A novel energy harvester for powering small UAVs: Performance analysis, model validation and flight results', Sensors, 19, p. 1771. Available at: https://doi.org/10.3390/S19081771

Civil Aviation Authority (2020) CAP 722: Unmanned aircraft system operations in UK airspace – guidance & policy. Available at: https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=415

Clothier, R. A. and Walker, R. A. (2015) 'The safety risk management of unmanned aircraft systems', in K. Valavanis and G. Vachtsevanos (eds.) Handbook of unmanned aerial vehicles. Cham: Springer International Publishing, pp. 2229-2275.

Colomina, I. and Molina, P. (2014) 'Unmanned aerial systems for photogrammetry and remote sensing: A review'. ISPRS Journal of Photogrammetry and Remote Sensing, 92, pp. 79-97. http://dx.doi.org/10.1016/j.isprsjprs.2014.02.013

Commission of Culture and Education (2022) Finale de la Ligue des Champions au Stade de France: Un fiasco inevitable. Available at: https://www.senat.fr/rap/r21-776/r21-776.html (Accessed: 24 March 2024).

Connolly, E. (2020) Now what? Five scenarios for the post-coronavirus sports industry. Available at: https://www.sportspromedia.com/from-the-magazine/five-scenarios-coronavirus-sports-industry-tv-rights-recession/ (Accessed: 14 March 2024).

Creswell, J. W. and Creswell, J. D. (2018) Research design: Qualitative, quantitative, and mixed methods approaches. Thousand Oaks: Sage Publications Inc.

Cronk, B. C. (2017) How to use SPSS: A step-by-step guide to analysis and interpretation. London: Routledge.

Dalton, A., Wolff, K. and Bekker, B. (2021) 'Multidisciplinary research as a complex system', International Journal of Qualitative Methods, 20, p. 16094069211038400. Available at: https://doi.org/10.1177/16094069211038400

Daniel, K. and Wietfeld, C. (2011) Using public network infrastructures for UAV remote sensing in civilian security operations. Dortmund: Technical University Dortmund.

Dastgheibifard, S. and Asnafi, M. (2018) 'A review on potential applications of unmanned aerial vehicle for the construction industry', Sustainable Structure and Materials, 1(2), pp. 44-53. http://dx.doi.org/10.26392/SSM.2018.01.02.044

Daud, S., Yusof, M., Heo, C., Khoo, L., Singh, M., Mahmood, M. and Nawawi, H. (2022). 'Applications of drone in disaster management: A scoping review,' Science & Justice, 62(1), pp. 30-42. https://doi.org/10.1016/j.scijus.2021.11.002

Davis, F. D. (1993) 'User acceptance of information technology: System characteristics, user perceptions and behavioural impacts', International Journal of Man-Machine Studies, 38(3), pp. 475-487. Available at: https://doi.org/10.1006/imms.1993.1022 de Ávila Costa, G. L., Gomes, T. C., de Oliveira, B. B., Rodrigues, G. O., de Oliveira Simonetto, E., de Fátima Barros Estivalete, V. (2022) 'Organizational citizenship behaviours and social support at work: Scenario analysis through system dynamic', Pensamento & Realidade, 36(2), pp. 1-16. http://dx.doi.org/10.23925/2237-4418.2021v36i2p.01-16

de Casterle, B., Gastmans, C., Bryon, E. and Denier, Y. (2012) 'QUAGOL: A guide for qualitative data analysis,' International Journal of Nursing Studies, 49(3), pp. 360-371. Available at: https://doi.org/10.1016/j.ijnurstu.2011.09.012

Denyer, D. and Tranfield, D. (2009) 'Producing a systematic review', in D. A. Buchanan and A. Bryman (eds.) The SAGE handbook of organizational research methods. London: SAGE Publications Ltd., pp. 671-689.

de Silva, S., Phlernjai, S., Rianmora, M. and Ratsamee, P. (2022). 'Inverted Docking Station: A Conceptual Design for a Battery-Swapping Platform for Quadrotor UAVs,' Drones, 6(3), 56, pp. 1-25. doi:10.3390/drones6030056

DiCicco-Bloom, B. and Crabtree, B. F. (2006) 'The qualitative research interview'. Medical Education, 40(4), pp. 314-321. Available at: https://doi.org/10.1111/j.1365-2929.2006.02418.x

Dilshad, N., Hwang, J., Song, J. and Sung, N. (2020) 'Applications and challenges in video surveillance via drone: A brief survey', in 2020 International Conference on Information and Communication Technology Convergence. New York: IEEE, pp. 728-732. Available at: http://dx.doi.org/10.1109/ICTC49870.2020.9289536

Dixon-Woods, M., Agarwal, S., Jones, D., Young, B. and Sutton, A. (2005) 'Synthesising qualitative and quantitative evidence: A review of possible methods', Journal of Health Services Research & Policy, 10(1), pp. 45-53. http://dx.doi.org/10.1258/1355819052801804

Dixon-Woods, M., Bonas, S., Booth, A., Jones, D. R., Miller, T., Sutton, A. J., Shaw, R. L., Smith, J. A. and Young, B. (2006) 'How can systematic reviews incorporate qualitative research? A critical perspective', Qualitative Research, 6(1), pp. 27-44. Available at: https://doi.org/10.1177/1468794106058867

Drisko, J. W. and Maschi, T. (2016) Content analysis. Oxford: Oxford University Press.

Dudovskiy, J. (2022) PESTEL analysis. Available at: https://research-methodology.net/pestel-analysis/ (Accessed: 14 March 2024).

Dung, N. D. and Rohacs, J. (2018) 'The drone-following models in smart cities', in Proceedings of the 2018 IEEE 59th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), Riga, Latvia, 12-14 November 2018, pp. 1-6. Available at: https://doi.org/10.1109/RTUCON.2018.8659813

Dunnington, L. and Nakagawa, M. (2017) 'Fast and safe gas detection from underground coal fire by drone fly over', Environmental Pollution, 229, pp. 139-145. Available at: https://doi.org/10.1016/j.envpol.2017.05.063

Eckstrom, D. R. (2020) Facial recognition software for patrol. Available at: https://hdl.handle.net/20.500.11875/3127 (Accessed: 14 March 2024).

Endsley, M. R. (1999) ‘Situation awareness in aviation systems’, in Garland, D. J., Wise, J. A. and Hopkin, V. D. (eds.) Handbook of aviation human factors. Hoboken: Lawrence Erlbaum Associates Inc., pp. 257-276.

Endsley, M. R. (2017) ‘Toward a theory of situation awareness in dynamic systems’, in E. Salas (ed.) Situational awareness. London: Routledge, pp. 9-42.

Enemark, C. (2013) Armed drones and the ethics of war: Military virtue in a post-heroic age. London: Routledge.

Ensley, M. R. (1995) ‘Toward a theory of situation awareness in dynamic systems’, Human Factors Journal, 37(1), pp. 32-64. http://dx.doi.org/10.1518/001872095779049543

Euchi, J. (2021) ‘Do drones have a realistic place in a pandemic fight for delivering medical supplies in healthcare systems problems?’, Chinese Journal of Aeronautics, 34(2), 182-190. http://dx.doi.org/10.1016/j.cja.2020.06.006

European Union Aviation Safety Agency. (2020) High-level regulatory framework for the U-Space (Opinion No. 01/2020). Available at: https://www.easa.europa.eu/sites/default/files/dfu/Opinion%20No%2001-2020.pdf (Accessed: 14 March 2024).

Fahlstrom, P. G., Gleason, T. J. and Sadraey, M. H. (2022) Introduction to UAV systems. London: John Wiley & Sons.

Federal Aviation Administration (2022) Section 44807: Special Authority for Certain Unmanned Systems. Available at: https://www.faa.gov/uas/advanced_operations/certification/section_44807 (Accessed: 24 Mach 2024).

Federal Aviation Administration. (2023) Unmanned aircraft systems (UAS). Available at: https://www.faa.gov/newsroom/unmanned-aircraft-systems-uas (Accessed: 24 March 2024).

Fernandez-Pacheco, A., Rodriguez, L., Price, A., Perez, M. and Alonso, N. (2017). ‘Drones at the service for training on mass casualty incident: A simulation study,’ Medicine, 96(26), pp. 1-4. doi:10.1097/MD.0000000000007159

Ferrari, M. (2023). ‘Test, swarm, normalize: how surveillance technologies have infiltrated Paris 2024 Olympic Games,’ Cad. Metropole, 25 (56), pp. 75-96. https://doi.org/10.1590/2236-9996.2023-5603

Ferrari, R. (2015) ‘Writing narrative style literature reviews’, Medical Writing, 24(4), pp. 230-235. http://dx.doi.org/10.1179/2047480615Z.000000000329

Field, A. P. and Gillett, R. (2010) ‘How to do a meta-analysis’, British Journal of Mathematical and Statistical Psychology, 63, pp. 665-694. Available at: https://doi.org/10.1348/000711010X502733

Foina, A., Sengupta, R., Lerchi, P., Liu, Z. and Krainer, C. (2015). ‘Drones in smart cities: Overcoming barriers through air traffic control research,’ Workshop on Research, Education and Development of Unmanned Aerial Systems, Cancun, Mexico, pp. 351-359. doi: 10.1109/RED-UAS.2015.7441027

Gallacher, D. (2016) ‘Drone applications for environmental management in urban spaces: A review’, International Journal of Sustainable Land Use and Urban Planning, 3(4), pp. 1-14. http://dx.doi.org/10.24102/ijslup.v3i4.738

Gallacher, D. (2016a). ‘Drones to manage the urban environment: Risks, rewards, alternatives,’ Journal of Unmanned Vehicle Systems, 4(2), pp. 1-16. https://doi.org/10.1139/juvs-2015-0040

Galletta, A. (2012) Mastering the semi-structured interview and beyond: From research design to analysis and publication. New York: New York University Press.

Gertler, J. (2012) US unmanned aerial systems. Washington DC: Congressional Research Service.

Ghasri, M. and Maghrebi, M. (2021) ‘Factors affecting unmanned aerial vehicles’ safety: A post-occurrence exploratory data analysis of drones’ accidents and incidents in Australia’, Safety Science, 139, p. 105273. http://dx.doi.org/10.1016/j.ssci.2021.105273

Gheisari, M., Irizarry, J. and Walker, B. N. (2014) ‘UAS4SAFETY: The potential of unmanned aerial systems for construction safety applications’, in Construction Research Congress 2014: Construction in a Global Network. Lyon: HAL Open Science, pp. 1801-1810.

Gohari, A., Ahmad, A., Rahim, R., Supa’at, A., Razak, S. and Gismalla, M. (2022). ‘Involvement of Surveillance Drones in Smart Cities: A Systematic Review.’ IEEE Access, 22, pp. 11-28. doi10.1109/ACCESS.2022.3177904

Grosse, S. Moreau, E. and Binder, N. (2024). ‘Modelling of the Flight Performance of a Plasma-Propelled Drone: Limitations and Prospects,’ Drones, 8, 114, pp. 1-34. https:// doi.org/10.3390/drones8030114

Guddat, S., Görgens, C., Sobolevsky, T. and Thevis, M. (2021) ‘Meldonium residues in milk: A possible scenario for inadvertent doping in sports?’, Drug Testing and Analysis, 13(11-12), pp. 1906-1910. Available at: https://doi.org/10.1002/dta.3145

Hamid, M., Hussain, A. and Aman, A. (2019) ‘An overview of drone technologies’, Wireless Communications in Mobile Computing, 2019, p. 1351697. Available at: https://doi.org/10.1155/2019/1351697

Haque, S. R., Kormokar, R. and Zaman, A. U. (2017) ‘Drone ground control station with enhanced safety features’, in 2017 2nd International Conference for Convergence in Technology (I2CT). New York: IEEE, pp. 1207-1210. Available at: http://dx.doi.org/10.1109/I2CT.2017.8226318

Hartmann, K. and Steup, C. (2013) ‘The vulnerability of UAVs to cyber-attacks: An approach to the risk assessment’, in K. Podins, J. Stinissen and M. Maybaum (eds.) 2013 5th International Conference on Cyber Conflict. New York: IEEE, pp. 1-23.

Hatoum, M. and Nassereddine, H. (2022). 'The Use of Drones in the Construction Industry: Applications and Implementation,' 39th International Symposium on Automation and Robotics in Construction. Bogotá, Colombia, pp. 542-549. Available at: https://www.iaarc.org/publications/fulltext/075_ISARC%202022_Paper_5.pdf

He, D., Chan, S. and Guizani, M. (2017) 'Drone-assisted public safety networks: The security aspect', IEEE Communications Magazine, 55, pp. 218-223. Available at: https://doi.org/10.1109/MCOM.2017.1600799CM

Henley, J. and Walker, P. (2022) 'Fake tickets on 'industrial scale' caused Paris chaos, says French minister', The Guardian, 30 May. Available at: https://www.theguardian.com/football/2022/may/30/liverpool-fans-caused-initial-problems-in-paris-says-french-sports-minister (Accessed: 24 March 2024).

Hobbs, A. (2010) 'Unmanned aircraft systems', in E. Salas & D. Maurino (eds.) Human factors in aviation. 2nd edn. Burlington: Academic Press. Available at: https://doi.org/10.1016/B978-0-12-374518-7.00016-X

Hopper, D. (2021) 'Review: DJI Air 2S'. Australian Photography, 13 September. Available at: https://www.australianphotography.com/gear/review-dji-air-2s (Accessed: 14 March 2024).

Hosseini, N., Jamal, H., Haque, J., Magesacher, T. and Matolak, D. W. (2019) 'UAV command and control, navigation and surveillance: A review of potential 5G and satellite systems', in 2019 IEEE Aerospace Conference. New York: IEEE, pp. 1-10. Available at: http://dx.doi.org/10.1109/AERO.2019.8741719

Howard, J., Murashov, V. and Branche, C. M. (2018) 'Unmanned aerial vehicles in construction and worker safety', American Journal of Industrial Medicine, 61(1), pp. 3-10. Available at: https://doi.org/10.1002/ajim.22782

Hunter, A. (2022) 'Saint-Denis Convention undermined by chaos at Champions League Final', The Guardian. 5 June. Available at: https://www.theguardian.com/football/2022/jun/04/saint-denis-convention-undermined-by-chaos-at-champions-league-final-liverpool-real-madrid (Accessed: 24 March 2024).

Huttunen, M. (2019) 'Civil unmanned aircraft systems and security: The European approach', Journal of Transportation Security, 12(3), pp. 83-101. Available at: https://doi.org/10.1007/s12198-019-00203-0

Ibis World. (2020) How to conduct a PESTLE analysis. Available at: https://www.ibisworld.com/blog/3-step-pestle-analysis/99/1127/ (Accessed: 14 March 2024).

International Civil Aviation Organization. (2022) 'The safe and efficient integration of UAS into airspace'. Available at: https://www.iata.org/contentassets/e45e5219cc8c4277a0e80562590793da/safe-efficient-integration-uas-airspace.pdf (Accessed: 24 March 2024).

Irizarry, J., Gheisari, M. and Walker, B. N. (2012) 'Usability assessment of drone technology as safety inspection tools', Journal of Information Technology in Construction, 17, pp. 194-212.

Jamil, S., Rahman, M., Ullah, A., Badnava, S., Forsat, M. and Mirjavadi, S. S. (2020) 'Malicious UAV detection using integrated audio and visual features for public safety applications', Sensors, 20(14), p. 3923. Available at: https://doi.org/10.3390/s20143923

Javaid, A. Y., Sun, W., Devabhaktuni, V. K. and Alam, M. (2012) 'Cyber security threat analysis and modelling of an unmanned aerial vehicle system', in 2012 IEEE Conference on Technologies for Homeland Security (HST). New York: IEEE, pp. 585-590. Available at: http://dx.doi.org/10.1109/THS.2012.6459914

Javid, M., Haleem, A., Khan, I., Singh, R., Suman, R. and Mohan, S. (2022). 'Significant Features and Applications of Drones for Healthcare: An Overview,' Journal of Industrial Integration and Management. https://doi.org/10.1142/S2424862222500245. Available at: https://www.worldscientific.com/doi/epdf/10.1142/S2424862222500245

Jiang, T., Geller, J., Ni, D. and Collura, J. (2016) 'Unmanned aircraft system traffic management: Concept of operation and system architecture', International Journal of Transportation Science and Technology, 5(3), pp. 123-135. http://dx.doi.org/10.1016/j.ijtst.2017.01.004

Jungermann, H. and Thüring, M. (1987) 'The use of mental models for generating scenarios', in G. Wright and P. Ayton (eds.) Judgmental forecasting. London: John Wiley & Sons, pp. 245-266.

Kardasz, P., Doskocz, J., Hejduk, M., Wiejkut, P. and Zarzycki, H. (2016) 'Drones and possibilities of their using', Journal of Civil & Environmental Engineering, 6(3), pp. 1-7. http://dx.doi.org/10.4172/2165-784X.1000233

Khan, M. A., Alvi, B. A., Safi, A. and Khan, I. U. (2018) 'Drones for good in smart cities: A review,' in Proceedings of the International Conference on Electrical, Electronics, Computers, Communication, Mechanical and Computing (EECCMC), 28-29 January 2018. New York: IEEE, pp. 1-6. Available at: https://www.researchgate.net/publication/316846331_Drones_for_Good_in_Smart_CitiesA_Review (Accessed: 14 March 2024).

Kim, D. (2020) 'Pedestrian and bicycle volume data collection using drone technology', Journal of Urban Technology, 27(2), 45-60. Available at: https://doi.org/10.1080/10630732.2020.1715158

Ko, Y., Kim, J., Duguma, D. G., Astillo, P. V., You, I. and Pau, G. (2021) 'Drone secure communication protocol for future sensitive applications in military zone', Sensors, 21(6), p. 2057. Available at: https://doi.org/10.3390/s21062057

Kosow, H. and Gaßner, R. (2008) Methods of future and scenario analysis: Overview, assessment, and selection criteria. Bonn: German Development Institute.

Kramar, V. (2019) 'UAS (drone) Arctic challenges: Next steps', in S. Balandin, V. Niemi and T. Tutina (eds.) Proceedings of the FRUCT'25. New York: ACM, pp. 507-514. Available at: https://fruct.org/publications/acm25/

Kramer, M. (2018) ‘Best practices in systems development lifecycle: An analysis based on the waterfall model’, Review of Business and Finance Studies, 9(1), pp. 77-84.

Krishna, C. L. and Murphy, R. R. (2017) ‘A review on cybersecurity vulnerabilities for unmanned aerial vehicles’, in 2017 IEEE International Symposium on Safety, Security and Rescue Robotics (SSRR). New York: IEEE, pp. 194-199.

Kumar, G. D. and Jeeva, B. (2017) ‘Drone ambulance for outdoor sports’, Asian Journal of Applied Science and Technology, 1(5), pp. 44-49.

Kunovjanek, M. and Wankmüller, C. (2021) ‘Containing the COVID-19 pandemic with drones: Feasibility of a drone-enabled back-up transport system’. Transport Policy, 106, pp. 141-152. Available at: https://doi.org/10.1016%2Fj.tranpol.2021.03.015

Kwon, D., Yoon, G., Kim, S. Y. and Kwon, Y. (2017) ‘A study on auto patrol drone development for safety management’, in Proceedings of the International Conference on Computer and Data Analysis, 19-23 May 2017. New York: IEEE, pp. 293-297.

Lahmeri, M. A., Kishk, M. A. and Alouini, M. S. (2022) ‘Charging techniques for UAV-assisted data collection: Is laser power beaming the answer?’ IEEE Communication Magazine, 60(5), pp. 50-56. Available at: https://doi.org/10.1109/MCOM.001.2100871

Le Monde (2022) ‘Champions League chaos caused “severe damage” to France’s image: Government report’, Le Monde, 10 June. Available at: https://www.lemonde.fr/en/sports/article/2022/06/10/champions-league-chaos-caused-severe-damage-to-france-s-image-government-report_5986318_9.html (Accessed: 14 March 2024).

Leasher, T. J. (2017) Utilization of drone technology to improve tower worker safety and productivity. Available at: https://thekeep.eiu.edu/cgi/viewcontent.cgi?article=1117&context=honors_theses (Accessed: 14 March 2024).

Lee, S. and Choi, Y. (2016) ‘Reviews of unmanned aerial vehicle (drone) technology trends and its applications in the mining industry’, Geosystem Engineering, 19, pp. 197-204. http://dx.doi.org/10.1080/12269328.2016.1162115

Legislation.gov.uk (2018) Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005 (EC) No 1008/2008 (EU) No 996/2010 (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91. Available at: https://www.legislation.gov.uk/eur/2018/1139/annex/IV (Accessed: 14 March 2024).

Li, X., Guo, D., Yin, H. and Wei, G. (2015) ‘Drone-assisted public safety wireless broadband network’, in Proceedings of the 2015 IEEE Wireless Communications and Networking

Conference Workshops (WCNCW), New Orleans, LA, USA, 9-12 March. New York: IEEE, pp. 323-328. http://dx.doi.org/10.1109/WCNCW.2015.7122575

Liebl, F. (2002) 'The anatomy of complex societal problems and its implications for OR', Journal of Operational Research Society, 53(2), pp. 161-184. http://dx.doi.org/10.1057/sj.jors.2601293

Mahajan, G. (2021). 'Applications of Drone Technology in Construction Industry: A Study 2012-2021,' International Journal of Engineering and Advanced Technology,11(1), pp. 224-238. https://doi: 10.35940/ijeat.A3165.1011121

Maher, A. and Inoue, M. (2016) 'Generating evacuation routes by using drone system and image analysis to track pedestrian and scan the area after disaster occurrence', in Proceedings of the 10th SEATUC (Southeast Asian Technical University Consortium) Conference, Tokyo, Japan, 22-24 February 2016, pp. 22-24. http://dx.doi.org/10.13140/RG.2.1.4749.9121

Manrique, D. A., Müller, C. T. and Mellado-Bataller, I. (2017) 'Drones for search and rescue missions: A survey', Journal of Intelligent Robotics Systems, 88(1), pp. 183-202. Available at: https://doi.org/10.1007/S10846-016-0442-6

Marangunić, N. and Granić, A. (2015) 'Technology acceptance model: A literature review from 1986 to 2013'. Universal Access in the Information Society, 14, 81-95. Available at: https://doi.org/10.1007/s10209-014-0348-1

Minh, D. and Dung, N. (2023). 'Applications of UAVs in mine industry: A scoping review,' Journal of Sustainable Mining, (22), pp. 128-146. https://doi.org/10.46873/2300-3960.1384 2300-3960

Mohsan, S. A. H., Khan, M. A., Noor, F., Ullah, I. and Alsharif, M. H. (2022) 'Towards the unmanned aerial vehicles (UAVs): A comprehensive review', Drones, 6(6), p. 147. Available at: http://dx.doi.org/10.3390/drones6060147

Mollá, R., Santamarina-Campos, V., Abad, F. and Tipantuña, G. (2018) 'Storyboarding as a means of requirements elicitation and user interface design: An application to the drones' industry', in V. Santamarina-Campos and M. Segarra-Oña (eds.) Drones and the creative industry. Cham: Springer Publishing International, pp. 83-97. Available at: https://doi.org/10.1007/978-3-319-95261-1_6

Money, W. and Turner, A. (2004) 'Application of the technology acceptance model to a knowledge management system', in 37th Annual Hawaii International Conference on System Sciences. New York: IEEE, p. 9. Available at: https://doi.org/10.1109/HICSS.2004.1265573

Moro, R., Keicho, N., Motozuka, K., Matsukura, M., Shimamura, K. and Fukunari, M. (2021). '28 GHz Microwave Power Beaming to a Free-Flight Drone,' IEEE Wireless Power Transfer Conference (WPTC), San Diego, CA, USA, pp. 1-4. doi: 10.1109/WPTC51349.2021.9458030

Munir, A., Aved, A. and Blasch, E. (2022) 'Situational awareness: Techniques, challenges, and prospects', AI, 3, pp. 55-77. Available at: https://doi.org/10.3390/ai3010005

Nadobnik, J. (2016) 'The use of drones in organizing the Olympic Games'. Handel Wewn. 365, 288-299. Available at: https://www.researchgate.net/publication/339055204_The_use_of_drones_in_organizing_the_Olympic_Games (Accessed: 14 March 2024).

Nandi, A., Zhang, T. and Larcher, A. (2020) 'A review on agricultural drones and their applications', Computers and Electronics in Agriculture, 174, p. 105507. Available at: https://doi.org/10.1016/J.Compag.2020.105507

NASA (2004). 'Beamed Laser Power For UAVs,' NASA Facts, March 2004, pp. 1-2. Available at: https://www.nasa.gov/wp-content/uploads/2021/09/120329main_fs-087-dfrc.pdf

Neuendorf, K. A. (2018) 'Content analysis and thematic analysis', in P. Brough (ed.), Advanced research methods for applied psychology. New York: Routledge, pp. 211-223.

Nguyen, H. V., Nguyen, H. V., Manley, T. W. and Saidi, K. S. (2020) Survey of drone usage in public safety agencies. Washington DC: US Department of Commerce, National Institute of Standards and Technology.

Nyaaba, A. and Ayamga, M. (2021). 'Intricacies of medical drones in healthcare delivery: Implications for Africa,' Technology in Society, 66, 101624. https://doi.org/10.1016/j.techsoc.2021.101624

Onwuegbuzie, A. J., Leech, N. L. and Collins, K. M. (2012) 'Qualitative analysis techniques for the review of the literature', Qualitative Report, 17(28), pp. 1-28. Available at: https://doi.org/10.46743/2160-3715/2012.1754

Otto, F., Pawlowski, T. and Utz, S. (2021) 'Trust in fairness, doping, and the demand for sports: A study on international track and field events', European Sports Management Quarterly, 21, pp. 731-747.

Outay, F., Mengash, H. A. and Adnan, M. (2020) 'Applications of unmanned aerial vehicle (UAV) in road safety, traffic and highway infrastructure management: Recent advances and challenges', Transportation Research Part A: Policy and Practice, 141, 116-129. Available at: https://doi.org/10.1016%2Fj.tra.2020.09.018

Pauner, C., Kamara, I. and Viguri, J. (2015) 'Drones: Current challenges and standardisation solutions in the field of privacy and data protection', in 2015 ITU Kaleidoscope: Trust in the Information Society (K-2015). New York: IEEE, pp. 1-7. http://dx.doi.org/10.1109/Kaleidoscope.2015.7383633

Perera, R. (2017) The PESTLE analysis. Avissawella: Nerdynaut.

Portas, J. A. B., Campaña, I., Bergesio, L. and Barbolla, A. M. B. (2022) 'Drone flight planning for safe urban operations: UTM requirements and tools', Personal and Ubiquitous Computing, 26(4), pp. 924-930. Available at: https://doi.org/10.1007/s00779-019-01353-7

Postma, T. J. B. M. and Liebl, F. (2005) 'How to improve scenario analysis as a strategic management tool?', Technology Forecasting and Social Change, 72(2), pp. 161-173. http://dx.doi.org/10.1016/j.techfore.2003.11.005

Pranav, D. S., Dubey, T. and Singh, J. (2020) ‘A literature review: Artificial Intelligence in public security and safety’, EasyChair, preprint no. 4578. Available at: https://easychair.org/publications/preprint/KHQL (Accessed: 14 March 2024).

Pressman, R. S. (2014) Software engineering: A practitioner’s approach. New York: McGraw-Hill Education.

Rathee, G., Kumar, A., Kerrache, C. and Iqbal, R. (2022). ‘A trust-based mechanism for drones in smart cities,’ IET Smart Cities, 4(4), pp. 255-264. https://doi.org/10.1049/smc2.12039

Rejeb, A., Rejeb, K., Simske, S. and Treiblmaier, H. (2021) ‘Humanitarian drones: A review and research agenda’, Internet of Things, 16(1), p. 100434. http://dx.doi.org/10.1016/j.iot.2021.100434

Rigano, C. (2019) Using artificial intelligence to address criminal justice needs. Available at: https://nij.ojp.gov/topics/articles/using-artificial-intelligence-address-criminal-justice-needs (Accessed: 14 March 2024).

Rigopoulos, G., Psarras, J. and Askounis, D. (2008) ‘A TAM model to evaluate user’s attitude towards adoption of decision support systems’. Journal of Applied Science, 8(5), pp. 899-902. Available at: https://doi.org/10.3923/jas.2008.899.902

Ringland, G. (1998) Scenario planning. Chichester: John Wiley & Sons.

Roldán-Gómez, J., González-Gironda, E. and Barrientos, A. (2021) ‘A survey on robotic technologies for forest firefighting: Applying drone swarms to improve firefighters’ efficiency and safety,’ Applied Science, 11(1), p. 363. Available at: https://doi.org/10.3390/app11010363

Rother, E. T. (2007) ‘Systematic literature review X narrative review’, Acta Paulista de Enfermagem, 20(2), pp. 5-6. http://dx.doi.org/10.1590/S0103-21002007000200001

Said, K., Onifade, J., Githiria, M., Abdulsalam, M., Bodunrin, J., Genc, B., Johnson, O. and Akande, J. (2021). ‘On the application of drones: a progress report in mining operations,’ International Journal of Mining, Reclamation and Environment, 35(4), pp. 235-267. https://doi.org/10.1080/17480930.2020.1804653

Salamh, F. E., Karabiyik, U., Rogers, M. K. and Matson, E. T. (2021) ‘A comparative UAV forensic analysis: Static and live digital evidence traceability challenges’, Drones, 5(2), 42. http://dx.doi.org/10.3390/drones5020042

Saputro, N., Akkaya, K., Algin, R. and Uluagac, S. (2018) ‘Drone-assisted multi-purpose roadside units for intelligent transportation systems’, in Proceedings of the 2018 IEEE 88th Vehicular Technology Conference (VTC-Fall), Chicago, IL, USA, 27-30 August 2018. New York: IEEE, pp. 1-5.

Sargent, R. G. (2013) ‘Verification and validation of simulation models’, Journal of Simulation, 7(1), 12-24. Available at: https://doi.org/10.1057/jos.2012.20

Saunders, M., Lewis, P. and Thornhill, A. (2023) Research Methods for Business Students. London. Pearson.

Sekaran, U. and Bougie, R. (2016) Research methods for business: A skill-building approach. 6th edn. London: John Wiley & Sons.

Shah, I., Jhanjhi, N. and Brohi, S. (2024). 'Use of AI-Based Drones in Smart Cities,' in I. Shah and N. Jhanjhi (eds.) Cybersecurity Issues and Challenges in the Drone Industry. Hershey, Penn: IGI Global pp. 17-41.

Shahmoradi, J., Talebi, E., Roghanchi, P. and Hassanalian, M. (2020) 'A comprehensive review of applications of drone technology in the mining industry', Drones, 4(3), p. 34. Available at: https://doi.org/10.3390/drones4030034

Sharma, S., Muley, A., Singh, R. and Gehlot, A. (2016) 'UAV for surveillance and environmental monitoring', Indian Journal of Science and Technology, 9, p. 43. http://dx.doi.org/10.17485/ijst/2016/v9i43/104396

Skorup, B. and Haaland, C. (2020) How drones can help fight the coronavirus: Mercatus Center research paper series. Fairfax: Mercatus Center.

Sky Sports (2022) 'What actually happened during the Champions League Final?', Sky Sports, 13 February. Available at: https://www.skysports.com/watch/video/sports/football/competitions/champions-league/12624479/what-actually-happened-during-the-champions-league-final (Accessed: 14 March 2024).

Soh, Y. M., Ngo, T. T. and Yang, W. (2020) 'A survey on drone delivery systems', Electronics, 9(3), p. 470. Available at: https://doi.org/10.3390/Electronics9030470.

Sreeram, S., Nisha, K. K. and Jayakrishnan, R. (2018) 'Virtual design review and planning using augmented reality and drones', in Proceedings of the 2018 Second International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 14-15 June 2018, pp. 915-918. http://dx.doi.org/10.1109/ICCONS.2018.8662919

Statius Management Services Limited (2022) PESTEL analysis. Available at: https://www.statius.co.uk/tag/pestel-analysis/ (Accessed: 14 March 2024).

Stewart, P. (2016) Drone danger: Remedies for damage by civilian remotely piloted aircraft to persons or property on the ground in Australia, University of Technology Sydney Law Research Series. Available at: https://classic.austlii.edu.au/au/journals/UTSLRS/2016/24.html (Accessed: 14 March 2024).

Stroud, D. and Weinel, M. (2020) 'A safer, faster, leaner workplace? Technical-maintenance worker perspectives on digital drone technology "effects" in the European steel industry', New Technology Work and Employment, 35(1), 297-313. http://dx.doi.org/10.1111/ntwe.12174

Stuckey, H. L. (2013) 'Three types of interviews: Qualitative research methods in social health', Journal of Social Health and Diabetes, 1(2), pp. 56-59. http://dx.doi.org/10.4103/2321-0656.115294

Sudman, S. and Bradburn, N. M (1982) Asking questions: A practical guide to questionnaire design. Newbury Park: SAGE Publications, Inc.

Tan, Lim, Park, Low and Yeo (2021). 'Public acceptance of drone applications in a highly urbanized environment,' Technology in Society, 64, 101462. https://doi.org/10.1016/j.techsoc.2020.101462

Tanzi, T. J., Chandra, M., Isnard, J., Camara, D., Sébastien, O. and Harivelo, F. (2016) 'Towards "drone-borne" disaster management: Future application scenarios', in Proceedings of the XXIII ISPRS Congress, Commission VIII (Volume III-8), Copernicus GmbH, Prague, Czech Republic, 12-19 July 2016, vol. 3, pp. 181-189. Available at: https://doi.org/10.5194/isprs-annals-III-8-181-2016

Taylor, M. C. (2005) 'Interviewing', in E. D. Holloway (ed.) Qualitative research in health care. New York: Open University Press, pp. 39-55.

Tkáč, M. and Mésároš, P. (2019) 'Utilizing drone technology in civil engineering', Journal of Civil Engineering, 14(1), pp. 27-37. http://dx.doi.org/10.1515/sspjce-2019-0003

Tobi, H. and Kampen, J. K. (2018) 'Research design: The methodology for interdisciplinary research framework', Quality & Quantity, 52(3), pp. 1209-1225. Available at: https://doi.org/10.1007/s11135-017-0513-8

Tran, K. N. and Shen, X. (2019) 'A survey on drone applications: Security and privacy issues and challenges', IEEE Communication Survey and Tutorials, 21(3), pp. 2333-2360. Available at: https://doi.org/10.1109/COMST.2019.2890514

Tran, T. and Nguyen, D. (2022). 'Management and Regulation of Drone Operation in Urban Environment: A Case Study', Social Sciences, 11(10), p. 474. https://doi.org/10.3390/socsci11100474

Ullah, H., Nair, N. G., Moore, A., Nugent, C., Muschamp, P. and Cuevas, M. (2019) '5G communication: An overview of vehicle-to-everything, drones, and healthcare use-cases'. IEEE Access, 7, pp. 37251-37268. http://dx.doi.org/10.1109/ACCESS.2019.2905347

Usman, A. S. and Nonyelum, O. F. (2018) 'Application of the Systems Development Life Cycle (SDLC) in 21st-century military sector', IUP Journal of Information Technology, 14(1), pp. 58-64.

Van Teijlingen, E. R., Rennie, A. M., Hundley, V. and Graham, W. (2001) 'The importance of conducting and reporting pilot studies: The example of the Scottish Births Survey', Journal of Advanced Nursing, 34(3), 289-295. Available at: https://doi.org/10.1046/j.1365-2648.2001.01757.x

Wall, T. (2013) 'Unmanning the police manhunt: Vertical security as pacification', Socialist Studies/Études Socialistes, 9(2), 32-56. Available at: https://doi.org/10.18740/S4F591

Wang, S., Jiang, F., Zhang, B., Ma, R. and Hao, Q. (2019) 'Development of UAV-based target tracking and recognition systems', IEEE Transactions on Intelligent Transport Systems, 21(8), pp. 3409-3422. Available at: http://dx.doi.org/10.1109/TITS.2019.2927838

Watkins, S., Burry, J., Mohamed, A., Marino, M., Prudden, S., Fisher, A., Kloet, N., Jakobi, T. and Clothier, R. (2020). 'Ten questions concerning the use of drones in urban environments,' Building and Environment, 167, 106458. https://doi.org/10.1016/j.buildenv.2019.106458

Wengraf, T. (2001) 'Preparing lightly-structured depth interviews: A design for a BNIM-type biographic-narrative interview', in T. Wengraf (ed.) Qualitative research interviewing. Thousand Oaks: Sage Publications, Inc., pp. 111-152. Available at: https://dx.doi.org/10.4135/9781849209717.n6

Wilkinson, S. (2015) 'Focus groups', in J. A. Smith (ed.) Qualitative psychology: A practical guide to research methods, 3rd edn. London: SAGE Publications Ltd., pp. 199-221.

Willsher, K. (2022) 'Police "aggressive and provocative" in Paris, Liverpool fans' groups tell hearing', The Guardian, 21 June. Available at: https://www.theguardian.com/football/2022/jun/21/police-aggressive-provocative-paris-liverpool-fans-groups (Accessed: 24 March 2024).

Woo, S., Jin, K., Woo, Y., Su, P. and Hu, Y. (2021). 'Applications of Drones for Environmental Monitoring of Pollutant-Emitting Facilities,' Proceedings of the National Institute of Ecology of the Republic of Korea, 2(4), pp. 298-304. https://doi.org/10.22920/PNIE.2021.2.4.298

Yaacoub, J. P., Noura, H., Salman, O. and Chehab, A. (2020) 'Security analysis of drones systems: Attacks, limitations, and recommendations', Internet of Things, 11, p. 100218. Available at: https://doi.org/10.1016/j.iot. Available at: 2020.100218

Zhaoxuan, L. I. U., Kaiquan, C. A. I. and Yanbo, Z. H. U. (2021) 'Civil unmanned aircraft system operation in national airspace: A survey from Air Navigation Service Provider perspective', Chinese Journal of Aeronautics, 34(3), pp. 200-224. Available at: https://doi.org/10.1016/j.cja.2020.08.033

APPENDICES

Appendix 1: Scoping Systematic Review Findings

Table A1: Scoping systematic review findings

Industry	Study Title and Authors	Year of Publication	Study Goal	Type of Drone Used	Type of Sensors Used	Type of Software Used
(A) Engineering.						
Construction 1/9	Usability assessment of drone technology as safety inspection tools Irizarry *et al.* [17]	2012	To see if using drones is beneficial on a construction site known to be dangerous.	Aerial quadcopter	✈ A camera able to record and take photos.	✈ An iPad and iPhone ✈ Software to switch the views between the bottom and front cameras and an emergency reset button to turn the drone's motors off
Construction 2/9	Utilizing drone technology in civil engineering Tkáč and Mésároš [18]	2019	It reviews the types of drones and their components that can be used in civil engineering. It mentions the benefits of how drones can be used.	Mentions four types of drones that can be used in civil engineering: ✈ Fixed-wing ✈ Multirotor ✈ Single-rotor ✈ Fixed-wing hybrid VTOL	✈ Integration of laser scanning and aerial photogrammetry ✈ Remote monitoring and progress reports ✈ Equipment tracking and automating ✈ Surveys of buildings and landscapes ✈ Topographic mapping ✈ Thermal imaging recording	N/A

Construction 3/9	Site inspection drone. A solution for inspecting and regulating construction sites Ashour *et al.* [19]	2016	The study created a drone and experimented with it seeing if it could inspect a construction site.	Site inspection drone (SID)	✈ IR camera ✈ Range finder ✈ RBG camera ✈ Depth sensor	N/A
Construction 4/9	A review of potential applications of unmanned aerial vehicles for the construction industry Dastgheibifard and Asnafi [20]	2018	The applications of drone usage in the construction industry and how beneficial they are.	UAV	N/A	3D mapping
Construction 5/9	Utilization of drone technology to improve tower worker safety and productivity Ciarletta [21]	2017	The aim was to see if the rates of injury or death of inspectors could be reduced if drones were used in their place and what benefits they offered.	UAV drone	Imagery and videos	GPS
Construction 6/9	UAS for safety: The potential of unmanned aerial systems for construction safety application Gheisari *et al.* [22]	2014	It aims to see if drones can be used in a live construction site by experimenting with a drone and investigating what benefits this would have.	AR Drone	Cameras	N/A

Construction 7/9	Unmanned aerial vehicles in construction and worker safety Howard *et al.* [23]	2018	The study aims to understand how UAVs can be used during the construction and preconstruction phases of industry as well as the hazards they bring.	UAV	N/A	N/A
Construction 8/9	UAS-BIM-based real-time hazard identification and safety monitoring of construction projects Alizadehsalehi *et al.* [24]	2017	This study aims to improve safety during construction and preconstruction phases by integrating BIM, data capturing and drone technology. In their paper, they present a framework for monitoring construction safety in real-time accurately and approximately.	✈ Remotely piloted vehicle (RPV) ✈ Remotely operated aircraft (ROA) ✈ Remote controlled (RC) helicopter. ✈ Unmanned vehicle systems (UVS) ✈ Model helicopter	N/A	GPS
Construction 9/9	Virtual design review and planning using AR and drones Sreeram *et al.* [25]	2018	This study aims to provide a design and planning review before construction, in places where human access is difficult and occasionally unsafe, using a combined model of AR and drones.	UAV	N/A	Unity and Maya

Mining Industry 1/3	Reviews of unmanned aerial vehicle (drone) technology trends and its applications in the mining industry Lee and Choi [26]	2016	It sees if drone technology is beneficial in the mining industry.	✈ Fixed wings UAV ✈ Fixed-wing UAV with a triangular glider. ✈ UAV with rotary wings.	✈ Infrared thermal imaging camera ✈ RGB camera ✈ Infrared camera ✈ Laser scanner	3D geological modelling
Mining Industry 2/3	A comprehensive review of applications of drone technology in the mining industry Shahmoradi *et al.* [27]	2020	The study aims to review the different drones being used in the mining industry, as well as their applications.	✈ Fixed-wing and rotary-wing drones. ✈ Multirotor. ✈ Helium gas balloon.	✈ Infrared sensors ✈ RGB sensors ✈ Stereo cameras ✈ Laser range finders ✈ Ultra-wideband radar ✈ Hyperspectral sensors ✈ Magnetic sensors ✈ Visible and near-infrared spectral range sensors ✈ Air quality sensors ✈ Ultrasonic sensors	N/A
Mining Industry 3/3	A safer, faster, leaner workplace? Technical-maintenance worker perspectives on digital drone technology 'effects' in the European steel industry Stroud and Weinel [28]	2020	The study examines how maintenance workers perceive the integration of drone technology into the steel industry in European countries.	N/A	N/A	N/A

Smart Cities 1/2	The drone-following models in smart cities Dung and Rohacs [29]	2018	The study reviews different models that follow drones, especially with their increasing use in smart cities.	✈ Markov drone ✈ SD models	N/A	N/A
Smart Cities 2/2	Drones for good in smart cities: A review Khan *et al.* [30]	2018	In the last few decades, the term drone has rarely been used without mention of combat or target killing. As with all technologies and innovations, their value depends on their use and who is using them. Drones were only associated with military applications. The paper notes other safe ways for drones to be used, especially in a smart city.	UAV	N/A	N/A
(B) Environment and Urban.						
Environmental Monitoring 1/3	Fast and safe gas detection of underground coal fire by drone fly over Dunnington and Nakagawa [31]	2017	The study aims to see if a gas sensor mounted on a drone is as effective as physical sample taking or as effective as sensors mounted on the ground. It wanted to see if the drone with the sensor could produce similar results to other sensors and other research in the area.	N/A	✈ Gas sensor technology includes infrared, electrochemical, catalytic, metal oxide, conductive polymer, and terahertz spectrometry ✈ The Dragger X-am 5600 senses gas and is mounted on the drone	N/A

Environmental Monitoring 2/3	Drone applications for environmental management in urban spaces: A review Gallacher [32]	2016	It reviews if drone usage is acceptable in environmental management looking at urban spaces in particular	Micro drones	✈ Aerial sensing includes Electromagnetic spectrum (visible light, infrared and ultraviolet), atmospheric composition, and data collection from detached sensors (camera traps, sound recorders and animal tracking devices)	✈ Delivery ✈ Broadcast-dispersal of liquids, gases, or particulates over a wider area ✈ Retrieval-collection of samples for later analysis
Environmental Monitoring 3/3	UAV for surveillance and environmental monitoring Sharma *et al.* [33]	2016	It reviews how drones and their application can be used to monitor an environment. It is more of a literature review.	✈ Quadcopter ✈ Multirotor	✈ Radio transceiver ✈ Temperature and smoke sensor	✈ Flight controller ✈ Brushless direct current motors ✈ Lithium polymer batteries ✈ Video telemetry ✈ Data telemetry R.F. module ✈ GPS ✈ Electronic speed controller
Urban Management 1/2	Drone flight planning for safe urban operations Besada *et al.* [34]	2020	The paper researches an unmanned traffic management system that is used to collaboratively plan flights considering traffic constraints and limitations.	✈ Parrot drone ✈ Pixhawk or Ardupilot autopilots	Tactical conflict detection and resolution process-checks for potential future loss of the drone separating diverging from their intended flight plan	✈ Unmanned traffic management programme, or to the European U-space concept from the SESAR programme ✈ Mapping information from Google Maps which is downloaded into drones

Urban Management 2/2	Pedestrian and bicycle volume data collection using drone technology Kim [35]	2020	The study aims to see if drones can differentiate between pedestrians and bicycles and if they can be used to notify people of conflicts. It considers how it can be used for future planning of roads.	DJI Phantom 4 Pro drone	N/A	✈ Aerial imagery ✈ Three-axis gimbal-stabilized camera with a wide-angle lens and 4k videos
Traffic Management 1/3	Applications of unmanned aerial vehicles (UAV) in road safety, traffic, and highway infrastructure management: Recent advances and challenges Outay *et al.* [36]	2020	This was a detailed literature review giving a history of drone usage in road safety, traffic, and highway infrastructure management.	UAV	N/A	N/A
Traffic Management 2/3	Unmanned aircraft system traffic management: Concept of operation and system architecture Jiang *et al.* [37]	2016	The study does a literature review to see if unmanned drones could be used to organise traffic.	UTM-unmanned traffic management drone	Ground-based radar	✈ GPS ✈ TCAS is a collision system

Traffic Management 3/3	Drone-assisted multi-purpose roadside units for intelligent transportation systems Saputro *et al.* [38]	2018	The paper proposes to use autonomous drones to assist first responders in ITS scenarios by providing an RSU that serves multiple purposes.	Flying RSU	✈ IEEE 802.11p is the core communications technology ✈ A public LTE coverage	Swarm aerial proxy control
(C) Public.						
Security Organisation First Responders 1/3	Unmanning the police manhunt: Vertical security as pacification Wall [39]	2013	It notes the use of drones from military to cosmetic use in the USA. It notes issues stopping the domestication such as the FAA that blocked widespread access for both public and private spaces to use national airspace. It notes barriers to the usage of drones to ensure effective security.	✈ Civil and commercial UAVs ✈ Honeywell T-hawk drones ✈ Shadow Hawk ✈ Wasp III ✈ USA Predator drone	✈ Scope technologies ✈ Tracking devices ✈ Geospatial satellite-tracking devices ✈ Closed-circuit television	N/A
Security Organisation First Responders 2/3	Using public network infrastructures for UAV remote sensing in civilian security operations Daniel and Wietfeld [40]	2011	Many new application areas, such as in-depth reconnaissance and surveillance of major incidents, can be realized on this basis. The article reviews the current state of the art and research activities related to UAS communication.	Civilian concepts of operations (CONOPS) for UAV	CBRN detection	✈ ISM-based Air-to-Air (A2A) Links ✈ 3D-visualization ✈ UI for decision support and route planning

Security Organisation First Responders 3/3	A survey of robotic technologies for forest firefighting: applying drone swarms to improve firefighters' efficiency and safety Roldán-Gómez *et al.* [41]	2021	The study aims to see if drone usage is beneficial for firefighters and if they support it.	Quadcopter drone has a size and weight of no more than 1600 × 1600 × 800 mm unfolded and 15 kg, including drone and payload	Surveillance and monitoring sensors	✈ Navigation: Fusion of IMU measurements ✈ Visual odometer and GPS/GLONASS/ GALILEO signal ✈ A GNSS receiver
Public Security 1/8	Drone-assisted public safety networks: The security aspect He *et al.* [42]	2017	The study noted how to use UAVs for the public safety network, its benefits, and the risk of something going wrong.	Established UAVs	✈ GPS ✈ Wireless sensor networks (WSNs) ✈ Mobile ad-hoc networks (MANETs) ✈ Equipped with sensors to monitor parameters in the environment to search for specific items	Communication modules
Public Security 2/8	Drone-assisted public safety wireless broadband network Li *et al.* [43]	2015	Its purpose is to propose a drone-assisted multi-hop device-to-device (D2D) communication programme to extend network coverage as a way to extend network coverage over areas where it is hard to deploy a land-based relay.	Drone-assisted multi-hop D2D communication	N/A	Communication

Public Security 3/8	A study on auto-patrol drone development for safety management Kwon *et al.* [44]	2017	This paper investigates if drones can be used to reduce crime rates.	✈ Fixed-wing ✈ Multirotor ✈ Hybrid ✈ Quadcopter-based auto-patrol drone.	LED sensor	✈ Arduino platform-based APM board ✈ GPS
Public Security 4/8	Beach safety: Can drones provide a platform for sighting sharks? Butcher *et al*. [45]	2019	The purpose of this study is to determine whether drones can reliably detect shark analogues in the water across a range of environmental conditions on New South Wales beaches.	Standard multirotor drone (DJI Inspire 1)	Vibration absorbing board, and a circular polarising filter (ProMaster Digital HGX CPL-46 mm)	DJI Zenmuse X5 camera (DJI MFT 15 mm F/1.7 ASPH lens)
Public Security 5/8	Malicious UAV detection using integrated audio and visual features for public safety applications Jamil *et al*. [46]	2020	The study investigates different ways to detect UAVs that are being used illegally and criminally.	UAV	✈ Detection sensors ✈ Image sensors	✈ AlexNet: extracting features for images ✈ SVM ✈ Malicious UAV detection ✈ Mel frequency cepstral coefficients
Public Security 6/8	Survey of drone usage in public safety agencies Nguyen *et al*. [47]	2020	The study aims to understand what first responders who use UAVs, as well as civilians, understand using this technology.	UAV	N/A	N/A

Public Security 7/8	Security analysis of drone systems: Attacks, limitations, and recommendations Yaacoub *et al.* [48]	2020	A comprehensive review of the different aspects of drone cybersecurity is presented in this paper, including two main aspects: drone security vulnerabilities and the security concerns associated with compromised drones. They discuss countermeasures for securing drone systems and detecting malicious UAV detection.	✈ Drone-to-drone (D2D) ✈ Drone-to-ground Station (D2GS) ✈ Drone-to-network (D2N) ✈ Drone-to-satellite (D2S) ✈ Multirotor drones ✈ Fixed-wing drones ✈ Hybrid-wing drones	N/A	✈ Evading radar-detection ✈ Anomaly-based detection ✈ Signature-based intrusion detection
Public Security 8/8	Key technologies and system trade-offs for detection and localization of amateur drones Azari *et al*. [49]	2018	The study gives a summary of how to detect amateur drones.	✈ Amateur drones ✈ Surveillance drones	Passive R.F. sensing and detection	N/A
Mega and Sporting Events 1/2	Drone ambulance for outdoor sports Kumar and Jeeva [50]	2017	The purpose of this paper is to provide first aid for injured sportsmen participating in outdoor activities. In addition to preventing fire accidents during outdoor sporting events. Drones are usually used to accomplish this.	✈ Multirotor drones ✈ Fixed-wing drones ✈ Hybrid-wing drones	✈ GPS ✈ Thermal and smoke sensors	✈ Thermal camera ✈ GIMBAL camera

Mega and Sporting Events 2/2	The use of drones in organizing the Olympic Games Nadobnik [51]	2016	This paper explains how modern technology is being used to organize mass sporting events, focusing on UAVs (drones) during events such as the Olympic Games.	✈ Quadcopter, hexacopter or octocopter ✈ Hermes 900: US-Israeli-made drone ✈ Dragan flyer X4-ES16 ✈ Titan Aerospace	Infrared light sensor	✈ Cam recorders and camera ✈ GPS
(D) Healthcare.						
COVID-19 1/3	How drones can help fight the coronavirus Skorup and Haaland [52]	2020	The study aims to see how drones can be helpful to encourage social distancing and reduce human-to-human contact.	N/A	N/A	N/A
COVID-19 2/3	Do drones have a realistic place in the fight for delivering pandemic medical supplies in healthcare system problems? Euchi [53]	2021	During the pandemic, the study sought to clarify if drones could aid treatment. A detailed summary was provided.	UAV	Thermal sensors	N/A

COVID-19 3/3	Containing the COVID-19 pandemic with the feasibility of a drone-enabled backup transport system Kunovjanek and Wankmüller [54]	2021	The study aims to see if drones are feasible to reduce the risk of infection.	Their approach relied on the retrofitting of drones of private owners and public institutions (e.g., disaster management agencies, non-governmental organizations etc.	N/A	N/A
Healthcare and medicine 1/3	Drones in medicine—the rise of the machines Balasingam [55]	2017	It reviews the benefits and limitations of drones in the medical sector.	N/A	✈ Imaging ✈ GPS	N/A
Healthcare and medicine 2/3	5G communication: An overview of vehicle-to-everything, drones, and healthcare use cases Ullah *et al.* [56]	2019	This paper examines three major use cases of 5G: V2X communication, drone communication, and healthcare. The aim is to identify which use case is most challenging for future research. Their discussion of V2X networking was followed by discussions of V2V, V2P, V2I, and IV networking, as well as their applications.	✈ Single UAV ✈ Multiple UAV	✈ V2X communication ✈ Vehicle-to-infrastructure (V2I)	✈ Vehicle onboard unit (OBU) ✈ Roadside unit (RSU) ✈ Safe communication channel ✈ Radio transceiver ✈ Nighttime pedestrian detection ✈ Infrared sensors ✈ GPS ✈ Audio and visual entertainment ✈ Onboard Internet facilities

Healthcare and medicine 3/3	Drone transport of microbes in blood and sputum laboratory specimens Amukele *et al.* [57]	2016	The study aims to see if microbiological specimens could be transported with UAVs.	Small fixed-wing aircraft (Aero, 3D Robotics, Berkeley, CA)	N/A	N/A
Disaster relief 1/4	Humanitarian Drones: A Review and Research Agenda Rejeb *et al.* [58]	2021	This study seeks to improve the understanding of current tools and technologies that humanitarian organizations can use to support efficient and effective rescue interventions by systematizing the growing but still limited literature on drones.	UAV	N/A	N/A
Disaster relief 2/4	Towards" drone-borne" disaster management: Future application scenarios Tanzi *et al.* [59]	2016	Various humanitarian relief scenarios are discussed in the paper. Also, the article examines possible issues that may arise in such scenarios. The authors examine recent experiments to determine whether autonomous flight operations have inherent advantages, both on a solo basis and in formation. After sketching out an embedded security architecture and its specific hardware capabilities, the question of autonomy is discussed.	✈ Sense fly ✈ Blimps ✈ Fixed-wing drones ✈ Vertical axis drones	✈ Optical sensors ✈ Tele-detection ✈ Light detection and ranging (LIDAR) ✈ EM detection	✈ Conveying messages using a disruption-tolerant network technique ✈ GPS ✈ Cognitive module, providing basic artificial intelligence algorithms

Disaster relief 3/4	Generating evacuation routes by using drone systems and image analysis to track pedestrians and scan the area after a disaster occurrence Maher and Inoue [60]	2016	The purpose of the study is to see if drones can be used to help with disaster events. The study aims to see how a drone will act when tasked with finding humans, victims that are hard to find because of being under rubble or tracking different people if they are running away from danger and are lost.	AR Drone	✈ HD Camera (720p 30 fps and 60 fps vertical QVGA camera) ✈ Ultrasonic sensors	✈ Fully reprogrammable motor controller ✈ Water-resistant ✈ The motor's electronic controller
Disaster relief 4/4	An RPA system in major incident management: Concept and pilot, feasibility study Abrahamsen [61]	2015	In pre-hospital environments, rotor-wing drones can transport tools and audiovisual equipment, and they can serve as flying platforms for sensors and audiovisual equipment. This paper introduces the ways and methods a drone can be used in a hospital setting as well as what it can do in major incidents to reduce injury of the S&R teams, as well as find victims quickly. There are many ethical issues.	✈ Remotely controlled multirotor UAV ✈ Rotor-wing RPA. The RPA was propelled by six standard brushless electric (DC) rotors, the rotor span was 84 cm and the maximum take-off weight was 3 kg	✈ Flight control was mixed manual, RC, and autonomous (autopilot) ✈ Global positioning module ✈ Laser ✈ release hook ✈ Searchlight	✈ Aerial imagery and remote sensing ✈ Video camera ✈ Avalanche beacon

Source: Author

Appendix 2: Detailed Overview of Industry-based Sensors

Table A2: Industry-based sensors

Sensors Table															
Sector	Industry	Study	Basic Sensor						Advanced Sensor			Advanced Software			
			GPS			Camera									
			Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear	Yes	No	Not Clear
Engineering	Construction 1/9	Usability assessment of drone technology as safety inspection tools	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Not Clear**			Ad-Software **Yes**		
Engineering	Construction 2/9	Utilizing drone technology in civil engineering	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Yes**			Ad-Software **Not Clear**		
Engineering	Construction 3/9	Site inspection drone: A solution for inspecting and regulating construction sites	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Yes**			Ad-Software **Not Clear**		
Engineering	Construction 4/9	A review of potential applications of unmanned aerial vehicles for the construction industry	GPS **Not Clear**			Camera **Not Clear**			Ad-Sensor **Not Clear**			Ad-Software **Yes**		
Engineering	Construction 5/9	Utilization of drone technology to improve tower worker safety and productivity	GPS **Yes**			Camera **Yes**			Ad-Software **No**			Ad-Software **No**		
Engineering	Construction 6/9	UAS for safety: The potential of unmanned aerial systems for construction safety applications	GPS **Not Clear**			Camera **Yes**			Ad-Sensor **Not Clear**			Ad-Software **Not Clear**		

Engineering	Construction 7/9	Unmanned aerial vehicles in construction and worker safety	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Engineering	Construction 8/9	UAS-BIM-based real-time hazard identification and safety monitoring of construction projects	GPS **Yes**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Engineering	Construction 9/9	Virtual design review and planning using AR and drones	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Yes**
Engineering	Mining Industry 1/3	Reviews of unmanned aerial vehicle (drone) technology trends and its applications in the mining industry	GPS **Not Clear**	Camera **Yes**	Ad-Sensor **Yes**	Ad-Software **Yes**
Engineering	Mining Industry 2/3	A comprehensive review of applications of drone technology in the mining industry	GPS **Not Clear**	Camera **Yes**	Ad-Sensor **Yes**	Ad-Software **Not Clear**
Engineering	Mining Industry 3/3	A safer, faster, leaner workplace? Technical-maintenance worker perspectives on digital drone technology 'effects' in the European steel industry	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Engineering	Smart Cities 1/2	The drone-following models in smart cities	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**

Engineering	Smart Cities 2/2	Drones for good in smart cities: A review	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Environment and Urban	Environmental Monitoring 1/3	Fast and safe gas detection from underground coal fire by drone fly over	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Yes**	Ad-Software **Not Clear**
Environment and Urban	Environmental Monitoring 2/3	Drone applications for environmental management in urban spaces: A review	GPS **Not Clear**	Camera **Yes**	Ad-Sensor **Yes**	Ad-Software **Yes**
Environment and Urban	Environmental Monitoring 3/3	UAV for surveillance and environmental monitoring	GPS **Yes**	Camera **Yes**	Ad-Sensor **Yes**	Ad-Software **Yes**
Environment and Urban	Urban Management 1/2	Drone flight planning for safe urban operations	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**

Environment and Urban	Urban Management 2/2	Pedestrian and bicycle volume data collection using drone technology	GPS **Not Clear**	Camera **Yes**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Environment and Urban	Traffic Management 1/3	Applications of unmanned aerial vehicles (UAV) in road safety, traffic, and highway infrastructure management: Recent advances and challenges	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Environment and Urban	Traffic Management 2/3	Unmanned Aircraft System traffic management: Concept of operation and system architecture	GPS **Yes**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Yes**
Environment and Urban	Traffic Management 3/3	Drone-assisted multi-purpose roadside units for intelligent transportation systems	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Yes**	Ad-Software **Yes**
Public	Security Organisation First Responders 1/3	Unmanning the police manhunt: Vertical security as pacification	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Yes**	Ad-Software **Not Clear**

Public	Security Organisation First Responders 2/3	Using public network infrastructures for UAV remote sensing in civilian security operations	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Yes**
Public	Security Organisation First Responders 3/3	A survey on robotic technologies for forest firefighting: Applying drone swarms to improve firefighters' efficiency and safety	GPS **Yes**	Camera **Not Clear**	Ad-Sensor **Yes**	Ad-Software **Yes**
Public	Public Security 1/8	Drone-assisted public safety networks: The security aspect	GPS **Yes**	Camera **Not Clear**	Ad-Sensor **Yes**	Ad-Software **Yes**
Public	Public Security 2/8	Drone-assisted public safety wireless broadband network	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Public	Public Security 3/8	A study on auto-patrol drone development for safety management	GPS **Yes**	Camera **Not Clear**	Ad-Sensor **Yes**	Ad-Software **Yes**
Public	Public Security 4/8	Beach safety: Can drones provide a platform for sighting sharks?	GPS **Not Clear**	Camera **Yes**	Ad-Sensor **Yes**	Ad-Software **Yes**

Public	Public Security 5/8	Malicious UAV detection using integrated audio and visual features for public safety applications	GPS **Not Clear**	Camera **Yes**	Ad-Sensor **Yes**	Ad-Software **Yes**
Public	Public Security 6/8	Survey of drone usage in public safety agencies	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Public	Public Security 7/8	Security analysis of drone's systems: Attacks, limitations, and recommendations	GPS **Yes**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Yes**
Public	Public Security 8/8	Key technologies and system trade-offs for detection and localization of amateur drones	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Yes**	Ad-Software **Not Clear**
Public	Mega and Sporting Events 1/2	Drone ambulance for outdoor sports	GPS **Yes**	Camera **Yes**	Ad-Sensor **Yes**	Ad-Software **Not Clear**

Public	Mega and Sporting Events 2/2	The use of drones in organizing the Olympic Games	GPS **Yes**	Camera **Yes**	Ad-Sensor **Yes**	Ad-Software **Not Clear**
Healthcare	COVID-19 1/3	How drones can help fight the coronavirus	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Healthcare	COVID-19 2/3	Do drones have a realistic place in a pandemic fight for delivering medical supplies in healthcare systems problems?	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Yes**	Ad-Software **Not Clear**
Healthcare	COVID-19 3/3	Containing the COVID-19 pandemic with drones-the feasibility of a drone-enabled backup transport system	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Healthcare	Healthcare and medicine 1/3	Drones in medicine—the rise of the machines	GPS **Yes**	Camera **Yes**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Healthcare	Healthcare and medicine 2/3	5G communication: An overview of vehicle-to-everything, drones, and healthcare use cases	GPS **Yes**	Camera **Not Clear**	Ad-Sensor **Yes**	Ad-Software **Yes**

Healthcare	Healthcare and medicine 3/3	Drone transport of microbes in blood and sputum laboratory specimens	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Healthcare	Disaster relief 1/4	Humanitarian drones: A review and research agenda.	GPS **Not Clear**	Camera **Not Clear**	Ad-Sensor **Not Clear**	Ad-Software **Not Clear**
Healthcare	Disaster relief 2/4	Towards "drone-borne" disaster management: Future application scenarios	GPS **Yes**	Camera **Not Clear**	Ad-Sensor **Yes**	Ad-Software **Yes**
Healthcare	Disaster relief 3/4	Generating evacuation routes by using a drone system and image analysis to track pedestrians and scan the area after a disaster occurrence	GPS **Not Clear**	Camera **Yes**	Ad-Sensor **Yes**	Ad-Software **Yes**
Healthcare	Disaster relief 4/4	An RPA system in major incident management: Concept and pilot, feasibility study	GPS **Not Clear**	Camera **Yes**	Ad-Sensor **Not Clear**	Ad-Software **Yes**

Source: Author

Appendix 3: Interview Protocol - Challenges Associated with Drone Deployment in Qatar

Study Approach and Aim

This interview is structured based on PESTLE analysis to explore six key areas of challenges affecting drone operations: Political, Economic, Social, Technological, Legal, and Environmental.

PESTLE Analysis

Figure A3.1: PESTLE analysis
Source: Ibis World (2020)

Example

P	E	S	T	L	E
Governmental policy	Economic growth	Population growth rate	Technology incentives	Weather	Discrimination laws
Political stability	Exchange rates	Age distribution	Level of innovation	Climate	Antitrust laws
Corruption	Interest rates	Career attitudes	Automation	Environmental policies	Employment laws
Foreign trade policy	Inflation rates	Safety emphasis	R&D activity	Climate change	Consumer protection laws
Tax policy	Disposable income	Health consciousness	Technological change	Pressure from NGO’s	Copyright and patent laws
Labour law	Labour law	Lifestyle attitudes	Technological awareness		Health and safety laws
Trade restrictions	Unemployment rates	Cultural barriers			

Figure A3.2: Example of PESTLE analysis application
Source: Statius Management Services Limited (2022)

Demographic Information

Where do you work? *

This section concerns your professional experience (the sector you work in, or in which you have the most experience):

- Research and higher education
- Civil aviation
- Military aviation
- Interior security
- Police
- Firefighting
- Government innovation and authorities, public services, and business development
- Oil and gas sector
- MoTC
- Environmental sector
- Qatar RC Club
- Qatar World Cup Security Community

General Questions

Are you aware of any drone applications in your sector? *

- Yes
- No
- Not Sure

Do you think drone applications are useful to your sector? *

- Yes
- No
- Not Sure

Do you think there is enough effort to adopt drone applications in your sector? *

- Yes
- No
- Not Sure

Do you have any comments?

Your answer:

____

Political

Do you agree that the following factors are challenges?

Lack of clear government policy. *

- Yes
- No
- Not Sure

Lack of safety policy. *

- Yes
- No
- Not Sure

Lack of security policy. *

- Yes
- No
- Not Sure

Lack of organisational policy to adopt drone applications. *

- Yes
- No
- Not sure

Lack of collaboration policy between different government departments concerned with drones. *

- Yes
- No
- Not Sure

Political concerns with neighbouring countries (flying zones and borders). *

- Yes
- No
- Not Sure

Can you think of any other political challenges?

Your answer:

____

Economic

Do you agree that the following factors are challenges?

Availability of government funding. *

- Yes
- No
- Not Sure

Availability of funding in organisations to finance drone projects. *

- Yes
- No
- Not Sure

Availability of funding for individuals to finance drone projects. *

- Yes
- No
- Not Sure

Can you think of any other economic challenges?

Your answer:

____

Legal

Do you agree that the following factors are challenges?

Lack of laws to cover drones and their application. *

- Yes
- No
- Not Sure

Lack of drone ownership laws. *

- Yes
- No
- Not Sure

Lack of laws related to flying. *

- Yes
- No
- Not Sure

Lack of laws on who can operate/fly drones. *

- Yes
- No
- Not Sure

Lack of legal framework for drone operations and neighbouring countries. *

- Yes
- No
- Not Sure

Lack of laws to cover drone incidents. *

- Yes
- No
- Not Sure

Lack of laws to cover drone insurance. *

- Yes
- No
- Not Sure

Can you think of any other legal challenges?

Your answer:

___

Social

Do you agree that the following factors are challenges?

Cultural barriers. *

- Yes
- No
- Not Sure

Safety emphasis. *

- Yes
- No
- Not Sure

Lack of awareness related to drones' benefits. *

- Yes
- No
- Not Sure

Lack of trained people?

- Yes
- No
- Not Sure

Resistance to change?

- Yes
- No
- Not Sure

Privacy emphasis?

- Yes
- No
- Not Sure

Fear of taking responsibility?

- Yes
- No
- Not Sure

Can you think of any other social challenges?

Your answer:

Technological

Do you agree that the following factors are challenges?

Lack of research and development (R&D). *

- Yes
- No
- Not Sure

Lack of technological awareness. *

- Yes
- No
- Not Sure

Technological changes. *

- Yes
- No
- Not Sure

Lack of technical support. *

- Yes
- No
- Not Sure

Can you think of any other technological challenges?

Your answer:

Environmental

Do you agree that the following factors are challenges?

Country weather. *

- Yes
- No
- Not Sure

Military and sensitive restricted zones/areas. *

- Yes
- No
- Not Sure

Civil aviation airspace zones. *

- Yes
- No
- Not Sure

Highrise buildings. *

- Yes
- No
- Not Sure

Safety and security of drones in certain areas of certain people (to bring drones down). *

- Yes
- No
- Not Sure

Can you think of any other environmental challenges?

Your answer:

Appendix 4: Ethics Approval and Consent Documentation

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

31 March 2023

LETTER OF APPROVAL (Conditional)

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 05/04/2023 AND 30/09/2023

Applicant (s): Mr Khalifa AL-Dosari

Project Title: Civilian Drones for Safety & Security of Mega Sporting Events: The Case of the 2022 FIFA World Cup in Qatar.

Reference: 41777-LR-Mar/2023- 44514-3

Dear Mr Khalifa AL-Dosari

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**
- **Please ensure that you monitor and adhere to all up-to-date local and national Government health advice for the duration of your project.**
- **Please adapt the Consent Form to your own study and remove the witness statement, as this is only relevant to vulnerable participants**
- **Please add a line at the end of your Participant Information Sheet to state that for queries and complaints, your participants may contact Professor Simon Taylor (simon.taylor@brunel.ac.uk) – Chair of the CEDPS Research Ethics Committee**
- **Please note that only online research study is covered by this Letter of Approval**

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to any conditions that may appear above.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- If your project has been approved to run for a duration longer than 12 months, you will be required to submit an annual progress report to the Research Ethics Committee. You will be contacted about submission of this report before it becomes due.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Simon Taylor

Chair of the College of Engineering, Design and Physical Sciences Research Ethics Committee

Brunel University London

Appendix 5: Framework Evaluation Instrument

*** Indicates a required question**

Purpose

Dear Participant,

Please find attached a copy of the developed framework "Civilian UAS/Drones Deployment Framework for Qatar", part of a road map to support the deployment of UAS (drone) applications in Qatar. As a key stakeholder, your participation will provide significant and valuable information that will be used in PhD research. The interview will take around 20 minutes to present and discuss the proposed framework. After that, you will be kindly asked to give your opinion by answering the questionnaire, which will take around five minutes.

No reference will be made in the thesis or any other publications associated with this research that could personally identify you.

Your help and cooperation is highly appreciated.

Interviewer Information

Name: Khalifa Al-Dosari
Programme: PhD
University: Brunel University of London.
Address: Uxbridge, UB8 3PH
Email: 2012682@brunel.ac.uk

General Information

Please select the sector you work in, or in which you have the most experience: *

- Research and higher education
- Civil aviation
- Military aviation
- Interior Security
- Police
- Firefighting
- Government innovation and authorities, public services, and business development
- Oil and gas sector
- MoTC
- Environmental sector
- Qatar RC Club
- Qatar World Cup Security Community

Framework Validation and Evaluation

Please rate your level of agreement with the following statements related to the developed framework shown in the picture using the scale of 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, and 5 = Strongly agree.

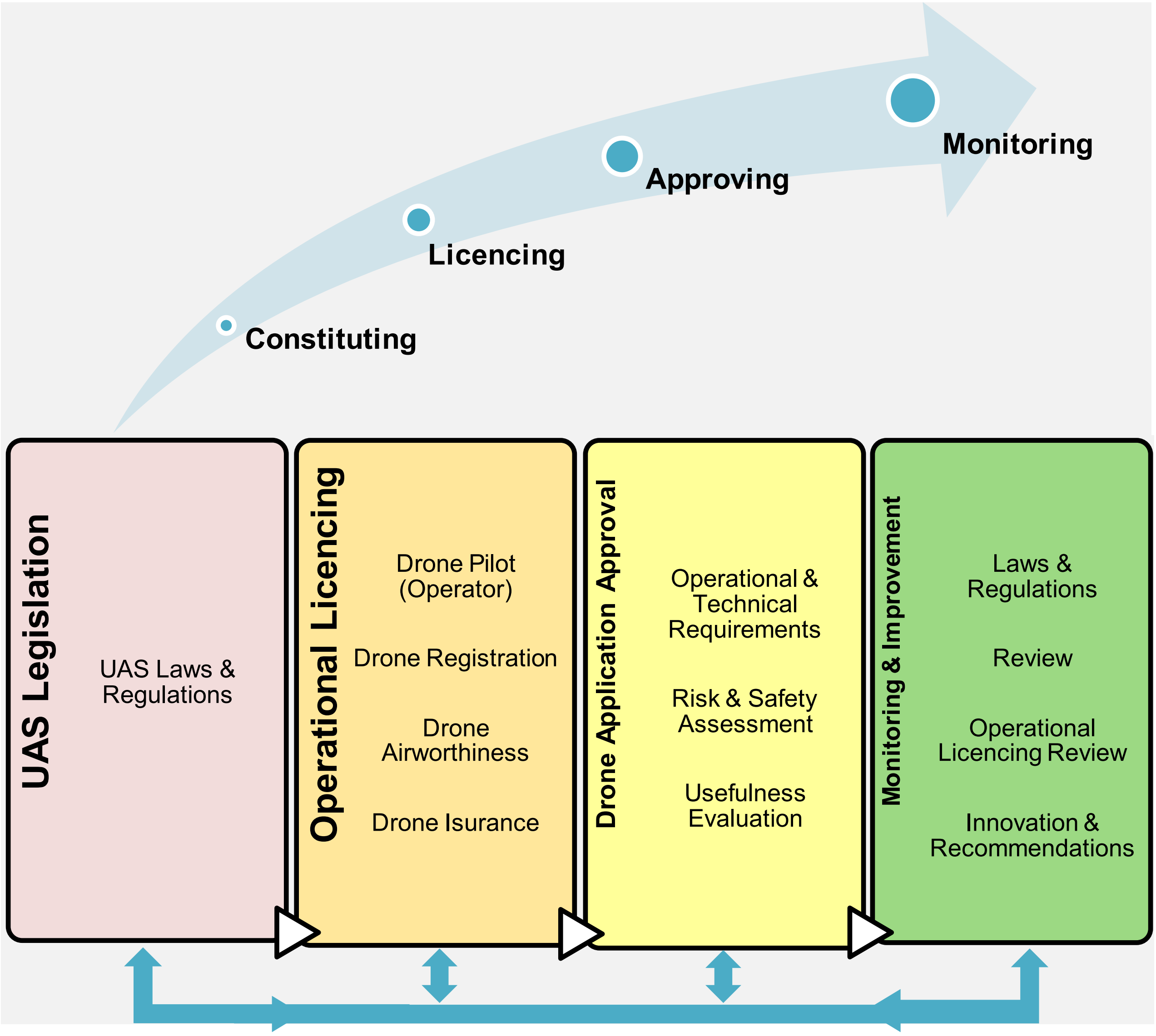

Figure A5: Proposed framework

Source: Author

1. The framework is clear and easy to understand. *

- 1
- 2
- 3
- 4
- 5

2. The framework is systematically well-structured. *

- 1
- 2
- 3
- 4
- 5

3. The framework is comprehensive (includes all essential aspects). *

- 1
- 2
- 3
- 4
- 5

4. The framework is applicable. *

- 1
- 2
- 3
- 4
- 5

5. The framework is efficient. *

- 1
- 2
- 3
- 4
- 5

6. The framework is practical. *

- 1
- 2
- 3
- 4
- 5

7. The framework is appropriate for Qatar. *

- 1
- 2
- 3
- 4
- 5

8. The framework helps stakeholders to understand civilian UAS/drone deployment needs. *

- 1
- 2
- 3
- 4
- 5

9. The framework is easy to implement. *

- 1
- 2
- 3
- 4
- 5

10. Overall assessment. *

- 1
- 2
- 3
- 4
- 5

Suggestions

1. Do you have any suggestions to strengthen/improve the proposed framework?

____

2. Please indicate any weaknesses/limitations (if they exist) of the proposed framework.

____

3. Please provide any additional comments/suggestions/recommendations that may enhance the proposed framework.

____

Appendix 6: Scenario Analysis of Mega Sporting Events Incidents

This mega sporting incident scenario analysis concerns the case of the France 2022 Champions' League Finals, and an evaluation of the FC and drone camera surveillance impacts on C&CC situational awareness for dynamic decision-making.

The main objective of this study is to perform a scenario analysis on a situation of S&S professionals at a mega sporting event being overwhelmed with people in a similar scenario to the France 2022 event. The first part of the study will be to raise awareness of security and safety professionals towards the possible consequences of mega sporting incidents through evaluation of the damage that occurred after the France 2023 incident. Moreover, during this study, two options of surveillance imaging from the current cameras with security professionals and FCs will be compared against supportive surveillance imaging from drones, to see which will better support risk management through better situational analysis for MSEs.

* Indicates a required question

You mainly work in the sector of *

- Safety
- Security

Possible Consequences of 2022 Champions League Finals

After viewing the video of the France 2022 Champions' League Finals incident, please rate your agreement with the following statements related to the possible consequences of the mega sporting incident, noting that:

(1 = Strongly disagree, 2 = Disagree, 3 = Neither agree or disagree, 4 = Agree, 5 = Strongly agree)

Possible damage due to media coverage *

- 1
- 2
- 3
- 4
- 5

Possibility of putting people at risk *

- 1
- 2
- 3
- 4
- 5

Possible negative impact on the reputation of the country *

- 1
- 2
- 3
- 4
- 5

Possible damage to the event itself *

- 1
- 2
- 3
- 4
- 5

Possibility of facing challenges to host future events *

- 1
- 2
- 3
- 4
- 5

Possible financial loss *

- 1
- 2
- 3
- 4
- 5

Possible traumas to people involved *

- 1
- 2
- 3
- 4
- 5

Possibility of damage to a future career as a safety and security professional *

- 1
- 2
- 3
- 4
- 5

Possible damage to property and infrastructure *

- 1
- 2
- 3
- 4
- 5

Possible damage to international relations *

- 1
- 2
- 3
- 4
- 5

Observations

How many people do you think are facing the security guard in Picture 1 (FC Surveillance Feed)? *

Figure A6.1: FC surveillance feed using Lego
Source: Author

Your answer:

___

How many people do you think are facing the security guard in Picture 2 (Drone Camera Surveillance Feed)? *

Figure A6.2: DC surveillance feed using Lego
Source: Author

Your answer:

From the FC Surveillance Feed (Picture 3), I can see a crowd in: *

Figure A6.3: FC surveillance feed from France ’22
Source: Sky Sports (2022)

- 10s
- 100s
- 1000s

From the Drone Camera Surveillance Feed (Picture 4), I can see a crowd in: *

Figure A6.4: DC surveillance feed from France '22
Source: Sky Sports (2022)

- 10s
- 100s
- 1000s

Opinion on Situational Awareness

Rate your agreement with the following statements.

Drone camera surveillance can enhance C&CC situational awareness for dynamic decision-making. *

- 1
- 2
- 3
- 4
- 5

Appendix 7: Evaluation of the Drone Safety and Security Surveillance System (D4S) Prototype

*** Indicates a required question**

Perceived Usefulness

1. With the new D4S, decisions are easier. *

- 1
- 2
- 3
- 4
- 5

2. With the new D4S, decisions are more accurate. *

- 1
- 2
- 3
- 4
- 5

3. With the new D4S, decisions are quicker. *

- 1
- 2
- 3
- 4
- 5

Perceived Ease of Use

1. The new D4S is easy to use. *

- 1
- 2
- 3
- 4
- 5

2. The new D4S and methodology is easy to understand. *

- 1
- 2
- 3
- 4
- 5

Behavioural Intention to Use

1. I think that using the new D4S is a good idea. *
- 1
- 2
- 3
- 4
- 5

2. I think that using the new D4S is beneficial. *
- 1
- 2
- 3
- 4
- 5

3. I have a positive perception of using the new D4S. *
- 1
- 2
- 3
- 4
- 5

Usage

1. I intend to use the new D4S. *
- 1
- 2
- 3
- 4
- 5

2. I intended to use the D4S instead of the established procedure. *
- 1
- 2
- 3
- 4
- 5