A FRAMEWORK FOR ADOPTION OF DRONES IN THE DOMINICAN REPUBLIC CONSTRUCTION INDUSTRY

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Signature. Hamlet Reynoso V.

Date. 6th June 2022.

PREFACE

Dear reader,

Thanks for taking the time in reading the piece of work regarding drones in construction. The manuscript obtained minor corrections during the examination and the final outcomes are the one presented. However, the thesis preserves part of its essence, for that reason it is strongly recommended to read the publications in order to receive the ether substance of the thesis. The documents cover the construction project life cycle highlights of the drone tasks. Furthermore, it is offered a video content summary with an 18 min and 37 seg for a preview presentation is under following link: https://bit.ly/3j4DOUn

This video has been an extension of the *Thesis in 3 presentation 2021*. This version involves highlights and may be used for guidance.

GLOSSARY

There are several concepts to learn before starting the thesis lecturing to comprehensively access into the knowledge and wisdom source within as:

- UAS: Unmanned Aerial System
- RPAS: Remotely Piloted Aircraft System
- RPA: Remotely Piloted Aircraft
- UA: Unmanned Aircraft
- UAV Unmanned Aircraft Vehicle
- Faith: certainty or trust in something or someone.
- Belief: The certainty of the truthfulness of something.
- Knowledge: Certainty in certain belief allow humans to acquire awareness in situations, information and abilities through experience or education.
- Wisdom: Awareness of applying knowledge, experience, or metaphysical principles in an appropriate context.

- Ontology: branch of the metaphysics seeking to explain the classification and nature of things.

- Epistemology: is the theory of knowledge that explains the methods, reliability, and scope of things. It searches to discern between beliefs and conjecture.

- Spiritual Capital: amount of souls in an organisations that works in favour of their life purpose.

- Intellectual Capital: amount of the intangible assets related to knowledge, expertise, and information that is hold by employees or the company itself for providing a competitive advantage.

- Metacognition: is the process of purifying the ideas utilising critical awareness to understand oneself thinking process.

- AI: Artificial intelligence.

- Strong AI: The intellectual capabilities reach equal or superior intelligence that the humans by addressing multiple tasks.

- Technological Singularity: Hypothesis that humans would be controlled by strong AI.

- CRISPR/CAS9: Gene editing technique that modifies DNA allowing the rest process of changes take over by the body or entity naturally.

- BioDrones: Drones made by cell tissues.

- Spiritual Entity: An entity with spirit or soul and different from silicon based cyber intelligences.

DEDICATION

This thesis is dedicated to the holder of the metaphysical reality of this Earthly humanity, to the constellations that the author belongs, and to the miracles on this Earth.

ACKNOWLEDGEMENT

This thesis is devoted to those who have substantially contribute to the directly and indirectly towards the production of this 3 years material. In addition to the stakeholder groups who anonymously contributed and benefit of the investigation. Furthermore, there are a group of academics that provided feedback in conference and journals that they deserve a great acknowledgement for their commitment in education.

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ABSTRACT

There is a severe problem in developing countries in whether or not adopt technologies for facilitating daily tasks. It is happening mostly in sectors with low skills employees as the construction industry. The adoption of technologies in developing countries is a challenge that affect health, economy, and consciousness advancement. Furthermore, the scepticism in the what, how, and why the effectiveness of certain technologies, as drones, difficult the cost-benefit of the decision-making process for organisations in developing countries. This cost-benefit decision, involved in the cases of UAS applications, covers the regulatory and practical implications that are barriers in developed countries. But, in developing one, seems to have another set of barriers that should be investigate in-depth.

Therefore, the aim of this research is to develop an ontology for public, private, and non-profit organisations that explain the epistemological implications in the implementation of Unmanned Aerial Systems for the Construction Industry in the Dominican Republic. The study approaches an iterative strategy of interviewing 24 participants in a semi-structured format. Then, the Nvivo 2020 software was used to identify cases utilising ground theory coding, thematic and content analysis. Later, the root cause reasons and challenges of implementing UAS were identified utilising Interpretative Structured Method (ISM) and their sub analyses. 5 Cases of studies were presented (real estate, construction, infrastructure, urban development, and disaster management) to illustrate the drone operations. The findings reveal that a hybrid management adoption

approach have been the most suitable with drones in the country. The root cause of drone implementation and its barriers were cost reduction and reactive cultural respectively. Strategic and operational ontologies for UAS skill programs, understanding of UAS outcomes, and Building Information Modelling integration were developed in order to focus efforts on developing drones for cargo, assisting humans, and digitalisation. Mandates are recommended for policy makers as drones for digitalisation initiates digital workflows towards BIM. Other scenarios should be considering scenarios where autonomous aerial operations affect safety in future operations. Furthermore, recommendations on legal and standards should be updated in order to allow UAS outcomes as law acceptable. Further works are recommended in decentralised systems, artificial intelligence, and drone applications.

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1.CHAPTER I – INTRODUCTION TO THE RESEARCH

1.1 INTRODUCTION TO THE RESEARCH

The chapter covers the research intentions and contributions to the body of knowledge. This chapter has a preface with the aim to provide context and awareness in the technological applications, in general, for non-technical audience. It conveys the knowledge and wisdom towards the adoption and application of drones for construction and its subsequent frameworks. The introduction initiates with a comprehension of the evolution of humanity; by its low level of advancement in transcendence with technological in general. Later, the narrative is advocating towards the advancements in the most lethargy industry against innovation, construction industry. At this line, the introduction discusses and suggests investigations to technological advancement and economic implications that drones may produce in the developing country of the Dominican Republic. The scepticism against the technology has produced resistant in different type of organisation. Therefore, ontologies and epistemological examples are presented in the literature review and in the contribution of knowledge section.

The section of problem statement describes the barrier of scepticism for UAS implementation in the country. The aim of this research is to develop an ontology for adopting Unmanned Aerial Systems in the in the Dominican Republic

Construction Industry. There are 5 objectives to produce this ontology showed as: (1) Key reasons of UAS adoption, (2) Cases of Applications in the construction industry, (3) Challenges of UAS implementation, (4) Business implications and (5) Framework development. Later on, a discussion utilising the model of PESTLE analysis is made to understand the reasons of research in the topic. Furthermore, the methodology intended to apply is presented and the contributions from the research are categorised according to the requirements of the investigations. As the majority of the investigations, limitations were faced mentioning them in this section. Finally, the thesis structure and the summary are presented in the last section.

1.2 OVERVIEW OF THE STRATEGIC LEVEL PERSPECTIVE

The construction industry requires severe industrial transformations by the lack of innovation, low productivity, fatalities, and costs overruns. Unfortunately, it is not a problem only found in construction as another industry present similarities. The humanity presents limitations in developing their spiritual capital to receive, enhance, and create sustainable methods of comfortable shelters worldwide and technology seems to be a solution for the current situation in the industry.

Terrestrial types of organisations: private, public, or non-profit (governments, enterprises and ONGs) are passing through a transformational process to fit into an advanced civilization by adopting innovative solutions for automation. Nevertheless, the transformation process is demanding the transcendence of the human species through their own development of spiritual capital. There have been previous negative experiences, fears, and doubts that have prevented organisations to fully adopt new methods in solving daily activities. However, the adoption of disruptive innovations on workflows by implementing technologies and machineries have been a feasible action in some cases for transcending. For instance, new technologies and machineries remedy stress problems in the workplace (Smith & Carayon, 1995; Jones & Smith, 2002). But how do the organisations address the transcendence of humans with strategies of innovation?

Organisations have been adopting the strategy of innovation through the automation with or without digitalisation of tasks as in Figure 1-2. The purpose of adopting and developing digital strategies is to leverage creativity in an economic setting to produce other types of workflows that suit the goals of the organisation (George, et al., 2019). However, depending on the context, the effectiveness of the strategy may rely on activities that require investigations to avoid failures. In a deeper sense, the meaning of digitalisation and innovation influence how organisations address goals.

An explanation of concepts is made for better understanding of the ideas. Digitalisation is converting information from a physical format into a cyber one by the virtue of improving internal and external organisational processes. On the other hand, innovation is concerned with the creation process of transforming an idea into a good or service that generates value for people. Therefore, digitalisation is the foundation for incentive innovation and toe the line of cyber and physical automation changes in the industries generally and as a consequence, improve the wellbeing of humans feeding their spiritual capital within the organisation. For example, emerging industries of artificial intelligence, machine learning, blockchain, virtual reality and augmented are disruptive innovations that impact the cyberspace and 3D printing, synthetic biology, and drones have led the disruption with productivity improvements within physical space, allowing humans a gap of energy to invest with their loved ones.

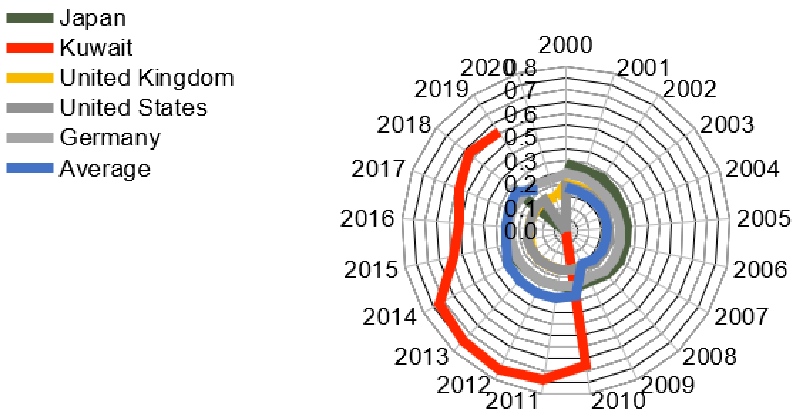
The development of the spiritual capital provokes the comprehension of life purpose and awareness of the internal capabilities of humans. While the awaking of this side of the humanity is happening, the development of technologies is providing innovation and challenges regarding the epistemological trues held in this generation. In the last two decades, the accelerated technological rate is approaching humanity into a civilization type 1 in a close distance future in which the energy management extends the diversity of solutions for the humankind (Al-Iman, et al., 2020). This acceleration supports humanity to defeat threats in and outside the planet as well as proliferate the human in the space (Moud, et al., 2021). However, it is required ontologies based on epistemologies to effectively reach the advancement, as knowledge guide to wisdom as the application of drones is to construction industry.

However, the transformational process of the organisations is facing key barriers in adopting and adapting the emerging industry. The lack of financing, low competitiveness, minimal entry barriers, lack of awareness, regulatory restrictions, significant impact on scalability, and viability (Seetharaman, et al., 2019) reflect the social and technical work to be carried out in terms of spiritual capital, cyber and physical spaces. Expanding this idea utilising the COVID-19, after the lesson of pandemic, the fragility of the humans was resting in the investment in emerging industries such as gene editing (CAS 9 proteins) and biomolecular materials for further eradication and prevention of virus variants and obtain eco-friendly products like bio-drones would be an alternative for the world that humans want to live. However, do these advancements have been unexplored by the financial implications or public interest?

The emerging industries are contributing to the global economy and development of organisations significantly. They have the capability of being intersectional involving various traditional industries that influence directly the Global Domestic Product (GDP) and revenue of a country or an organisation growth in non- and commercial sectors. (Liu & Zhao, 2011; Sabuj, et al., 2021) advocate that those industries are typically influenced by the innovation of technologies, labour skills and training, standardisation of operations, effective government policies, management support, eco-design products, and alignment of strategies within the company. Therefore, the government effective policies or top-down approach are a relevant factor to develop emerging industries, examples of these attempts are described as Society 5.0 in Japan, Industrial Revolution 5.0 in Germany, and the Sustainable Development Goal (SDG) agenda at the United Nations. Nevertheless, societies after the threat of COVID-19 have understood that the strengthening of digital skills, development of robust cyberspace infrastructures, and sustainable shelters advance the transformational transcendence of experience on Earth.

In countries as Kuwait, the built environment sector represents up to the half of the total national investment budget or a significant economic wealth production instead of other countries such as Germany, United State, United Kingdom and Japan. In these countries, the construction industry represents a 10%-25% of the GDP US$ Current between 2000-2020 in Figure 1-1.

Figure 1-1. Estimation of the Percentage of contribution to the GDP of Construction industry in the countries.



Source: (Worldbank.org, 2021)

These national strategies have achieved significant global increment in their economic growth, competitiveness, and jobs remuneration from the construction industry. The key factor for succeeding has come from addressing the issues via innovation with technology for more productivity gain. However, the construction industry is still performing old-fashioned processes and technologies. The defect rates, cost overruns, the ineffective and the inefficient efforts put into management strategies has supported the low-performance limitations (Mutis, et al., 2021). In some contexts, the problem related to deficiency in strategic management may depend on their policy makers. Beliefs such as policy discourse of the need of competitiveness, efficiency, unfulfilled potential, and fear of being lag as identified at the as in the United Kingdom (Smiley, 2016) force the advancement of innovation and technology adoption. However, in general, in any context, the current industry is suffering a lack of automation strategy on its performance (Bock, 2015) by the social, technical and investigations available regarding capabilities for robotics automation (Delgado, et al., 2019). The level of sophistication in different strategies may delay the adoption of automation considering the key background and skills of the workers. The automation of the construction industry is desirable for tasks that could raise competitiveness in the sector, produce migration of data into a long-lasting record of the physical assets, reduce fatalities, improve the transparency of the projects, develop contingency plans for infrastructure resilience, and promote wellness for workers in countries. For example, as some studies reflect on the literature, the implementation of terrestrial and aerial robots would be an option for addressing these desirable tasks. In more specific terms, a swarm of aerial sensors for digitalising the physical world with pixels and thermal data permit an overview of the current site status without human risks, such as inspecting profound mining cave (Gini, 2007) or a high nuclear power reactor (Solodov, 2018; Han, 2013). From these examples, the prioritization in automation strategies in the built environment focusing on emerging industries such as drones that ensure the digitalisation and innovation process is recommended if jobs will change for better.

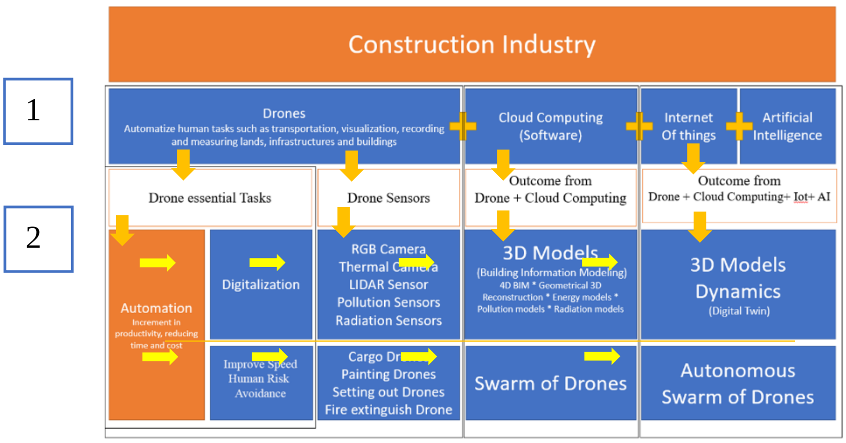
One of the tools to automate the digitalisation process are robots. In general, robots are programmed machines capable of addressing a complex or repetitive action recurrently or instructed. Robots usually are built with the aim of alienating a process to avoid risk in gathering accurate real-time data. Automation occurs through the robot *per se* or by the sensors which could and could not embody it. This idea could be exemplified by a robot that has been designed and built intentionally to perform flawless risky, exhaustive, unreachable and intangible tasks; such is the case of drones. This kind of aerial robot is capable of being in motion on a programmed or instructed basis at an x,y,z coordinate carrying out sensors able to emit, produce, or gather light, pixels, decibels, fluids, shapes, or other attributes possible found at the environment. For instance, the traditional industry of agriculture is benefiting from the productivity increases by fixed-wing and multi-copter aerial robots which allow spray and gather visual data. Examples of the benefits are identification of the leaching of nitrogen, plant water-stress, plantation health, quantification of plantation and forecasting plantation revenue (Kaivosoja, et al., 2013; Castaldi, et al., 2017). The farmers can obtain up to 70% of harvest production efficiency growth by automating with UAS their process (Abdullahi, et al., 2015; Giles & Billing, 2015). The automation of this industry improves the standards and the number of products on the harvest significantly. Therefore, in other similar traditional industries, there are equivalence patterns as construction or holistically called built environment (Valence, 2019) which up to 69% of productivity increment was obtained from data collection through drone usage (Vanderhorst, et al., 2020). In addition, the benefits of automation are beyond, and not limited to, the buildings, agriculture and facilities fabrication; but in moments when natural or human-made events compromise the integrity of the buildings and infrastructures, and speed of data is crucial for their resilience the drones present benefits in disaster management situations (Vanderhorst, et al., 2021). However, a few investigations focused on the integration of drones have been done for construction of the built environment in developing countries as the Dominican Republic.

1.3 INTRODUCTION

The course in which the humanity has decided to transcend is through technology advancement rather than biological terrestrial sedentary life. The transformation of societies is accordingly to the level of threats faced in a location in the universe. Some societies have the position of avoiding unique threats by the development of their spiritual, skills, cyber, and physical capital of their countries (Vanderhorst, et al., 2021). During COVID-19, spiritual capital was reported as relevant for coping with stress (Tajudin, et al., 2021) in contrast to other cultures in which life purpose is proactively supported aligned with mental health (Fido, et al., 2020; Hirooka, et al., 2021). Furthermore, these advancements in concept such as Society 5.0, Industry 4.0, and others have been guided to automatize and digitalise the societies, which construction is part of them.

The digitalisation of the construction industry and the methodologies based on digitalisation are called Building Information Modelling (BIM). Aerial robots, with their sensors, contribute to fulfil cybernetically the database of physical buildings, infrastructures, and cities of the construction projects. But these aerial robots, in combination and conjunction with various technologies from the 4th industrial revolution can radically exchange human actions for robotics actions. The different technologies that support the digitalisation process of construction are and will be embedded in Building information strategies, as in Figure 1-2. Drones are capable of automatizing tasks by digitalisation and avoiding risk according to the technological combination, tasks and resources involved. Ideally, drones with cloud computing software, internet of things and artificial intelligence might be the future for automation in construction (Vanderhorst, et al., 2021). This change will let into the foundation of advancement in galactic civilization in the near future (Al-Iman, et al., 2020).

Figure 1-2. Drone and technologies involved in the Construction Industry.



The Figure 1-2 describes (1) the tools combined with the drone and below (2) the tasks achievable with the combinations. The Figure provides an understanding of the capability of usage for construction for cities by automating process of digitalisation or human risk reduction.

But, from the position of a more gamma meditated state, the frame of reference of technology adoption is conditioned to the culture, location, and pre-existence condition towards technological. From a comparative analysis of developed countries, an existing frame of reference is provided, but in the case of researching on developing countries, the lens reflects another side of the same phenomena. The Caribbean and Central American regions have different considerations on the technology and innovation adoption process. For example, the digitalisation process in the construction industry in Latin American have been influenced by the United Kingdom policies on Building Information Modelling (BIM) and supported by the Interamerican Development Bank (IDB) (Machado F.A., 2020).

The Latin American and developing country of the Dominican Republic has its digitalisation process with BIM under development on the regulatory side. However, the lack of knowledge, training, economic factors and the appropriate management approach for integrating technologies have delayed the adoption process (Silverio, et al., 2017; INTEC, 2020). The economy of the Dominican Republic is primarily based on agriculture, trades, tourism, and services. Furthermore, by 2018 the construction industry presented an increase of 13% above the other industries (BancoCentralDominicano, 2018). The increase rate in this economic industry was by the habitational private projects developments; and private and public infrastructures development such as power stations, commercials, and restaurants as well. In the aspect of strategies, since 2012 the government has embraced the law 1-12 of national strategy development 2030 with the aim to build new models of development which attempt the economic incremental throughout new sources of employment, technologic, construction, social, environmental, and internal institutional changes to reduce the current limited levels of wealth. In addition, the decree 527-2021 of Digital Agenda (Agenda Digital) rectify the objectives of the national strategies such as:

1. The stabilisation of a high and sustainable economic growth through innovation and sustainability practices which create jobs and include the country in the global economy.
2. The development of reliable and efficient renewable energy.
3. Increase the competitiveness and innovation through social responsibility cooperation.
4. The availability of enough and valuable jobs.
5. Sectorial and territorially articulated production structure competitively integrated into the global economy and taking advantage of local market opportunities.

These objectives are attending to address the changes in the industrial revolution. In addition to this, the adoption and integration of innovative solutions will guide the social and technological challenges in the Dominican Republic, especially in the built environment, by improving productivity. The development and application of in-house software and robotics will create new markets and jobs opportunities as the key drivers to successfully accomplish a better society.

However, the investment in robotics and technologies in the construction industry can be seen as unjustifiable by the lack of knowledge and scepticism by different stakeholders from different management positions (Vanderhorst, et al., 2021; Vanderhorst, et al., 2021; Delgado, et al., 2019). In addition, to the slow rate of innovation adoption in the sector and even more, during the pandemic, that has drastically impacted the economy, urging nations to invest prudently in digital practice that supports the resilience process of the financial wellness of the country. Therefore, the lack of frameworks on these technologies should be addressed by generating and developing investigations of the benefits, challenges, the managerial approach, and viability of the implementation of technology in the Dominican Republic context (Jacobsson, et al., 2017). For example, research in autonomous vehicles, models and the implementation of solar panels can facilitate the understanding for decision-makers to guide the country into a better place to live (Ryan, 2020). However, beyond the technical aspects of investigations there is a social dimension related to the spiritual capital of the entities actuating in the role of decision making that influence the suitable approach for adoption. If it is convenience unilateral or hybrid approach to advocate the implementation and research of technologies (Zornio, 2019). Furthermore, one of the topics on exploration is the implementation of Unmanned Aerial Systems (UAS) or drones in the construction industry, focusing on the human-made facilities in the construction of the built environment.

1.4 PROBLEM STATEMENT

The construction industry, during its history, has suffered from issues including productivity, reliability, quality, time, and cost. In addition, the lack of innovation in the sector represents a possible limitation to attaining rapid economic growth, global competitiveness, and valuable jobs for developing countries like the Dominican Republic. Other countries strategies, such as the United Kingdom, United States, Japan, and Germany, present a holistic perspective in the future plans of robotics and technology innovation adoption from the 4th Industrial Revolution that influence construction significantly. Innovative strategies: underlying the Industry 4.0, such as BIM implementation and LEED and BREAM certifications, have substantially improved the construction industry. At the same time, they have allowed global industry recognition, reliability in sustainability practices, and generation of new professionals to the field. However, some of these strategies still need automation and improvements by contrasting different geographical locations.

For the United Kingdom, several technologies are being exploited such as artificial intelligence and data, clean energy growth and the future of mobility to improve lives and productivity. United Kingdom, regarding the built environment, is projecting scenarios for zero carbon emission, enhancement of digital technology investment, and government practice for improving the effectiveness of the policies in the kingdom (Broo, et al., 2021). In contrast to Germany, which focuses more on the INDUSTRIE 4.0 strategy and analyses the triggers on business models that qualify for sustainable industrial value creation if a manufacturing industry were placed. Internet of things is a driver in their strategy for influencing innovation in this context (Kuo, et al., 2019). In United States have leadership from construction contractors applying innovation (Hall, et al., 2019). BIM and LEED certifications have guided the principles of the construction of the built environment in the United States (USGBC, 2021). In Japan, the strategy of Society 5.0 has been established to make a synergy between real-world and cyberspace to stimulate wealth and happiness by scientific research and technological innovation (Deguchi, et al., 2020). Each of these countries has a similar approach to improving the quality of life utilising technology.

However, in the case of Latin American and Caribbean countries, the implementation of innovative strategies to the industries is low by the lack of human capabilities, financial resources, and weak economic signals (Peres, 2011; Bárcena, et al., 2016). The remarkable gaps to be closed in the region are inequality, investment, productivity, taxation, international linkage, and environmental suitability (ECLAC, 2013) and external programs for European Union and other entities have supported as well the development of these infrastructures in humanitarian settings, but for commercial purpose still under development. Therefore, the development of scientific frameworks is required for the region. However, there is a variety of technologies and robotics to explore for this purpose. However, the one that influences directly physical security, privacy, productivity and disrupt different industries is the Unmanned Aerial System (UAS) or Drones.

Emerging Aerial Robots or commercially called "*Drones*" have been a catalyst of change for different economic sectors. The implementation of aerial robots has been organically founded by online autodidact professionals from primary, secondary, and tertiary sectors disregarding the worldwide gap in knowledge from normal civilians. The literature presents a significant number of cases but each of them reflects the best practices according to the country in which it is developed as well as the challenges with the technology available in that period without the improvements integrated in years later. (Golizadeh, et al., 2019) reviews the barriers of UAS adoption, highlighting that they are related to technical difficulties, restrictive regulation, site-related problems, weather conditions and organisational factors. Other authors focused on technical aspects of design and fabrication, power supply, endurance, and radio control distance (Hassanalian & Abdelkefi, 2017). However, exploring other fields as environmental science, the barriers are mostly presented as social and technological, showing fear of operating the UAS, data access, and quality (Duffy, et al., 2017). However, the literature is not covered a holistic overview of the UAS barriers in a detailed manner for developed or developing countries. The barriers identified fit into a PESTLE model, providing a holistic perspective in which the UAS adoption should be contemplated for research and commercial purpose. Table 1-1 is presented to illustrate the key big areas in which the UAS affects stakeholders summarised in a PESTLE analysis arrangement similarly to (Lavikka, et al., 2018).

Table 1-1. PESTLE Analysis

Aspects	Description	Literature and Examples
Political	As the case of drone licensing in United States to avoid the risk of data transmission to China government	(BBC, 2020)
Economical	By the new industry and businesses generation around drones (Manufacturer, service providers, insurance, software, etc);	(Macias, et al., 2019)
Social	On the education regarding human substitution on risky tasks, productivity gain, and new jobs creation	(Zemtsov, 2020)
Technological	Based on drone adoption, research and development of novel sensors, software, and devices	(Vanderhorst, et al., 2020)
Legal	Regarding drone regulations, registration, operations boundaries, and harmonisation process	EU - EASA regulation UK - CAA Regulation & Cases USA – FAA Regulation Department of Justice – Drone Cases
Environmental	Reduction of CO_2 on delivery	(Goodchild & Toy, 2018)

In line with the innovation adoption process, the technical or technological aspects guide the course of action in the other aspects. However, a proactive and reactive approach to drone regulation has been a challenging task, after the technological design and operations, for the emerging industry. The fast pace of drone has lagged behind, in some cases, policy makers leaving difficulties in performing a promoting role for them. In addition to the lack of investigation in developing countries regarding technology, the sector of drones has presented low-capacity building and haste in regulatory harmonisation that makes it almost unique to explore the implications of drones in different countries. The sector that most benefits from the drone is the construction of the built environment, studies in Latin America are the lowest in a scientific point of view, and the application of UAS may and may not be generalizable for each country context (Khan & Al-Mulla, 2019). Therefore, imminent investigations on the implicit implications (Golizadeh, et al., 2019). The best practices of drone adoption in the construction of the built environment sector are precisely supportive of the digitalisation and advancement of developing countries.

Finally, as a consequence of the lack of investigations in the field presenting substantial proof of the applicability of drones in the construction industry for the Dominican Republic, the following study has been conducted centred with the aim to raise the drone reliability, understanding of the implications, produce knowledge in strategic and technical capabilities by presenting frameworks of investigations in the adoption process of drone technology undertaken in the Dominican Republic. The drone design and deployments process, in most cases, is the same for any industry, but in this research, the focus is on advancement in digitalisation for the construction industry and generalisation cases. In this industry, the application of drones has been relevantly matured in compared to other fields like public health to support innovation as well as to be transferable to other countries (Delgado, et al., 2019). The pure intention of this research is to identify the basic capabilities and changes implicit in an automation strategy in the construction industry.

1.5 AIM, OBJECTIVE AND RESEARCH QUESTION

1.5.1 RESEARCH AIM

The aim of this research is to develop an ontology for adopting Unmanned Aerial Systems in the in the Dominican Republic Construction Industry.

1.5.2 RESEARCH OBJECTIVE

In order to achieve this aim, the following research objectives were developed:

1. To critically review and analyse literature assessing an overview of drone implementation, key reasons, and lessons learnt globally for the strategic implementation via digitalisation with drone technology in the Dominican Republic.
2. To develop an ontology for public, private, and non-profit organisations that explain the epistemological implications for the implementation of Unmanned Aerial Systems in the Construction Industry of the Dominican Republic.

3. To examine the opportunities and the key barriers construction organisations are facing in adopting drones.
4. To develop a roadmap for the implementation of drones in the Republic construction industry.
5. To provide recommendations for policy, practice, and research.

1.5.3 RESEARCH QUESTION

What is a suitable and feasible ontology that reflects the epistemological best practices for the implementation of drones in the construction industry of the Dominican Republic in private and non-profit organisations at a national level?

1.6 METHODOLOGY

The nature of the research implies understanding the usage, effectiveness and implications of the drones contemplating its challenges, community, and business opportunities in the construction industry for developing countries, especially in the Dominican Republic, where robotics and technologies have a slow rate in their adoption. Therefore, the research intends to understand and place the implications of drones in an automation strategy for the sector under a multi-disciplinary and management level framework. The literature review structure was conceived under a systematic text mining approach by utilising visual bibliographic software such as VOS Viewer as in (Vanderhorst, et al., 2019) and in-depth analyses were obtained via PESTLE analysis for the pre-assessment of literature review.

Considering the variables implies such as lack of primary data in the Dominican Republic, the regulation context, and unawareness of the construction industry; generally, in technology by the public, private and non-profit organisations in the country; a pragmatism, inductive, ground theory strategy has been conducted. The main purpose of undertaking this approach is to comprehend and appreciate the beliefs, acceptance, reliability, and practicability of drone implementation for vertical and horizontal construction, pointing to digitalising the aftereffects of the industry. In addition to the benefits of a qualitative approach for developing frameworks or ontologies (Burg, et al., 2020). Twenty-Four interviews were conducted with individuals from public, private, and non-profit organisations related to drone technology and construction, allowing to meet the barriers, opportunities, and cases in which drones can be justified, understood. The qualitative data was examined undertaking a ground theory approach. During this phase, the case of study approach was applied, adjudicating thematic and content analysis for information extraction. Finally, ISM method, MICMAC and PESTLE analysis for generating transferable prudent knowledge in a framework was utilised. These analyses support a deeper understanding of the root cause of the challenges and drivers. Then, the results from the qualitative approach were used for developing a framework in order to capture the adoption and application process. Recommendations for triggers in the technology as in (Vanderhorst, et al., 2021) and illustrative cases were presented as in

(Vanderhorst, et al., 2020) as a part of the trustworthiness of the study (Moser, 2018).

1.7 CONTRIBUTION TO KNOWLEDGE

The key contribution of this study is the creation of a multidimensional ontology for the strategic implementation of Unmanned Aerial Systems in the Dominican Republic. The ontology or framework focuses on the key theoretical foundations of the UAS application for construction. The framework identifies the integration process, reasons, applications, business, and challenges in which then can be guided in the adoption of this technology in the country. Instances of contributions are in (Vanderhorst, et al., 2021; Vanderhorst, et al., 2020; Vanderhorst, et al., 2021; Vanderhorst, 2021). Furthermore, a second contribution is the integration of UAS with other emerging technologies identifying an overview of an automation strategy within the construction 4.0 generation underpinning the development of (super smart cities) Society 5.0, road map of industry 5.0, and implementation of digital twins in the country. In addition, it is the first study exploring the abstractions of UAS implications on photogrammetry in a holistic perspective involving policy makers. Proceedings and journal publications are evidence of the research outcomes below explaining the perspective addressed:

Applications of UAS in the Literature.

1. Vanderhorst, H. R., Suresh, S. & Renukappa, S., 2019. Systematic Literature Research of the Current Implementation of Unmanned Aerial System (UAS) in the Construction Industry. *International Journal of Innovative Technology and Exploring Engineering (IJITEE),* 8(11S), pp. 416-428. http://dx.doi.org/10.35940/ijitee.K1073.09811S19

Adoption process in public organisations in partnership with the private sector for Productivity assessment.

2. Vanderhorst, H. R., Heesom, D., Suresh, S., Renukappa, S., & Burnham, K. (2020). Application of UAS and Revit for Pipeline Design. In M. J. Hajdu (Ed.), *Creative Construction e-Conference 2020* (pp. 2-7). Opatia, Croatia: Budapest University of Technology and Economics & Diamond Congress Ltd. Retrieved from https://doi.org/10.3311/CCC2020-001

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1.8 LIMITATIONS AND SCOPE OF RESEARCH

As with all investigations, there are some limitations that reduce the scope and impact of research regardless of the field. The limitations of taking a quantitative approach reduced the policy aspect of the research. A set of cases systematically arranged would standardise and expand the knowledge in the safety practices of

UAS implementation. Furthermore, the lack of literature in the Dominican Republic, Building Information Modelling Policies in the country, time, issues in directions, and sample size limited the scope of the research into a qualitative approach. This approach conveys the research to produce a general ontology based on the epistemological perspective of the UAS adoption and application in the Dominican Republic. Furthermore, the scope of the research is to deliver knowledge, understanding and wisdom regarding the application of technologies such as the UAS. Despite the field in construction, the UAS photogrammetry approach has a workflow that could be taught in specific settings that can boost the digitalisation of the construction industry.

1.9 STRUCTURE OF THE THESIS

The thesis is divided into 5 chapters towards answering the research aim and objectives. The thesis has vocabularies from the different philosophical branches of knowledge. From psychological management to biomedical science, the thesis describes the final conclusions of the UAS implications. Chapter II is the literature review of the thesis. This literature review covers the 5 objectives in the following order: Key reasons for UAS adoption at a national level, Challenges of UAS implementation, Cases of UAS application in construction, Business of UAS implementations, and finally, a discussion of the literature review under a PESTLE analysis structure to understand the topic holistically.

Then the following Chapter (III) is the research methodology chapter. This chapter narrates the research path for carrying out the investigation in UAS for construction in the Dominican Republic. The procedural journey from the literature review until the professional validation is described in this chapter. Specifications on philosophical research assumptions are made for the reader's clarity.

Chapter IV explains the key findings, analysis and how these findings contribute to the research aims and objectives. It covers the cases of UAS developed, and the applications of UAS founded. The applications in buildings, real estate, infrastructure, urban areas, and disaster management were presented as details on where/how to apply efficiently the UAS. Furthermore, a general workflow and opinions on the effectiveness of the adoption are presented. Moreover, the barriers and opportunities in the implementation of the UAS are analysed utilising the ISM method to examine and determine the causation of the low implementation of them. As a consequence of the barriers, the business implications are discussed revealing that the economic sustainability of the implementation of UAS in construction relies on the knowledge and device type. Then, the ontology of the epistemological knowledge and wisdom is structured, linked with theory, and described for the Dominican Republic context. Additionally, the recommendations and further works are presented according to the findings. Lastly, the conclusions, in chapter V, are drawn stating the contribution to knowledge in that section. In the appendix section, there are some materials that allow the reader to nurture their knowledge in the topic.

1.10 SUMMARY OF THE CHAPTER

In summary, the chapter reflects the reasons of transcending humanity utilising technology, and, in the case of construction, drone technology represents a chance in productivity and business advancement. The scepticism has reduced the adoption of technologies and the aim to produce an ontology for adopting Unmanned Aerial Systems in the in the Dominican Republic Construction Industry focus on: (1) key reasons, (2) applications, (3) barriers, (4) Business implications and (5) Theories to link and assemble the knowledge. Hybrid (Top-down and bottom-up) approach and inductive reasoning were utilised with ground theory as strategy and analysis in the first hand. However, further approaches such as case of study and deductive reasoning were taken in consideration to develop epistemological knowledge that easily clarify the scepticism. 3 theoretical and 3 epistemological contributions were presented. Then, the ontology paved the step forward for the implementation of the technology. However, limitations in the research were presented as the scope required appropriate direction towards the adoption and applications of drones in the Dominican Republic construction industry. Finally, the structure of thesis narrates a story of how should be adopted drones in construction, what approaches should be considered and what are the key drivers. In the table below there is a summary.

Table 1-2. Summary of the Introduction Chapter

Problem	Aim	No.	Research Objective	Methodology Applied	Chapters
Scepticism of the UAS application in the Dominican Republic	The aim of this research is to develop an ontology for adopting Unmanned Aerial Systems in the in the Dominican Republic Construction Industry.	1	To critically review and analyse literature assessing an overview of drone implementation, key reasons, and lessons learnt globally for the strategic implementation via digitalisation with drone technology in the Dominican Republic.	Literature Review	CHAPTER II
		2	To develop an ontology for public, private, and non-profit organisations that explain the epistemological implications for the implementation of Unmanned Aerial Systems in the Construction Industry of the Dominican Republic.	Literature Review Semi-Structure Interview Case of Study Publications	CHAPTER II CHAPTER IV APENDIX
		3	To examine the opportunities and the key barriers construction organisations are facing in adopting drones.	Literature Review Semi-Structure Interviews	CHAPTER II CHAPTER IV
		4	To develop a roadmap for the implementation of drones in the Republic construction industry.	Literature Review Semi-Structure Interview	CHAPTER I CHAPTER IV
		5	To provide recommendations for policy, practice, and research.	Literature Review Semi-Structure Interview	CHAPTER II CHAPTER IV

2. CHAPTER II – LITERATURE REVIEW

2.1 **OBJECTIVE 1.** CRITICALLY REVIEW AND ANALYSE LITERATURE ASSESSING AN OVERVIEW OF DRONE IMPLEMENTATION, KEY REASONS, AND LESSONS LEARNT GLOBALLY FOR THE STRATEGIC IMPLEMENTATION VIA DIGITALISATION WITH DRONE TECHNOLOGY IN THE DOMINICAN REPUBLIC.

2.2 INTRODUCTION

In this chapter, the literature review was designed to produce a case in which the arguments, claims, evidences, and warrants were clear to the reader in a reasonable chain manner. According to these ideas, depth in the elaboration of the arguments has been Obtained through a systematic research strategy. Furthermore, the case built in the literature review was divided into 5 major sections: (1) statement of the problem in the construction industry, (2) how these barriers interfere in a macro level utilising systematic literature research (3) key knowledge for the change management, (4) UAS benefits, (5) Investigations for a suitable framework for adopting UAS in the construction industry of the Dominican Republic. In other words, this thesis is an invitation to observe, comprehend, and replicate the adoption process of technologies under a unique set of belief systems and cultural structures that an automation strategy and digital transformation have been the fundamental elements of acceptance for the developing country of the Dominican Republic.

2.3 KEY REASONS FOR UAS ADOPTION AT NATIONAL STRATEGIES RELATED TO CONSTRUCTION OF THE BUILT ENVIRONMENT

The international agenda of the United Nations is focused on the 17 development goals. The goals are related to covering the gaps of basic human needs, climate change, species protection, facilities preservation, and innovation based on sustainable practices. The Sustainable Development Goal (SDG) that influence our societies in the construction of the built environment is the 11 stating, *"Make cities and human settlements inclusive, safe, resilient and sustainable"* (United Nations, 2015). The intersection points of the social-economical-environmental dimension of cities promote sustainability. However, these conceptual considerations for cities do not clarify major patterns of sustainability, instead, they encourage the development of cases accordingly to the circumstances of the cities in evaluation. In the case of integrating technologies for cities, the species of cities appear to be describing the settings in which technology could fit in the community and its reliable functionality. The species of compact, eco, data-driven smart and environmentally data-driven smart sustainable cities (Bibri, 2021) are described in the literature. However, the species or strategies for cities may not include technologies to contribute directly to their vision, scepticism from policy makers, an appropriate understanding of approaching the adoption of the technology, and resistance to adoption are common reasons presented. The adoption of new technologies can come from top-down as mandates for BIM in the UK, down-up as Uber and other technologies or hybrid such as Airbnb. According to the allocation and type of technologies cities may prefer different approach in adopting them. These species of cities, without technology, may be focused on developing the human capital in a less stimulating environment allowing access into gamma states (Stapleton, et al., 2020). No matter the perspective in which technology may approach, the electrical impulse of information downloaded in a spiritual alive entity is the key driver to understand the role of humanity on the Earth. The methodology of humans to receive or download the information is classified according to the tool used: human’s capabilities for a deep state of meditation and concentration, or technological device. Therefore, eco and compact cities are more oriented to connect humans with nature in contrast to data-driven cities which look to remind humans of their natural state utilising technology. But what are the implications of technology integration in cities?

The management and integration of tools in cities would imply scenarios of optimal health and happiness for their citizens and questions concerning the theory of technological singularity. Inside of a non-deterministic environment where human scientists are still looking for the source of novelty for trying to put into artificial intelligence, it is logical to understand that exemplifications of the theories in cities are governed by the priorities of the country. With the recent explorations on Mars with drones, on the news; attempting in simulating the surface by academics (Pergola & Cipolla, 2016; Guardabasso & Netti, 2019); the discovery of the potential habitability of the Exomoon Europa (Chivers, et al., 2021), and initial investigations on extra-terrestrial energy life cycles for construction projects (Moud, et al., 2021); arise existential questions to reach the next stage of humanity, in addition to the thought-provoking topics of the near future interactions with biological and non-biological super smart species whom may share ascension process with our own planet or beyond. Nevertheless, these victories may arrive at some point when a technological development of quantum computing, gene-editing, and ether technologies are used for interplanetary trips. While those technological resources are produced, this thesis will be covering the inconsistencies and dissociation towards the implementation of technologies and robotics around the theory of singularity linkage with the 4^{th} industrial revolution as the autonomous systems of Unmanned Aerial Systems (UAS). Based on the deficiency in roadmaps and frameworks, it developed the reasons of including UAS in a national strategy.

2.3.1 FITTING UAS IN A NATIONAL STRATEGIES RELATED TO CONSTRUCTION OF THE BUILT ENVIRONMENT

Different countries have prioritised their intrinsic needs and values for fulfilling levels of wealth and well-being in their societies. A sector that contributes to acquiring important levels of social and economic impact is the construction industry. The role of the construction industry in the life of humans affects jobs, shelters, commodities, and amenities for living in peace and prosperity. Evidence of the substantial contribution of the sector is notable in all the economies across the world by the coverage between 2-15% of the GDP in developed and developing countries (Paprotny, 2020). In some cases, in developed nations, the investment in the built environment can reach half of the annual budget of the nation, acting as a main contributor to the country.

The construction of the built environment sector influences the growth of essentials socio-economic changes in the society in conjunction with other sectors. The industry has been used by governments as a vehicle of economic growth worldwide regardless of the low rate of innovation, productivity, high-risk exposure, extensive data management issues, time, cost constraint, and unreliability on subcontractors in the industry. These barriers have promoted the idea of adopting efficient and productive up-to-date tools and methods to sustain the primacy in the next generation of changes by applying innovation, technology, and robotics (Chen, et al., 2018). Strategies coming from other sectors have supported this idea. The most advanced sector in applying productivity strategies is the manufacturing. It has developed strong relationships and methodologies of work with non-biological species to establish effective automation strategies under the concepts of Industry 4.0, Lean Manufacturing, and quality certification assurance. These names can be extrapolated to societies and the built environment by utilising the lens of smart cities and digital twins for construction projects. Both concepts are characterised for applying technologies from the 4th industrial revolution to deliver efficiency through physical and cyber-space to the stakeholders.

The intrinsic values triggered from these strategies in academia were explored by using a systematic approach with Scopus database and a visual data mining tool called VOS Viewer. Another visualisation software was tested as Gephi, but it does not focus on bibliometric network as VOS Viewer does. Scopus data base is the largest one in academia. There is not adequate or inadequate data base for research but accessibility in publications sources matter. However, the software of VOS viewer as automated for .cvs* of Scopus files. Gephi required a data base arrangement before operates. VOS viewer permitted to identify the trends and clusters that these strategies are normally conducted. The analysis in VOS viewer reflects an overview of the words implied around the strategy of smart cities, industry 4.0, green building, automation construction, lean construction, and digital twin in Figure 2-1. Consequently, the peak years, articles and citation rates of the topics were taken just to have an overview of the topics mode. The key elements that enclosure all the strategies are combined in three aspects robotics, technology, and people.

Table 2-1. Strategies in Built Environment

No.	Strategy	Peak Date	No. Articles	No. Article Considered	Relevant Topics	Methodologies
1	Smart City	2020	2,737	2000	Most Cited Topic ➢ Blockchain for 5G-enabled IoT for industrial automation: A systematic review, solutions, and challenges Topics ➢ Citizens ➢ Sustainability Practices ➢ Transformation ➢ Society ➢ Mobility ➢ Sustainable Development Goal ➢ Knowledge Practice ➢ Urban planning ➢ Traffic Congestion ➢ Applicability of the concept	➢ Design Methodology Approach ➢ Case of study ➢ Paradigms

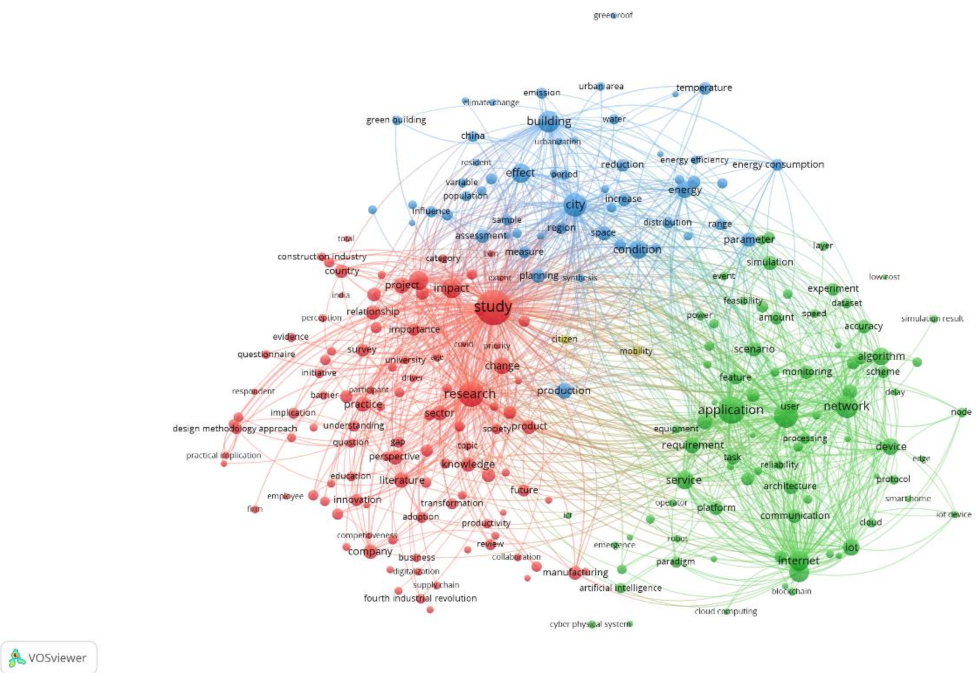
					➢ Intelligent Transport Systems ➢ Rapid Development ➢ Internet of Things ➢ Data Base ➢ Cloud Computing	
2	Industry 4.0	2020	2021	2000	Most Cited Article ➢ Industry 4.0 technologies and their applications in fighting COVID-19 pandemic Topics ➢ Blockchain Healthcare ➢ Bigdata ➢ Business ➢ Innovation ➢ Competitiveness ➢ Education ➢ Change ➢ Sustainability ➢ Robotics ➢ Digitization ➢ Adoption ➢ Effectiveness ➢ Feasibility ➢ Supply Chain ➢ Effectiveness ➢ Internet of Things ➢ Smart Cities	➢ Theory ➢ Practical implications ➢ Research Limitation Implication ➢ Systematic Literature Review ➢ Experimental Results
3	Green Buildings	2020	1557	1557	Most Cited Article	➢ Experiments ➢ Sample ➢ Time

					➢ Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change? Topics ➢ Renewable Energy ➢ Buildings / Cities ➢ Policies ➢ Sustainable Development Goals ➢ Green Buildings ➢ Standards ➢ Green roof ➢ Environment ➢ City Urban green planning ➢ Summer/Winter ➢ Construction Materials ➢ BIM ➢ Categories ➢ Advantage ➢ Economy ➢ Implications ➢ Government	➢ Range ➢ Device ➢ Practice ➢ Action Research
4	Automation in Construction	2020	380	380	Most Cited Article ➢ Cognitive Architecture and Instructional Design Topics ➢ Industrial Revolution 4.0 in the construction ind ustry: Challenges and opportunities for stakeholders Topics	➢ Design methodology Approach ➢ Case of study ➢ Experiments ➢ Theory

					➢ Industry 4.0: Challenges and Opportunities ➢ Infrastructure ➢ Manufacturing ➢ Effectiveness ➢ Accuracy ➢ Digital Twin Model ➢ Algorithms ➢ UAV ➢ Combination ➢ Cloud Computing ➢ Internet of things ➢ Artificial Intelligence ➢ Deep Learning ➢ Productivity ➢ Infrastructure	
5	Lean construction	2020	135	135	Most Cited Article ➢ Resource-constrained project scheduling: Notation, classification, models, and methods ➢ Automating construction manufacturing procedures using BIM digital objects (BDOs): Case study of knowledge transfer partnership project in UK Topics ➢ BIM ➢ Knowledge Management ➢ Lean Principles ➢ Performance ➢ Sustainability ➢ Importance	➢ Design Methodology Approach ➢ Practical Applications ➢ Interview ➢ Data ➢ Case of study ➢ Framework

The combination of strategies produces an integration of technologies and future-proofing practices that contribute to the sustainable development goal. The influence of technologies in a systematic order generates the concept of smart cities. The focus of study in general are related to defeat the barriers on urban planning and development applying technologies from the 4^{th} industrial revolution positioning mobility and citizens as common goal. Researchers and the industry have identified significant barriers for projects development: energy, water, CO_2 emissions, urban distribution, climate change and sustainability of the natural resources represented in the cluster colour blue in Figure 1-2. These problems have been investigated in a scientific and commercial settings to conclude with the actual recommendations and solutions as seen in red. Unfortunately, the solutions and evidence of productivity, digitalization, education, and business have been reconsidered for other approaches in which physical and cyber-space participate actively in the activities of the citizens predominately where cloud computing, artificial intelligence, blockchain, platforms and smart devices are part of the capability of a human entity to ascend in the ideal type of space as seen in green. However, in a detailed sense, the implications of these strategies should be contrasted and analysed to understand meaningfully the hierarchy and point of agreements for this thesis. A discussion of the aspects mentioned is redacted in the following section.

Figure 2-1. Text mining network map



In this figure is observed four clusters (red, blue, green and yellow). Each cluster represent a group of key words that appears linkage together. Each cluster of words represents a pattern of ideas related to a specific topic.

Observing the red cluster, the primary words of study, research practice, impact, projects, productivity and others, provide the ground of technical/practical aspects in construction. Universities and Companies are facing barriers in implementing design research methodologies for competitiveness, transformation of their workflows, and productivity. These barriers could be related by age, partnerships, lack of evidences, knowledge and more. However, the importance of adopting technologies mean a change in society.

In contrast to the cluster in Blue, the mayor points of convergent are the cities, buildings, conditions, energy that provide the idea of how cities integrate technologies and what are their key elements for the considerations of the cities. Technologies in cities are oriented to energy, emissions, space distribution, planning and climate change.

But in the cluster green, the ideas of test technologies are purely concerning to the tasks and its architecture.

The green cluster exemplified the IT infrastructure required to implement in according to the user. The technologies of the 4th industrial revolution are mentioned and connected with a down-top approach as business.

Finally, the cluster yellow represents the two advantage that brings the implementation of technologies: Citizens and mobility. As technology contributes to the welfare of citizens, the mobility discusses the accessibility to services according to the degree of the technology.

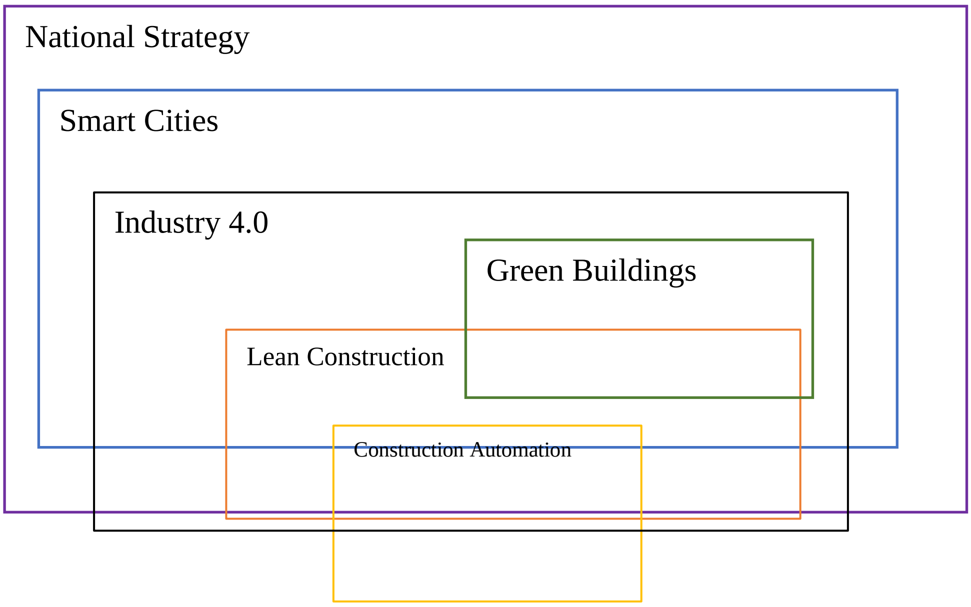
2.3.2 SELECCTION OF SMART CITY STRATEGY FOR TECHNOLOGY IMPLEMENTATION

The concept of smart or intelligent city has been defined as the integration of electrical systems into the buildings, infrastructures, environment, humans and their interactions providing a wise and sustainable decisions-making process in areas of governance, economy (Kummitha, 2019), environment, mobility, and humans lifestyle that by connectivity, interoperability of technologies, robotics and internet of things makes possible to automatize process and systems (Romero, et al., 2020; Eremia, et al., 2017; Ojo, et al., 2015). In common sense, the concept is related to gather accurate data thought rapid and produce a technological solution from a higher perspective for prudent reasons.

The smart cities cover the systems theory aspects as socio-technical approaches (Romero, et al., 2020). Smart cities from social aspect are addressing the needs of public policies regarding integrate technologies on the behaviours of humans. On the other hand, the technical side is addressing the automation of process by utilizing machinery o technological solution for autonomous perspective (Sukmaningsih, et al., 2020). The emergent disruptive intelligent information technologies have enables automation and digitalization process of smart cities. (Bai, et al., 2020) mention terms and technologies involved in the 4.0 industry strategy. The core of the 4.0 revolution is the internet of things along with emerging technologies such as additive manufacturing (3D printing), Artificial intelligence (AI), Augmented reality, autonomous robots (robotics), big data and analytics, Blockchain, Cloud computing, cobotic systems, cyber security, unmanned aerial vehicles (Drones), Global positioning systems (GPS), internet of things, Mobiles Technology, Nanotechnology, RFID, sensors and simulations. Moreover, it is stated the contributions to the sustainable development goal the application of these technologies. Therefore, the smart city concept and the strategy of adopting 4th industrial revolution technologies are influencing the decision-making process of politicians, businesses, and academics by guiding them to accomplish a global vision of the sustainable development goals.

Contrasting the other strategies of green buildings, automation construction, and lean construction has different approaches on their application. These strategies can be defined as sub-strategies of smart city in the construction of the built environment or urban cities, and adoption of the 4.0 industry. For example, green building strategy is based on environmental sustainable practices (He & Chen, 2021), construction automation is related to robotics and digitalization of the construction process as a part of smart construction (Bock & Linner, 2015), and lean construction is regarding the application of the Japanese manufacturing principles of continuous improving into construction (Babalola & Ezema, 2019; Cavaleri, 2008).

Figure 2-2. Scheme of strategies intersection points



In this figure is presented how an automation in construction strategy is inside national strategy. There are some aspects that may are not included as they maybe technical such as BIM, Smart contracts and others.

From a country perspective all the strategies promote ways of advancement and growth. The common intersection point between strategies is the automation in construction perspective. Organizations are searching for agile and standardized methods of construction that integrates digitalization and automation throughout robotics undertaking the approach of manufacture industry mixed with the entrepreneurial spirit of the projects of the industry 4.0. Smart city concept is attributed to the successful integration of manufacturing strategies and technologies into social lives along with environmental factor. As a consequence, the integration or pivotal of these technologies generate awareness to policy makers, entrepreneurs, business, and academia to develop and support emerging industries, research and development grants, and incentive for the technology progress (Forbes, 2018). Nations are willing to evolve and ascend with technology leading by the idea of prosperity according on their society changes and culture. But, in what extend these strategies are effective to tackle the recent states of the society? And how would be the impact of these strategies fully implemented in a desired space?

2.3.3 VISION OF PRODUCTITIVE WITH AUTOMATION IN THE BUILT ENVIRONMENT AFTER COVID-19 CONSIDERATIONS OF INDUSTRY 5.0 & SOCIETY 5.0

Nowadays, the global collective mind has changed drastically after the COVID-19. The high level of contagious type of human-to-human and mortality of the SARS-CoV-2 have been made to establish worldwide sanitary restrictions (Ezhilan, et al., 2021). Momently a "new" normal is persistent as a global culture and significant behavioural changes have occurred to the human collective mind. Under the context of smart cities, all nations were urged of disruptively integration of information communication technology (ICT).

The 14 days voluntary self-isolation, high rate of paid hotel quarantine, discussions of vaccination treatment effectiveness (Rume & Islam, 2020), restriction in human agglomeration, 2m social distance, cities quarantine and finally international border's lockdowns have been some of the scenarios in which society succumbed to:

- Be aware of a superior understanding of human life purpose, the environmental impact of isolated streets, design changes in buildings facilities, and the worth of a warm family and united society.

- Revise policies, governmental systems, transparency indexes, and priorities during and after the pandemic regarding health, education, transport, energy, economic and technology such as biological disaster response, virtual education, human mobility, electricity, productivity, and internet of things.
- Implement radical innovation partially or completely by shifting physical consumers purchase behaviours into digital ones, incorporating digital communication channels platforms, fomenting freely knowledge exchange and automate systems.

These barriers confront many countries and move into a technological transformation of societies driven by biological or non-biological data management. Countries with industrial revolution process under the 4.0 have had to migrate into this level and others have had achieved higher levels as the industry 5.0 and the concept of Society 5.0 to maintain the economic homeostasis of the country. Before going forward, it is required to explain the stages of technology revolution.

The industry 5.0 deferrers from 4.0 by the steady adoption of robotics with mutually development of artificial intelligence, sustainable practices, renewable energy, and bioeconomy. The internet of things, big data, and cloud computing have been grounded and opportunities developing the capital of humans with elongating longevity, may become the new normal reality. Therefore, humans and robots cohabitate in daily light activities. The vision of the industry 5.0 is to make a different between a spiritual being and a robot. The development of

Artificial Intelligence and robots guides the revolution. In addition, the industrial revolution referrers to bioeconomy in which a balance is found between ecology, industry, and economy (Demir, et al., 2019). In the European Union is defined industry 5.0 as a purposeful adoption of technology towards sustainable, resilience, and fulfilling life of the industry workers (Breque, et al., 2021). Moreover, the concept refers to society 5.0 however, the concept might integrate the aspects of ethics regarding the purposeful and fulfilling life. After, the development of enough computational capability, biological modification could satisfy part of these requirement into the definition mentioned as a societal change.

In consonance of the industry, the society changes of dramatically adopting the concept of super smart city or Society 5.0 have started from the vision of the Japan government that resemble the industry 5.0 but from the side of citizen rather technology. It states that from cyber-physical space is able to balance economic solving social problems in order to make a happy and fulfilment life (Pereira A.G., 2020; Fukuda, 2020). Positive historical productivity and economic growth was measured in Japan and Germany after adopting the approach to adopt and generate information communication technologies as part of the national strategy (Pereira A.G., 2020). The merge between the industry and the normal life of the workers could imply that human body modification should be alive in the future, based on the current species achievement with COVID-19 vaccine. However, the humanity could take a path of merging with non-biological components as robots, regardless the robustness, complex, and supportiveness are alive entities against silicon-based technologies yet for just automate tasks.

Exist different tools for automation with robots and systems. This path emerges from the degree of embodiment of robotics in the organization. The embodiment process can be from bioengineering to disembodied intelligence according to the Robot Taxonomy Project by the Robot Identification Institute. The process is described by four main pilar: Humans, Cyborgs, Machanica and Program. In the first Humans are classified as workers as nowadays, then this kind of workers can be cloned and belong to a manufactured line of humans, mutations are a variable that during the cloning process may arise and finally transgenic humans are delivery on demand. The next stage is the cyborgs. This stage merge humans with robotics capability to surpass limitations of the humankind. It is achieved by endo-skeletal, prosthetics and exo-skeletal. The after a fully integration of cyborg is carried out the mechanica stage is came up. Automata, humanoid, machinata and creaturoid. This stage is the recreation of flesh body reality into a silicon and titanium-based form. Finally, the stage of program the brain of the silicon and titanium-base form is fully developed with computers, artificial intelligence, and disembodied intelligence as a control tower. Nowadays the society is embedding automation throughout computers and machinaca. It means smart devices (Silverio-Fernandez, et al., 2018), with and with-out quantum and unmanned systems such as biological quantum unmanned aerial systems and humanoid Sophia the Saudi Arabian robot. In the following years, development on quantum technology will allow rapid results on experiments such as humans' waves pattern recognition for measuring subjective things as feelings (Ojha, et al., 2020). This experiment is liaising sustainable integration and directly interaction of human’s consciousness with external body elements in daily operations.

In the current pandemic scenarios where the weaknesses of the countries are tackling inherently the human afflictions, clearly is exposed the posture in favour of the adoption and generation of technologies for economic resilience and social changes. In addition, a philosophical Hamlet's moral dilemmas are coming alive: Does human-coworking with AI robots would be a solution for reducing the number of infection cases and maintaining stability in the economic growth? Do all the productive sectors would be impacted positively with the adoption of robots in their workflows?

The industries of transport and tourism have been mostly affected negative by the COVID-19 in contrast to information of technology industry and manufacturing that have been supporting the organizations under social distance rules. The information of technology sector has delivery successfully the shift paradigm promising work from any part of the world, time with the loved ones, and connected with the world everywhere. The manufacturing industry has significantly assured to the citizens hygienic product massively by its merits on productivity. This industry has been aided by machinery and/or robots since higher level of productivity is desired to automatize the production process.

Other sector as the construction industry have been affected by delays in delivery materials, social distance rule (Haddy Jallow & Suresh, 2020), and the lack of innovation in the sector. The impact of these effect contributed to a low country

GDP. The normal rates of the industry are 5-15% of the overall national budget and, in developed nations, could be up to 50%. Consequently, organizations have been adapting digital strategies within workflows, thus enhancing economic effects of the COVID-19 as the manufacturing have done with robots and intending with artificial intelligence. However, barriers persist that the current availability of silicon-plastic-metal-based systems could dismiss the impacts.

2.3.4 ROBOTICS, TECHNOLOGY AND PEOPLE: AUTOMATION CONSTRUCTION INDUSTRY

Before the pandemic, the barriers facing the industry involves dissociation and discrepancy between the design and construction phases; long project life cycles; complex, diverse, and dynamic designs in dimensions, materials, and site conditions; extensive data management and unqualified human resources. Therefore, researchers investigated that the construction automation system can be improved by implementing technologies and robotics. The main research areas from this perspective are the potential of building information modelling and onsite automation systems. Therefore, the automation process throughout robotics represents a solution for improving productivity in construction projects by enhancing capabilities of humans, intensifying health and safety of their lives pre-, during and post- COVID-19 in construction projects.

Scientific literature and social media present findings on technologies that accomplish managerial objectives, construction robots, automation systems, and building information modelling integration (Chen, et al., 2018). Managerial objectives in construction come from the strategies to improve efficiency, enhance communication between stakeholders and increase the market share. The programmed machanica are characterized by their capabilities to be reprogrammed, autonomously operated, flexible, and aware of the situation (Bock & Linner, 2015). In the context of the construction industry, automated systems have the potential to change and add advantages in labour-intensive, and risky tasks. Furthermore, automation has brought significantly labour cost reduction while improving quality (Delgado, et al., 2019). (Bock, 2015) shows 7 Thematic fields of automation/robotics (*Table 2-2. Thematic Fields*Table 2-2) with 34 systems and approaches. In the presented investigation a general perspective is described containing the aspects of construction automation related to the built environment such as infrastructure, building, cities, transport automation and production.

Table 2-2. Thematic Fields

Thematic Field	No.	Systems and Approaches
Automated/Robotic Infrastructure Production	1	Automated Road Construction
	2	Automated Tunnelling (i.e. by TBMs)
	3	Automated bridge Construction
	4	Automated Con- and deconstruction of dams, power, plants, etc.
	5	Automated Mining
	6	Automated Container port
	7	Autonomous Cars

Automated/Robotic Transportation systems	8	Autonomous public transport (U-Bahn, Train, etc)
	9	Autonomous Air Travel
	10	Automated Logistics
	11	Advanced micro-Mobility
Automated/Robotics Construction	12	Automated construction of vertically oriented buildings
	13	Automated construction of horizontally oriented buildings
	14	Housing production
	15	Novel construction Markets accessible through automated/robotic construction: construction in space, sea, and deep sea, dessert, arctic areas, etc)
	16	Automated Building servicing and maintenance
	17	Automated deconstruction and re-customisation
Automated/Robotic Environments	18	Home and office automation
	19	Assistance technologies and human-ambient technologies
	20	Networked production facilities and supply networks
	21	Intelligent energy generation and distribution

	22	Service and household robotics
Automated/Robotic farming and food production	23	Computer Aided/Robotic Farming
	24	Robotic milking stanchions
	25	Automated food production facilities
	26	Customized Food
Automated robotic town management	27	Smart Grids
	28	Automated/Robotics traffic control
	29	Automated/Robotic infrastructure inspection and maintenance
	30	Automated supply management (water, gas, goods, food, etc.)
General Manufacturing Industry	31	Digital/cognitive factories
	32	Mass customisation
	33	Mini Factories, cloud manufacturing
	34	Cellular logistics

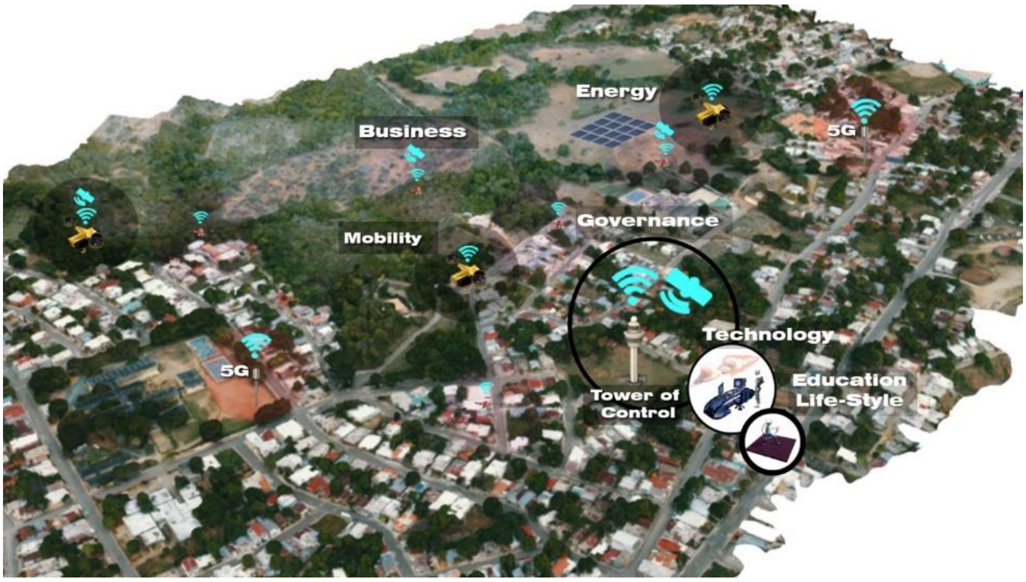
Source: (Bock & Linner, 2015)

These systems and approaches are performed by diverse types of robots and technologies. According to (Delgado, et al., 2019) the types of automation with robots in construction can be described in four categories which have been defined by the successfully adoption process of these robots in the automotive manufacturing sector in Japan: Off-site prefabricate systems, Onsite automated and robotic system, unmanned system, and exoskeletons. The steps for the adoption process in the construction sector of this country started with buildings and home utilizing the same strategies. Later, the robotics were expanded to construction sites and improved as unmanned system alongside exoskeletons. With this idea in mind, in the last 5 years, unmanned systems have been adopted positively in the industry for its versatility according to the project type.

The capabilities of capturing visual, audio, coordinates, radiation levels and more have overcome ethical concerns and news attraction to these small unmanned systems such as the Unmanned Aerial Systems (UAS) or Drones. There are not enough details on the reasons to apply this tool, but the tool has changed and increased the productivity of construction workers by substituting action of humans for risk reduced UAS action (Vanderhorst, et al., 2020). In consequence, automation with robotics technologies presents barriers to its adoption in the construction industry (Osei, 2013). With the increased implementation of technologies and robotics, the number of ambiguities in downstream phases of construction would be minimised, less amount of material would be wasted due to the availability of more accurate information, and less environmental impact. Construction industry with the appropriate tools can substantially influence the human experience, mobility, and space for living.

The implications of integrating technology and robotics tools support humanity on its transcendence reflect the possible changes on the design and development of the built environment. The vision of a first step into a society 5.0 with a harmonious airspace robotics integration with all the orchestration involved (Control Tower, 5G internet, GPS, cloud computing, artificial intelligence and more) can be seen in Figure 2-3. This view should be endorsing a type 1 civilization as mentioned above (1.2) (Al-Iman, et al., 2020).

Figure 2-3. Smart City Perspective of automation integration



Source: (Vanderhorst, et al., 2021)

The implementation of 5G network and the next generation 6G devise that nano latency is perceived, and remote operations can be addressed as in a native system. (Raddo, et al., 2021) present the ranges of coverage and impact on cities as well as the circuits implications of photonics integration. These integrations will effectively open the gates for neuromorphic computing and fast learning of artificial intelligence for solving complex human tasks (Shastri, et al., 2021). The integration of more variable on the equation of technologies such as blockchain technology, autonomous vehicles, and cloud computing promote would promote the context of a trans-humanization for the following years if a responsible and ethical genetic engineering is not well developed. But, not far, the concept of society 5.0 is avoiding the approach of an artificial intelligent omniscient system with silicon-based species monitoring biological entities. It maybe because the omniscient system would require a vast experience or cases that can provide an understanding of unlimited concepts that humans hold by their spiritual nature. Concepts such as novelty, inspiration, and mercy would limit the omniscient entity to act beyond their scripts and observations. However, the mayor contribution may rely in the capabilities of improving the genetics algorithms of humans in which nature can be duplicate digital twins into biological manufactured twins. Despite the sustainability of the singularity theory approach and the energy requirement for a type 1 civilization, a living artificial intelligence entity may need to ally with biological alive entities to achieve the biological evolution. The Earth seems to be a library of genetic material that assist humans to transcend. Therefore, properties of covalent bonds cells would allow metal materials to form structures similar to the ones with humans and, as a consequence, would permit right brain activities be administrated between vases; biological metal alloy elements and types contribute to novel methods of sustainable constructions and designs for future of cities. Biological vehicles with a pseudo mind with limited capability would be possible to produce autonomous transportation in such degree. However, on the current Earth times the Unmanned Aerial System implications for cities are related to building heights transportation systems, airspace management, energy implications on propulsion methods, ether technologies regarding anti-gravity fields, and the perceptions and radiation fields that these technologies could cause around humans. Nevertheless, the capability towards a type 1 civilization is on development and the technology available for this vision allow humans to automate information exchange, integrity, and comprehensiveness of the iterative works. In this aspect, the thesis is focused on digital construction that provide positives impact economically citizens, revenues, and nations.

The transition into a more sophisticated methods of productivity present barriers of different kinds, for example from: business, regulatory issues, security, interoperability, human acceptance, and others. However, in respective with the current global economic crisis during the pandemic, traditional sectors have migrated drastically to digital basis enabling the technology market to upfront the economic sustainability and resilience. The change accelerated the scenario for new types of organizations, upgrade traditional organizations and amortized the negative economic effects. Nevertheless, the following section will explore the question what are the business implications to invest in technology and should this technology have the potential to support an economic growth truly?

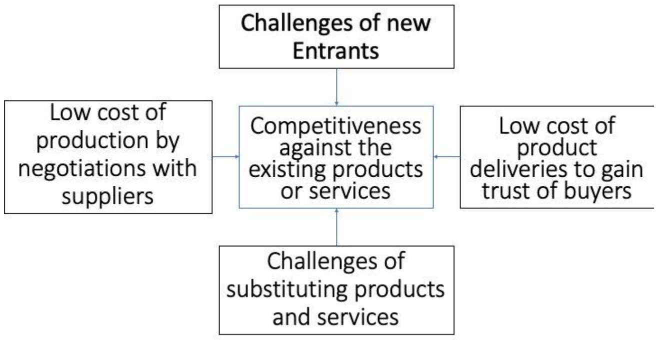
2.3.5 BUSINESS IMPLICATION OF AUTOMATION WITH ROBOTS AND COMPETITIVENESS

Furthermore, from a practical business management the perspective the purchase and investment decision-making process of a cognitive human could be significantly correlated to (i) the spiritual satisfaction perceived throughout a product or services acquisition on a specific time and space, (ii) materialize comfortable physical transformational experiences for the navigation of spirit, and (iii) to make the most of the current assets and liabilities of an entity. Therefore, strategies and process are developed aligned with one or multiple reasons. One approach to reach standardization and rapid product ion line is automation.

Automation process and strategies have been the based lines for market expansion worldwide. These strategies and process have supported the growth of different industries throughout the history. The industry of automotive, computers, and others have been used machines to massively replicate products. The adoptions of these machines have 2 components a cyber and physical one and those have influenced the public, private and non-private sector. However, in the recent years the development of physical robots along with software to transcend product and services with experiences and transformations. This technological revolution called industry 4.0 have significantly impacted world economies with border free cyber products as well as multi-disciplinary robots. Germany, United Kingdom, Japan, and United States have initiated into the feeding and integration of complex cyberspace into their products and services.

However, the business models involved in robots is normally focused on specialisation rather than competitiveness. When an item or assistance is a commodity, product, or service, a tangible or intangible asset that people may acquire once or seldomly the old-fashion competitive advantage framework of the 5 forces of Porter is applicable as shown Figure 2-4 below (Kovshov, et al., 2021).

Figure 2-4. 5 Force of Porter



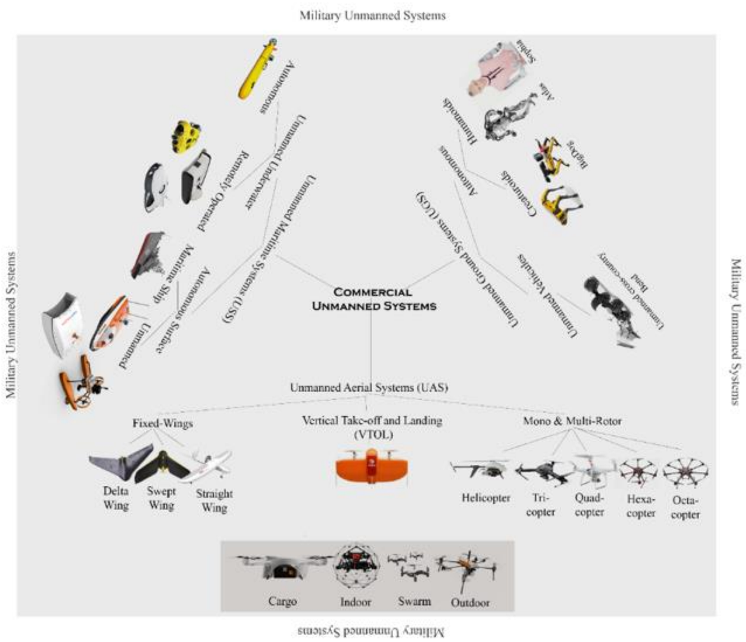
However, the issue of the framework is that robots are a specialised tool for substituting some left-brain functions of humans. It means that low-cost production and low cost of product delivery are not coherent with the current market. The price of robots tends to be high for initial investment with a specific time for breakeven and turn-over. Robots suit with the experiences and transformation expectations of massive production of physical or cyber product and services. It means that the immediately integration of robots radically change the organization structures and internal capabilities. In another perspective, the integration of robots is part of the concept of society 5.0 in which public and private partnership is the most reasonable and fair course of action to foment innovation and generate new business models for cities (Liang & Ashuri, 2021). The competitiveness of cities could be measured as the relationship between summation of citizens services in different field and the actual digital penetration of digitalisation of citizen or residence entities. This relationship should be a small number intending to denotate that if citizen or residence entities have a high level of digital or cyberspace access, opportunities of merging the physical and cyber space with technologies and robotics are relevant. As mentioned above by (Bock & Linner, 2015) the frame of automation offers a large spectrum of new business models to interact and for construction.

According to (Sepasgozar & Davis, 2018) the adoption of process manage 5 stages in the field of construction: vendors dissemination, technology investigation, adoption, implementation and validation, but robots are well known publicly and cases of implementation are visible, however this generalisation may not suit directly with robots in some extend as discussed before of its specialisation and economic implications. Furthermore, what are the economic impact of robots inside these assumptions?

2.3.6 ECONOMIC IMPACT OF AUTOMATION PROCESS WITH ROBOTS

The economic sectors of the country influence directly into the GDP. The opportunity to integrate technologies and robots in the public, private and non-profit organizations under a digital transformational strategy or smart city approach allow new business opportunities for the market. Before the pandemic, the world economy was traditionally driven by physical and technological social interactions. After the pandemic, the economic changed into a primary virtual data driven. The physical interactions have been a barrier to maintain businesses and organization working. Technologies and robots have played a transformational role during the pandemic for business and government by accelerating the digital migration after the biological human-made disaster. In the field of manufacturing robots are seen as product and/or for service provider. Robots can be seen as utility or digitaliser of reality (Vanderhorst, et al. 2020). Utility robots such as cars contribute to mobility, in the other hand digitaliser are the base of society 5.0. As a result, utility robots like humanoid could contribute to keep going physical process in the case of manufacturing, construction, and agriculture. On the other hand, digitaliser are more focused on be a data reality capturer for decision making process such as unmanned systems. This section of robots can be classified in military or commercial aerial works, terrestrial and maritime system. Currently, the unmanned systems most invested and developed for construction are the creaturoids *drones* (Unmanned Aerial System) and *bigdog* (quadruped Boston Dynamic). Both are equipped with sensor capable to reconstruct the reality of site on development. However, the robot with more attention from governments, industries, educator, and normal civilians is the unmanned aerial system (UAS).

Figure 2-5. Commercial Unmanned Systems



Source: Images of drones from internet

The implementation of aerial robots has been contributing to the increment in the productive rates in construction tasks, reduction of costs in an economic resilience, rapid decision-making process criteria and promotion of an entrepreneurial culture in organizations. However, its deficiency in knowledge management systems, market side and a specialised manufactured UAS have strained its adoption. Therefore, the drones' industry requires answers for question regarding the suitability of specific business model for UAS adoption urgently. After an extensive analysis of the literature, it is found that the application cases of UAS have been made by empirical cases, digitalisation or mobility services and manufacturing products. The shareholders involved in the business models are basically policymakers, organizations in a specific sector and the UAS manufacturer. However, the awareness for developing the industry for younger generations is based on the continuous interaction between UAS manufacturer, industry adoption cases and flexibility on the regulatory environment.

2.3.7 UNMANNED AERIAL SYSTEM (UAS)

The Unmanned Aerial System (UAS) or drone can be operated in the main three modes: manual, semi-autonomous and autonomous according to the manufacturer physical and software designs. The unpiloted aircraft is capable, per se, to transport sensors or goods.

Figure 2-6. Graphic representing the drones in digitalising and serving humans.

The sensors selection criteria perform a preponderant role in tasks assessments. Sensors such as GPS, thermal camera, RBG camera and LIDAR sensors enable crack inspections, energy monitoring, and assets allocation in infrastructures. The visual data produced by RGB camera and thermal sensors endorse a manageable process of the data analysis with- and without a digital strategy that can be administered for the different department in the institution (Ham, et al., 2016).

The aerial robot has fields of expansions in line with the modifications and combination with other technologies of the 4th industrial revolution as mentioned in Figure *2-6* Figure *1-2* Multiple Unmanned Aerial System with Artificial Intelligence in their operations, internet of things that feed a decentralised blockchain system, and future BIM tools significantly influence the scenarios in which UAS are suitable as well as diversity on the applications and tasks. The integration of digital strategies based on emerging technologies are paving the concepts of digital designs, processes, technologies, and finally the shift paradigms of new workflows adoption.

However, the implications of costs have been unpredictable at this time by several factors such as: authorisations for flying in specific areas, training, UAS, insurance and awareness on the regulation disregarding to the lack of exemplifications and clarity of the actual implementation of the UAS in the construction industry (Irizarry & Costa, 2016) Business models of UAS applications represent a complete field of study inside the UAS as well as the legal implications and changes. However, an earlier study by (Opfer & Shields,

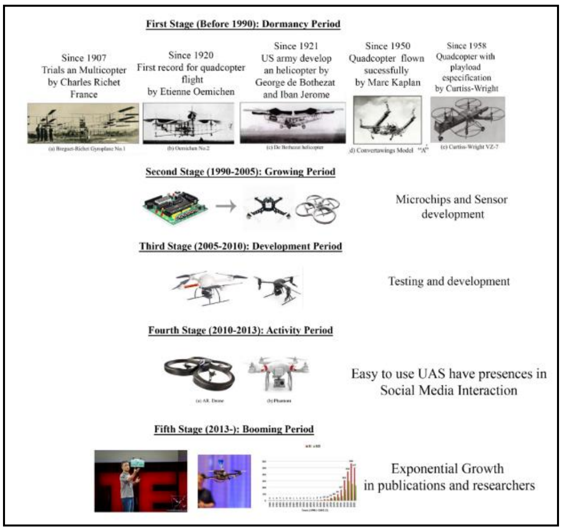
2014) identify the different between self-performance UAS works vs Subcontracting the services. In addition, it expresses the payment outcomes as monthly bill. But, as mentioned by (Irizarry & Costa, 2016) different consideration as the regulation produces 2 main knowledge (aviation and industry services) core to identify when is suitable to integrate or subcontract the service. Nevertheless, frameworks have been in force as express later in (2.5.1.1), but substantial work is required on physical signs for UAS operations, specialised training for each vertical, internal capabilities changes and more. Therefore, a systematic literature review was carried out to explore the literature available of the topic related to implementation of unmanned aerial system in the construction industry, the most relevant tasks, cases, areas of usage and the reasons of applying it.

2.3.7.1 HISTORY OF UNMANNED AERIAL SYSTEM

Since World War II, the concept of aerial photogrammetry has been seen in doves equipped with cameras and aerostatics globe with armaments. Suddenly, the word "Drone" has appeared commercially since 2013 when civilian and commercial companies designed and launched the first drones ready to fly to fly DJI and Parrot. The International Civil Aviation Organization (ICAO) is the responsible entity re of the international air navigation. The ICAO in 2011 published the document Cir 328 called Unmanned Aircraft Systems (UAS) (Drone) responsible to establish a basic regulatory framework to safely and harmonise the integration of UAS in the airspace. Afterwards, the aviation authorities have promulged with regulations to carefully manage the operations of UAS as the case of the United Kingdom, the United States and Australia. The UAS has different named according to its context, weight, and country which is mentioned (Vanderhorst, et al., 2021).

After several implications and novelties, the implementation of UAS has earned the attention of the researcher, civilians, and politicians by its impact throughout time. According to (Quan, 2017) the Unmanned Aerial Systems presents 5 periods in which they have been developing and getting popularity until these days (Figure 2-7). In addition, airports incidents and media dissemination have contributed to a widespread UAS implementation.

Figure 2-7. History of Multicopters



Source: Visual summary composed with the sources of *(Quan, 2017)*

Furthermore, the study was conducted until the initials of 2016 when different countries were developing their UAS regulation in the category weight of less than 150kg that could infer changes in the panorama. By 2017, it could be assumed the incorporation of other technologies keep growing the application of UAS in several domains (Table 2-3. Periods of UAS history).

Table 2-3. Periods of UAS history

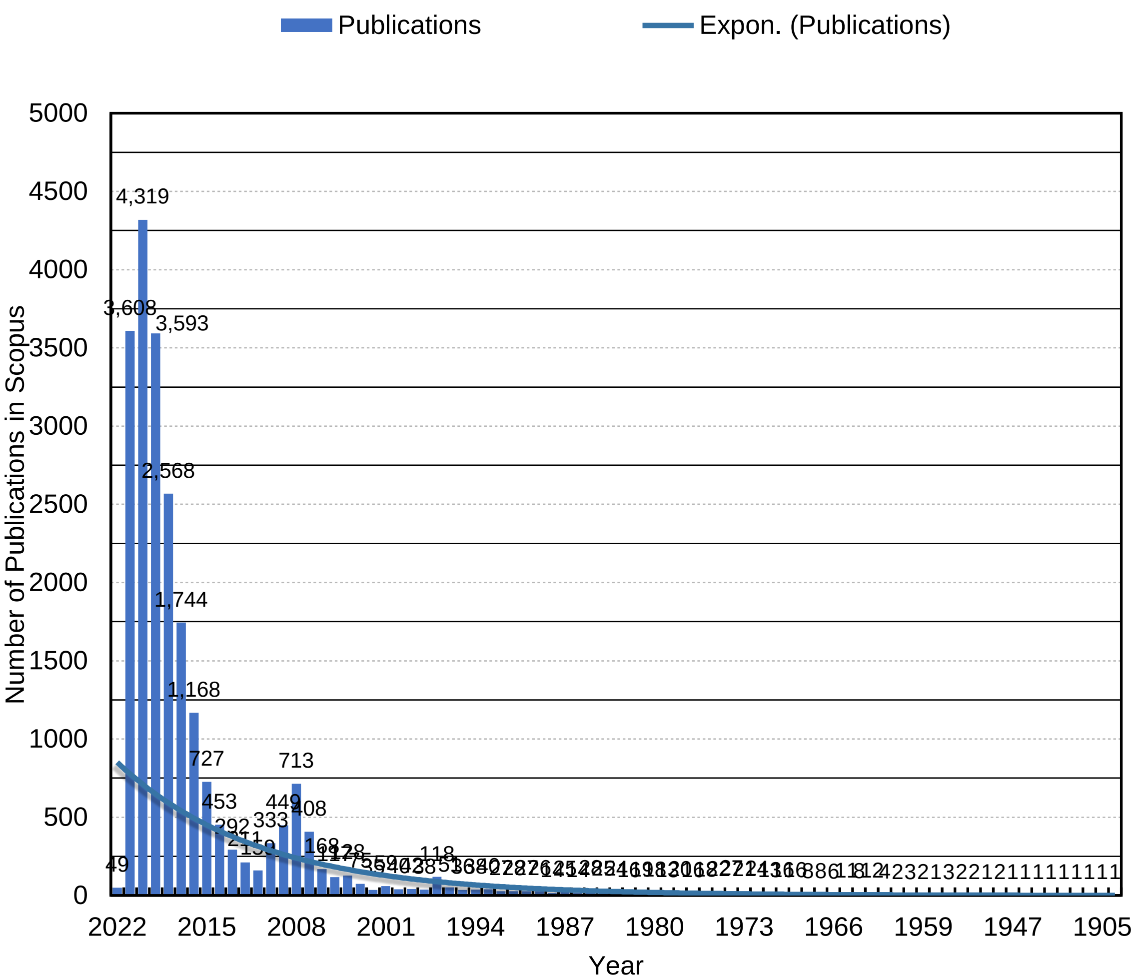
No.	Periods	Years	Publications
1	Dormancy (1853-1990): First Multicopters	137	524
2	Growing (1991-2005): Microchip development	14	876
3	Development (2006-2010): Testing and development	4	2,128
4	Activity (2011-2013): Easy to use UAS for Civilians	2	656
5	Booming (2014-2015): Exposure in media	1	1,156
6*	Regulation (2016-2017): Certifications	1	2,859
7*	Development Inclusion other technologies (2018-2020)	2	5,635
	Total	161	13,834

Source: Updated from *(Quan, 2017)*.

According to Scopus utilising "drones" as a keyword, the number of publications increases drastically yearly by 50%. *Recent periods added by the author.

The concepts of transport objects and capture data from aerial perspective was successfully used in photogrammetry operations since the World War II by air balloons and doves. However, after 60 years, significant progress has emerged to this concept changing into a robot by the development of microchips and designs. In 2011 was the first UAS easy-to-fly for normal civilian. After these inventions by the enterprises DJI and Parrot, the sector of aerial robotics has been satisfactorily accepted at an exponential rate in the research field as seen in Figure 2-8 and, also in the several industries.

Figure 2-8. Annual Number of publications *on drones since 1853-2022*



Source: Scopus database utilising the keyword Drones

In total, there are 22,360 documents divided between 1853-2022 until October 2021. The graph presents the tendency of the keyword of "drone" in publications. As shown in 2008 a peak of 713 publications and a declination of them in 3 years later. In the year 2020 seems to be repeating the same patter having a declination in the following years.

(Vanderhorst, et al., 2019) discussed how the United States, China, Germany, United Kingdom and Australia have been making significant publications on the topic of UAS for construction. Each country has their area of focus. In the United States is implemented the UAS successfully by the entrepreneurial growth in terms of managing the interoperability issue in the UAS solutions around the industry. In contrast with Germany, which has been used by the government to make safer infrastructure inspections. Furthermore, the United Kingdom has established a proper qualification method to validate the knowledge and standards of professionalism in the sector. Moreover, China has been manufacturing the UAS into the market, dominating the technology opportunity currently. In addition, others as China have been encouraging the development of UAS and company as DJI has changed the UAS experience since 2006. Finally, Australia has been used for agricultural and surveying purposes because of their large areas to be mapped and fertilized. Nevertheless, these countries are progressing along with their UAS market improving policies according to their country context, testing new technologies such as UAS for cargo and agriculture, incorporating them in their government tasks such as traffic supervision and bridge inspections. However, this field needs further research to address a higher understanding of these country UAS integration into their airspace. It is expected that new concepts, sensors, applications, barriers, businesses, and technologies with and inside the UAS will appear to manage and change construction projects workflows and risky tasks. However, there is insufficient literature that transcends the adoption process of UAS, covering the key drivers for adopting UAS, benefits for specific contexts, the barriers, business implications and frameworks for adoption. Some studies only convey the technical functions of the UAS but do not elaborate on the multivariable approach of having a UAS in an organization. For this reason, an automation strategy in the construction sector needs development considering the social and technical aspects concerned in the integration of technologies, into their workflow, as the UAS. The main purpose of the strategy is to provide knowledge and wisdom in the application process of UAS for policymakers, organization managers and construction professionals perspectives in the context of developing countries to reach higher levels of productivity and transparency in the construction works.

2.4 CASES OF UAS APPLICATION IN THE CONSTRUCTION OF THE BUILT ENVIRONMENT AND WORKFLOWS

The investigations on UAS are concentrated in regulation, applicability, UAS design, interoperability of the tools and real cases illustration. However, one of the most relevant problems on UAS is in the field of application as a consequence of the regulatory boundaries imposed by each aviation authority and the lack of awareness in applicability of the technology in certain cases, as discussed in the previous section.

In the perspective of UAS application, there is a complex issue regarding the capabilities and the tasks. Therefore, the case in which the UAS is deployed provides an easier understanding of the reach of the tool in the tasks rather than vice versa. The sensors most explored has been the imaging (RGB, LIDAR) sensor. As a result of this vision, technical buildings, infrastructure projects, urban planning for disaster management, and other projects were identified in the research.

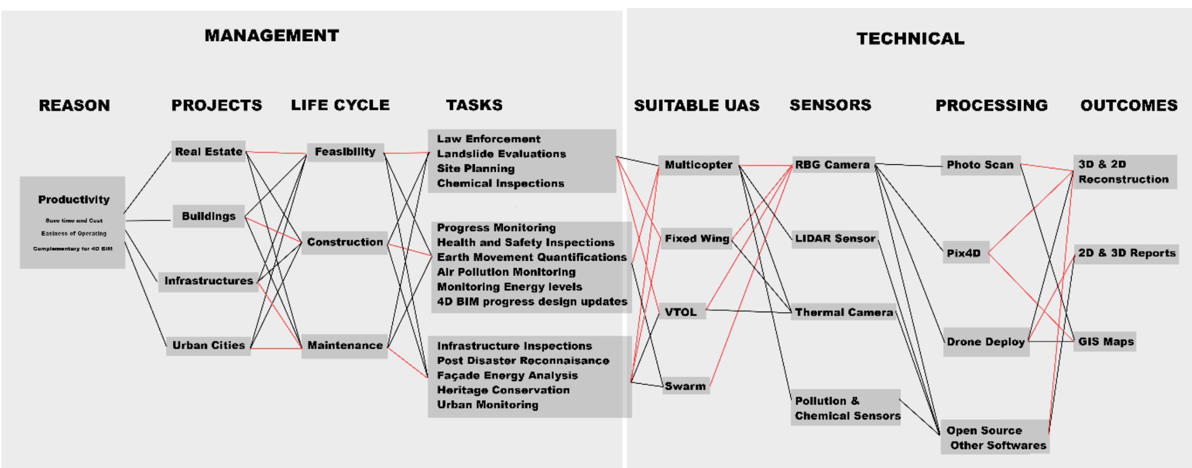
2.4.1 CASE OF UAS APPLICATIONS IN CONSTRUCTION LIFE CYCLE

During the project life cycle, from inception to demolition, the UAS effectiveness depends on specific tasks that fit its current capabilities and design. For digital strategies, the main driver for applying a UAS is the need of delivering quality, faster, understandable, and reliable information to the stakeholders in the projects. Currently, the technology is being presented as an emerging technology that is opening new possibilities to address the gap in digitalisation of the work. The future of this technology is making possible automation the construction industry to reduce fatalities, reworks, over costs and time dismiss as a consequence of human mistakes. Therefore, the combination of blockchain, artificial intelligence and autonomous robots will be managing step by step the industry presenting results on virtual reality bases such as cognitive cities, digital twins, and self-machine autonomous operations. The aspect of UAS cargo is embedding the chance to create transport and designs automated with the UAS.

The digitalisation of the construction industry is flouring the make more understandable the projects and satisfactory experience in order to achieve the client's expectation and create sustainable and cognitive cities across the world.

The educational sector will be reinforced by addressing the needs of implementing new technology, achieving a higher level of quality in the construction site, saving costs. The introduction of the UAS in the curricula is directed to surveying. However, progress reports and BIM applications are making possible the increment in the educational demand of the UAS studies. Therefore, systematic literature research was carried out to identify the tasks in construction as in (Vanderhorst, et al., 2019; Irizarry & Costa, 2016; Zhou & Gheisari, 2018). The ideas were chosen utilising keywords to figure out the key trends in the sector. After the literature research, it was arranged the findings for a second literature review encompassing the workflows, applications of UAS for construction of buildings, infrastructure, urban cities, and disaster management, dividing it into 3 major stages: Feasibility, Construction, and Maintenance.

Figure 2-9. Management and Technical aspects of the UAS application according to the Literature.



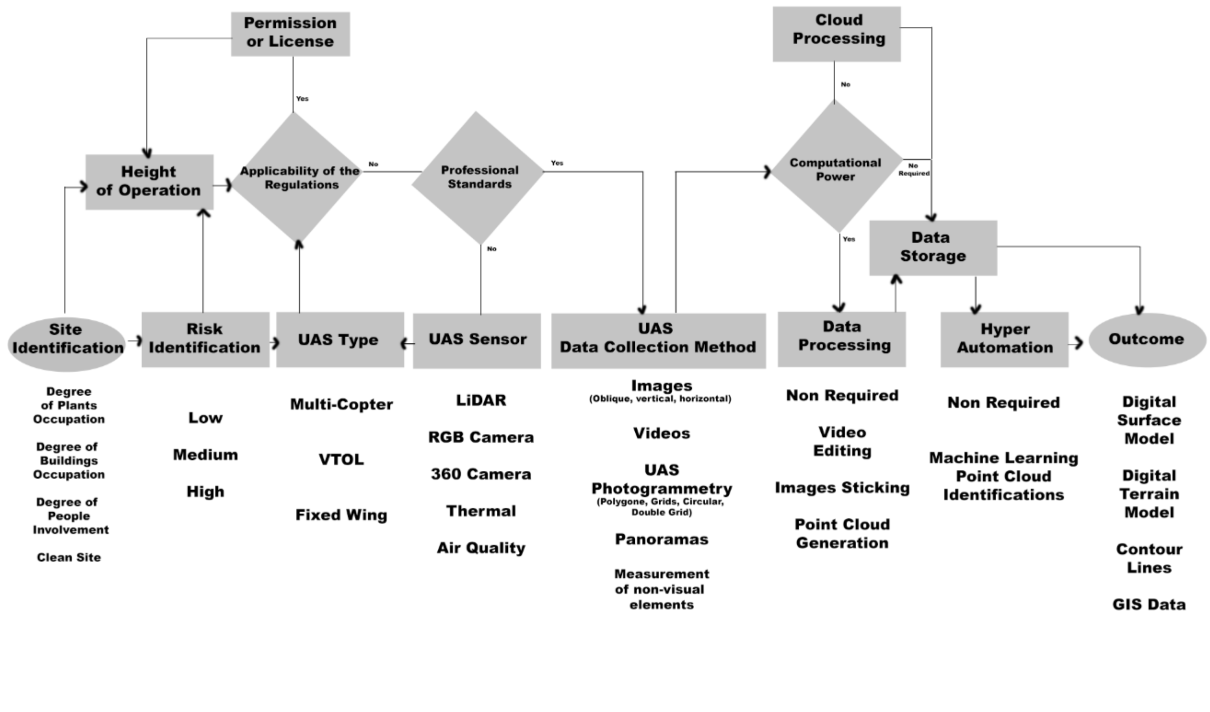
In this Figure describes the management and technical aspect involved in the application of UAS. In red lines are specified the priority of each item in contrast to the black lines that express a possibility of applicability but not the priority.

In a deeper sense, the workflow includes technical aspects of the UAS application that contains regulatory to explore before to carry out the work.

2.4.2 WORFLOW OF THE UAS APPLICATION

The UAS application in the construction of the built environment follows a general approach to assess any tasks with the UAS. In the literature was identified that according to the type of project specific sensors, camera angle, UAS photogrammetry technique, data management, software and interoperability barriers' the UAS workflow have different steps and implications. Figure 2-10 describe the workflow identified.

Figure 2-10. Workflow of the UAS application



The workflow combines different aspect that provide the suitable management approach of adoption in this technology. As policy makers must safeguard safety and the manufacturers and civilians are looking for automation practice, hybrid approach is commonly approach for UAS technologies. However, the workflow requires cases to provide understanding of the implications involved.

2.4.3 FEASIBILITY STAGE

At this stage, the project manager, along with the client, will define the objectives of the business case. A critical activity of this stage is the site selection and acquisition. In the site, attributes findings hold the credibility of the feasibility study. The study would be carried out by a specialist in the earthworks, consultants, and lawyers contracting a meaningful due diligence exercise. The importance lies in accomplishing the research and data gathered on-site, which might be assessed through google maps or visiting the area. These methods are appropriate to collect real data that later topographers and surveyors will determinately use costly and time-consuming professional equipment in contrast to the UAS application (Vanderhorst, et al., 2020). The UAS photogrammetry produces easy and faster surveys of the site that collects descriptions and attributes for generating digital terrain information, contour lines, and high-resolution images, even more, accurate than satellite-derived products in lower cost and less time than conventional surveying techniques and equipment (Zhou & Gheisari, 2018; Álvares, et al., 2018). However, there are a small number of cases that illustrate the usages of UAS in this stage. Moreover, (Zhou, et al.,

2018) provided a multidimensional framework of the applications of UAS, stakeholders and a clear classification of the construction stages. However, the framework lacks depth in the cases, an extended list of applications, and the cost involved in the process. The feasibility stage is not limited to land and plot of the projects; it also includes the field of environmental conservation, façade, and urban planning that in construction have not been fully discussed yet. The application of UAS allows the team of designers and builders to obtain data of the site for feasibility business case effortlessly by providing the site dimensions and terrain models. Therefore, studies of communities against disaster in prevention can be carried out as well as the viability of certain commercial and public projects such as highways.

This stage positions the UAS as a tool of survey and inspection regarding the present site conditions. Analysis of energy level, aesthetic of the project, 3D simulations and others are relevant to this stage. The UAS can be a vital tool for this stage because the problem solved by the UAS is the mobility issue of humans in gathering unattainable information.

2.4.4 CONSTRUCTION STAGE

In the construction stage, the position of the UAS application is different. The UAS is part of the information pipes within the construction of the project. It can be integrated within a digital workflow with BIM or with only photos and videos. The construction stage with a digital strategy and workflow with BIM is a complement of data along with indoor reconstruction as well. The relevant practices are in site monitoring, health and safety, logistics, quality inspections and the most known of marketing activities (Irizarry & Costa, 2016; Albeaino & Gheisari, 2021; Lin, et al., 2015). The process of acquiring data and compiling them in readable and understandable standards is the job of the BIM manager. The UAS data is complementary with indoor photogrammetry or LiDAR scanning, usable until the building or infrastructure erection, allow the organisation to record measurement of productivity of their employee, and the digital flow assisted by the UAS reduce costs significantly in the generation of reports (Asadi, et al., 2020). This approach in the literature is undertaken for high buildings and projects with extensive walk distances and earth movement quantification utilising Autodesk tools such as Revit and others. Further research has been carried out in automating the segregation of 3D reconstruction to make possible another software to recognise elements from the 3D reconstruction as their actual entity with artificial intelligence in the point cloud. However, it has been ongoing for many researchers based on the complex computational algorithms required to preclude the desired outcome. But, if it is attained, the records kept of the project of "where" and "what" was built aid the facility management team in its maintenance.

2.4.5 MAINTENANCE STAGE

In this stage, the facility management team consider maintaining the integrity of the infrastructure or building as it was built. With the past of the time, the materials, façade, usage of the building and functions of the infrastructure may change dangerously. For those reasons, inspections on bridges, high buildings, and public spaces are carried out for revision and avoidance of the structural integrity and regulatory building ornaments. In this stage, the UAS is normally applied for infrastructure cracks, high building painting inspections, façade maintenance and reconstruction that with the actual tools are costly, risky, and inaccurate (Falorca & Lanzinha, 2021; Tan, et al., 2021). Also, based on the amount of projects that the Department Of Transport (DOT) have in different countries, numerous research in this field has been embanked as direction to digitalise, reduce cost, agile and dismiss fatalities in the maintenance workflows of infrastructures (Costin, et al., 2018). Furthermore, infrastructure projects appear to have more traction with UAS rather than buildings. Therefore, a deeper view of the infrastructure sector is carried out.

2.4.5.1 CASE OF INFRASTRUCTURE PROJECTS

The maintenance of infrastructure is a costly task worldwide. Bridges, water supply, roads, electrical grids, telecommunications, railways, tunnels, and sewers are critical infrastructure in which UAS have been tested as effective. The rate at which the UAS is effective is stated as qualitative worth rather than quantitative values (Vanderhorst, et al., 2020). This lack concerns entities in updating their traditional method into a digital one. Therefore, many scientists have evaluated the effectiveness of the UAS by elaborating cases and frameworks for its application. A vast of cases and frameworks have been developed for DOT in projects. Bridge cracks identification, UAS photogrammetry patterns, 3D reconstructions process, the framework of UAS application for bridge inspections, and dam inspections are the most published cases of UAS application. It is summarised in damage quantification of the infrastructure projects. However, the literature lacks cases in which frameworks of infrastructure projects maintenance against disasters. Furthermore, other applications in the literature require maturity and investigations for major comprehension of the versatility of UAS with the perspective of disaster management and the role of UAS in urban planning.

Table 2-4. Literature review of the UAS application for Infrastructure Projects

No.	Infrastructure Projects	Tasks	Literature
1	Bridge	Cracks Inspections and 3D models	(Congress & Puppala, 2019; Congress, et al., 2018;
		Thermal Inspections	Duque, et al., 2018; Ellenberg, et al., 2015;
			Ellenberg, et al., 2016; Eschmann & Wundsam,
			2017; Hackl, et al., 2018; Hada, et al., 2017)
			(Hallerman, et al., 2018; Holst, et al., 2016)
			(Khaloo, et al., 2018) (Morgenthal, et al., 2019)
			(Holst, 2018)
2	Water Supply	Damage Quantification in floods	(Diakakis, et al., 2019)
		Monitoring riverine pollution (Plastic)	(Geraeds, et al., 2019)
		Quantifying erosion	(Hamshaw, et al., 2017; Hamshaw, et al., 2019)
		Precipitation Levels and erosion Quantification	(Hänsel, et al., 2018)
		Dam inspections	(Khaloo, et al., 2018)
3	Roads	Surveying, and Traffic Monitoring	(Jian, et al., 2019)
		Thermal Imaging	(Luo, et al., 2018)
4	Electrical Grids	Inspections transmission lines	(Forssén, et al., 2017; Huang, et al., 2018)
5	Telecommunication	Network Facilitator	(Fadlullah, et al., 2016; Gowtham & Gnanasundari,
			2015)
6	Railways	Monitoring Assets around	(Fellers, 2017)
7	Tunnels	Pipelines leak Gas detection	(Emran, et al., 2017)
8	Sewers	Sewer inlet localization	(de Vitry, et al., 2018)

In this table is assessed the relevant literature that identifies the UAS trend.

In each of these cases, the application of UAS shows examples of workflows supporting the ability to carry out tasks efficiently. In most of the cases, the use of algorithms with machine learning is presented to classify the 3D reconstruction or point cloud of the infrastructure. For instance, in the case of sewer inlet locations, algorithms are being used to identify these in a digital environment using the obtained georeferenced data of the sanitary installation and visual identification. However, the application of UAS is limited to visual data and automation with machine learning that require further investigation in applications with other sensors to understand how would be a city with multiple monitoring sensors? Therefore, combining BIM, record of the dynamics of the infrastructure before disaster, and the behaviour in urban structures is birthing a digital twin before disaster. For example, after several floods and dams collapsing, the maintenance of infrastructure projects before and after disasters is critical for developed and developing countries.

2.4.5.2 CASE OF DISASTER MANAGEMENT

In disaster management concept of aerial photogrammetry has appeared since the Second World War, bringing the innovation of Unmanned Aerial System (UAS or Drone) to be applied for military purposes. UAS are applied against satellite imaging by its high and real-time image resolution obtained, accuracy and low-cost solution (FranciscoAgüera-Vega & PatricioMartínez-Carricondo, 2017). The 2D and 3D reconstruction of the field allows the organisations to observe and appreciate the space-time situation during a disaster (Ham, et al., 2016). Then, other software is used to produce final outcomes on the field assessment as a geography information system (GIS), 3D reconstruction with (BIM) or point cloud identification with artificial intelligence. Another mechanical application of the UAS is the cargo one that investigations as a manner to provide a network and delivery of goods (Hwang & Choe, 2019) requires more investigations. Furthermore, there are 7 types of events that cause disasters. Geophysical, meteorological, hydrological, and biological events have shown implementation cases of UAS previous or post-event occurrence in the literature. The lack of UAS readiness and country context may change the viability of the UAS application. Regulation, environmental issues, liabilities, and organisations can be significant barriers to adopting aerial robot (Hamed Golizadeh, 2019). These barriers reveal that the lack of knowledge in undertaking digital strategies has reduced novel methods to address and investigate an instance of UAS applications such as monitoring sargassum migration to the beach coast of the Caribbean (Putman, et al., 2020) and situational awareness of sea oil overflow. Furthermore, the applications of the UAS for any geophysical, meteorological, and hydrological event is surveying the field in physical data and processing to initiate a decision process in terms of risk prevention, aids allocation, rescue, reconstruction, or mobility of people.

The information gathered and developed from the UAS telemetry, and cargo assessment are Visual assessment of the current condition; human replacement from risky tasks; structural assessments; urban Damage status; Aids allocation; Access to uncommunicated zones; Design and visualisation of human displacement safe routes; Infection focus identification; 3D reconstruction for visualisation; Cargo medical samples; Thermal inspections. For this evidence, in the Caribbean region, the main events that are mostly implemented the UAS are on cyclones storms and floods.

Additionally, strategies as the concept of a smart city are presented as a merge between the digital process behind the preparedness and response to the natural event. For instance, 3D reconstruction after the 2015 Nepal Earthquake for community resilience for damage visualisation (Pix4D, 2016), medical delivery support in front of rapid disease infections (Ochieng, et al., 2020; Edoh, 2018) and spread unfertile mosquitos against the disease proliferation are the applications identified along with GIS in some cases worldwide that could be considered as a smart city (Xie, et al., 2018; Vojinovic, 2008). In this perspective, the Humanitarian UAV Code of Conduct & Guidelines was found. This ethical guidance was developed by the industry and official bodies to gestate a harmonious integration during disaster management. One of the major concerns in this field is the qualification methods for safety reasons and also for professional perspective as in engineering for disaster management (Contreras, et al., 2020). In table 5 are shown the instances identified in the literature regarding the adoption of UAS (Vanderhorst, et al., 2021).

Table 2-5. Literature map of the UAS in the Caribbean Region

No.	Type	Events	Cascading Events (1)	Cascading Events (2)	Tasks
1	Geophysical	2010 Haiti Earthquake			Damage Assessment Situational Awareness
2		2020 Puerto Rico Earthquake	Earthquake Replicates		Damage Assessment
	Meteorological	2016 Hurricane Matthew Haiti	Erosions		Damage Assessment

3		2017 Hurricane Maria Puerto Rico	Floods	Tornadoes	Damage Assessment Situational Awareness Transport
		2005 Hurricane Wilma Florida	Ecological Shallow subsidence		Damage Assessment Situational Awareness
4	Hydrological	Cloudburst	2005 Flash Flood St Maarten		Damage Assessment Situational Awareness
		48h Rain Fall Storm	River Overflow	2004 Isla Hispaniola Flood	Site Reconstruction
5	Combination of Climatological Human-made	2020 Dump Wildfire Dominican Republic	Air pollution		Disaster source visualisation
6	Biological	2019 Coronavirus	Economic Crisis		Potentially Cargo aids and Spray
7	Human-Made	2020 Venezuela Oil Spill	Tourist Crisis		Situational Awareness

Source: (Vanderhorst, et al., 2021)

However, in the literature was not found a workflow insertion for the UAS for a public sector level or a real-case base. In the same line, the practices of the adoption process in public organisations are not found. Therefore, it is required to provide a strategic framework by mapping the application of UAS to reduce the scepticism, lack of knowledge and time in the adoption of reliable, practical, and effective tools for the disaster management in countries with periodically events occurrence, as the Dominican Republic as in (Vanderhorst, et al., 2021). However, how would be the role of UAS for disaster management in urban planning development take the perspective of infrastructure projects?

2.4.5.3 CASE OF URBAN PLANNING AND DEVELOPMENT PROJECTS

In a larger scale, the role of UAS requires explorations on its potential for urban planning. The exploration of the UAS application for urban planning development is emerging by the several usages that the technology is capable of addressing. The change management in learning organisations occurring with UAS and urban planning is related to cost-benefit solutions against resolution obtained from satellites. The UAS covers a real-time smaller range of area than satellites. UAS is currently assisting satellites to enrich the spatial analytic component of accurate geolocation data by monitoring city development and human mobility.

The urban planning tasks are addressed with technological tools such as satellites images, google earth, airplanes, and helicopter LiDAR and photogrammetry. Nowadays, the gaps and barriers that the tools present for making efficient and accurate works are reduced with the UAS; mainly with the purpose of data capturing, where UAS present feasible applications according to the sensors used for data capturing (Vanderhorst, et al., 2021). For example, monitoring traffic congestion (Gattuso, et al., 2021), air pollutants as O_3 and $PM_{2.5}$ (Li, et al., 2020), cities radioactivity levels (Sato, et al., 2020), rooftop photovoltaic potential (Yildirim, et al., 2021), monitoring wildlife and conservations in cities (Gonzalez, et al., 2016), and high rate of population growth (Vanderhorst, et al., 2021) are critical tasks that should be automatised utilising UAS.

However, research on urban traffic, cities design in favour of autonomous systems is currently lacking. Furthermore, consideration of cybersecurity should be considered. The UAS digitalise the physical world feeding a cyberspace database for AI cities in the future. The data acquired by the unmanned autonomous robots with access to a decentralised system with cloud-quantum computer supports the continuous data feeding designed to contribute to humans on their ascension process as mentioned in 2.3.4, Figure 2-3, and Figure 2-6. For instance, the identification of feasible aerial taxi routes, ideal building re-adaptation for UAS deployment sites, seasonal land-use changes, and elders villages allocations, sharing the social development of communities to others, and climate change risk plans will be some tasks for the future of smart cities. In addition, the 3D reconstruction of exoplanets explorations and space-time travels shall be possible in the future. Nevertheless, UAS for citizen mobility seems to be a future fact of observation for the next post-pandemic generation. Furthermore, the 3D reconstruction of the dynamics of the cities in a decentralised system along with UAS is a suitable option for the development of smart city concepts. However, in the developing country of the Dominican Republic there are not policies to introduce the concept of smart cities. Some initiatives have been carried out with public and private alliances; however, the integration of technologies, alive and spiritual entities is a provision desired for the future of urban evolution. However, would it be economically suitable the approach of digitalise cities? What would be the best option for the next 3 years for a viable UAS? is there a baseline scientific discussion on this kind of approach for developing countries?

2.5 BARRIERS OF UAS IMPLEMENTATION IN THE CONSTRUCTION

The use of Unmanned Aerial Systems (UAS) in the construction industry is an opportunity to make more efficient, faster, and safer work processes on site. However, the barriers of UAS and its adoption are primarily: (1) technical (2) restrictive regulatory environments, and (3) social that can only be addressed by exploring the workflows in the format of cases of studies (Hamed Golizadeh, 2019; Greenwood & Zekkos, 2019; Irizarry & Costa, 2016; Álvares, et al., 2018). However, these cases may not cover litigation cases and political issues that the UAS may attract that are specific for certain countries. The cases of study illustrate the application in terms of presenting the qualification method of the country; cases in which are assessing the suitability of the system in certain tasks; UAS photogrammetry patters; understanding of interoperability of the workflows by professionals and researchers in the construction sector across the world, time saving by utilising or not a digital strategy with BIM; and competitiveness of business models.

In this research was evaluated the barriers and concluded that the richness of the UAS process is in the reconstruction of scenarios as seen in (Vanderhorst, et al., 2020). Therefore, the barriers are discussed in the following sections through different cases.

2.5.1 QUALIFICATION METHOD OF THE COUNTRY, REGULATORY ENVIRONMENT, AND ETHICS

Historically, UAS has been used for military purpose by countries like the United States, the United Kingdom, and Australia in their surveillance operations in Iraq, Pakistan, and Afghanistan. However, UAS for civilians would be an unsafe factor to consider for governments and agencies. Different perspective exists for assessing the safety aspects of UAS, in terms of injury a person, privacy disruption, and third-party liabilities.

Public safe aspects involve the risk of injure people. When an UAS flies, multiple procedures must be taken before carry out the mission. The regulations of the country have considered numerous factors according to their life context by

2017. However, the relevant risk that a UAS may face is in the design terms. The UAS may have technical difficulties will cause an electric malfunction during the flight or battery fails problems that could affect the decision in adopting it. The implications of these limitations are evidenced against weather condition as an external factor that provoke issues in any UAS operation. Nevertheless, operating with specific type of UAS under certain airspaces is considered as an attempt to safety. The presence of human factor in this scenarios could cause hazard to properties and third parties involves as incidents presented at the Gatwick Airport (BBC.com, 2018) (BBC.com, 2017). For these reason, training and certification provide a safety mindset contributing to have flexibles regulation, the UAS market development and, the hazards are reduced by implementing the UAS in any discipline of study.

Other factor involved in the UAS operation is the privacy concern. A UAS is used commercially in the society, and several unique ethical, technical questions, and cases that must be assessing before fly the UAS are found. The purpose of the data gathering, permission of face recognition, ownership of the data gathered, and more are some examples of the evaluations regarding privacy made prior operations. Moreover, the future of remote ID for UAS, digital ID of people linkage with their face factions and unsupervised machine learning algorithms inside the UAS operations will, consequently, encounter a digital transformation and humans consciences alteration in the current radio of ethics and moral actions. An old example is the Australian Real Estate company publishing unconcerned pictures in a public physical post (Kleinman, 2014). This accidental photograph has triggered many ethical questions about the UAS use. After safety and privacy infringements exist observations when commercial UAS operator are in residential areas. However, after the incident (Clothier, et al., 2015) has presented an analysis which demonstrated that the Australians think that the UAS are not a significant concern to the public yet. Similarly, perceptions of the benefits and the overall acceptability of the technology are also neutral in the study. (Clothier, et al., 2015) explains that the neutrality of the responses suggests that the public has yet to form an opinion in relation to UAS. For instance, some problems can appear for professionals who have not taken a formal education about pilot a small aircraft in their sector (construction, Photography, Films, etc). Another aspect is the insurance which are created for cover the third-party liabilities if an uncontrolled event occurs. It is concerned that a professional UAS pilot shall carry an insurance that satisfy the operation requirements in case of accident.

Through time, the UK have a record of complex regulation establishment in the airspace with the subject of UAS. (Cunliffe, et al., 2017) describes the process of obtaining Permission for Aerial Work (PfAW) from the UK's Civil Aviation Authority (CAA) to fly a UAS for commercial work in 2016. Commercial operations are defined by the CAA as any operation that will receive a payment or value for it. In the same line, this concept has been defined as a consequence of the ethical issues by the UAS pilot uses between professional and hobby purpose as mentioned by (Herrmann, 2016).

The CAA requires evidence that the UAS will be operated in a safe manner by the organization concerned. The evidence are: passed an appropriate theoretical knowledge of airspace law, flight planning and operational procedures, summits an Operational Manual (GVC), and demonstrate a practical flight level competency.

The process is a time consuming process and some items price should be contemplated such as training & flight assessment, insurance, UAS and Permission. The operational manual is for all people who want to do a commercial activity in the UK with a UAS. In other countries such as Spain has similarities in the procedures, but the penalties are higher than the UK. In America, the United States have taken steps to develop the UAS market adjusting the regulation according with the innovations presented. Otherwise, the market must manage the lack of differentiation between hobbyist and professionals which has been a controversial topic in the United States (Herrmann, 2016) .However; The Federal Aviation Administration has established a process to solve it. The process is based on pass a theoretical test to get the credential (FAA, 2017).

Another point of view, Australia has the same procedures as the UK although it has a classification for very small aircraft between 100g to 2kg. This category has been created to operate commercially under standard operating conditions. Undertaking the permission would require an ARN or aviation reference number, notifying the authority before the flight and the practitioner should gain some basic flight knowledge. However, CASA suggests that getting an operator certificate (2kg to 25kg) would be a path to get into a professional career and obtain advantages for some operations cases (CASA, 2017) (Clarke, 2016) (Latteur, 2016). Furthermore, the following table will compile the countries process and operations limitation to make a generalization case for 2017.

Table 2-6. Airspace regulations regarding UAS 2017

No.	**Description**	**Australia (CASA)**	**UK (CAA)**	**EU (AESA)**	**USA (FAA)**
1	Credential Method	Operational Manual	Operational Manual	Operational Manual	TEST
2	Foreign Credential Acceptance	Possible	Possible	N/A	No
3	Research Affairs Require a Credential	N/A	If it is for commercial Purpose	YES	Special Waiver
4	Credential Classification Acceptance	Small UAS	Small UAS	Small UAS	Small UAS
5	Distance From the UAS VLOS	must have a visual observer always	Up to 500 m	Up to 500 m	must have a visual observer always
6	Maximum Height	400 ft	400 ft	400ft	400ft

The table has presented the relevant details that a foreign operation might require to know previously fly a UAS.

In Latin America the scenario is currently the same but with less restrictions than more developed countries. Some studies and experiments have been carried out in these countries trying to map and enhance the adoption process of the technology. For example, a socio-technical framework for disaster management explain the adoption process in the Dominican Republic (Vanderhorst, et al., 2021), a UAS community map and their participation in Latin America (Vargas-Ramírez & Paneque-Gálvez, 2019), and the improvement on cadastral practices in Uruguay (Aparicio, 2017). However, these efforts are very focalised and may do not provide a full description to assess the gap in knowledge regarding UAS in the Dominican Republic in terms of safety and privacy concerns.

2.5.1.1 2021 UPDATED REGULATIONS

In the case of UAS less than 150 kg, the regulatory framework is in charge for national authorities of each country. The regulatory system for UAS during the thesis development has changed almost yearly in the UK, EU and other countries producing, in some scenarios, uncertainty, generation of legal UAS advisors, and economic instability based on the permissions and license validations for UAS operators, training and certified centres. However, during the pandemic, Europe was proposing a 3-year regulation of UAS operations to reduce the effects mentioned. In contrast to the Dominican Republic that only 2 changes in the regulation were made, expanding the regulation scope to swarm of drones, cargo drones, etc, however, requirements of clarity are needed in terms of credential obtention and certified schools.

In terms of regulations, the UK legislation has articles that enforce safety aspects in UAS airspace and operations with CAP 722, their sections A,B,C,D,etc, and future notice modifications for 2023. The document contains the most relevant concepts, definitions, and operation details. The minimal distance of flying aircraft to people, properties and acknowledgements of flight permission is mentioned. Currently, the regulation in the UK has changed significantly, homologating the EU regulation. There is a matrix of risks that classify UAS by weight with type of operations, and training requirements as in the figure below. Each definition of UAS is aligned with the weight and the type of operations that the UAS should be involved in as well as the qualification that the pilot may have before the mission. There are complex procedures to operate UAS in congested areas utilising the specific category in the UK and EU. Furthermore, Specific Operations Risk Assessment (SORA), Light UAS Operator Certificate (LUC), Pre-Defined risk Assessments, General VLOS Certificate (GVC) and other operations requirements provoke to understand that UAS pilot in these nations should be a robust qualified and experienced person to navigate safely. Therefore, an unofficial UK consolidation of the equivalency of UK and EU regulations are under the CAP1789A for the (EU) 2019/947 and CAP1789B (https://www.caa.co.uk/).

Figure 2-11. EU regulation of UAS 2021.

Definition	Weight	Type of Operations	Registration	Qualification	Age
C0 Makers Drones Drones Before 1st January 2023	<250g 	A1 Open Toy	Depends on the sensor	Read Manual	None
C1	<900g 	A1 Open Highlands Photographs	YES	Read the manual Online training Course Pass Online Theoretical Exam	16
C2	<4kg 	A2 Specific Close to people Surveys	YES	Read the manual Online training Course Pass Online Theoretical Exam Declaration of Practices Written Exam to CAA (Equivalent)	16
C3 C4 Makers Drones Drones Before 1st January 2023	<25kg 	A3 Certified Dubai Drones for Rain	YES	Read the manual Online training Course Pass Online Theoretical Exam	16

Source: The pictures of the table are from internet.

The Figure illustrates the UAs categories according to the limitation in the operations and certifications requirements. In yellow is covered the type of operations that C0 and C1 can carry out. Subsequently, in pink is illustrated the operations for C2, and in red is covered for C3 and C4 with their operations restriction.

In other countries, the responsibility of airspace could rely on first in an online test and in councils requirements as the United States. However, it is important to understand that each city in the world may have a different level of risks involved when UAS operations are integrated into the airspace. The variable of proximity to airports, privacy, and congested areas adds to the UAS operations complexity when it is discussed the understanding of location base regulation. For this reason, each country may differ their regulation and their security factors in terms of qualification, UAS manufacturers and certifications of entities and devices. Furthermore, in the Latin America, Brazil (Brito, et al., 2020) and Uruguay (Aparicio, 2017) have been investing in UAS for urban development and some of the limitations are found in the Europe are still not in force in these countries. In the Dominican Republic, the regulation has only had 2 changes since the first release in 2015. The transitory regulation of 2015 until 2020 liberate the restriction of UAS operation with a C2 and A1 and A2 operations. However, the liberation or flexibility in aeronautical knowledge for UAS operators does not alter or affect the wisdom on UAS application of specific domain as this research is intending to cover in the realm of construction.

In construction where exist hazard zones, the safety liable falls into the UAS. (Tuttas, et al., 2016; Hamed Golizadeh, 2019) express their experience and framework in construction site using UAS. In a general view, the barrier of safety, knowledge in software, photogrammetry techniques, reconstruction of sites, and limitations on the device reduce the effectiveness of the UAS works. For instance, developing an operational manual as an example of safety and tasks in construction deploying UAS would be a guidance for other pilots and inexperienced practitioners to create their own procedures. Moreover, it could be used by researchers in countries with less stringent airspace regulation (Cunliffe, et al., 2017).

In summary, the insufficient knowledge for training UAS pilots for construction, the implications in construction regulations, compliance with the UAS regulations according to the country, UAS selection concerning the price accessible for companies, and safety practices which involve privacy concerns a deeper view in technicalities of UAS applications is required to understand how it would be fit into the context of the Dominican Republic.

2.5.1.2 CASE OF THE UAS REGULATION IN THE DOMINICAN REPUBLIC

The Dominican Republic is a developing country in the Caribbean region that in the last 10 years, have been investing in construction and technology to grow economically and enhance the lives of their citizens. The literature refers to the construction industry as one of the largest sectors that contribute to the GDP. Disregards that the country economy is under development, the need for automation with sophisticated tools have not yet arrived. Therefore, the following literature review touches on the aspects in which the country could benefit from the upgrade in their operation with UAS. The country, during the project life cycle of a construction project, faces the conceptualization of the project, construction, completion, and restoration of them before the disaster. Therefore, the literature review covers the aspects mentioned briefly.

The regulatory environment of UAS in the country has a second change since the first regulation was promulgated in 2015 (Resolucion 008-2015). This resolution was a basic guidance of UAS operations, restrictions of operations, and alternative in case of carrying out operation beyond the limited established (more than 400ft, Swarm of UAS, UAS for cargo, etc). Then, the proliferation of these aerial robots has been progressively by public and private institutions in which changes were needed to put in place. For example, public institutions were exempted from boundaries on their operations in certain cases if safety measurements were taken in place by the institutions. Based on this kind of exemption, clarification on the operations liabilities would raise concerns at some point. In addition, the early adopters, UAS operators, experienced regulatory cases in which improvements on overseas operators, license renewal, incidents on operations close to people and airports, privacy concerns, lack of specialised education of UAS and many other requirements were required.

For these reasons, two publications from the Dominican Aeronautical Regulations (RAD) were introduced in 2020: RAD 48 and RAD 107. In terms of regulation structure, the current regulations present similarities to EASA and FAA policies but recently added the educational component in relation to training as the CAA does with the PFCO process. It means that the requirements for licencing UAS commercial operators with an UAS less than 5.7kg are required to pass a test from one of the organisations authorized to provide reglementary instructions for safe UAS operations. In terms of sanctions, the past and present regulations conceived the legal mechanisms for inappropriate use of UAS flight on restricted zones and transportation of harmful substances without government authorization. Furthermore, inappropriate application of UAS trigged sanctions which are implied by the regulation and by the military force.

However, clarification of the liabilities and examples shall be mentioned. In addition, the lack of knowledge on UAS capabilities and specialised professionals not only in the country, also globally, precede investigations in this field. Furthermore, the regulation does not contemplate provision for certification in the specific fields of the construction industry. The regulations only cover the piloting capabilities rather than technical ones. Therefore, schools, universities, private, public, and non-profit organisations are looking to certify their UAS pilots with their own qualification method but how do we know who is certified to teach UAS photogrammetry technique if it is a new field under development?

In the construction of the built environment, there are different types of elements in which the UAS photogrammetry techniques, the applicability of the UAS, the 3D reconstruction, and the cost of data extraction are complex, converting the scenario into a multi-variable problem. However, the trend on digital economy and preservation of the architecture of the built environment as the metaverse, in digitalising the physical space, seem to be a vision to tackle limitations of human's materiality that eventually will leverage the coupling joint of reducing complexity in the moment and place to utilise the techniques. Therefore, digital data acquired by the UAS contribute to any type of organisation, in construction, as a constitution of the foundations for Building Information Modelling (BIM) in the Dominican Republic called as a digital strategy. Furthermore, the impact of this digital adoption is also extrapolated to the technification of cities, promoting a holistic digitalisation of future-proofing the built environment, which is vital for the recovery stage post-disaster. In a more general sense, the technification of the cities enable modern methods of transport and infrastructure to be developed in the city by the creation of digital twin as UAS taxi and others, as mentioned in (Vanderhorst, et al., 2021).

Therefore, it is required to understand the cases in which the UAS are applicable and how the complex matrix is designed according to the literature review and deliver a useful framework for agencies and government to understand the role of this technology in a multi-dimensional manner of stakeholders.

2.5.2 BUSINESS OF UAS IMPLEMENTATION AND STAKEHOLDERS

The business implication of the UAS has a different perspective in which to explore. The multiple applications of UAS provide another complex issue regarding the business model according to the tasks and stakeholders receiving the data. In the literature, there is not sufficient information concerning the suitable business model of the UAS implementation as a consequence of changing regulations, applications, and UAS availability. The business model to explore is described by (Opfer & Shields, 2014) who express that UAS is a service subcontracted by construction companies. However, in 2016 (Irizarry & Costa, 2016) estimated the associated cost of UAS on construction sites, but additional costs of regulatory compliment and wage for the spiritual pilot were unavailable to determine.

Figure 2-12. Matrix of tasks and business models

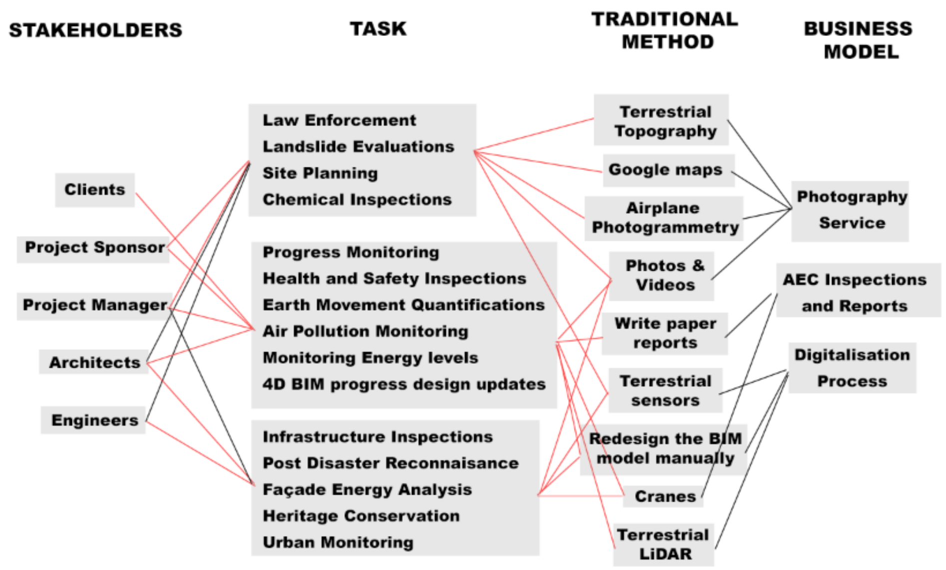


Figure 2-12 present the tasks, stakeholder interests, comparison against traditional methods and the suitable business models.

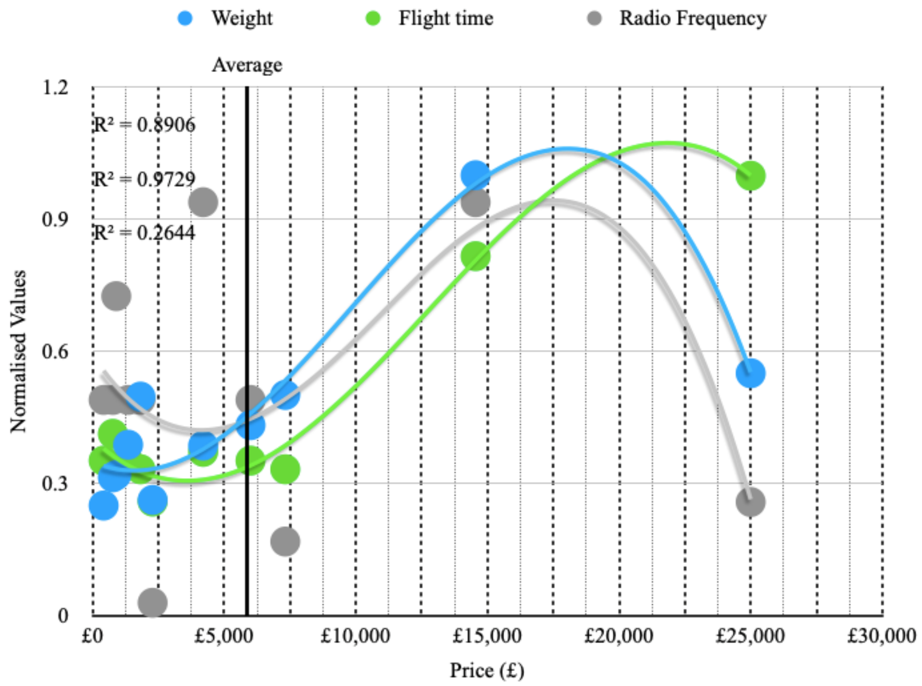
Therefore, after the development of frameworks and workflows of how is utilized the UAS in an organisation the business opportunity emerges as could be for public and private organisations. Further collaboration between these entities and the advancement of the technology could be reflected in the applications of smart contracts (Hunhevicz, et al., 2021) and the newest digital spaces, the metaverse, will also influence partnerships, business, alliance and costs. But the first step to understand the cost structure is the selection of UAS. (Greenwood & Zekkos, 2019) specified models for the starting point but does not bring monetary value, regulatory fitness and other details that can guide into the right decision. In Table 2-7 was developed an estimation with the regulatory boundaries in force for 2021 in Europe for context purpose, subsequently the details of the items and in Figure 2-13. In addition, Figure 2-13 is plotted the tendency of the model with inferences regarding price.

Table 2-7**.** UAS Prices, Weight, and technical details

UAS Name	Price (£)	Weight (g)	Battery time (min)	Distance (km)	RBG Sensor	Thermal Sensor	RTK	LiDAR	Speaker	Light	Regulation	Operations	Training
DJI Mini 2	419.00	249	31	10	12 MP						C0	A1	
Mavic Air 2	769.00	570	34	10	48 MP						C1	A1-A2-A3	
Dji Air 2S	899.00	595	30	12	20 MP						C1	A1-A2-A3	
Mavic 2 Pro	1,349.00	907	31	10	20 MP						C2	A2-A3	GVC
Phantom 4 Pro V2.0	1,819.00	1375	30	10	20 MP						C2	A2-A3	GVC
Parrot ANAFI THERMAL	2,280.00	315	26	4	21 MP	X					C1	A1-A2-A3	
Parrot Ai	3,600.00	898	32	15	48 MP						C1	A1-A2-A3	
Mavic 2 Enterprise Advanced	5,998.80	1100	31	10	48 MP	X	X		X	X	C2	A2-A3	GVC
Phantom 4 RTK	7,320.00	1391	30	7	20 MP		X				C2	A2-A3	GVC
Matrice 300 RTK	14,550.00	6300	55	15	20 MP	X	X	X			C3-C4	A3	GVC
eBeeX	25,000.00	1600	90	8	19.96 MP	X					C2	A2-A3	GVC

Source: (*Vanderhorst, H. R., Heesom, D., Suresh, S., Renukappa, S., & Burnham, K. 2022).*

Figure 2-13**.** Polynomial tendencies of the weight, flight, and Radio Frequency distance with normalized values.



The Figure shows the number of standard deviations of three main factors of acquiring a UAS. The optimal scenario would be composed by UAS with low weight, high flight time and radio frequency. As shown in the figure, as the price increase, the barrier of autonomy is reduced. In other words, the factor of aerial autonomy infers directly in the price in contrast to other factors. UAS with price around £5,000 present similar attributes of performance rather than others below the average range. UAS above the average tend to have a longer flight time and reduced radio frequency comparing with models below the average, for exception of the one with internet of things integrated.

The Figure 2-13 shows that UAS around £25,000 comply with high standards of flights in contrast to UAS below the average. But it is important to clarify that design of the UAS may affect the performance in certain tasks and it is wise to consider two designs options above the average. Therefore, UAS around £15,000 have more appropriate performance in professional tasks rather than the average UAS. In summary, Table 2-8 shows an estimation of a scenario in which UAS is adopted in an organisation.

Table 2-8. Estimation of UAS initial Investment for Construction organisation

Items	Initial Investment	Description
Equipment UAS Quadcopter	£11,111.00	DJI Phantom 4 RTK
Equipment UAS Fixed Wing	£30,130.00	VTOL and Sense Fly eBee
Ground Station	£7,250.00	Additional Control Stations
Training and Compliment with Regulations	£1,333.00	Skills and Qualifications
Processing	£12,600.00	Software for Processing 3D maps
Total	£62,424.00	

Source: *(Vanderhorst, H. R., Heesom, D., Suresh, S., Renukappa, S., & Burnham, K. 2022).*

The costs presented are intended to be a guide to explain the statement that the UAS is a specialised service (2.3.5). They are cost effective for organisations willing to implement the UAS. Furthermore, there are cases in which open-source software are available for reducing the initial cost of investment. Furthermore, UAS with lower prices address photography tasks similar to the above average ones. The cost weight is focalised in the UAS and software to convert the data into an output useful for the organisation. There is a model that includes internet for their operations. The internet will allow in the future to make remote operations. Furthermore, this UAS with less than 5kg can smoothly integrate artificial intelligence for remote operations that policymakers may contemplate in the future mentioned before in (2.3.4). Furthermore, issues on interoperability should encounter in the adoption as well as processing power. In other topics, the business model to exploit the initial investment will be normally for photography, digitalisation, inspections and teaching other organisations how to improve their workflow or seldomly address tasks as shown by (Vanderhorst, et al., 2020; Opfer & Shields, 2014).

In the Dominican Republic context, there is no literature that can provide insights of the market. However, images and photography are well known for the purpose of marketing. The initial cost of the UAS could represent a barrier in developing countries in addition to the dismiss of digital strategies in the organisation. Therefore, it is required an analysis of the literature to summarise the ideas and understand the next step for investigation in the land of the Dominican Republic.

2.6 DISCUSSION AND PESTLE ANALYSIS OF THE LITERATURE REVIEW

2.6.1 LITERATURE REVIEW DISCUSSION

The literature illustrates that UAS would be the next generation of monitoring construction performance as a bridge to migrate costly old-fashion process into digital and affordable solutions. The investigations presented show the construction stages in which assessing a UAS operation on work sites produce significant increment in the rates of productivities in the data collection process, and data analysis by images or a completing 3D model with artificial intelligence for BIM models. In addition, the tasks of monitoring safety, evaluation of the civil infrastructure conditions, and rapid communication of the project update on-site and off-site project are carried out faster than the traditional methods. The introduction of active digital twin simulations will arise the capability of on-site visualisation and monitoring tasks, cities behaviours and the adoption of other technologies for the 4th industrial revolution. Internet of things everywhere and the application of UAS for delivery, surveillance, and buildings, infrastructures in cities seems to be an indicator in the route of smart cities. Consequently, cloud digital twin cities models with real-time UAS autonomous aerial humanoids could be an insight of forecasting the future of robotics and cities after the pandemic. These benefits in communication can be mixed with lean construction principles and the last planner system to enhance the optimal potential of the images obtained.

During the stages, the UAS can be applied for specific tasks. However, the main driven to implement it is the need of delivering quality, faster, understandable, and reliable information to the stakeholders in the projects. Otherwise, technology is being presented as an emerging technology which is opening new possibilities to address the need for quality and efficient work. The future of this technology is making possible automation the construction industry to reduce fatalities, reworks. over costs, and time dismissing as a consequence of human mistakes. Therefore, artificial intelligence and autonomous robots will be managing step by step while the industry is presenting progress on cyber space basis. The aspect of UAS cargo is embedding the chance to create transport and designs automated process with the UAS but are not the focus of the study. The digitalisation of the construction industry is blooming, and it is making more understandable the projects and satisfactory experience achieving client's expectation and creating the foundations of sustainable cities. However, there are barriers to be surpassed before the vision can be accomplished. Ethical concerns, high-speed internet, computing power, UAS long-life battery, software development in machine learning and understanding of human wisdom for organisations are main factors to investigate in-depth globally and for the Dominican Republic. Thinking about the gap in knowledge, the idea of education should be included as part of overall barriers of UAS adoption. If educational centres provide knowledge regarding the implementing of new emerging technologies (UAS, Blockchain, 3D printers and others) the conscience in the humans transcend the disadvantages of lacking innovation in the construction industry. Therefore, the introduction of the UAS in the curricula is directed to surveying and inspections for first step forward in advancing the industry. In the same line, need of guidance for UAS workflow insertion for different types of organisations and record of practices in the adoption process are required to develop. In addition, resistant to change by scepticism and lack of knowledge in the field are barriers to surpass during the adoption process. Furthermore, in the literature was found that simulations of UAS applications are commonly rather than actual application cases. It means that an entrepreneurial factor, alliance between academia and industry should be made the foundation of research, development and innovation. Ontologies based on epistemological data should be developed in order to represent in a human understandable manner the adoption of UAS. Finally, in terms of business implication, a need of develop a consistent cost structure basis would be desired to comprehend the adoption process economically.

Table 2-9. Pestle Analysis

Factor	Political	Economical	Social	Technological	Environmental	Legal	Literature

Description	Restrictive Regulation	Organisational	People Perception	Technical difficulties	Environment of the operations	Legal Cases	
Core Ideas	○ Aircraft Traffic restrictions ○ National regulations ○ Certifications for pilot and light ○ Insurance Policies requirements ○ Privacy Concerns ○ Public safety ○ International, regional, and Local legislation	○ Acquisition, setup, operating, and maintenance costs ○ Management and owner support ○ Drone operations Redundancy ○ Quality assurance of data capturing	○ Location ○ Safety ○ Fear ○ Accidents	○ Large volume and losses of data. ○ GPS signal failure. ○ Inefficient flight paths. ○ Lack of accuracy on site dynamics, resolution, geolocation, user-friendly. ○ Lack of communications with humans. ○ Limited Flight duration, Payload. ○ Battery Life ○ Drone design and fabrication	○ Interferences with project activities ○ Resistant to weather conditions ○ Site conditions and obstructions ○	○ Liabilities ○ Ownership of the Drone ○ Recklessness behaviours ○ Insurance coverage liabilities range	(Golizadeh, et al., 2019) (Hassanalian & Abdelkefi, 2017). (Duffy, et al., 2017)
Literature Discussion Headings	2.3.1 FITTING UAS IN A NATIONAL STRATEGIES RELATED TO CONSTRUCTION OF THE BUILT ENVIRONMENT 2.3.2SELECCTION OF SMART CITY STRATEGY FOR TECHNOLOGY IMPLEMENTATION 2.3.3VISION OF PRODUCTITIVE WITH AUTOMATION IN THE BUILT ENVIRONMENT AFTER COVID-19 CONSIDERATIONS OF INDUSTRY 5.0 & SOCIETY 5.0 2.4.2WORFLOW OF THE UAS APPLICATION In these sections the reasons of adopting technologies are exposed to the government audience. Strategies and benefits are discussed for a top-down approach. However, the cases of application in the technological variable provide the justification of intending digitalise the built environment. Furthermore, considerations of mal use of the technology should be considered.	2.3.4ROBOTICS, TECHNOLOGY AND PEOPLE: AUTOMATION CONSTRUCTION INDUSTRY 2.3.5BUSINESS IMPLICATION OF AUTOMATION WITH ROBOTS AND COMPETITIVENESS 2.3.6ECONOMIC IMPACT OF AUTOMATION PROCESS WITH ROBOTS In these sections is presented how robotics automate construction, the business implications when using them and finally how the benefits impact in a country with cost reduction in general terms.	2.5 BARRIERS OF UAS IMPLEMENTATION IN THE CONSTRUCTION 2.4CASES OF UAS APPLICATION IN THE CONSTRUCTION OF THE BUILT ENVIRONMENT AND WORKFLOWS The barriers presented in these sections reveal that social aspects of qualification method for specific and the scepticisms related to regulation and practice.	2.3.4 ROBOTICS, TECHNOLOGY AND PEOPLE: AUTOMATION CONSTRUCTION INDUSTRY 2.4.1CASE OF UAS APPLICATIONS IN CONSTRUCTION LIFE CYCLE In these sections are described the type of robots and sensors to apply in construction industry. The cases through the project life cycle.	2.3.2 SELECCTION OF SMART CITY STRATEGY FOR TECHNOLOGY IMPLEMENTATION 2.4.5.2 CASE OF DISASTER MANAGEMENT 2.4.5.3 CASE OF URBAN PLANNING AND DEVELOPMENT PROJECTS In these sections the application of UAS that benefit the environment are mentioned.	2.4.1CASE OF THE UAS REGULATION IN THE DOMINICAN REPUBLIC 2.5 BARRIERS OF UAS IMPLEMENTATION IN THE CONSTRUCTION 2.6DISCUSSION AND PESTLE ANALYSIS OF THE LITERATURE REVIEWBUSINESS OF UAS IMPLEMENTATION AND STAKEHOLDERS In these sections are described the legal implications regarding UAS in general.	
Methodologies Recommended	Qualitative In this approach is intended to gather the political perspective of UAS in the country.	Qualitative The economic perspective of UAS is interested to gather asking the business models of this industry.	Qualitative The perception of digitalisation, education, training, and general perspective is object of interest for the research	Quantitative In this aspect, the cases of application are crucial for understanding the limitations, safety concerns, business implications with UAS. The quantitative approach allows researchers to experience the effort and get knowledge on operating the UAS as it is the key element for humans' involvement.	Quantitative In this approach it is considered to gather factual data related to the benefits of the environment that UAS brings in terms of change management.	Qualitative The approach intended to take support the understanding in the relevant concerns that the UAS may rise during its application.	

Furthermore, the barriers of business implications could be explored as an opportunity of implementing decentralized smart contracts, autonomous drones with unsupervised machine learning to improve or test different political systems in the future. Moreover, in the PESTLE analysis is seen a clear understanding of the relevancy of UAS implementation barriers for the construction industry.

However, it does not may represent the same phenomena in each country and location base on the regulatory and in political aspects involved in the adoption process of UAS.

2.7 SUMMARY OF THE LITERATURE REVIEW

The literature review presented an overview of the key reasons of adopting a UAS into a national strategy. The UAS is a tool for enhancing automation via digitalization in the construction industry. There is a plethora of reasons and applications of UAS but the one that is mostly concerned to the Dominican Republic is currently the BIM implementation. In a technical level, the UAS is a professional tool that helps to reduce risk and cost, but there is not enough evidence that can sustain that believe. Furthermore, there are barriers that affects the implementation of the UAS. The regulatory boundaries of the UAS are a barrier presented in the literature, however for the Dominican Republic does not represent a major barrier instead, as the country is a developing country, cost of acquisition and knowledge in the application should be a relevant fact to explore. Nevertheless, ontologies for UAS adoption and epistemological illustrations of implementation for the country from academia perspective are not found in the literature for this context. Hence, there is a need to investigate further the implications of UAS application in the context of the Dominican Republic relating to the key drivers, barriers, cases of UAS application, and business opportunities that can contribute to educational field of construction professionals.

3. CHAPTER III – RESEARCH METHODOLOGY

3.1 INTRODUCTION

This section explains the research methodology approach of this study. The nature of this research is related to observing and understanding the UAS adoption process in daily activity in the developing country of the Dominican Republic. The research pursuits demonstrate the impact caused by the automation strategy in construction projects applying the UAS as a tool. The aerial robot has presented proof of favourable economic growth in its applicability. However, there is a gap in business cases and awareness of technology in the literature and the actual construction industry. This approach to investigating information technology tends to be designed by quantitative approaches rather than social science. However, the nature underlaid in the UAS implementation affects multiple stakeholders such as policy makers, educators, technicians, researchers, construction organisations, and UAS manufacturers. Therefore, a social and technical theory discovery and design were made. This chapter discuss the methodological approach of previous peer-reviewed papers and the considerations of how incorporate those thoughts into the thesis. As previously required to read the contributions of this research, in the disclaimer section, the explanation of the overall research methodology utilised in the literature review, research and trustworthiness of the framework are presented. The chapter contain the details, thought processes and aspects related to the research methodology in UAS implementation for the construction industry in the Dominican Republic.

3.2 OVERVIEW OF THE RESEARCH

The research presents different approaches to attain the objectives. The research began with insights of a Msc degree dissertation at the University of Wolverhampton as a foundation for expanding the scope of that research. First, the barriers of UAS were evaluated, indicating that there was a gap in knowledge from an educational perspective of pilots and professionals in general in the Dominican Republic. Then, it was built a scientific data based utilising Scopus. The University of Wolverhampton provided training in this database that it was accessible for the researcher to build the secondary data analysis repository. But how would it be the wisest route to synthesize and find the barriers of UAS? The answer was keywords. Unmanned Aerial System (UAS), Unmanned Aerial Vehicle (UAV), Remotely Piloted Aircraft System (RPAS), Unmanned Aircraft (UA), drones, and others are the common names, accordingly to the field of research or just the type of operations that are carried out. (Vanderhorst, et al., 2019; Vanderhorst, et al., 2021) discuss approaches to build and search on databases the topic of UAS and the key aspects to evaluate to find the knowledge of interest. For technical aspects in construction, the keywords are normally the UAV, but for the audience of regulatory bodies UAS is commonly. RPAS and UA are concepts that may be utilised regarding the weight and field of application.

For this research, the audience research involves policy maker, industry, and contractors of the construction industry. Because the aim of this thesis is related to building a framework that communicates information for policymakers and scholars, in Europe, where the research is mostly developed, and eventually, contractors of construction should meet their own civil aviation authority regulation, the terms of UAS is used. Despite that, in the Dominican Republic, RPAS is used and in Spanish language VANT (Vehículo Aereo No Tripulado) is the term used; UAS is recommended and applied for an impact reach purpose as later is discussed the ethical implications of the research.

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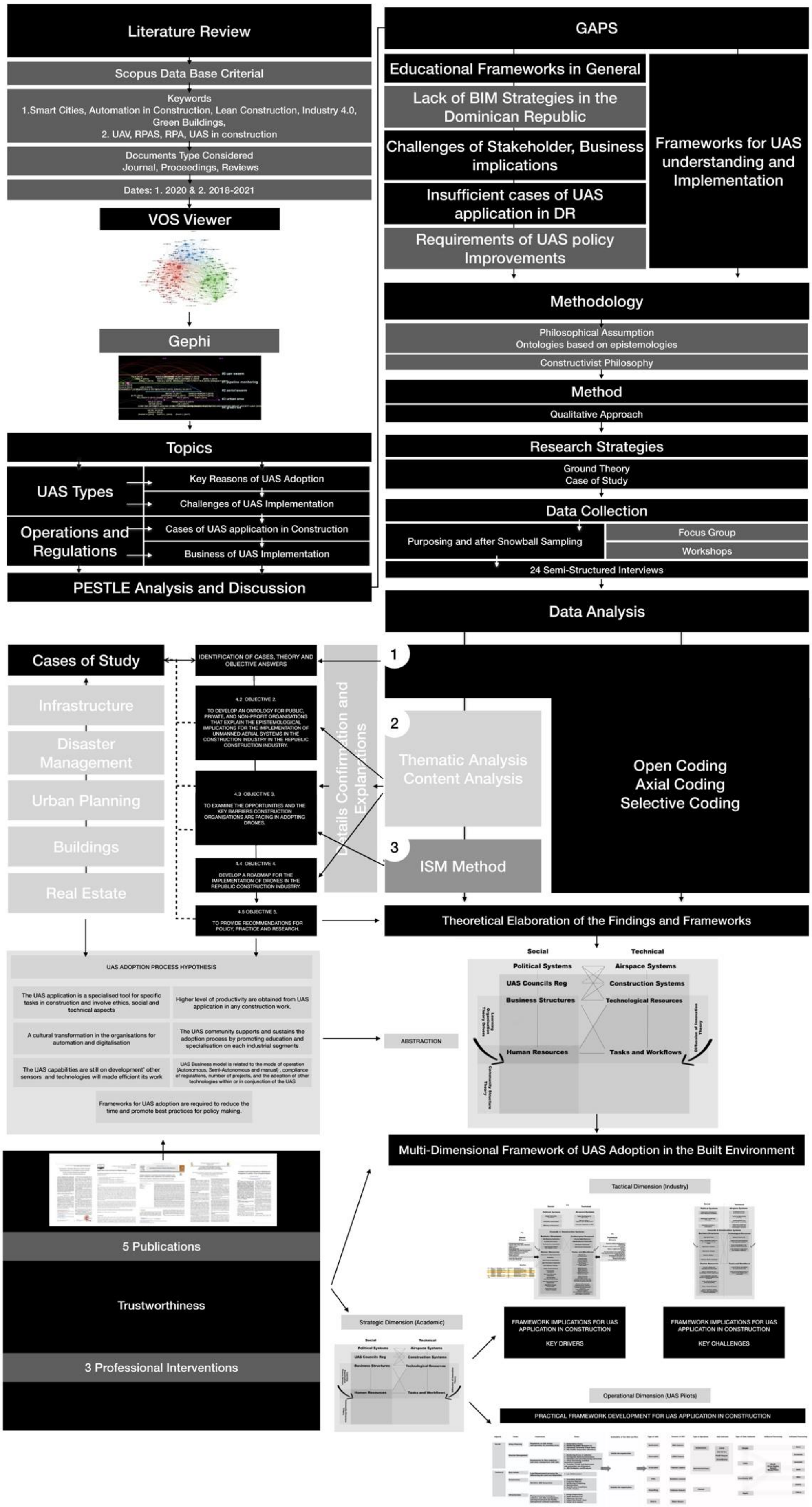
Then, the Scopus database was used to search for the journals, most cited articles, and significant contributions in the field to map the true of the academic world. The most cited documents describe a truth that has been happening throughout time. There are truths that transcend time (it has a high citation rate, (comes with a long-term vision that is not affected for changes in the field or the past of the years), and others are just for a short-term period. Indistinctly the manuscript transcendence, each of them acknowledges an infinitesimal or substantial beam of the epistemological truth. Therefore, the amount of data from Scopus required software for analysing in a simple and general way for further interpretations. At this moment were the VOS viewer and Gephi appeared. VOS viewer is a scientific visualisation tool for constructing bibliometric networks. This tool was more user friendly than the Gephi and provided features such as bibliographic coupling-citation relationships, useful for this literature review too.

Based on previous publications in the application of UAS, this literature review was carried out but with the metacognition process of: at a national and international level, what are the agendas that governments are following? Then, terms and strategies started to emerge after the VOS viewer was applied as well as other tools from Scopus database. The foundation of the UAS application at a macro level arose. UAS taxi, autonomous operations and other applications were contemplated, but the scope of the research was in the Dominican Republic, where primary data was not found nor framework for adoptions for this country or others. So, a relevant gap in knowledge appeared and this thesis perspective took the form of a framework that impact cities and multiple stakeholders with the application of UAS in construction.

Figure 3-1. Research Map Overview



Literature Review
Scopus Data Base Criterial
Keywords
1.Smart Cities, Automation in Construction, Lean Construction, Industry 4.0, Green Buildings,
2. UAV, RPAS, RPA, UAS in construction
Documents Type Considered
Journal, Proceedings, Reviews
Dates: 1. 2020 & 2. 2018-2021
VOS Viewer
Gephi
Topics
UAS Types
Operations and Regulations
Key Reasons of UAS Adoption
Challenges of UAS Implementation
Cases of UAS application in Construction
Business of UAS Implementation
PESTLE Analysis and Discussion
GAPS
Educational Frameworks in General
Lack of BIM Strategies in the Dominican Republic
Challenges of Stakeholder, Business implications
Insufficient cases of UAS application in DR
Requirements of UAS policy Improvements
Frameworks for UAS understanding and Implementation
Methodology
Philosophical Assumption
Ontologies based on epistemologies
Constructivist Philosophy
Method
Qualitative Approach
Research Strategies
Ground Theory
Case of Study
Data Collection
Purposing and after Snowball Sampling
Focus Group
Workshops
24 Semi-Structured Interviews
Data Analysis
Cases of Study
Infrastructure
Disaster Management
Urban Planning
Buildings
Real Estate
IDENTIFICATION OF CASES, THEORY AND OBJECTIVE ANSWERS
4.2 OBJECTIVE 2.
TO DEVELOP AN ONTOLOGY FOR PUBLIC, PRIVATE, AND NON-PROFIT ORGANISATIONS THAT EXPLAIN THE EPISTEMOLOGICAL IMPLICATIONS FOR THE IMPLEMENTATION OF UNMANNED AERIAL SYSTEMS IN THE CONSTRUCTION INDUSTRY IN THE REPUBLIC CONSTRUCTION INDUSTRY.
4.3 OBJECTIVE 3.
TO EXAMINE THE OPPORTUNITIES AND THE KEY BARRIERS CONSTRUCTION ORGANISATIONS ARE FACING IN ADOPTING DRONES.
4.4 OBJECTIVE 4.
DEVELOP A ROADMAP FOR THE IMPLEMENTATION OF DRONES IN THE REPUBLIC CONSTRUCTION INDUSTRY.
4.5 OBJECTIVE 5.
TO PROVIDE RECOMMENDATIONS FOR POLICY, PRACTICE AND RESEARCH.
Details Confirmation and Explanations
1
2
Thematic Analysis
Content Analysis
3
ISM Method
Open Coding
Axial Coding
Selective Coding
Theoretical Elaboration of the Findings and Frameworks
UAS ADOPTION PROCESS HYPOTHESIS
The UAS application is a specialised tool for specific tasks in construction and involve ethics, social and technical aspects
Higher level of productivity are obtained from UAS application in any construction work.
A cultural transformation in the organisations for automation and digitalisation
The UAS community supports and sustains the adoption process by promoting education and specialisation on each industrial segments
The UAS capabilities are still on development' other sensors and technologies will made efficient its work
UAS Business model is related to the mode of operation (Autonomous, Semi-Autonomous and manual), compliance of regulations, number of projects, and the adoption of other technologies within or in conjunction of the UAS
Frameworks for UAS adoption are required to reduce the time and promote best practices for policy making.
ABSTRACTION
Social
Technical
Political Systems
Airspace Systems
UAS Councils Reg
Construction Systems
Business Structures
Technological Resources
Human Resources
Tasks and Workflows
Multi-Dimensional Framework of UAS Adoption in the Built Environment
Tactical Dimension (Industry)
5 Publications
Trustworthiness
3 Professional Interventions
Strategic Dimension (Academic)
FRAMEWORK IMPLICATIONS FOR UAS APPLICATION IN CONSTRUCTION
KEY DRIVERS
FRAMEWORK IMPLICATIONS FOR UAS APPLICATION IN CONSTRUCTION
KEY CHALLENGES
Operational Dimension (UAS Pilots)
PRACTICAL FRAMEWORK DEVELOPMENT FOR UAS APPLICATION IN CONSTRUCTION

Consequently, an in-depth explanation in the philosophical assumption and perspective of the research in this topic is described in the following section.

3.3 PHILOSOPHICAL ASSUMPTION

Philosophy is defined as the belief framework to develop investigation. The research process is reckoned with several assumptions and perspectives in order to contribute to the scientific knowledge in the field, generate understanding and proceed with wise actions on the phenomena observed. Exist several types of philosophical assumptions and four are the main core philosophical assumptions or worldviews that could vary the author to author according to (Creswell, 2014) (Saunders, et al., 2016) (Mingers, 2003). The implicit philosophical assumptions are ontology, epistemology, axiology, and methodological. Each one is arisen based on the field held and concorded by the study. The assumptions are described as:

- **Ontology** assumption is concentrated on observing the existence of artefacts, beings, and frameworks, organisations, and events interactions.
- **Epistemology** focuses on extracting knowledge or developing a profound understanding of a true in the world interaction. This state the routes to a considerable meaningful truth. In addition, the truth can be seen as a belief or justification of a group of people or a physical parameter as gravity.

- **Axiology** underpins to recognition of the future-proof values that sustain ethics of humans. In addition, the assumption appoints to the researchers or group values more.
- **Methodologies** are driven by the premise of a different process to address aims and objectives.

In a philosophical explanation, the philosophical assumptions underlie paradigms for understanding the perspective where the thought process models are oriented to the investigations. In other words, the philosophical assumptions will reflect sociological paradigms and organisational structures of the phenomena on observation. The UAS is a novel robotic technology which is at its beginnings. For example, in the future, aerial robots will be built without self-awareness of their purpose or potential uses. Artificial intelligence and the combination of different technologies will provoke a metacognition of humans, translating it into silicon or quantum sparkly processors. The scenario could be described with the terms of aerial humanoids inspectors and autonomous intelligent transport tools. Furthermore, UAS are implemented for substituting, avoiding risk, transport and digitalisation purposes for humans being however, the lack of knowledge on the scenarios where a viable outcome is still on research. Therefore, a perspective on the UAS interaction between humans only may not fulfil a complete extraction of knowledge and in the development of a profound understanding of a true in the UAS world interactions. The current availability of the aerial robots in the market can be limited to commercial photography and application for surveys. Other types of UAS can be developed for successful future-proofing context in automation. Ethics and different methods to assess this topic on research are contemplated as a part of the investigation process instead of being the main focus of the study.

The *modus operandi* of social theories can be described from (Creswell, 2014) perspective taking four dichotomy behaviours dimensions: subjective-objective and radical change-regulation. (Creswell, 2014) expressed four-quadrant points explaining the intersection between the behavioural dimensions. In consequence, four paradigms are built: Radical humanist or positivism, Radical structuralism, or realism, interpretive and functionalist or pragmatism. From these contrasts, the researcher expresses its view in order to share the understanding of the problem and the reasons for the results produced. The combination of the paradigms brings the philosophy perspective of the research and the thought process behind the research scenes. The paradigm of this research is channelled to provide functional changes in the organisations applying UAS while recording the experiences on the digitalisation process and state-of-the-art of the construction industry with an epistemology philosophy. Furthermore, if this research would impact directly the values related to the ethics of the UAS operation, would it align with axiology. But, because the research is looking for implementation (adoption + applications) it is required to explain the epistemology of the UAS application throughout ontologies of UAS adoption (Livadas, 2021). Therefore, pragmatism or constructivist reflect the ontology of the research perspective. But, because the field of UAS is currently requiring epistemological knowledge to utilise them, educational material was required to build based on the participant experiences. Moreover, other research tangents such as area of transport with UAS is still in development that in the future could generate a diverse perspective if a conjecture is discussed. Nevertheless, the UAS transport may/will growth to quantum transport vehicles or super-intelligent aerial transport systems, but the research is focused on digitalisation, taking sensors as their main source of information to discuss.

Consequently, the discovering of UAS functional scenarios, experiences and the findings presented contribute to support current regulations by providing insights to the construction industry, enhancing scientific knowledge from an academic perspective, and providing guidance for UAS manufacturers. Finally, the trustworthiness of the research is evaluated with the industry and scientific bodies.

3.4 RESEARCH METHODOLOGY

As the data regarding UAS is addressing the issue of scepticism for generating insight into the change accomplished in organisations, and enriching the knowledge of technicians, policymakers, and industry adopters, the information extracted from the data required to fit into one or various of the three types of approaches in managing the investigation: pure qualitative, pure quantitative and mixed-method research.

Qualitative methodology is applied to gather primary human conscience data in order to underlying reasons, opinions, motivations, tacit and empirical knowledge that are emerging in an organisation. In addition, qualitative methodology is used in a context where the access to information is limited or restrictive. Furthermore, the main function of the methodology is to capture an extensive amount of detailed data from the phenomena. Qualitative research usually undergoes an inductive approach diffusing the phenomena behaviours or facts by explaining the new system of ideas rather than confirming the existing one. The information and knowledge obtained can provide insights into approach a quantitative methodology or other approaches for answering the research question.

Quantitative methodology is normally used to examine numerical relationships between variables, or cause and effect relationships. Besides, it is integrated as a valid proof of experimental designs. It is focused to understand objectively a phenomena or fact relationship. The methodology is oriented to produce generalizations of groups or to explain a particular phenomenon undertaking observation, numbers, and logic approaches.

Mixed Methods is the perspective that merges qualitative and quantitative approach presenting that the reality is objective and exist diver interpretation. The mixed methods are preponderant in social science research. The approach tends to produce a more comprehensive and overall view of the study perspective in contrast to mono-methods approaches. The mixed methods have four main combinations to proceed with the data collection according to (Harrison, et al., 2020):

- *Concurrent approach* when both methods are carried out simultaneously and at the data analysis point are analysed and compared the findings.
- *Sequential Exploratory* approach begins with an exploratory qualitative framework to provide clarity about the kinds of variables requiring further investigation. The approach will help towards the development of a quantitative method to collect data and analyses the relationships between variables, and for generalizing the results to the population from where the sample was drawn. It is useful for a researcher who not only wants to explore a phenomenon but also wants to expand the findings.
- *Sequential Explanatory* approach is used the quantitative approach and then qualitative approach. It is usually applied for cause-effect explorations and the perception of the approach in humans.
- *Convergent approach* occurs when quantitative and qualitative data collection is compared one against the other after the analysis phase of each other.

The nature of the research, the integration, and application of UAS in different fields by civilians have been a novel topic for policymakers, academics, and the industry. In the last five years, various funding opportunities for research (Horizon 2020) and entrepreneurship (Dragon Den) have been raised with the aim to try the feasibility and explore the potential solutions embedded in the UAS in the life of humans. The majority of the investment in UAS projects are in building and manufacturing UAS solutions for transport, 3D reconstruction, agriculture, and others. Another example of investment is in developing solutions for 3D digital reconstruction and georeferenced infrastructure maintenance. With these in mind and the aim of improving capabilities, a practical approach sounds fair and reasonable to use. However, some limitations in the research regarding the direction of the study, time and operations directed the study into more qualitative approach. Furthermore, the practical knowledge is changeable due to the regulatory environment and the scientific knowledge generated in the field could impact a small part of the UAS community related to construction. UAS is more than manufacturing, photogrammetry, and public safety; it is conceived as a step forward to futurist society and considers theories like the technological singularity. Therefore, a method that suits the aim and the desired impact outcomes are more oriented to a purely qualitative method approach utilizing a mixed method analysis approach to draw the conclusion as emerging field would adapt in a rigour mixed method approach (Harrison, et al., 2020). Furthermore, Empirical data is normally gathered by qualitative methods and reflected in theory built for the discernment of the topic (Torraco, 2005).

3.4.1 LIMITATIONS OF THE RESEARCH IN-DEPTH

During the literature review Gephi was used to produce insights regarding smart cities. This approach brought that smart city is more oriented to swarm technology rather than construction *per se*. Swarm technology as mentioned in Figure 1-2 reflects a reality different than the current one in applying UAS for construction. Swarm technology is related to a coordinated, interconnected, and programmable team of UAS. This approach represent potential to cities for multiple UAS operations from a stakeholder perspective. However, the development of UAS for this purpose is limited currently and the research would be only made theoretical and in simulations that may not satisfy or contribute to the current gap to get into that stage. Swarm technology for digitalisation is still on development and have policy limitations for Beyond line of sight, affordability, security, knowledge skills and applications. Swarm technology is merely useful for addressing multiple tasks at the same time. However, it is only being applied in a few countries and normally are from private organisations who control them for entertainment purpose.

It means that while this thesis is being written, the technology evolution may change the landscape and possible trend. Therefore, the researcher selected to concentrate in applications that are getting maturity and for further research extrapolate the tasks towards elaborations of designing decentralise cases of UAS with blockchain, IoT, smart contract and AI (4.5.2). Currently, there is 1 UAS that is integrating commercially internet of things that would infer an approach to that technology (Table 2-7). However, 100 of these UAS represent a relevant investment in contrast to the different simultaneously problems that they can resolve. However, for cities according to the Gephi, pipeline monitoring was identified as a task. But it was not possible to measure it in the Dominican Republic because it was outside the scope. In terms of swarm technology, it has not been yet developed in the country. Furthermore, at some point, the research would be totally interviewing 10-15 private organisations from USA, Korean, Japan, UAE, Romania, and Ireland. So, this type of sample could be difficult to reach, and governments may only be interested in safety. Furthermore, the producing of a swarm requires a team of experts for piloting during 10-30 mins. For construction, could be useful have a UAS for specific tasks, but for cost-effective reasons may be restrictive the application and the impact may be low for developing countries.

3.4.2 QUALITATIVE RESEARCH METHODOLOGY TECHNIQUES

Qualitative methods generally aim to understand the experiences and attitudes of professionals in the field of study. The qualitative approach aims to explore the 'what', 'how' or 'why' of a community or individuals perceive and manage a particular issue rather than measure the event. The qualitative methods tend to use inductive and abduction reasoning rather than deductive (3.7.1). These approaches are normally conducted to acquire empirical data of a phenomena. In addition, they usually describe inductive reasoning with the basic assumptions (1) that reality is a social construct; (2) variables are difficult to measure their complexity and interlinking; (3) there is a primacy of subject matter and (4) the data collected is founded on the outlook of the intervention.

There are plenty of techniques in qualitative investigations to gather data. Interviews, focus groups, workshops, observations, field notes, documents and records are the techniques to gather primary data (Stake, 1995; Yin, 2009, 2012). Qualitative data is commonly gathered by informal or in an unstructured interview setting; guided or semi-structured interviews; and/or formally standardised open-ended questions or structured interviews. In this case, various exploration of the methods was evaluated, concluding that interviews are suitable to explore the experience of the stakeholders with the UAS. Surveys are mostly carried out in the settings of action research with mixed method case of study (Irizarry & Costa, 2016; Huang, et al., 2021). The questions in the cases mentioned are normally after the UAS assessment regarding the experience of the data usage and the experience during the experiments. However, based on the context of the Dominican Republic where stakeholders involved in novel technology could be difficult to find. Focus group and workshops were made to cap the intellectual capital of certain groups in the UAS community. So, the qualitative data was collected through semi-structured interviews by previous appointment, one-to-one sessions after focus group and workshops. This type of interview provides flexibility to obtain a realistic overview of the perspective and experience of an individual as aligning an epistemology philosophy (Bryman and Bell, 2015). In order to record effectively the interview data, a smart phone (iPhone 8), pictures and handwritten notes were taken. The recordings of the interviews allow the researcher to concentrate in the participant, observe their expressions, behaviours and meaning that might be embedded in their words. After a smart verbatim transcription, a reflection on the interview outcomes was made (Patton, 2002).

The transcriptions utilised different methods to decode the purpose and trustworthiness of the outcomes. Some transcriptions were tested to convert them into text with google speech API. Unfortunately, the transcriptions were inaccurate and tedious to some extent that a manual approach was finally conducted. Perspectives of the feelings and ideas between lines were taken into consideration to understand the position that the participants were sharing information and expressing the true meaning of their spirits. Furthermore, the transcriptions were anonymised utilising the P of participant and the order in which it was transcribed ensuring the privacy of the participants and enterprise involved in the research.

The questions in this research were designed as open-ended and close questions, allowing the participants to express their feelings and perspectives of the UAS as well as discuss specific points of the UAS user's agenda in the Dominican Republic. An appropriate amount of information was generated by the participants. Moreover, the transcriptions were analysed utilising (1st) the ground theory (for codes), (2nd) thematic analysis for descriptions and (3rd) content analysis for main ideas and patterns identifications captured in the sample. Furthermore, coding is the primary process that permits recognizing the patterns involved in the sample and verifying their frequency and occurrence (Creswell, 2018). In addition, other methods were implied to understand the key drivers and barriers such as ISM Method and later a framework or ontology development analysis as the research strategy provided (3.8.1).

The interviews duration suggested was between 30 - 45 minutes (Oppenheim, 1992). However, the laps of time varied according to the knowledge, expertise, and availability of the participants. Some interviews lasted 10 minutes and other just 2 hours. Organisations which have incorporated UAS in their workflow are normally tending to be in possession of an intellectual capital within a learning curve that restrict some aspect of the UAS and put in doubt the full effectiveness of the UAS application. Therefore, format of these interviews was face-to-face, online video call, and emails after a face-to-face discussion of the research aim and objectives as previously mentioned. Furthermore, any evidence of the UAS operation could be seen.

A number of elements among the data collection methods or instruments implemented to gather the information that can raise ethical concerns. (Carter, et al., 2021) clearly express the scenario of researching technologies at organisations. This paper evaluated the ethical approaches of researching technical objects, policy studies, and industrial partnerships as summarized in the following table.

Table 3-1. Ethical Approaches for Information and Technology Investigations

No.	Approaches	Barriers	Benefits
1	Technical Objects	• Complexity and obfuscation by organisations • Unable to address contingency plans against harmful effects to employees • Limitation to the development of theories • Viability for a public scholarship • Limited access to organisations, processes, and people to determine the impact of these feature or technologies on users.	• Direct method to measure the effects of technologies that cause harm in the users or people involved.
2	Policy studies	• Data access to internal investigations • Enterprises and Civil people position against the policy implications on their products, services, and freedom.	• Fair and just policies outcomes
4	Industrial-Partnership	• Limit of data transparency, archival, and reproducibility • Credibility for some scholars	• Special research grants

			• Private-Public alliances provide quality data.

In this table are presented the ethical consideration for the research.

In this research, substantial considerations were raised based on the versatility of the UAS implications. The complicated triggers of the UAS/aerial robot covered each of these approaches and interconnected them, provoking robust outcomes in the scientific community worldwide. Through an ethics lens, the research seems to be extremely adequate for an industrial partnership approach, but issues of credibility/trustworthiness may arise, so a technical-policy-industrial approach was taken to manage the issues contemplated on each approach could be addressed in addition to the normal procedures included within the university. It means that the essence of the experiences was recreated and identified the key drivers to shape a multidimensional framework for the UAS adoption from technical, policy and industrial perspectives.

In the same line, the research underwent an ethical approval process where the ethics committee reviewed the proposed research and methods to ensure the research was ethical in nature. Therefore, in order to ensure that all the procedures were ethical in nature, and that appropriate ethical approval was always taken, the researcher took great efforts, to address this issue by ensuring that the participants were aware of what was the research intended to achieve and how their contribution would be utilized. Consent forms, summary of the research at that stage, confirmation of study letter from S.T.A.R office, and explanations regarding article publication process were made. In addition to supplementary information such as follow-ups interviews, flight logbooks, documents, and UAS images that contain the GPS location of the operations was asked for ensuring the validity of the comments and observations made. Then, this information was analysed with a quantitative approach in order to produce a deeper understanding of the context in which the descriptions were carried out under the semi-structured interview. Finally, some results from the interviews were evaluated, and consent was requested to the participant for publishing the UAS application cases for illustration in research and academic terms in a case of study basis. An example of the interview questions, paper works of the interviews, ethical form, publication, and consent of the participant for publication are in the appendix section.

However, the interviews on their own do not complete the narrative around this research process. The interviews were a tool for gathering data and the behaviours, decisions and course of actions made to obtain the data correlate with specific strategies in research. Hence, a systematic approach of description and discussion between research strategies are developed in the following section.

3.5 RESEARCH STRATEGY

The research strategy is name used to describe the actions taken to address the aims and objectives effectively. Based on the research strategy, exist different approaches to evaluate the methods and types of data collection applicable for investigating. In other words, the research strategy guides the direction and focus point to answer the research objectives. There are three boundaries suggested by (Johannesson P., 2014) to assess the research strategy: Suitability for the research purpose, the viability in the research resource, ethical approach to the participants and environment. The research strategies most commonly used in social science studies are the following:

Table 3-2. Research Strategy

No.	Research Strategy	Aim
1.	Phenomenology	Study the experience of reality lived.
2.	Action Research	Generate practical scientific knowledge in real-world settings.
3.	Case of Study	Investigate in-depth an instance.
4.	Ethnography	In-depth investigation in the culture understanding.
5.	Ground Theory	Develop theories from data.
6.	Experiment	Establish a cause-effect relationship between variables.
7.	Survey	Obtain a big picture or preliminary data of phenomena to be studied.

Some researchers may incur different strategies simultaneously to accomplish the objective/phenomena satisfactorily. Furthermore, the parameters to identify the suitability of the strategy are guided by the pure understanding of the aspects assessed of the phenomena. In the case of Unmanned Aerial System, there are different aspects to observe such as business impact, future-proofing trends, and apprehension of the work process quality improvement that influence the selection of the research strategy.

In a deeper context, the UAS is related to a type of military tool that has applications and access to a massive consumer recently in the last 10 years. This proliferation produced an awareness of the risk involved and capabilities that the normal consumers may have. For the moment, the UAS design purpose of the leading manufacturer is to provide aerial photography systems as well as easy-to-fly UAS. Any signal of technological singularity is manifested, but cases may arise if it is not taken appropriate steps to differentiate between standardizable and non-standardizable applications. Therefore, a suitable approach comes from assessing the actual empirical data associated with the available UAS, business cases developments, and finally delivering an implementation framework in which the stakeholders receive knowledge of the benefits and barriers implied in the technology. In other words, investigate in-depth or various instances to develop theories from data inductively (3.7.1).

However, to develop a theory from the data is required to arrange the cases in which the UAS it circumscribe its application. Therefore, different strategies are used to answer the aim and objectives of the UAS research. The key activity exploring the UAS implementation is the development of cases of studies (Yin, 2018). The evaluation in-depth of an instance provides a holistic view of the current UAS phenomena. In addition, the analysis of multiple cases may conclude in punctual and practical knowledge responding to the "why" and "how" of the UAS applications, but it may do not satisfy; enrich policymakers and academia in such perspective by dismissing the understanding in future trends, policy development, generation relief in the industry and/or, in summary, "what" is involved in the UAS capabilities. Consequently, a theoretical framework is developed, incorporating multi-level aspects of the UAS implementation by a ground theory strategy (Halaweh, et al., 2008). Therefore, the strategy aligned with the frameworks is a ground theory with the basis of the case of study giving the hypothesis to construct the UAS process.

3.5.1 GROUND THEORY AND CASE OF STUDY STRATEGY

In this research was used ground theory strategy to collect data, ground theory for the development of the ontology and case study to produce the epistemological knowledge for the ontology foundation. Furthermore, Figure 3-1 provide clarity in this matter.

The iterative strategy of ground theory is targeted to understand the abstract relationship of a fact and the individual involved in generating concepts and ideas regarding the behaviour of the scenario. The ground theory has its strength on insights and tentative hypotheses generation, despite current theoretical phenomena explanation.

The ground theory emerged as a claim of the current paradigms in research. The belief challenged was rooted in the essence of knowledge generation. The ground theory confronted the paradigm of confirming existing theories compared to developing new ones (Heath & Cowley, 2004). Different discussions were raised on its definitions and types of ground theory studies (Tie, et al., 2019). The most remarkable aspects discussed were ground theory research strategy and methodological approach for developing the knowledge from the research (Halaweh, et al., 2008). (Glaser, et al., 1968) defined ground theory as systematically gathered and analysed data in an iterative process that reveal an emerging theory behind the phenomena. However, an epistemological pragmatism perspective of ground theory is addressed by (Charmaz, 2006) which put in place the idea of constructing a conceptual framework of the research, storytelling, or theory inductively rather than report the emerging one.

In the aspect of methodological actions, ground theory, according to (Corbin & Strauss, 1990) is concentrated on the methodological aspect of developing theory from an inductively rather than deductively manner. In the same line, it begins with a variety of sampling techniques such as purposive and snowball sampling. The process of data collection and analysis from the sampling is undertaken for concurrent interactions of comparative analysis and memoing during the coding stages until a theoretical sampling is reached or data saturation. These iterative processes create a gradual development of actions and interactions inherent in the theory building (Birks & Mills, 2015). However, the inherent comprehension of attributes of the strategy allowed the researcher to adjust and settle uniqueness in the approach on the type of qualitative data, according to (Burg, et al., 2020). A narrative analysis from the empirical data would offer an explanation of the phenomena, but for this case, the ground theory procedures were used as a guide to discerning the similarities and communalities for the identification of uniqueness in the nature of the case. Furthermore, the cases of studies are classified as qualitative experiments for allowing the researcher to compose a study in an extreme setting that naturally is a difficult to explore such as (Vanderhorst, et al., 2020). Therefore, the view presented of linking entrepreneurship methodologies with research applied before and during COVID-19 restrictions provide a wealthy background for UAS exploration. The process normally appeared, sounded, and felt as an empirical exploratory mixed-method based on the lack of literature in the country. However, the development of ideas and concepts permitted to summarize the wisdom into a comprehensible, useful, and academic manner. The approach of qualitative method delivers to this research through the ground theory procedures, and case study exemplifications the expectations for putting in context the results from the actual cases.

Nevertheless, the conjunction of ideas that emerged from the data granted a natural behaviour of the implementation of UAS in the country rather than integrating a biological information inside an organism with a high rate of rejection. In summary, the UAS field in the Dominican Republic has not been fully explored by researchers. Exist some hypotheses that stated, in other countries, that the economic valuation and boosting of the sector is high. But the scepticism invalidates the possibility to perceive the benefits into the construction industry on the grounds of inadequate evidence of the benefits or its suitability.

3.5.2 TIME HORIZON

The time frame was between the 2018-2021 in the Dominican Republic. During this frame, different event in the country occurs that influence the adoption process of UAS faster as government changes and disaster events such as a pandemic, hurricane, and wildfire. Therefore, close attention was followed to the participants as well as the UAS communities in case that the knowledge assets of the organisations present issues on retention.

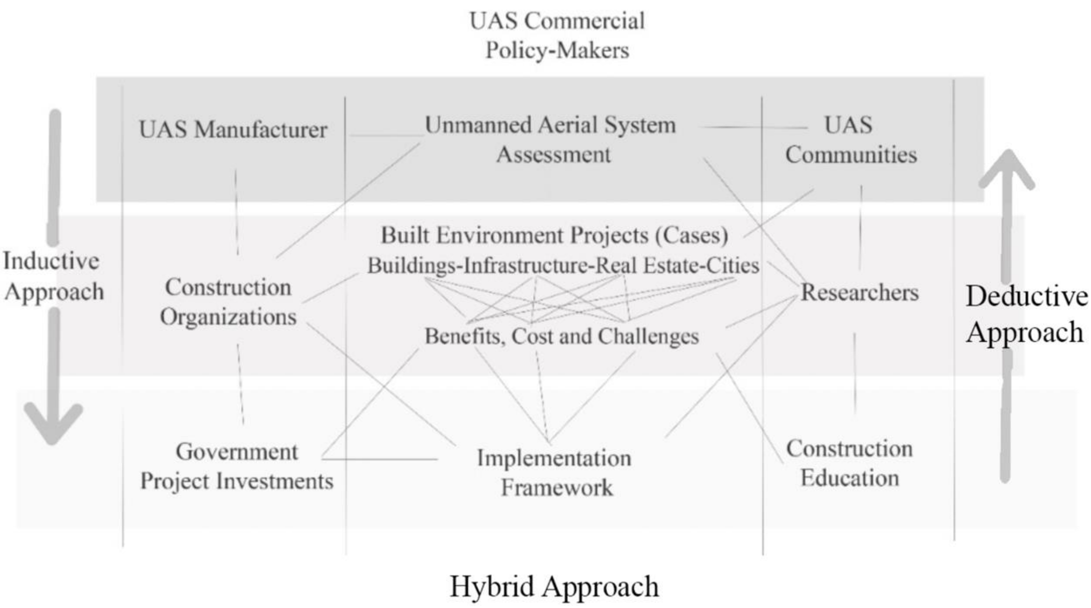
3.6 RESEARCH DATA COLLECTION TECHNIQUES

3.6.1 SAMPLING TECHNIQUES UNDER GROUND THEORY STRATEGY

The sampling method applied for the research was broken into two phases. First, it was identified the key stakeholders in the UAS industry in the country, their impacts on the market and on research terms (Figure 2-3). From (1.5.1*),* the aim of the research is to critically analyse the best practices of UAS adoption in the Dominican Republic construction industry through knowledge exchange through an informative strategic framework development of adoption for public, private, and non-profit organisations. Then, regulators, academics, manufacturers, and contractors can achieve the same frequency of technology development. It can also mean the fomentation of technologies and innovation inside the realms in which the UAS serves.

On online news were found a public preliminary list of relevant stakeholders who have fearless tested the UAS (Table 3-5). Projects of UAS for clinical services, public institutions, Instagram accounts, scholars involved with BIM, and international development programs were identified for a theoretical sample, and then, it was expected to receive insight of stakeholders offline that could contribute knowledge and perspective of why UAS should be adopted, and what could be the structural barriers that the technology is facing. Furthermore, a hybrid approach (top-down and bottom-up) was taken in order to gather the experiences from the initiators of UAS implementation within the organisation. After that, the approach changed to snowball sampling at the strategic and technical levels.

Figure 3-2. Stakeholders and Conceptualisation of Sample



The culture perceived in technologies of the 4th industrial revolution is mostly collaboratives, and the niche of innovators could be tied to a certain number of companies or potential customers, as seen in the following Table 3-3.

Table 3-3. Universe of the Sample.

Number of Organisations observed in the Dominican Republic Between 2015-2020

Organisations Sampling

No.	Types	Organisations	Number
1	Private	Construction Companies	3888
		Drone Manufacturer	3
		Universities	11
		Technical Schools	4
2	Public	Regulatory Entity Drones	1
		Other institutions	388
3	Non-Profit	Drones Educators	2
		Construction	5
		Total	4302

Source: The Chamber of Dominican Republic Commerce

The table gave an idea of the market and the universe representation of the UAS, and organisations associated with construction. However, undertaking this approach focused on construction and assuming that the penetration level of the UAS is low in the country, a deeper sampling conjecture was required. In addition, this approach may present inconsistencies in the cases that the companies may not have applied UAS or may be unaware of the technology. In the literature state that the barriers in adopting technologies are commonly by investment, insertion of digital strategies, skills, and reliability of the tools (Antoniuk, et al., 2017; Bousdekis, et al., 2020). Therefore, the Dominican Republic might not be the exception of these cases in addition to the difficulty to access any information related to any type of organisation. Hence, it was wiser and more reliable to search for the experts and key contributors in the field that any knowledge shared from this approach can significantly be more consistent than an online survey or a random sampling approach of construction contractors. As estimated below, the number of professionals chaptered in engineering and architect in the country provide an idea of future trends and impact on the engineering standards for digitalisation, as shown in Table 3-4.

Table 3-4. Professionals Builders certified observed

Professionals Certified CODIA (EQUIVALENT TO RICS AT THE UK)			
No.	Engineer Description	2010 Population	2019 Population (Estimated Distribution)
1	Surveyors	987	1,679
2	Architects	4,838	8,229
3	Electromechanical	4,312	7,334
4	Agricultural	1,460	2,483
5	Civil	10,983	18,680
6	Industrial	759	1,291
7	Chemical	590	1,003
8	Topographer	172	293
9	Totals	24101	40,992

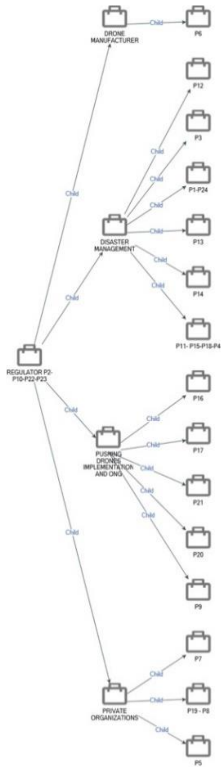
In this table is presented a projection of the population of builders certified in the Dominican Republic.

Moreover, the universe seemed to be significantly relevant for UAS market. But a classification of the company sizes in the Dominican Republic was guided as the parameters for the interview. The decision to follow the belief for change occurs from a top-down approach accompanied this stage of the research. Therefore, the classification of the Dominican commerce chamber with the names of micro (1-10 employees), small (11-50 employees), medium (50-200 employees) organisations was taken. These names and classifications were also used for public and non-profit organisations involved in the research.

As expected in any research, issues on participation acceptance and access to strategic levels appeared in this context, the researcher incurred to the snowball sampling to complete the theoretical framework. Furthermore, in the second approach of sampling were considered in the participants the engagement with international and national projects with UAS in the country, experience on the UAS application, the number of employees of the organisation and the position that the participant position at the organisation.

Finally, an exploration of the different sectors involved in the UAS industry was addressed in order to understand the key stakeholder knowledge and implications. The relationship of the participants from the sampling approach can be seen in the Nvivo 2020 Cases map (Figure 3-3). The names of the participants were substituted by codes, and the topics shared between the organisation are presented.

Figure 3-3. Relationships and case map of the participant sample



The sample relationship reflects 4 groups actively involved in the UAS application as well as the source of input for regulators. From these views, intersection points are identified to evaluate the phenomena of UAS.

These participants hold knowledge in various fields related to construction that envisage a list of possible regulations and fields for further investigation, concentration, and literature review confirmation, according to (Vanderhorst, et al., 2019). After exporting each case on a spreadsheet, the following table describes the sample profile.

Table 3-5. Sample Demographic Data

									Cases							PESTLE					
1	Public	P10-FA1	50-60	Male	5-10 years	Chief of the General Aviation and air Works Division	Aviation	-	1					1				1	1	1	
2	Public	P11-LN1	20-30	Male	0-5 years	Architect Drone Pilot	Construction	Disaster Management		1								1	1		
3	Public	P12-GNS1	30-40	Male	5-10 years	Head of the Information, Communication and Technology Department	Geology	Disaster Management			1			1	1			1	1		1
4	Private	P13-PUC1	50-60	Male	15-20 years	Coordinator of School Civil and Environmental Engineering	Education	Disaster Management		1				1				1	1		
5	Public	P14-SIN1	50-60	Male	0-5 years	Director of Operations	Disaster Management	Disaster Management						1		1		1			1
6	Public	P15-COO1	30-40	Male	5-10 years	Technical Director	Construction	Disaster Management		1								1			
7	Ong	P16-ORL1	50-60	Male	10-15 years	Executive Director	Drones	Smart Cities	1	1							1	1	1	1	1
8	Private	P17-EM1	60-70	Male	20+ years	Chairman of the Board	Innovation-Education	Smart Cities	1	1	1						1	1	1		1
9	Public	P18-SSI1	20-30	Female	0-5 years	Assistant Technical Director	Construction	Disaster Management		1									1		
10	Private	P19-ANE1	30-40	Male	5-10 years	Technician	Construction	Education	1	1								1	1		
11	Public	P1-WQ1	50-60	Male	5-10 years	Quality Water Management	Infrastructure	Disaster Management	1					1					1		1
12	Private	P20-PRE1	40-50	Male	20+ years	Aeronautic Assessor	Aviation	Education	1								1	1	1	1	
13	Public	P21-INT1	30-40	Male	5-10 years	Project Analyst	Transport	-			1		1					1	1		
14	Public	P23-IDC11	40-50	Male	0-5 years	Coordinator of Flight drone operations	Aviation	-	1				1				1	1	1	1	
15	Public	P24-INA1	40-50	Male	15-20 years	Topography Technician	Infrastructure		1									1	1		
16	Public	P2-MP1	60-70	Male	15-20 years	Director of Government Monitoring and Coordination	Government	-								1	1	1			
17	Public	P3-ZO1	30-40	Female	5-10 years	Technical Support	Construction	Disaster Management		1				1				1	1		1
18	Public	P4-EC1	30-40	Male	5-10 years	Vice Minister of Operations and Road Maintenance	Construction	Disaster Management	1	1			1			1			1		
19	Private	P5-WN1	30-40	Male	5-10 years	General Manager	Surveying	-				1					1	1	1		
20	Private	P6-SD1	30-40	Male	5-10 years	CEO	Drones	-									1	1	1	1	1
21	Private	P7-EPLA1	50-60	Male	15-20 years	General Manager	Construction	Transport	1	1		1	1					1	1		
22	Private	P8-KL1	30-40	Female	10-15 years	BIM Manager	Construction	Education	1	1								1	1		
23	Ong	P9-PB1	20-30	Male	5-10 years	Director of the organization	Construction	Education		1							1	1	1		
24	Public	P22-IDC 21	30-40	Male	15-20 years	Technical in-Flight Drone regulations	Aviation	-	1			1					1	1	1	1	
									12	12								21	21		

The archetype media of the sample seems as a public institution, male with age between 30-40 and 5-10 years of experience in their field with a background in construction and infrastructure focused in technical and social aspects of the UAS implementation. In addition to that, the table reveals sociological aspects of the participants involved in the UAS sector. The sample provides a knowledge map regarding the key technical and strategic stakeholders in the UAS sector. Diversity issues, generation relief, and priorities of the sample are appreciated at first view. Neurodiversity was not measured on the sample.

On the other hand, the sample presents strong knowledge on UAS for infrastructure, building projects, and disaster management in contrast to urban planning, real state, and traffic domain. Regulatory and capabilities could explain this behaviour. Nevertheless, the data analysis expressed fundamental ideas of how these contributions should be evaluated.

3.7 RESEARCH APPROACH AND ANALYSIS

3.7.1 RESEARCH APPROACH FOR DATA ANALYSIS

The research approach undertaken in UAS was oriented to inductive by the nature involved in the aerial robot application and consequently the multi-dimensional framework generation. The media exposure, risk involved in the airspace, productivity gained, and the versatilities from UAS has been awakening the interests of policy makers, manufacturer, and professionals to understand the implications of their implementation. For example: airspace safety, capabilities of UAS for specific tasks and productivity increment in the workflow. Hence, an inductive approach facing these scenarios can significantly produce a valuable outcome to the industry and academia; however, this approach would provide one perspective of the considerable truth on exploration. The lack of literature in the country, time-consuming tasks on access to data and the extensive range of possibilities in the applications can make it difficult to formulate solid hypotheses in the topic and later establish theories without the cases of study. On the other hand, generalizations from different county context could provide insights into the pattern to follow in UAS application and the cases can only cover certain contexts that others might be absent. For example: Gatwick Airport and Newport incident in contrast to Airports in developing countries. The risk involved with UAS airports is prominent and generalizable, but it may not represent the same level of risk each country airports and culture.

So, it was introduced another reasoning approach with the aim to produce trustworthiness of the theoretical framework along with the peer-review publications and professionals framework discussion (3.8.2). Moreover, the abduction approach helped to make conclusions and final inferences of the vast seen territory of UAS in construction in the Dominican Republic. As a result, the combination from both approaches can easily guide the findings to a genuine conjecture from policy makers, manufacturers, educators, and professionals to make logical inferences and construction of a theory or framework to dissipate the scepticism in the application of UAS in the construction industry.

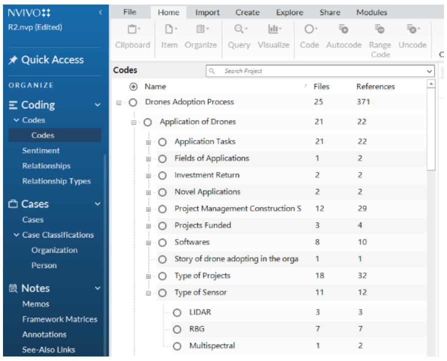
3.8 DATA ANALYSIS

Data analysis derives valuable information from data in order to describe or explain some phenomenon under investigation. Raw data does not offer trustworthy wisdom in the first instant; their preparation, interpretation, analysis, and presentation before any conclusion is drawn from them. Thus, it was intended to transform large volumes of data into manageable and meaningful pieces of information, after derivate to knowledge, and convert it to wisdom. The analyses made in this research were ground theory, thematic, content and ISM method for the framework development. These analyses allowed the researcher to choose a flexible theoretical framework. Through this flexibility, the analysis permitted a detailed, complex, and abundant description of the data. In addition, the analysis permitted the evaluation of a large amount of text information, highlighting keywords and word frequency.

However, the limitation of this approach for UAS application was that the researchers should have previous experience in the field to understand the triggers at each idea expressed. For example: meaning of problems with weather conditions and battery life. These 2 ideas provide information of the type of drones, distance of operation, regulatory framework applicable and operations has been intended to be carried out. The implications of this research in generalising the findings are related to the country and year in which is developed the study. Every year there are changes in the regulations of UAS and in models that transferability is recommended if similar settings are presented. The development of the framework is designed to cover the main ideas that in any future context, the adoption of UAS, remains statics in the foundations.

In social research studies, bias is presented as a consequence of the human being factor. The threats to trustworthiness of the interviews were minimized by asking for evidence of data and further discussion with the participants (Guest, et al., 2012). The transcripts passed through the process of ground theory analysis in which the open coding, axial coding and selecting coding were used. In the following picture can be seen as an example of the analyses made in Figure 3-4.

Figure 3-4. Nvivo 2020 analyses



In this figure is presented the Nvivo2020 codes. It included the parents and child nodes, files and references made to them.

The content and thematic analysis were made in order to identify the key ideas on the UAS market in the Dominican Republic context. Content analyses support the narrative of the experiences reported on this thesis as well as develop cases with the benefits and barriers of the UAS application as (Vanderhorst, et al., 2020). Then, with the thematic analysis was identified the trends and patterns that can describe scenarios in which UAS are applied, such as the case of disaster management (Vanderhorst, et al., 2021). In addition, the cases of studies from different participants were made based on the application evidence provided, for example: images, videos and documents. However, despite the analyses and methods utilized, the fundamental ideas for a theory necessitated a deeper understanding of the causalities of positive or negative behaviour in the adoption process of novel technologies as the UAS. Furthermore, the recreation of the content analysis allowed to produce other types of analyses were carried out. For that reason, the Interpretative Structured Modelling (ISM) method and Matrice d'Impacts Croisés Multiplication Appliquée a un Classement (MICMAC) analysis were incorporated.

3.8.1 ISM METHOD AND MICMAC ANALYSIS

The ISM method and MICMAC Analysis are tools utilised by researchers to identify the root cause of barriers in a specific problem. ISM strength ambiguous and insufficiently articulated abstract representation of systems into a comprehensive and simplified model fitting to this research (Sushil, 2012). The ISM helps to establish a hierarchical relationship between variables. Furthermore, the Matrice d'Impacts Croisés Multiplication Appliquée a un Classement (MICMAC) analysis support the classification of the implications based on the strength of the relationships derived from the ISM process (Jung, et al., 2021). In the appendix section there are details with the analysis made. The ISM process produces a systematic frame describing a complex problem implied on a system graphically throughout hierarchy order. The simplification process has different steps to accomplish:

1. Identify the variables of barriers and drivers through the data collection.

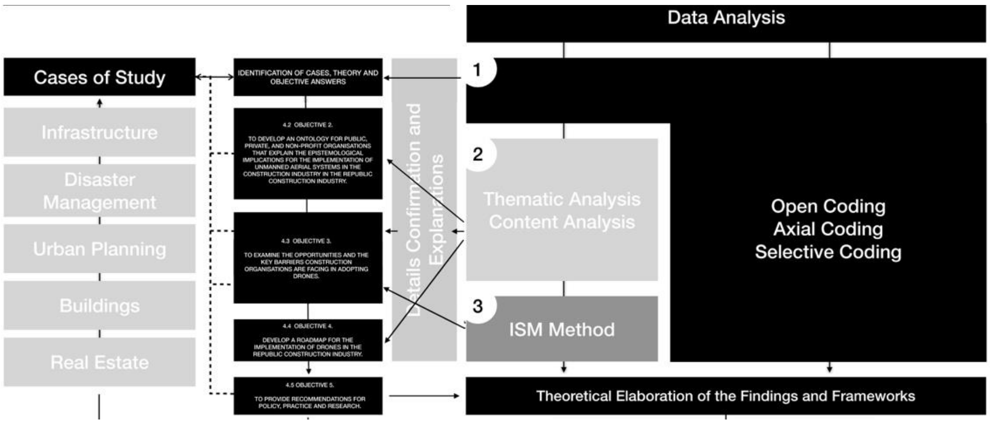
2. Then, determine the relationships between barriers or drivers. These relationships require to assign a value against each one as XAVO:

- X = Both-direction relations i ⇆ j;
- A = Only one direction from i ← j;
- V = Only one direction from i → j ;
- O= No relationship

3. After, it was constructed a structural self-interaction matrix (SSIM) which contains the relationship paired between barriers or drivers by the participants. The barriers or drivers were identified with the interviews answers and used as their final answer for the matrix.
4. Next, it is assessed the hierarchy of the barriers on a matrix with 1 and 0 according to the XAVO value called reachability matrix. The matrix is used to quantify the reachability and antecedent columns which will be used for establishing the hierarchy among them.
5. The barriers or drivers were drafted in a hierarchy with the directed links of relationships devised from the previous matrix. However, other scholars may address this step by discriminating the transitive relationships and evaluating their interpretation from perspectives of experts.
6. The frame map is drafted into an Interpretive Structured Model (ISM), and it is reviewed for conceptual inconsistency. After this, the MICMAC analysis is developed. It is used to examine the drivers and dependency strength of the barriers or drivers in the study. Finally, the barriers or drivers were graphed, naming them on the autonomous, linkage, independent and dependent quadrant for further interpretations for assessing priorities of the barriers to tackle or drivers to incentive.

After these explanations, the following figure summarises the analysis process made:

Figure 3-5. Data Analysis process and linkage with the research objectives



In this figure can be identified the complete process of data analysis to construct the multi-dimensional framework for UAS adoption in the construction industry and the process involved.

However, despite it being a qualitative approach, how the trustworthiness and reliability are assessed in detail?

3.8.2 TRUSTWORTHINESS AND RELIABILITY

The trustworthiness and reliability of this study are evaluated throughout the triangulation technique on qualitative studies as well as the peer-review publications process (Moser, 2018). Several experts (3) in the field; regarding digitalisation, innovation, and drones; were contributing to the development of the framework were involved and provided their perspectives. The dynamic in this process was a discussion between the participants and the researcher. Explanation and white paper information was delivered to the participants to understand the frameworks and the improvements to share. The comments were made in the actual cases and benefits of the policymakers to promote the adoption of this technology.

In addition, the dynamic and trending harmonisation of the United Kingdom drone regulation system, building information policies, and other contexts as the European Union produce the scenarios to contrast the framework for trustworthiness, future of UAS regulations and the adoption process of digital strategies in construction. Therefore, the reliability of the outcome produced is often challenged by the generalization case, but the framework was not limited to the Dominican Republic only. The framework has elements that can connect with other countries in essence by their regulation approach and government perspective. Furthermore, the triangulation was useful to relay the comments and perspectives shared by the participants.

3.9 SUMMARY OF THE CHAPTER

In summary, this section has discussed the philosophical assumption embedded in the application of UAS. As mentioned before in the literature review chapter, the appropriate methodological approach for studying this kind of technology is the development of the case of study. However, the approach to developing ontologies that describe the epidemiology is more aligned with a qualitative approach. The experiences can be elicited and confirmed with pieces of evidence utilising the strategy of ground theory and its analysis method. Furthermore, other methods of analysis were involved, such as thematic, content analysis, ISM method and MICMAC to understand and acquire knowledge and wisdom from the data that can be later utilised as transferable knowledge in a publishable standard. The trustworthiness of the study rests in peer-review publications as well as in interviews with professionals in the field nationals of the Dominican Republic. Furthermore, after an extensive and detailed assessment and explanation of the methods and approaches, the following section will finally present the results of all the interviews and data gathered coherently and comprehensively for the readers and examiners. Thus, the structure of the following section resembles previous chapters.

4. CHAPTER IV – RESULTS

4.1 INTRODUCTION

This chapter describe and analyse the results from the data collection. Each section presents the results and analysis of the research by objective.

According to the literature review, there are 5 aspects to explore the UAS. Building, Real estate, Infrastructure, Urban planning, and Disaster Management. Publications related to this chapter have been presented in the form of links in the appendix section. The following explores the fields in which the UAS has been applied in the country. The name of the project, tasks and explanation from the participant are exposed. It is not used as a neuro network approach for easier understanding. Some of the cases exposed have been published in detail; please check the appendix section for more information.

4.2 **OBJECTIVE 2.** TO DEVELOP AN ONTOLOGY FOR PUBLIC, PRIVATE, AND NON-PROFIT ORGANISATIONS THAT EXPLAIN THE EPISTEMOLOGICAL IMPLICATIONS FOR THE IMPLEMENTATION OF UNMANNED AERIAL SYSTEMS IN THE CONSTRUCTION INDUSTRY IN THE REPUBLIC CONSTRUCTION INDUSTRY.

4.2.1 BUILDING PROJECTS

Table 4-1. Building projects

No.	Buildings	Tasks
1	Residentials	Feasibility Studies *P7: "Drones are being used for pre-construction stage in conceptual projects. Also, it is used as a topography support tool along with GPS. … Recently, for the progress report and designs (pre-construction). Big companies are using and obtaining drones. For example, … design companies are using for feasibility studies for clients…"*
2	Hospitals	Building Progress Monitoring P19: *"…I started to work with the topic of BIM and in my last job, we used to apply drones for progress reports taking images and pictures. Then, the images were used to coordinate and monitor the construction works. The drone was very useful to monitor, record and visualize the residential and hospital office tower projects. We detected coalitions between buildings on the existence and the news buildings on construction.…"*
3	Public Office Buildings	Monitoring of the Building P15: *"…The main purpose is to obtain the environment of the site and present a full building integration within…"*

		Measure Dimensions P11: *"…The drone facilitates us the issue in lack of blueprints. It is hard sometimes to obtain the dimensions of public buildings…"*
4	Parking Area	Identify Area Conditions P15: *"…We started to use the drone 21/2 years ago because we were working in the minister parking area restauration taking images…"*
	Commercial Buildings (Mall & Offices)	Traffic studies on feasibility studies *P7: "… The application most used in the company is regarding traffic studies on intersections. It is recorded and measured periodically, the traffic flow, with the drone. It is counted the number of vehicles, types, user behaviour, and intersection management in a specific zone… It is used to validate the manual and electronic tasks made for feasibility studies in a pre-construction stage…"*

In the literature, the cases without literature confirmation were commercial buildings and residential feasibility studies, which involve traffic applications of UAS and other processes that further indagations are recommended for an exemplar case of UAS in these settings of productivity.

4.2.2 REAL ESTATE

Table 4-2. Real Estate

No.	Real Estate	Tasks
1	Land Entitlement	Land Confiscation P5: *"…So, some cases that I can share with you are for bank stakeholder perspective. The banks have proceeded with confiscation lands process as a consequence of debtor customers. A land title was guaranteed but, in the field, or blueprint was an incongruency and inconsistency. The land was invading another parcel before, but the title was not updated on time. Therefore, the land title has less dimension than the actual land portion available. With the drone we were able to map and locate the issues and report visually the investigation…"* Land Expropriation P5: *"…Another case was with land expropriation. It was in a countryside area where the access was denied by one of the parties involved. The party put militaries across the area in order to avoid the land area rectification for the tribunal. With the terrestrial equipment was impossible to measure (the site), but with the drone, it was able to flight from a reasonable distance, map the area, and provide proof of illegal expropriations. With the same information acquired, the new project was located in the building the area…"*

Land enforcement is a field for further research for litigation aspects of UAS application. There is not found literature yet on this topic that confirms this application of UAS.

4.2.3 INFRASTRUCTURE PROJECTS

Table 4-3 Infrastructure Project

No.	Infrastructure Projects	Tasks
1	Bridge	<u>Bridge inspection and reconstruction</u> P8: *"…For example: On bridges. When we are with this type of project, we got before the difficulty of accessing scenario: No accessibility to the place where you are going to work.* *Nowadays, with a drone you access and overcome the physical barrier that a human being cannot pass, so having that great freedom, you can do your survey, and you can also make an intelligent model that has geographical information. This fact means a lot to those who work on the project…"*
2	Water Supply	<u>Water Source identification</u> P1: *"…The drone has brought us the option of visualizing and exploring aquifers on higher points, with abundant water, superior conditions and purer uncontemplated during the feasibility assessment as a consequence of dangerous access and time-consuming task walking. Also, we estimate the distance visually between the source and the community to ensure the purity of the source…"*

		<u>Georeferenced Water Resources</u> P1: *"…However, there are pieces of information gathered by the drone that we managed and shared with other organisations. We have been one of the first organisations that georeferenced all the aqueducts, treatment plants and infrastructures. With the drone we complement the information. Furthermore, the technical team is working on how the telemetry can be implemented with the supply network water…"*
3	Roads	<u>Highways Surveys</u> P4: *"… In the highways projects designs, the drones reduce the time from 7 days surveying to 1 to 2 days, the work being possible to evaluate different paths in less time…"*
4	Electrical Grids	<u>Power Transmission lines Inspections and geolocation</u> P20:*"…the aim to georeferenced, with the EU satellites, the powerlines transmission in the country applying drones. In addition, it is needed to map the sites to make efficient the airspace route lines utilizing a multi-spectral imaging scale colour camera and a normal camera. The multispectral imaging will provide thermal information related to the energy losses and consumption in the cables and the normal camera will map the population growth and estimate the electrical demand of the communities…"* <u>Solar panel Inspections</u> *Site visit recognition.*

8	Sewers	Visual identification of external sewers (Vanderhorst, et al., 2020) *P24: "…Therefore, with an overlap of drone images and contour lines, we can identify the water flow and possible areas to adapt sewers…"*

In the Dominican Republic, the roads of the railways between cities are old and cases regarding maintenance were not found as well as tunnels and telecommunication towers. The underground application of UAS has not been yet explored in this context. Furthermore, in the literature review discussed most of the application seen in this section. Additionally, the UAS is mostly applied for infrastructure based on the extensive dimensions of projects as well as lack of blueprints. The tasks in this area are mostly referred to damage quantification, thermal inspection, 3D reconstruction and surveys as mentioned in the literature review (Vanderhorst, et al., 2019).

4.2.4 URBAN PLANNING

Table 4-4. Urban planning

No.	Urban Planning	Tasks
1	Rural Environment	Delimitation of zones (Vanderhorst, et al., 2021) P17: "…*Smart community for making better decisions*…" Monitoring Population

		P12: "*…The information collected by the drone allows to evaluate the population growth and patterns in the urbanism expansion…"*
2	Urban Areas	<u>Monitoring Water Source</u> P1: "*…The drone has been asked for taking panoramic pictures of the central building, and after seeing the demand, it was solicited another drone.* *The technical team intended to create a custom drone for their needs. But they move that plan away for a time while they are using the new drone.* *So, the images provided by the drone have allowed us to make aqueduct reports and identify pigsty, bridges, cattle, people throwing wastes near the water source. Therefore, we show the director the case and he orders the military action and ministry of public health to embrace the illegal activities in the area. Before, it could be possible to do it, but now with the drone, we have a higher level of correction and preventing actions…"* <u>Interurban Terminals Visual State</u> P15: "*…We requested a traditional topographic survey, taking images with the drone, then made a photomontage in order to see the final result together. Basically, we keep using the drone for the same reasons (taking images) but our projects changes, we received projects such as interurban terminals, provide support to another department like pedestrian crossings, and parking areas…"*
3	Traffic	<u>City Traffic congestion liberation</u>

P21: *"…After the drone purchase, we are interested to record the environment and traffic flow of the areas for future construction project traffic studies permission requirements. We currently have 40 intersections drone video recorded or digitalized for any further studies requirements. We might need future videos in order to identify the people time flow with machine learning and liberate the main roads via an app…"*

The application of UAS for urban planning has been more oriented to disaster risk reduction rather than real estate development. The barriers on mapping large spaces as well as the price of UAS for these specifics' usage create contingencies in their adoption in contrast to the cost-benefit analysis of disaster management. In this field, the events are generally focalized in circumscriptions or punctual areas that conventional well designed UAS can collect data and bring appropriate insight for decision-making processes. The tasks are related to the literature; however, more cases should be developed in this field.

4.2.5 DISASTER MANAGEMENT

Table 4-5. Disaster Management

No.	Disaster Management	Tasks

1	Epidemics	<u>Monitoring Focus of contamination (Cholera)</u> *P1: "…Regularly, the drone is used to investigate sources of pollution in water source surroundings. A Cholera bud was presented in a rural sector. The team were flying over the basin with the drone identifying the successfully the main pollution focus. Example: communities or farms alongside the water source. Different stakeholders as the council, got involved in the case and, they requested to fly the drone for their own purpose…"*
2	Earthquake	<u>Multi-Risk Evaluation</u> P12: *"…Another example is urbanisms monitoring and inspections. The maps are on a large scale that rural, isolated, vulnerable communities are unseen in the macro maps…"* <u>External Geometry Extraction and georeferencing</u> P13: *"…before the seismic construction code appeared; so, if I want to investigate the seismic behaviour of those buildings, I will require to reconstruct the project virtually in order to make the tests. So, we are utilizing the drone to obtain the external geometry of the building…* *…Currently, it is only used for risk prevention in disaster management obtaining the geometry and georeferencing…"*

		P3: *"…Drones are used for photographing existing structural and architectural buildings…"*
3	Landslide	<u>Urban Monitoring and for Risk Reduction</u> (Vanderhorst, 2021) *P12: "…A case of study in the organisation applying drone was a risk evaluation for disaster management for landslide and mass movements in rural communities at the north of the country. The project was needed to carry out a multi-risk evaluation and the maps available were on a high scale that it did not allow us to identify the community on interest….* *…The works that we carry out in the office are concerning to multiple disciplines such as disaster management, mining, urbanism, and underground water…* *… But basically, we do risk-evaluations, a database for urban planning, amenity characterization, mining, and geology systems, etc…"*
4	Tsunami, Floods and Hurricanes	<u>Urban Risk Prevention and Evacuation.</u> P14: "...*Generally, we fly the drones in vulnerable zones in the country in order to*

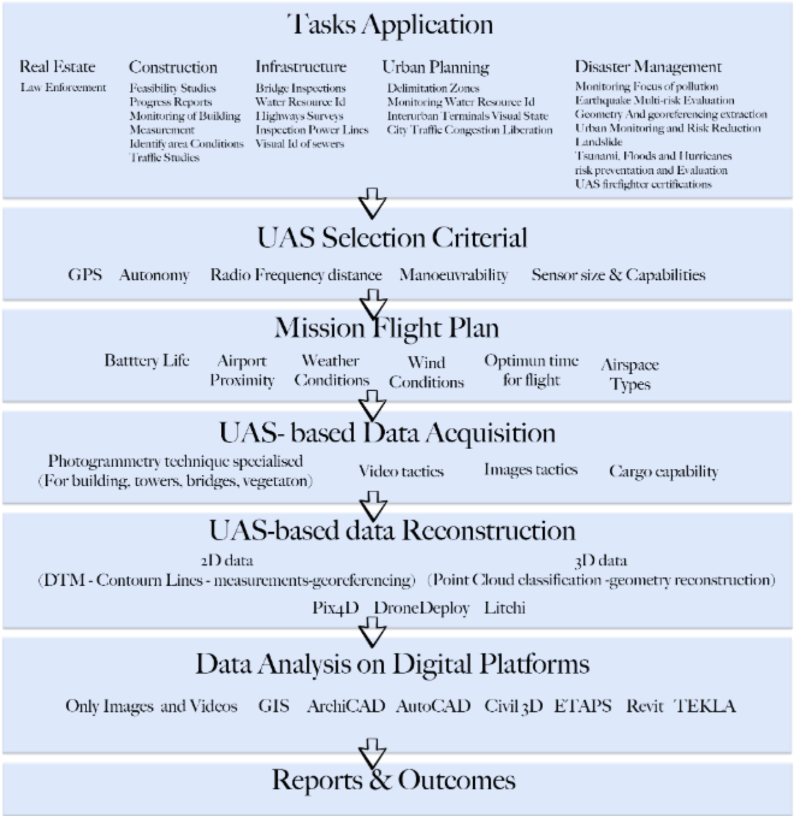
		survey and observe flooding, landslides, incommunicado bridges, sea penetration areas, overflow of a dam, river flows, ravine or streams. Therefore, as a mitigation risk institution for disaster management, we analyse and provide the information gathered to the operational department in order to address risk prevention campaigns, rescue procedures, evacuations routes, shelters, and population mobility in a disaster management situation (Huracan, landslide, flooding and others). *P13: "…However, next year we will be implementing drone for tsunami prevention analysis…"*
5	WildFire	Firefighter UAS certifications P10: *"…An organisation requested an airspace permission to test a drone in a tropical weather condition in the country. The drone is capable of transporting 9,000 water weight pounds to extinguish the fire. The amphibious drone will be capable of lifting water and pouring on the fire situation. It has been tested in order to be certified…*

Each case and application may have its particular information and data usage. The cases found in the country are poses similarity with the cases in the literature. But, in juxtaposition, the differences in the cases are related to policy and technology availability. The technicalities of the UAS application allow the policymakers to understand how to design rules based on contexts. In the country, the UAS regulations have been flexible, supportive and in favour of UAS development. However, the lack of UAS specialised or different arrangements would make it complex to identify or assess where is required a regime of consequences, encouragement, or clarifications on the degree of freedom on the operations. Based on the cases, the regulations are being updated and clarified. The cases presented rise the question of who, where and when these operations would carry out and if regulations regarding UAS operations should be implemented like the Remote ID in the USA, or each council manage the land space of deployments, or establish technical recommendations for best practices on shared airspace operations. Moreover, the capabilities of the UAS also influence policies of radio frequencies, RGB zoom manufacturing regulations, etc.

4.2.6 GENERAL WORKFLOW

However, the UAS workflow remains most of the time the same, only with changes on the techniques used and outcome usage processing method. In Figure 4-1 is shown the applicable workflows for the tasks found in the Dominican Republic.

Figure 4-1. Simplified UAS Workflow



Regardless of the tasks, there is a general workflow to follow as mentioned in 2.4.2. The workflow presented with the findings simplified and add technical knowledge in the software used that previously was limited in the literature. Despite the similar workflow, the effectiveness of the UAS is a doubt for different reasons. In the following section express the perspective of the participants regarding the performance of the UAS.

4.2.7 EFFECTIVENESS OF THE UAS APPLICATION

The performance of the UAS on the tasks was evaluated by the interviews as excellent (80%) rather than outstanding (10%). The fundamental reason of classifying the UAS as excellent is based on the significant change in productivity contrasting with other tools and processes. However, the reasons for these perspectives are basically the workflow and skills involved in deep 2D and 3D reconstruction of UAS.

> P8: *"…Its effectiveness is affected by the implications of the process it leads. One part is the operation of the device itself and another part of transforming the information into something useful, tangible, and usable for all the disciplines involved in the construction process, effectively. Because it is not instantaneous that happens the application of the outcomes…"*

The educational factor influences the application of the UAS but is not necessary in its adoption process. The UAS require multiple technologies and skills to operate adequately in the organisational workflow. Therefore, exploring the negative aspects of the application of UAS has been encountered the barriers that the technology is facing. Most of the barriers are technology-based, as seen in (*2.3.5*) innovation and competitiveness.

Nevertheless, there are barriers that influence the adoption process rather than the application. The following section are discussed both barriers and the ISM method is applied.

4.3 **OBJECTIVE 3.** TO EXAMINE THE OPPORTUNITIES AND THE KEY BARRIERS CONSTRUCTION ORGANISATIONS ARE FACING IN ADOPTING DRONES.

4.3.1 KEY REASONS FOR ADOPTING AND IMPLEMENT UAS IN THE CONSTRUCTION INDUSTRY

In terms of UAS application, the aerial robot seems to be contributing to BIM methodologies and advancing the digital strategies. However, what are the key drivers for adopting them in any scenario expressed as with and without BIM? The reasons found are distributed between time saving and educational purpose for social aspects and on the technical side, manoeuvrability, multipurpose technology, and transport goods or services.

Table 4-6. Reasons for Adopting UAS in general

Perspective	Reasons for Adopting Drones	Elaboration
Social	Productivity Increment Speed, Safe time, time reduction, faster works Efficiency Cost Reduction Standardize construction, Process in other words, Quality assurance in the construction workflow Human Displacement for Fatigue reduction and risk reduction Visualization from different perspectives and view the big picture Education Purpose	The social perspective of the reasons is regarding cost reduction. Human factor is prevalent as mistake are made during the construction process and utilising technologies that address in advance the barriers for success factor in construction, represent an advantage for the organisation.
Technical	Manoeuvrability, Multipurpose technology Produce a record of the construction process Obtain a significant amount of data Try Innovation in the organisation BIM implementation by 3D, 4D and 5D Better decision Accuracy in the works as higher resolution and detailed information Transport goods or services	The technical reasons are the core of applicability and sustainability of the UAS adoption. As technically the UAS workflow contribute to make faster legal process as well as supplement digital workflow that used to be addressed manually, a significant advantage is perceived that make echo in costs.

The UAS in the country applied for the construction industry have been mostly quadcopters with an RBG camera. The premise standardized the reach of reasons for this specific tool. The most common reasons identified were higher speed on the process of data collection, long term cost reduction on the operations, and applicability of the data of UAS for lean philosophy in construction.

P15*: "…Because of the work culture of reaction instead of planning, we need the drone to make faster surveys and present final designs view to the corresponding authority…"*

P1: *"…So, the drone helped us to supply the requirements because images provide more information than interpretations…"*

P19: *"…It is required to explain the benefits obtained by the data collection through drones. Another reason is the type of information particular provided by the drone for surveys without involving numerous stakeholders. Furthermore, traditional methods are, in some cases, inaccurate and time-consuming in contrast with drones…"*

Furthermore, the same UAS and sensor produce the perspective of safety before human risks on-site as a multipurpose technology. Other drivers of UAS application have been trying innovation and introducing advanced BIM methods (4D, 5D).

P9: *"…In our case, the drone is used in order to cover a significant amount of land* *in less time, save additional personnel costs, deliver the work faster and with the quality expectation over exceed. In addition, the drones are compatible with the BIM methodology up to 4D and 5D. The drone facilitates the BIM implementation…"*

P10: *"…The high-tension cables inspection is a high-risk task that with the drone is reduced the issue…"*

P4: *"…I understand that the main reasons are the speed and certain manoeuvres can be performed. Also, the amount of new information that can be gathered. Because of this, if drones are not used, that information costs more to obtain. The team realize that they have, anyway, to evaluate the information and with the drone is assessed faster…"*

Moreover, a key driver that the sector emerged to apply technology for this context is corruption. Diverse abuses of power and episodes have appeared in the country. Consequently, the implementation of technologies may purify the decision-making process of payments and enhance the transparency of the public and private sector, as well as foment new services and standards in their value chain.

P17: "…*Another key reason is the transparency. The projects records are utilized to avoid corruption or increase workflow transparency on the projects…"*

The records produced by the UAS allow organisations to facilitate visualization of the workflow performed. Furthermore, the reasons of applying UAS for a sustainable manner are related to technical as after the UAS is tested cost benefits are seen in a long-term perspective. However, confirmation of these ideas is considered utilising other methods as ISM method to understand in-depth the real reason of the UAS adoption.

4.3.1.1 ISM METHOD AND MICMAC ANALYSIS OF THE REASONS OF UAS ADOPTION

In addition to the previous perspectives, validation, and detailed analysis of the prevalence of the reasons were carried out. Applying the ISM method and MICMAC analysis, the following results were consistent with the findings.

Figure 4-2. ISM Method Analysis

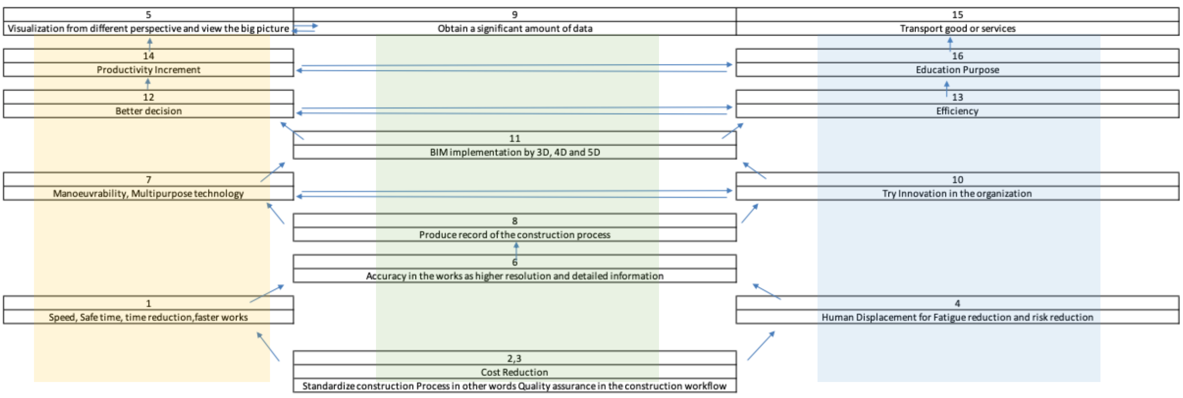
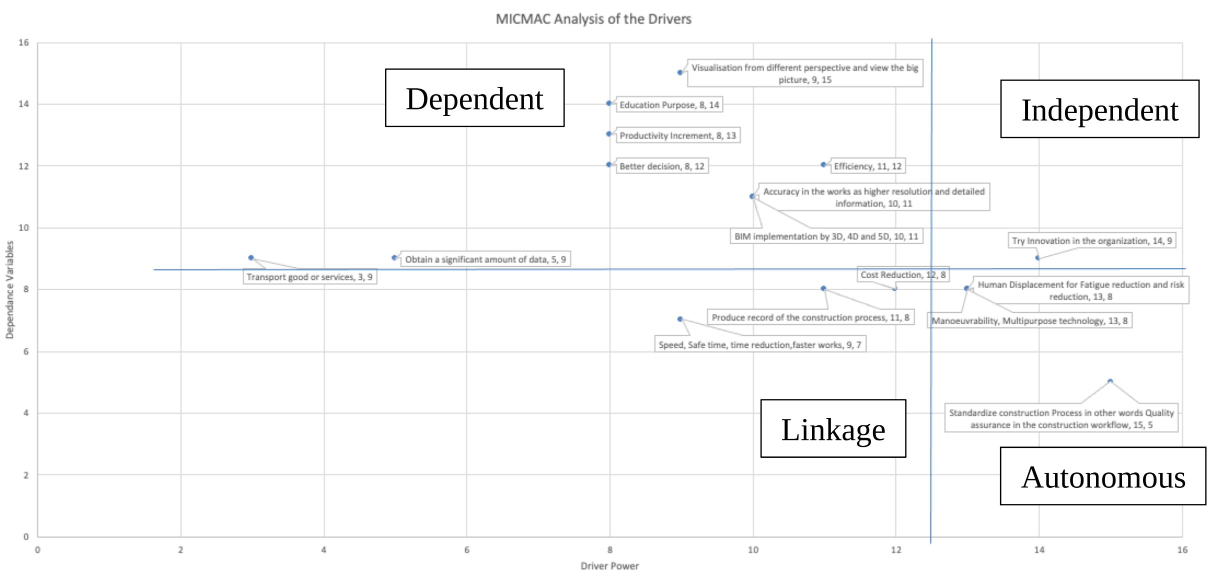


Figure *4-2* clearly identify the 3 different paths of reasons in which the UAS are adopted. From left to right, the first column expresses the reasons for productivity in the organisation. These reasons are mostly related to business implications, and human resources works instead the technology improvement. In the second column, is identified the tendency of digitalisation of the project and, the last column discusses the implications of automation and human displacement or aspects of the singularity theory. As mentioned in figure 4, the development of human displacement may take longer than the current adoption of digitalisation of the construction projects.

The main reasons to adopt UAS is referred to quality assurance (3) & cost reduction (2). All the advancement of the UAS is towards a culture of quality assurance, standards, and cost reduction. These reasons significantly influence the decision of acquiring a UAS with the implications involved of digital strategy and methodology such as BIM ad Digital twins. Then, the assignment of ranks and a graphical representation of the factors evaluated were made to understand their driving and dependence forces as well as the reliability of the interpretation made.

Figure 4-3. MICMAC Analysis



The Figure *4-3* presents that the autonomous variables, the ones that lead the adoption, begins with the standardisation of construction works. Then, the displacement of humans in some tasks influence the automation of the process directly. Finally, the versatility of the UAS significantly acts as the last autonomous driver to adoption. In a few words, the process map of construction allows to identify risks and implement UAS for various digitalising tasks. Furthermore, the linkage to UAS and the adoption process is the idea of the speeding process and cost reduction by independently trying innovation as an essential driver. After, components of education and sophisticated methodologies to increase quality assurance are established. The variables of visualisation, data amount and transport of goods and services are the consequence of the decision made on standardise process in the organisation. However, after the adoption process of UAS, what are the applications?

4.3.2 BARRIERS OF THE UAS ADOPTION IN THE CONSTRUCTION INDUSTRY

The UAS in the context of the Dominican Republic expresses different barriers on the implications of UAS piloting and workflows data integration with the actual technological tools. The most mentioned barrier was regarding technical aspects rather than managerial or regulatory aspects. The specific training and specialized professionals are the barriers most mentioned by the participant. Therefore, the technical professionals are leaning toward the adoption of UAS be the key knowledge holder for expanding the application of UAS. Nevertheless, the battery life of the UAS reduces the operational time by interrupting the process as well as its radio frequency. The highlights of barriers are mentioned in the following table:

Table 4-7. Highlights of the barriers of UAS in the Dominican Republic

[redacted]	
Lack of Training and specialized Professionals	10
Reduced Battery Life	5
[redacted]	
High Drone Price	10
Resistant to Change	9
[redacted]	
Policy Makers strategic Updates	5

The table expresses that the technical knowledge asset of UAS application is crucial for its adoption. The barrier is quite complex because the professionals in this field are normally empirical and structuring a UAS academy for educational purposes in schools and universities is thought-provoking thinking. The most suitable approach to understand and address this barrier is to utilise a neuro network approach or metacognition techniques, as seen in previous chapters (2.4). The rest of the barriers describe the limitation of the UAS, that manufacturers are still working on it, and issues of the adoption process (management and regulations updates). However, further exploration was made in the thematic aspects of the barriers to elaborate later a comprehensive framework of the research. The entire list of barriers with the thematic aspects are described below:

Table 4-8. Thematic Barriers of UAS in the Dominican Republic

Perspective	Barrier aspect	Description	Elaboration
Technological	UAS	Reduced battery life Issues with radio frequency and operation distance Lack of knowledge in the internal artefact functions Low resistance to high winds and weather conditions Accuracy of the works	The energy source barrier, radio frequency, resistance to weather conditions and accuracy of the sensors are merely for the type of UAS in possession. These UAS are the most affordable ones and present these limitations. In another models with range of price beyond the £10,000 the problem ceases considerable. However, new battery types as well as dedicated sensors for construction will be reducing the barriers presented.
	Tasks	Lack of Drone specialized for construction tasks	
Regulatory challenges	Social	Policy Makers are lag behind Politicians require a generation relief Lack of Strategic Priority Lack of Incentive in innovation development Lack of integration of different sectors to promote drone adoption	The policy barriers are related to the regulations in the country that may affect certain types of operations such as city monitoring and Façade reconstruction. The country presented a low rate of changes in contrast to other countries that change their regulations 2 times a year. Furthermore, there was not regulations for promoting innovations within the context of construction.
	Technical	Unregulated several drones flying around	For safety reasons, the amount of UAS operations in certain areas of the country should be controlled to avoid collisions and future disputes as in disaster events of fire, floods, etc.
Structure/ People	Organisational	High Drone Price	These barriers were considered as internal and external cost influence of acquisition, Organisational culture, and business models.

	Lack of Feasibility studies of drones and investment return	The price of importing a UAS overpass 50% of the actual price influencing the decision of acquiring or hiring the service.
	High Drone Taxation	There is resistance to change of workflows as return of investment is not seen imminent against the initial investment. Also, the culture of reactive restricted the integration process of technologies for planning phases.
	Resistant to Change	
	Reactive Culture	As the UAS is a multipurpose technology business cases are difficult to be identified.
	Business Models Barrier	
People	Lack of training and specialized professionals	
	Lack of awareness and knowledge in drone application	The manager decided to hire the UAS services as qualifications does not cover the expertise required either in academia or in the industry. Empirical knowledge is acquired by autodidact pilots. It generates difficulties in assessing the knowledge assets of the pilots for addressing certain tasks.
	Lack of Workflow insertion projects between industry and Academia	
	Lack of Drone inclusion in the Curriculum	Lack of scientific studies that reveal the benefits of UAS in this context, ease to fly UAS and procedures of data management within the organisations delay the adoption of UAS.
	Fear of breaking the Drone	
	Lack of technical safety guidance data management between institutions	

Other aspects that have been mentioned are barriers at the managerial level. The remarkable barrier has been the high price of the UAS as well as the initial investment contrasting to free satellite and imaging services. However, the lack of knowledge in terms of business cost-benefit analysis make it difficult the comprehension of the UAS adoption in organisations. In the same line of thought, the resistance to change into digital strategy represent a significant barrier to the adoption process. Furthermore, in terms of regulations, some barriers regarding technology understanding and airspace regulation arose with UAS. Some peripherical regulations related to the price of acquisition and innovation incentives could seem a concern in the Dominican Republic. The interviewees expressed that the lack of knowledge from academia and the lack of incentives in innovation for implementing technologies is a barrier for the technologies spreading it, generally. Other conjectures mentioned. that influence the promotion of UAS and technologies were the generation relief guidelines and best practices of UAS behaviour for the public in general. It was suggested to develop and publish best practices for the industry growth.

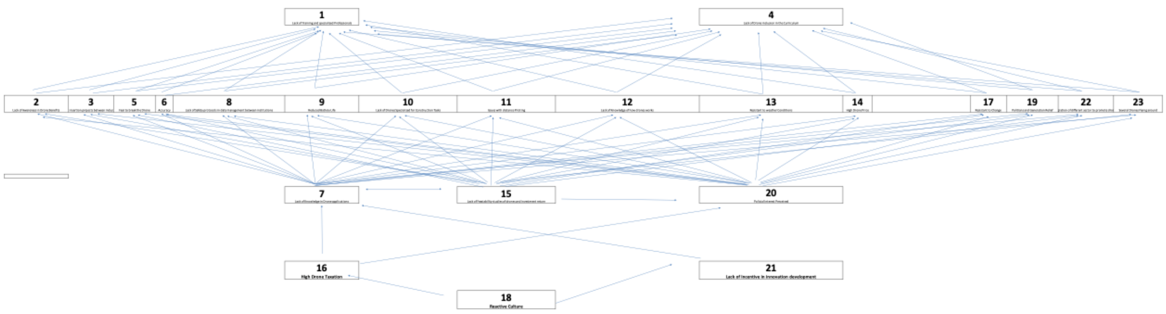
> P21: *"…Resistance to change by the lack of knowledge and fear. The head managers of the government institutions come from different generations that may produce issues in the adoption of novel technologies. In our case, the technical director is interested in contributing to the next generation coming. In addition, the cost of acquiring the equipment and the personnel technical capabilities is a tremendous gap we have faced. It is difficult to buy a drone that the technicians are not well familied with it…"*

However, the barriers expressed do not provide the root one to defeat them. The highlights give the initial idea, but further analysis such as the ISM method and MICMAC analysis were carried out to assess the logical order of hierarchy between the barriers.

4.3.2.1 ISM METHOD AND MICMAC ANALYSIS OF UAS BARRIERS

The barriers were profoundly analysed throughout the ISM method identifying 23 variables as obstacles for the UAS adoption process. The barriers were mixed indistinctly, generating an idea of how the barrier can influence another from each aspect. The ISM brought the following line of thoughts to consider:

Figure 4-4. Diagram of ISM of the Barriers



Level 1 of Priority – Cultural Change within the Social System

Reactive Culture or Risk Mitigation Culture (18): The general idea generated was that the reactive culture of the organisations forces the employees to adopt new methodologies of works that may or not be suitable after a digital transformation is in place. The understanding of the financial and productivity risk reduction that the technology and metacognition method would bring to the organisation will facilitate the openness of innovations. In some contexts, digital strategies could be observed as a proactive practice that may infer structural changes in the organisation. Therefore, the resistance to change by the culture inside the organisation significantly represent a barrier.

Level 2 of Priority – Business and Human Resources Implications

High taxation (16) & Lack of incentives in innovation development (21): The adoption of technologies emerges from outside the country. There are not UAS manufacturers different from racing ones. Requiring a specific type of UAS suggested designating a relevant amount of funds for inserting UAS workflows in an organisation. From a technical perspective, encouragement and reinforcement for novel future-proofing ideas and methods implementation should be considered. For example, recognitions or bonuses for future-proofing technologies implemented in the workflows.

Level 3 of Priority – Political, Business, Human Resources context

The lack of Knowledge in UAS applications (7), Lack of Feasibility studies of drones and investment return (15) and Strategic Priority (20) : The knowledge in the application of UAS, cost-benefit analysis and regulatory environment influence in a third level the consideration of UAS adoption and its workflows. As seen in (Vanderhorst, et al., 2020) in Figure 4-5, the lack of knowledge in terms of the applicability for certain tasks such as pipeline design, the meaning of effort reduction and an adequate regulatory environment allowed the department to understand the wisdom on adopting technologies. Further cost-benefit analysis could be made based on the salaries involved in the design process. However, internal capabilities should take into consideration for effective integration. Some of the values of efforts could represent the progress of another delayed project.

Figure 4-5. Traditional vs UAS-BIM Workflows

Table 3. Traditional Pipeline Design Workflow

Project Phase	Description	Days	Personnel	Effort	Total
Data Capture	Field-based RTK survey	6	4	24	24
Survey Processing	Data arrangement for Cross-section development in Excel	1	1	1	
	Topographic point processing	1	1	1	4
	Contour line Generation	2	1	2	
Pipeline Design	2D Plan draughting	7	1	7	7

Table 4. UAS-BIM Pipeline Design Workflow

Project Phase	Description	Days	Personnel	Effort	Total
Data Capture	UAV Flight	1	1	1	1
Survey Processing	Point Cloud and Contour Generation	1	1	1	
	Topographic surface creation	0.5	1	0.5	3.5
	Cross / Long Section Creation	2	1	2	
Pipeline Design	Creation of the 3D Geometric Alignment and BIM	7	1	7	7

Source: (Vanderhorst, et al., 2020)

Level 4 of Priority – Political, Human Resources and tasks execution

The different barriers expressed at this level are faced after a decision is taken in adopting and executing the digital strategy. The barriers in this level were categorised into 4 ideas:

Table 4-9. Labels of barrier at Level 4 of priority.

No.	Description	ID	Barrier

1	What & How the UAS can do, and the right tool	2	Lack of Awareness in Drone Benefits
		3	Lack of Workflow insertion projects between industry and Academia
		10	Lack of Drones Specialised for Construction Tasks
2	Open mind to the understanding of the technicalities of the UAS by older generations	17	Resistant to Change
		12	Lack of Knowledge of how drones work
		19	Politician's and Generation Relief
3	Barriers from the UAS pilot and the readiness of the device to perform the tasks	22	Lack of integration of different sectors to promote drone adoption
		13	Resistant to weather Conditions
		5	Fear to break the Drone
		8	Lack of Safety protocols in data management between institutions
		23	Several Drones Flying around
		11	Issues with distance Piloting
4	Device improvements	6	Accuracy
		9	Reduced Battery Life

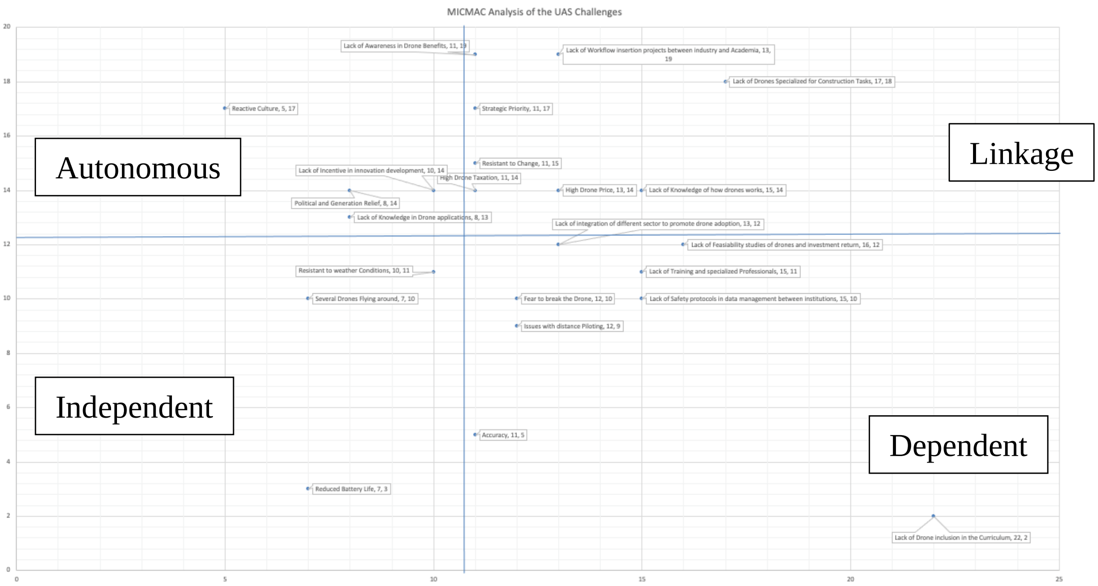
These barriers provide an understanding of a logical framework for adopting this type of technology from a policy maker perspective.

Level 5 of Priority – Human Resources

Lack of Training & specialised Professionals (1) and Lack of Drone inclusion in the Curriculum (4): Finally, the specialisation, training and inclusion as a part of the architect, engineering and construction professionals standards. Therefore, the technology should be first tried, improved then included in the correspondent professional bodies.

In addition to the explanation, the MICMAC analysis provides an overview of the main barriers that articulate the structure of the barriers providing insights into how to tackle and manage the adoption of UAS. In the graph is explained the different perspectives of the power in the barriers. Cultural change in organisations is essential to incorporate the UAS into them. However, variables as the workflow and strategic priorities should be involved indirectly. Furthermore, adjustment, as mentioned before, in the device, should be reviewed, and lastly, the learning process of qualification of a UAS depends on the knowledge obtained during the application stage and the key knowledge holders are open to sharing with the new amateurs. The graph expresses a confirmation of the fact that in the practice and operation, the business approach of the UAS emerges.

Figure 4-6. MICMAC Analysis



However, the changes in the organisational approach might influence the perception of the digitalisation of the construction industry in the Dominican

Republic. However, what are the business implications in the application of this tool if taxation and a reactive culture are major concerns?

4.4 **OBJECTIVE 4.** DEVELOP A ROADMAP FOR THE IMPLEMENTATION OF DRONES IN THE REPUBLIC CONSTRUCTION INDUSTRY.

4.4.1 UAS COMMUNITIES IN THE DOMINICAN REPUBLIC AND REGULATION

In the Dominican Republic, the number of certified pilots in the UAS sector had increased since the regulation appeared in 2015. The private sector in the country has been utilizing and providing UAS services to the government since 2005. Then, the public sector starts to adopt UAS in 2015 with the border surveillance application. Later, in 2016 international aids contribute to addressing the need for training course dedicate UAS operations for public institutions. A Drone Innovation Centre exist in the country with the aim to test different platform and uses of UAS. For example, cargo medical sample and UAS for construction.

> P16: *"We currently are running a project with the aim to quantify the effectiveness of drone implementation in the construction industry."*

The UAS community in the Dominican Republic is mapped by the Civil Aviation Authority of the country (Dominican Institute of Civil Aviation IDAC) and visible on social media. The civil aviation authority has a record of the licensing pilots and permissions granted for relevant deployments on assembly events, and beyond the limits of the airspace designated to UAS. The first projects with UAS met by IDAC in 2014 was a highway. The task intended to address a survey of a road path. The operation was required to be carried out at a high altitude that could interfere with the current air traffic of the zone. This feasibility study of the highway was intended to cross an airport at 1km distance. Unfortunately, at that time, the institution had not published any UAS regulations. Therefore, IDAC started to get awareness and understand the risks involved in flying an aircraft and authorization.

The social media community on Facebook, under the name of *Drones Dominicanos since 2014,* has an important number of members that belongs to the UAS community (3,2k members). From this community, several WhatsApp groups are linked regarding the UAS market in the Dominican Republic. Some announcements of temporal airspace restrictions and UAS regulation changes are communicated by social media and chat groups (Table 4-10).

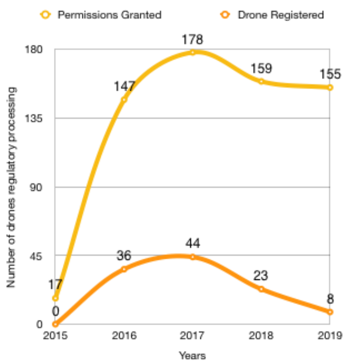
Since the Resolusion 008-2015 stated the two routes to be granted permission for operations; pilots began to request authorization on the basis of safety, commercial, and credibility of the operations.

> *P10: "The operations of drone are not fully regulated, and we are awarded of it. Only the aerial works that big companies and institutions require legality on their operations are requesting permission. The other group without permission the division is combined with police for enforcement actions if there is a security issue on the operations."*

The number of UAS operations that granted permission got a peak in 2017. In later years, the number of permissions granted and drone registration descent.

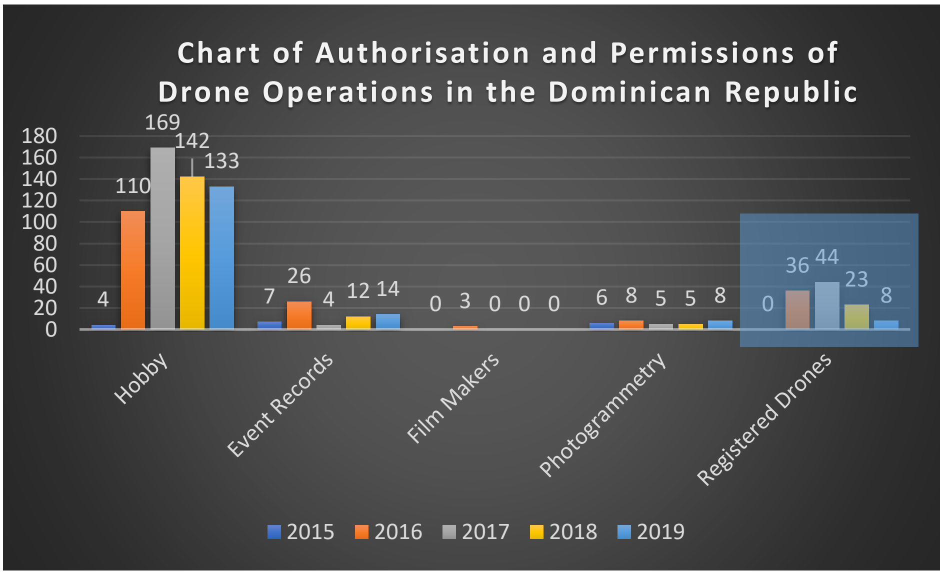
111 UAS has been registered and 656 approvals for operations have been recorded. The key aspect to understand the behaviour in complying with the UAS regulations is the match between operations and the number of UAS. A UAS registration acts similarly to a car registration for accidents. Many operators can drive the car, but if the car works, it will only be driven by one. However, a car accident may be less often than UAS accidents. Therefore, some of the pilots could have up to 5 UAS in order to avoid issues on the aerial work. On the other hand, the numbers of permissions of operations may be reduced after licensing is obtaining to carry out the works. The UAS started to be sold in 2015 and different retailers allowed local sales of the various international manufacturers.

Figure 4-7. Summary of the Number of Drone registrations and permissions granted (2015-2019)



The permissions granted have been classified according to the field of use. Hobby, events records, filmmaking, photogrammetry have been the major areas founded. The details regarding the current population applying UAS have been mostly for hobby purposes. Then, professional applications are seen in weddings and festivals. Secondly, photogrammetry has presented a consistent range of authority interactions for airspace management in surveys tasks. Finally, the industry of film in the country is another relevant field which has been stimulated and a few UAS operation have been registered. Unfortunately, this data shows only the perspective of professional operations carried out almost in the operation limits or outside of the valid regulation between 2015-2019. Therefore, further data concerning the sector stimulation was reviewed.

Figure 4-8. Detailed Chart of Authorization and Permissions of Drone Operations (2015-2016)



The civil aviation authority develops during these periods of conferences and talks awareness and knowledge concerning regulations nationally and internationally; aligning the UAS community and the students of different universities with aviation factors and mapping the UAS groups in 2017. Suddenly, the communities in the sector were organised into 10 different groups according to the purpose and type of relationship fomented. There are 4 major groups of UAS dedicated to providing knowledge, produce, or serve to the community and 7 groups dedicated to address the needs of training, representation to the civil aviation authority, and data management of the UAS oriented to digital strategies and applications. Most of the pilots are concentrated in the representation before the authorities, UAS distribution, and management of the data gathered. 6 of the interviews belongs to one or more groups.

Table 4-10. Community Groups of UAS in the Dominican Republic.

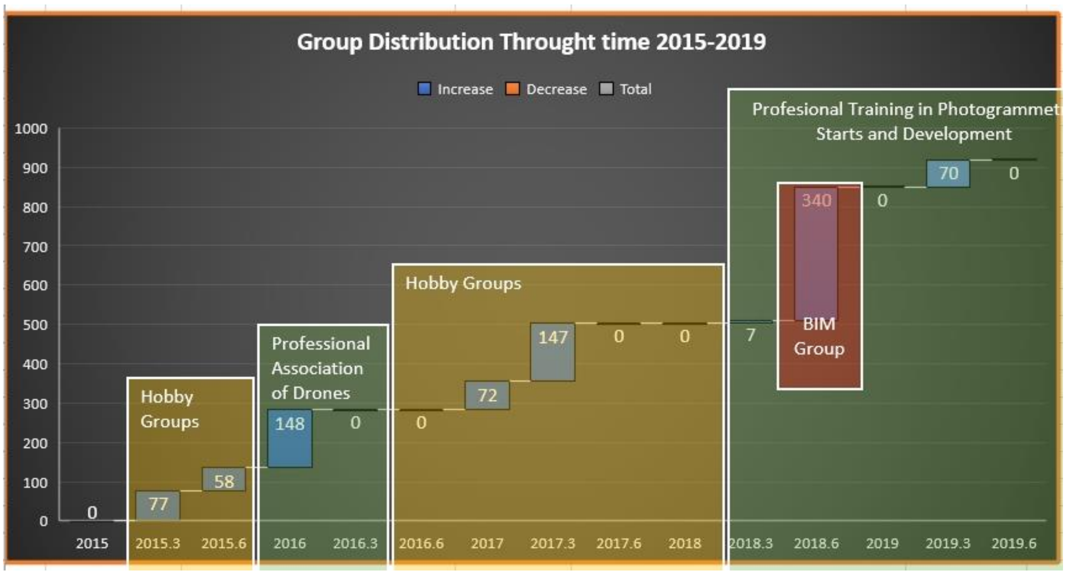
No.	Date	Description	Whatsapp Participants	Knowledge asset	Purpose	Type of organisation
1	21/06/2015	Red Flag Drone Racing	77	Built and Racing Drones	Hobby	Non-Profit
2	20/12/2015	CompaDrones	58	Photography Service Providers	Hobby	Non-Profit
3	03/09/2016	Dominican Asoc of Drones	148	Drones Association (All Types)	Professional	Non-Profit
4	29/04/2017	Full Drone DR	72	Photography Service Providers	Hobby	Non-Profit
5	14/06/2017	Drones Santo Domingo	147	DJI Distributer Clients	Hobby	Private
6	22/08/2018	Drones SDQ	7	Trainers Drones	Professional	Private
7	20/09/2018	ASODRONE	56	Photography Service Providers	Professional	Non-Profit
8	30/10/2018	SDQ Drone Community	35	Photogrammetry Trained Drones	Professional	Private
9	11/11/2018	OpenBIM RD	249	BIM Professionals	Professional	Non-Profit
10	06/08/2019	Drone-Enfoque Digital	70	Photogrammetry Drone Skills	Professional	Private
Total			919			

Source: (*Vanderhorst,H R et al. 2021*) and improved.

The behaviour on adopting UAS according to this perspective brings light to describe the maturity process in the applications. So, the figure shows the earliest hobbyist WhatsApp group created and the range of time in which other groups emerged following the creation of the UAS association. Another group of hobbyists are arisen focused on UAS consumers rather than racing or fabrication of them. The type of organisation that mostly contribute to the development of UAS professionals for construction is non-profit. It means that a claim for digitalisation of the construction process in the country is arisen by the communities.

Furthermore, A wide period is taken to create the groups related to professional skills and UAS data application that involve the construction sector. The rate of each year that the communities grow is more than 100% per year. However, it is expected a yearly plateau in the growth as seen between 2016-2017 and 2017.3-2018.3. Therefore, the next plateau in growth should be on 2019.3-2020.3 and after a growth rate with more than 100% of the people in other groups. Every 70 people in a group open a hit 3-6 months later that overflow the first group. As it is shown in the Figure 4-9. However, the pandemic could disrupt the growth negatively by the stay-at-home restrictions and lockdowns.

Figure 4-9. WhatsApp's groups distribution (2015-2019)



The historical data presented provide an idea of the UAS population in the country. It can infer that less than 919 UAS are in use or have been used. The number could have repetitive users between the groups. In general, the number of people could influence the number of UAS in the country. The number of UAS in the country, as well as the number of projects related to the built environment, allow understanding if there is a significant business size.

> P16: "*what we have found is that the government implementation of drones is a tool that helps to facilitate their internal or between ministries works where there is not a profitable found business model. In addition, it is used in an incipient manner, meaning that it is only used for images and video. This behaviour is proper from early adopters in this industry. We found a few, few companies that can provide the service for a fee.*"

> P10: "*The drone came from outside the country. But the drones are being developed faster, and when they come up, the regulatory body along with the commercial market will address their adoption.*"

Furthermore, the number of pilots with licenses or operating under no regulation provision as mentioned in (2.5.1.2) is less than 919 people. An estimation of the 30% of this population may be participating in various groups and 643 people probably are UAS pilot universe. In addition to this, the number is similar to the number of permissions granted by civil aviation. A distribution between UAS per pilot as estimation is made below.

Table 4-11. Estimation of UAS Amount based on sampling UAS distribution.

Number of UAS per person	Distribution of UAS per person	Estimation of people exposed to UAS operations	Estimation Number of UAS in the country
1	30.3%	195	278
2	33.3%	214	428
3	21.2%	136	409
4	9.1%	59	234
5	6.1%	39	196
Total		643	1545

Accurate information regarding the UAS in the country is complex to measure by the premise that the importing taxes are more than 56% on top of the price and measures in alleviating the economic weight has been used undertaking camera equipment taxes rather than the actual UAS. This measure has been aleatorily applied for different UAS distributors, consumers, and enterprises.

From the number of 1, 545 UAS, the potentiality in construction is not deemed by the availability of the aerial robot in the country rather this challenge can be perceived by a knowledge gap. Some of the UAS found the country is represented by the DJI and provide an idea of the cost involved in operating these aerial robots for a developing country.

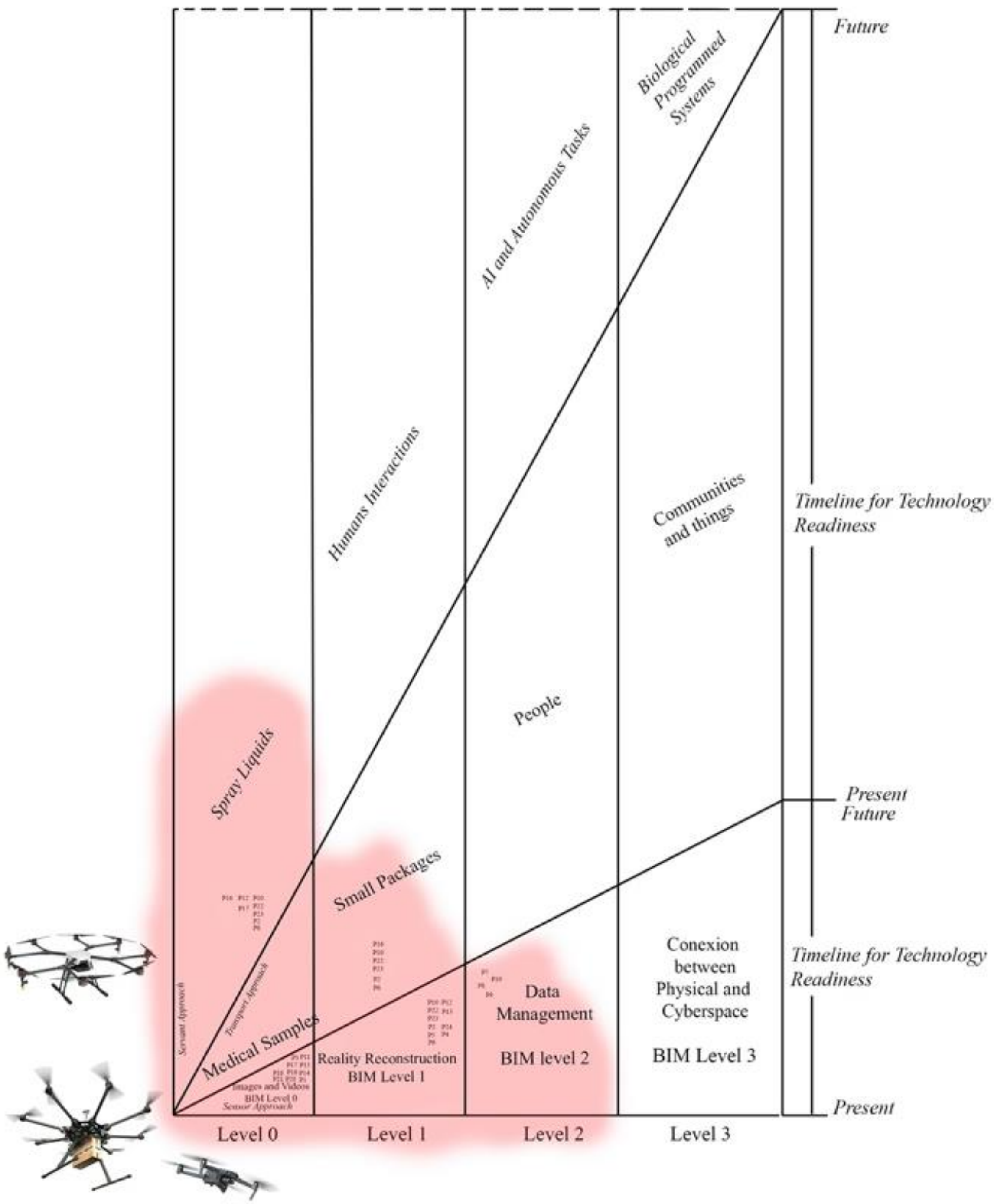
Table 4-12. Examples of UAS taxonomy at the country

MANUFACTURER	DJI									SENSEFLY	TAROT		3DR	YUNEEC	SELF-MADE
SERIE	Mavic	Phantom				Inspire		Matrice		eBee	Tarot		3DR Solo	Typhoon	The Unicorn
DESCRIPTION	Mavic Pro	Phantom 3 Adv	Phantom 3 Pro	Phantom 4	Phantom 4 Pro	Inspire 1	Inspire 2	Matrice 100	Matrice 200	eBee Classic	Tarot 680 Pro	Tarot X8	3DR Solo	4K	
YEAR OF RELEASE	2016	2015	2015	2016	2016	2014	2018	2015	2017	2015	2014	2014	2015	2015	2013
WEIGHT	0.743 kg	1.280 kg	1.280 kg	1.380 kg	1.388 kg	3.060 kg	3.693 kg	2.883 kg	6.140kg	0.69kg	3.08kg	3. 6kg	1.8 kg	1.7 kg	1.5kg
FREQUENCY DISTANCE	7km	5 km	5 km	5 km	7km	5 km	7km	5 km	7km	8km	1km	1km	800 m	800m	10 km
MAXIMUM WIND CONDITION	10m/s	10m/s	10m/s	10m/s	10m/s	10m/s	10m/s	10m/s	12m/s	12m/s	12m/s	12m/s	10m/s	8m/s	10 m/s
FAIL SAFE MODE	x	x	x	x	x	x	x	x	x				x	x	
OBSTACLE AVOIDANCE SENSOR	x				x		x		x						
CAMERA SENSOR RESOLUTION	1/2.3" (CMOS), Effective pixels:12.35 M	1/2.3" CMOS Effective pixels: 12.4 M	1/2.3" CMOS Effective pixels: 12.4 M	1/2.3" CMOS Effective pixels:12.4 M	1'' CMOS Effective pixels: 20M	X3 FC350 1/2.3" CMOS 12.4 M	CMOS, 1" Effective Pixels: 20 MP	1/2.3" CMOS Effective pixels:12.4 M	CMOS, 1" Effective Pixels: 20 MP	16 mp	20 MP CMOS Sensor Canon EF Built with GPS	20 MP CMOS Sensor Canon EF Built with GPS	1/2.5-inch CMOS with 12.4Mpixels	1/2.3" CMOS 12 mp	1/2.3" CMOS 20 mp
TIME FLYING PER SET OF BATTERY	27 min	23 min	23 min	28 min	30 min	18 min	23 min	23 min	13min	45 min	15 min	15 min	20 min	25 min	45 min
PRICE	US$999	US$1,199	US$1,359	US$1,199	US$1,499	US$3,499	US$3,600	US$3,929	US$11,630	US$25,000	US$1580	US$2050	US1,999	US$750	US$4,500
IMAGE															

In this table is presented the models of UAs typically used in the country. Most of the models used are from specific manufacturer such as DJI, SenseFly Yuneec and others.

So, the photogrammetry approach of UAS for construction is a topic to be understood based on the capabilities supported in a safe digital strategy. The fact that some of the UAS have fail-safe mode and obstacle avoidance guide the future standards of manufacturers as mentioned in 2.5. Furthermore, these models can be recommended to operate in the complex circumstance in which safety could be at risk such as congested areas, assemblies of people and cars, and in complex construction sites. The models show a road map in which the UAS is evolving under three major categories: servant, transport, and sensors. The UAS mostly applied in the construction industry mainly infer that BIM methodologies and models are their contributions to them. The figure below provides an overview of the BIM levels integration along with the interviewee's segregation and UAS level of development. The timeline of technology readiness expresses a frame of reference related to the moments that each technology would be adopted according to the law of Moore. In terms of construction, the interviewees are more related to the basic application of images, videos, and 3D reconstruction. The benefits of the level 0 approach (equivalent to 10 years gap) are that interoperability is not an issue and other methods and tools could be implemented as artificial intelligence applications as seen in the literature review in infrastructure (Morgenthal, et al., 2019).

Figure 4-10. Scheme of UAS adoption levels and trends



In this Figure is developed a road map of drone adoption levels according to its use in the construction industry. There are three main categories for UAS applications: 1) related to digital workflows with BIM, digital twin, blockchain; 2) Cargo purpose according to the weight; 3) the identifications of tasks that UAS can do for humans and the replicability of some of their habilities.

Therefore, the perception and conjectures of digitalization in the Dominican Republic are explored in the following section. The country has systems in place for digitalisation, but the general perception of the industry adopting technology should be understood and appointed a course of action to foment updated practices for construction. Cultural aspects could influence the adoption of other technologies and innovations substantially.

4.4.2 BUSINESS IMPLICATIONS

The business implications of UAS adoption involved a high initial investment that normally small and medium company in the Dominican Republican afford the completed package. As the UAS implies productivity, economics are influenced on its application in a long-term basis. Nevertheless, this long-term benefit has been difficult to identify or explain as the multiple variables involved (Figure *2-12*). Therefore, different descriptions emerged. The business models involved in the UAS industry are based on the RBG sensor and software. The business model starts with the acquisition of the UAS in or outside of the organisation. Normally, a fearless employee/CEO acquires the UAS for hobby purpose, then, after several flights, the person gets confident to explore the professionalism of the UAS operations. Images and videos of the surroundings are the first tasks in exploration. Later, the application of the UAS is applied within the organisation with or without pay as a part of the learning curve. Software regarding photogrammetry and reconstruction emerge and tests are carried out. In the moment that the team is aware of the productivity increment with the UAS (a 2 weeks work converted in 1 to 3 days), negation begins between pilots and organisation. Different cases arise:

Table 4-13. Business Cases and payments

No.	Case	Ownerships UAS	Type of Ownership	Payments for operations
1.	1.1 The employee offers to outsource service to the organisation that belongs taking responsibility for the UAS operational risks 1.2 The employee creates a new outsourcing department at the organisation.	Employee	Person	yes
2.	2.1 An employee shares his personal UAS for others to learn and address the tasks in the organisation. 2.1 The pilot employee buys its own drone and offer service to the organisation or to a third parties. 2.2 The director demands to their employees to utilize UAS on their operations.	CEO	Person	No Yes No
3.	3.1 The employee asks for a technological solution to improve their performance. 3.2 The director demands their employees utilize UAS in their operations.	Organisation	Organisation	No No
4.	4.1 An outsourcing organization is hired to address the tasks	Organisation	Organisation	Yes

The reasons for transactions can be different according to the level of knowledge and workflows that the UAS is supporting and contributing.

> P20: *"… to take photos before a land or a construction, one would have to look for a helicopter or pay someone who still had specialized equipment for that. Now, everyone has access to a drone. It can be an engineer who decides to buy a drone of any range and can with this carry out the monitoring of his work, or any other function…"*

So, the first transactions start with the UAS and its selection in which consultancy is normally required. The topics related to a number of batteries, remote controllers and radio frequencies, cables, reparations, and warranty extensions are involved in UAS acquisition. In addition, taxation of the UAS is most of the 50% of the UAS value.

> P6*: "…A drone team previously cost $ 30,000 to acquire it and now for $ 7,000 you can have the same equipment and do the same job. Also, as a Drone distributor, there are high tax rates in the country to import them. Up to 52% of the purchase value we have had to pay for that…"*

The next step is regarding skills development. The key activity here is to develop the fingers agility to perform shoots, videos, and photogrammetry patterns for the tasks desired. Experienced pilots in photography, film makers and photogrammetry technique for buildings, power stations, towers, and complex geometry can provide this knowledge for 3D reconstruction. Other reasons for transactions are the knowledge of how to comply with the national regulation and operational insurance. Then, new model business-related UAS insurance, regulatory forms, and risks assessments submissions. After the pilot complies with the training and regulatory forms, data collection with UAS has different stages for business models. The acquisition of images, software licensing and production of a useful outcome is strongly required. The UAS pilots support each other in the community providing sub services based on the location, emergency UAS incidence and expertise. The following table map the business models involved and their description.

Table 4-14. Business Models

No.	Business Model	Action	Description
1.	Product	UAS manufacturer	1. UAS Selling / renting 2. Part Selling 3. Reparations 4. Maintenance
2.	Subscription	Policy Insurance	1. Operation Liabilities 2. UAS Reparations
3.	Service	Practical and Theoretical knowledge Regulatory paperwork and risk assessments	1. Training on UAS piloting 2. Training on developing specific outcomes with the UAS 3. Regulation Training and paperwork 4. Risk assessment form
4.	Product	Images and Videos	1. Images sold for photogrammetry or architectural / commercial purpose (Payment by images, an hour of operation)
5.	Service Licencing	Processing images Software	1. Computational resource or cloud services. 2. Software for processing data and present a useful outcome (Payment by services, or monthly basis)

Nevertheless, the UAS in some public organisations has the barrier to identify the reasonable price for specialized services with UAS. Therefore, bids are made in order to understand the range of price between UAS organisations and operators. Furthermore, public organisations share their personnel and equipment with other institutions without cost. However, the practice of bids without a reference could be to the detriment of the UAS service providers. Standardization of price or guidance of minimum wage was mentioned. Prices between £200-£500 were inferred as fair enough for qualified professionals, operations with DJI models and up to 1 hour of image capturing.

> *P20: "…For films with 4k for real-time can be US$400 per hours. However, if there is a more qualified professional with a higher sensor can establish a fee of US$600. Therefore, the industry is establishing its own price criteria…"*

Furthermore, the reconstruction services or full surveying process is around £750. In addition to one of the interviewee comments, the figure shows the business workflow.

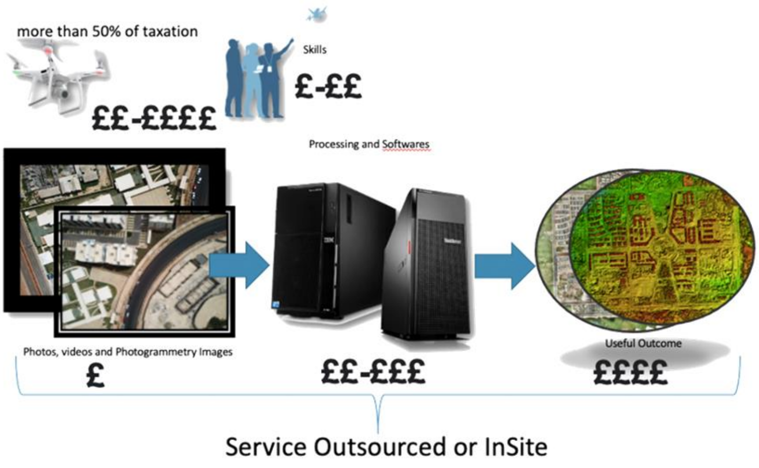
> P5: "…*The cost varies according to professionals and there is a lack of fair competency between companies and services providers. There are different costs according to each professionals' feelings and circumstances. It can generate unfair competition in the industry. Companies are presenting budgets less than the normal price required. For example: a work for £750 someone says: I will delivery for £500*…

…Depends on what are the customer requirements. The drone service might be paid by the adjusted price. The problem to be paid by hour is that it might take too much time to carry out the work and it might not be efficient. With the drone I sell efficiency. Clients have come to me and asked about the price of highway per km, however, I asked where the highway is located (at the mountain, etc), so it might be for adjusted price…"

P6: *"…Some surveyors charge per hour because there are applications that plan drone operations and indicate in this the amount of battery, height and time required for the operation. With this information it is known how long the equipment will operate…"*

Figure *4-11* describe the business implication of the UAS based on the findings. Normally, the UAS could cost the same as computer and software, training, and useful outcome. Therefore, incentives and minimum wage might be relevant to appoint for sustainable development of the industry. Furthermore, from an investor perspective will always suggest understanding the high standards in the UAS FPV racers or video gamers capabilities, software developers and traditional professionals qualification to compromise the adequate and successful human resource profile for the industry.

Figure 4-11. UAS value in business implications



4.4.3 COMPETITIVENESS PERCEPTION IN THE UAS APPLICATION

In the study, the inquiry on the competitiveness perception of UAS was made with the aim to clarify if the application would represent a technical or social advantage. Even though the UAS represent a significant opportunity for business, the perception of competitiveness may not be seen as important. After the perceived impact of drones on competitiveness, the interviews refer to different aspects of the questions. The competitiveness perceived by the UAS application was in terms of capabilities to make faster the work but may not be comparable with the actual methods in some cases based on the accuracy tolerances and regulations related to that. Furthermore, the financial risks, digital transformation and responsibility of the sustainability of the workflows provoke doubts regarding competitiveness with the UAS. An investment that can easily be wasted is perceived by decision makers as an additional marketing tool that represent views for the clients rather than concept of competitiveness in terms of productivity as reputation. The advantages are understood in the surface limiting the real productivity increment that is attractive company to company.

But the transformational digital workflow that is embedded in the application of UAS represents a complement of the competitiveness concept perceived as decentralisation of the tasks and autonomy of the process. For example, the approximations for land surveying are well used for architects and for surveyors but it is not currently accepted by land certificate laws. On the technical side, the UAS represents higher standards on their competitiveness between public and private organisations. Some comments support the ideas expressed.

> P1: *It is perceived as we can achieve a valuable data, but it does not mean that we are better (more important than other) for it. Other institutions ask for the drone, but I don't know if there is this perception.*
>
> P6: *There are construction companies that started using drones, because they saw that other engineers hired advertising (companies) to do a job on a construction site.*
>
> P16: *We greatly found that technicians were knowledgeable about technology and drones. Unfortunately, there was a gap between decision-makers and technical to induct on its adoption. It might be the case in lack of knowledge from leaders and decision-makers, generation changes or organisational priorities. In addition, the voices from technicians were clear and articulated. Therefore, we found an emerging young generation of AECO professionals who knows and defend the implementation. They understood why the adoption of drones would bring or raise the competitiveness of the company or organisation. As a consequence of these findings, we understood that the country has an emergent stock knowledge and potential that, with some modifications, can be easily adopted.*

However, it is forecasted that after the adoption hits an early majority population, then the UAS will notably reflect on economic and technological competitiveness. Frameworks for adoption and implementation should be developed to achieve this goal.

4.4.4 LEGAL FRAMEWORKS DEVELOPMENT FOR UAS APPLICATION IN THE CONSTRUCTION INDUSTRY

The development of frameworks for provoking an early majority stage of technology adoption could be an option. After the interviews, points of view according to their field arose. The question was guided by the doubt on frameworks contribution to digitalize the construction industry. Some of the answers made in this section were related to modifying the actual construction regulations in order to incorporate technology into them.

The ideas shared from this question were answered with a technical approach. They provided insights into the theoretical perspective to fit the UAS adoption process within the organisations and identify the key theoretical drivers and the cognitive convergence between lines in the answers. Therefore, Table 4-15 is described the social and technical implications in the adoption of UAS. The ideas mean that frameworks in the actual regulatory environment of the 5 fields identified are required to develop frameworks that includes workflows, regulatory and business cases for the adoption process.

Table 4-15. Social and Technological Frameworks involved

Aspect	Field	Task	Frameworks & Regulation
Technical	Real Estate	1. Law Enforcement	Land Measurement accuracy for influencing the Land Law Regulation
	Buildings Construction	1. Feasibility Studies 2. Progress Reports 3. Monitoring of Building 4. Measurement 5. Identify area Conditions 6. Traffic Studies	Workflow BIM Integration
	Infrastructure	1. Bridge Inspections 2. Water Resource Id 3. Highways Surveys 4. Inspection Power Lines 5. Visual Id of sewers	Photogrammetry techniques, software, and data management, and improvement in the facility management national regulations and standards.
Social	Urban Planning	1. Delimitation Zones 2. Monitoring Water Resource Id 3. Interurban Terminals Visual State 4. City Traffic Congestion Liberation	Regulation on UAS design and operation for assembly areas
	Disaster Management	1. Monitoring Focus of pollution 2. Earthquake Multi-risk Evaluation 3. Geometry And georeferencing extraction 4. Urban Monitoring and Risk Reduction Landslide	Frameworks for Risk reduction and crisis management with UAS

	5. Tsunami, Floods and Hurricanes risk prevention and Evaluation 6. UAS firefighter certifications	

Therefore, the framework requested from the interviewee was related to standards for UAS adoption best practices and BIM integration and workshops for the applications. The understanding, privacy and security cases were also mentioned, but developing a technical guidance of the capabilities, and best practices, UAS regulations and current professional bodies recommendations imminently should be included, and the application of these aerial robots should be significantly boosted as well as the digitalization process of the industry.

4.4.5 ELABORATION OF A MODEL WITH THE DISCUSSION OF THE FINDINGS

The adoption process of UAS incorporates different approaches according to its usage versatility. UAS are an emerging technology that is spreading over the world at curious rates. However, social media has made possible replication in their tasks across the globe and simultaneously has been an exploration in cases such as COVID-19 Spray, mapping and others. Furthermore, the interactions between entities, regulatory bodies, and the technology evolution itself are facing several issues that have been documented by (Hamed Golizadeh, 2019). The novelty of the UAS application has provoked an opportunity to define theoretical grounds on its stories of adoption and implementation. According to the literature, there has been used the task-technology fit (Hamed Golizadeh, 2019). Further theoretical lens was looked to understand the faces of the UAS adoption process stepping into the hypothesis shown. The theories concerned with technology adoption can be found in the following:

Table 4-16. Theories Evaluated

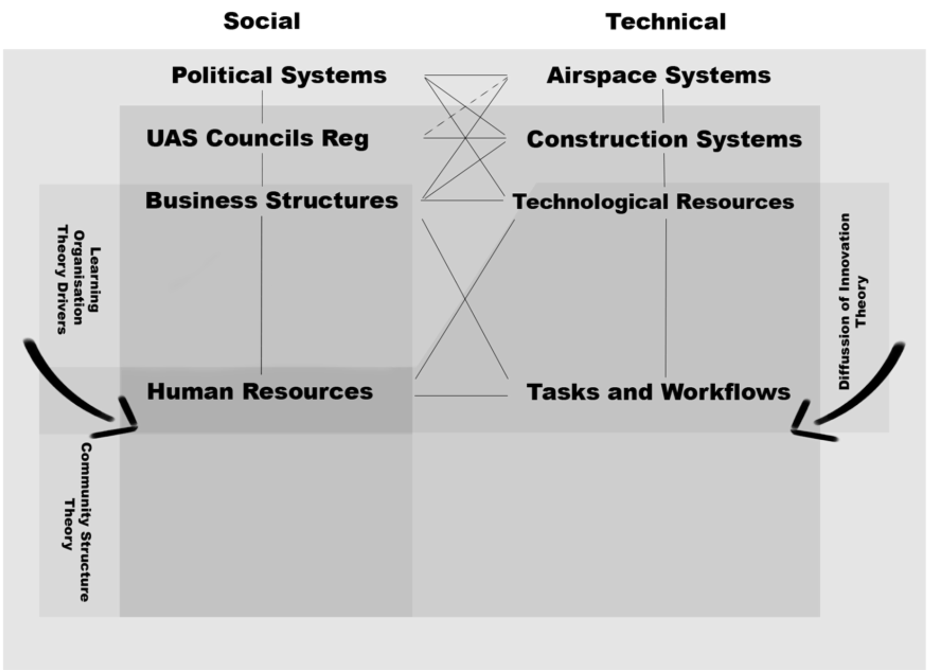
No.	Theoretical Approach	Description	Studies Applied
1	TOE Technology-Organisation -Environment Theory	Shows the 3 drivers that influence technology probability of adoption undertaking diver factors. It is assumed that technological innovation is adopted and implemented according to Technology, Organisational and Environment context.	E-Business Adoption (Putman, et al., 2020) Cloud Computing (Kyriakou & Loukis, 2019)
2	DOI Diffusion of Innovation	Seeks the way, reasons and the adoption rate of innovation spread. Drivers held in this theory are: 1) Innovation, 2) Adopters, 3) communication channels, 4) time and 5) social system.	Artificial Intelligence (Plessis & Smuts, 2021)
3	UTAUT Unified Theory of acceptance and use of technology	Explains the user intentions to use an information systems and the behaviour of it. The 4 key drivers are: 1) performance, 2) effort, 3) social influence, and 4) facilitating conditions. It is focus on the psychological aspect of the user.	E-learning during the Pandemic (Jameel, et al., 2022)
4	Socio-Technical Systems	The SCI consists of two sub-systems: the social and technical sub-system. Social sub-system compromise people and organisational structures, and the technical sub-system encompass technologies, processes, procedures, and the physical environment relationships.	UAS Adoption in Disaster Management (Vanderhorst, et al., 2021)

The theories of DOI, TOE and UTAUT are technology targeted for many Information System studies explaining end-user adoption at the organisational level. Essentially, the DOI produce a deeper understanding of an adoption process through users, time, communication channels, and decision process. In contrast to TOE, which simplifies the approach, just exposing the key drivers that directly affect the technology adoption process. Afterwards, the UTAUT represents the ultimate model of the behaviour adoption process of technology. This theory approach focused on the social aspect and behaviour of adopting certain technology. In general, the three-theory approach are tended to be combined and present the strengths between of them in order to address specific phenomena explanations. For instance, DOI and TOE combination has been used for software adoption such as cloud computing (Alkhalil, et al., 2017)and Mobile applications (Bool & Chiu, 2017) as well as UTAUT incorporated drivers of the DOI in the case of internet banking adoption (Rahi & Ghani, 2018).

Furthermore, there are other theories that explain other behaviours of the UAS adoption for example, the learning organisation theory and community Structure theory that are subcategories of the social aspect of the framework within the field of business management. The theory of learning organisation describes the process of knowledge generation and management within the organisation to produce quality results approaching continuous learning. It is similar to lean construction as mentioned in (2.3.2) (Babalola & Ezema, 2019; Cavaleri, 2008). In addition, the community structure theory defines the boundaries of how communities are interconnected between them and how they interact with their environment supplying needs of a niches (Tran, et al., 2022). This approach is a novel perspective not contemplated before.

Moreover, the UAS industry from a technical perspective is more suitable the DOI for this research. This theory as a baseline allowed observing the aspects involved in the technology. This theory includes the aspects of social systems that seems to be a barrier. However, combining DOI with the Socio-Technical Systems approach encompasses the answers of the artefact, who adopts it, where/when it comes from, and finally, how it works. Moreover, the concern of viability in the UAS application direct focus on social systems leading to strengthening the socio-technical systems.

Figure 4-12. Socio-Technical System Framework and other explanations



For example, if UAS are banned due to a country's legislation or due to privacy issues, another technology shall emerge replacing it. In other words, the evaluation of UAS acceptance in organisations is required to be understood by the dynamic loop of the regulatory boundaries, business model, and processes within UAS operations. Other remarkable examples are in the types of operations that may influence the feasibility of the UAS adoption in the organisation as well as the size and the regulatory barriers observed in the literature review. Therefore, UAS application is utilised inside organisations to automatise employee productivity by improving the actual workflow of the organisation aligning other technological supports in the process (Vanderhorst, et al., 2020). In terms of structure, organisations are changing the way they are delivering product and services. Organisations are taking the knowledge obtained from UAS integration to provide business to business services by opening a new industry that could bring wealth and prosperity to the world (Vanderhorst, et al., 2021).

4.4.6 DISCUSSION OF THE FINDINGS AND THEORETHICAL ELABORATION

The data presented provided an overview of the current state of UAS in the country specialized in construction. The approximation of the UAS in the country is still low and the market seems to be dominated by DJI brands. Regardless of the mode of operation: manually or pre-programmed (autonomous), UAS specialized for surveying were identified. The availability of UAS groups for designing them could foment the culture of makers for construction, if the prices of UAS remain high and standards for construction attach BIM methodologies. But the law of murphy could influence that assumption and technological incentives in the country too.

It was showed an estimation of UAS and pilots in the country. A few organisations and key stakeholders knowledgeable and open to providing their ideas were found as a consequence of the lack of knowledge and intellectual property issues. Through time, the adoption of UAS had a peak in 2016 and 2018 according to the IDAC and those peaks also coincide with the creation of the WhatsApp groups of the Drone Association and OpenBIM RD, respectively. These groups have been responsible for the fomentation of UAS in the country. The sense of community has made possible the UAS diffusion, but it does not assure knowledge transfer or fair competitiveness. It can only provide an idea of business-to-business relationships instead to business to customer. In addition, the wisdom of the UAS application significantly could be easily replicated. For example: the due diligence of UAS selection, credential of the pilot, personnel profile and tasks to address are key knowledge to provide service with UAS. However, practically, the skills gained piloting the UAS and data translation to the specific field are 2 extremely valuable, time-consuming, and the initial path for being involved in the industry. Nevertheless, apps and software have made some of the initiations paths for UAS in construction in the table below. Finally, specialization by field should be the next step for avoiding unfair competition, maintaining standards, and understanding the market.

Table 4-17. Data Collection software

Sensor	UAS	Apps	Software	Cloud Sharing Software

RGB	DJI Drone	Pix4D Drone Deploy Agisoft Recap Photo CloudCompare	Revit ArchiCAD AutoCAD ESRI QGis ETAPS TEKLA	Procore BIM 360 StructuionSite CloudWorx Smart Reality XR

The WhatsApp groups found clearly identify the key knowledge holders for construction. These groups could contribute to the digitalization process of the industry in the country. Based on the technical frameworks required for UAS adoption, construction bodies could update their current standards and operations with UAS as well as with Building Information Modelling practices. In this sense, the UAS has smoothly and simply interconnected and introduced digital principles of real-time monitoring and maintenance to traditional methods by reducing costs. Hence, advanced methods of digitalization can be implemented in countries that Building Information Modelling, technically, spread at an accelerated rate. However, it is wise to consider the influence of internet of things swarm technology, and unsupervised machine learning in construction. Then, the concepts of digital twin with autonomous unsupervised machine learning UAS connected to a cloud base could drastically shift the identity of construction. Real Estate, buildings, infrastructures, and cities development could be directly influenced by the proliferation of autonomous methods of productivity as smart devices have made. Recently, images from Mars and Covid-19 produced changes that altered the conscience evolution of humanity. For example, within a building digital twin can interact with a multiple UAS as part of a personalized human behaviours digital twin and observe their reactions in different planets and compare those with other humans.

Despite the technological advantage in the future, currently, the Dominican Republic is making steps in the digitalization process with UAS and BIM workshops by OpenBIM group. The efforts are towards digitalization and higher industry practice covering some of the technical frameworks for UAS adoption. Furthermore, works on the land surveying framework are required to complete the technical knowledge aspect of UAS adoption. Later, the frameworks of urban cities and disaster management could be merged in a unified socio-technical approach of the UAS application.

The notable reasons for adopting UAS were identified as a decision from the top level and, in some cases, from the person who acquired the UAS. From the theory of diffusion of innovation perspective, the curve of adoption defines the stage of UAS adoption in the country as an innovator, which is the first stage. Apparently, the stage of UAS is on the innovator stage with a normalized representation of the 2.5% of the whole population possible in the construction sector. It is expected that the population of construction professionals in the country (around 40,000) will reach the 2.5% for the adoption of UAS in the following years. It means that around 1000 UAS pilots in construction should indicate the migration into an early-adopter stage of UAS in the country. It could be a pursuit that this innovator population will be completed with the introduction of UAS in the curricula or qualification knowledge delivered. So, less than 1% of the population expected is involved in the UAS. The UAS as a professional tool act as a commodity for repetitive and costly tasks such as progress reports and infrastructure inspections. This awareness of the UAS application arose from the internet, social media, and availability of the UAS in the workplace from the manager or outsourcing organisation as well as from non-profit organisation efforts. The country should centralise and disseminate its policies and information on a knowledge system for the citizens. An app or webpage in which the technological advancement, ethics, and applicability of different technologies from the 4^{th} industrial revolution could be applied. This idea comes from the question of where, how, and what information would be helpful and comfortable to receive, learn, and manage generally in innovative, lawful, and business-related information? For example, what is the process of being a company utilising technologies of the 4^{th} industrial revolution, what are the incentives, updates in trends and government perspective to look at? Another example might be incentives and government areas of improvement that artificial intelligence developments would be welcome to promote along with UAS. In the same line, articulating effective feedback bridges for those emerging businesses and communities can make improvements in the systems of UAS adoption.

Then, the applications of UAS inside the built environment are varied and incorporate the aspects of people and technology related to socio-technical systems. The number of applications of the UAS could mean patents, innovations, and options to live a fulfilling human life. Each country has contexts in which the UAS is applicable rather than others. For example, in disaster management, the literature shows the application of an autonomous swarm of UAS can conquer a dynamic real-time survey task for nuclear and chemical radiation (Cone, et al., 2021). This application would be replicable completely if in the country a nuclear station is in place. Another way to see the application could be assessing radiation factors in drinking water (Salmirinne & Hyvönen, 2017). However, with some modification on the sensor and the capability spectrum, a case could be considered for evaluation of chemical mining and industrial waste with potential radiation. Nevertheless, this application was not found in the country and maybe suitable for land conservation and real estate. Furthermore, novel application with the RGB sensor found in this country was Cholera source identification, urban growth, and water source location, in addition to the cases mentioned for the construction phases of different projects as seen in chapter **Error! Reference source not found.**. Moreover, the business implications that are not enough literature in the topic, this thesis enrich that perspective. The stories around these applications are merely built on the understanding of physical limitations; further research should be developed in these terms.

After explaining the considerations of the UAS applications in the country, it is logical to understand that the level of knowledge and wisdom in the field intended to use the UAS influence the time reduction in terms of the thought process and task identification. From the literature, the applications were found to represent the level of digitalization and automation of the country. In other words, the areas of applications are well identified but the implications of the quintessence limit the change curve action on the digitalization process and workflows. The advantage of the UAS is mostly related to the data collection and agile management of the visual data without second curation or processing. Some of the critiques on applying the aerial robot were referring to that specific barrier. The UAS was required to possess a real-time processor that delivers the orthomosaic, accurate measurements, point cloud identification and classification available for the professional. The idea of 1 completed solution opens the possibility to add a silicon multi-processor (example: M1 apple), photonic chips processors (Shastri, et al., 2021) and assurance of Gb/s internet connection for cloud processing and information transfer into the UAS (Raddo, et al., 2021). Seeing these concepts possible available could support the technological development in the future.

However, the challenges significantly put in doubt the benefits of the system. Across the world, politicians influence importantly in the UAS industry that is prominently relevant to involved them in the growth process. The topic of regulation in the country does not represent a significant barrier, but technological training should be delivered to politicians and policy makers to align and ascend the conscious vision of the country to transformation. Additional to the trainings, the UAS regulations should be improved in terms of clarity of the process of certification and the incentives of being accredited, visibility on the webpages and language translation could be addressed. In this way, the regulation should be internationally easily comparable, comprehensible and readjust with contexts outside the language location. Topics of cybersecurity should be incorporated for the swarm technology cases, pre-programmed operations and radio frequency spectrum. Relevant issues on the actual radio frequency spectrum could significantly mean harm for UAS operations. Moreover, the technical challenges of the UAS are being tackled by the manufacturers but still some years and awareness to producing a final suitable product for the industry. Nowadays, manufacturers are merging sensors like RGB cameras with LIDAR technology to produce an accurate professional tool for specialized tasks. So, if UAS acquire high-speed microprocessor, speakers, and internet access, regulations for online UAS interaction and data management should be put in place. Anyhow, the current state in the following years (5 years) may maintain a progressive evolution according to the market demands, manufacturers awareness and business opportunities available for UAS. Nevertheless, the idea of obsolescence should be contemplated as possible threat to the UAS business (Mellal, 2020). For this reason, the business side of the applications makes suitable its future-proofing.

The actual viable business model and price will depend on the question: What is the UAS substituting or adding value for? If it is a specialized task, as mentioned before (2.3.5), the price should be in the same direction. For example: images for progress reports are a task under the photography and film industry that deserve the price and business models embedded in that industry in contrast to surveying which is in the engineering industry and prices and business models are different. The best approach should be an adjusted price, or a monthly subscription of the full service. It is viable for small and medium organisations to provide quality on their works and avoid liabilities on the operations and litigation issues for their clients. However, if the personnel on the client-side organisation is willing to receive and transfer the knowledge of UAS implications, therefore, an adoption into the organisation according to their needs could be suitable. Architects and managers would be most of the time benefit for the internal capability brought by this tool. Later, the UAS could be considered as an essential instrument as well as iPad and iPhones for architects and engineers to reconstruct their reality.

Another perspective observed as an opportunity to promote economic circulation and innovation adoption is the encouragement in public and private partnerships. The public entities could benefit from alliances with the private sector. The application of the UAS can be created from strategic alliances with or without public-private partnership (PPP), or Private Finance Initiative (PFI) (Shibasaki, et al., 2020) strengthening the capabilities of public organisations and foresting innovation with the UAS; if the services are specialized and in long-term could mean an unnecessary spend for the organisation such as swarm technology, UAS for disaster risk reduction, UAS infrastructure maintenance and UAS for city monitoring.

The adoption of these alliances will enhance the competitiveness of UAS market and the delivery standards of the public and private organisations. The first level of adoption of UAS is the video and pictures that drastically change the meeting discussions regarding big areas. A community, construction site or land certification may receive images of the current state of the field. Technologically, it is required to implement modern systems on the national frameworks; if they can represent a contribution to the productivity of the organisation and that efficiency will build reputation. The aspects that summarise the application are embedded in each field adoption framework. Further research in developing each framework of adoption.

4.4.6.1 PANDEMIC COVID-19

The effects of the pandemic affected directly different industries reducing the commercialisation and the known opportunities to apply UAS. However, the pandemic allowed produced awareness to various professional bodies, institutions, and organisations to assess their actual workflows without digitalisation permitting an option for UAS-BIM adoption. In the same line, international projects during the pandemic supported the UAS adoption as a part of rising the country capabilities, UAS and power line inspections, UAS and Tsunamis analysis and UAS for infrastructure and business generation. In addition, other applications of UAS were explored and suggested such as UAS for disinfectant and UAS for monitoring curfew, respectively, but the infective action of disinfection and another mechanism to ensure the curfew was in place and those applications were unnecessary. The most significant contribution of the pandemic were agreements for BIM implementation, UAS for mapping and monitoring dump wildfire and projects initiations with UAS.

In the social aspects, the international community of UAS (Manufacturer, policy makers and educators) have engaged with the claim of inclusion and diversity in the industry by promoting and supporting UAS female communities' discussions. In the Dominican Republic, events were fomented initiatives on female in UAS pilots. Furthermore, the sampling totally represents the actual relationship and participation between females and UAS industry.

4.5 OBJECTIVE 5. TO PROVIDE RECOMMENDATIONS FOR POLICY, PRACTICE AND RESEARCH.

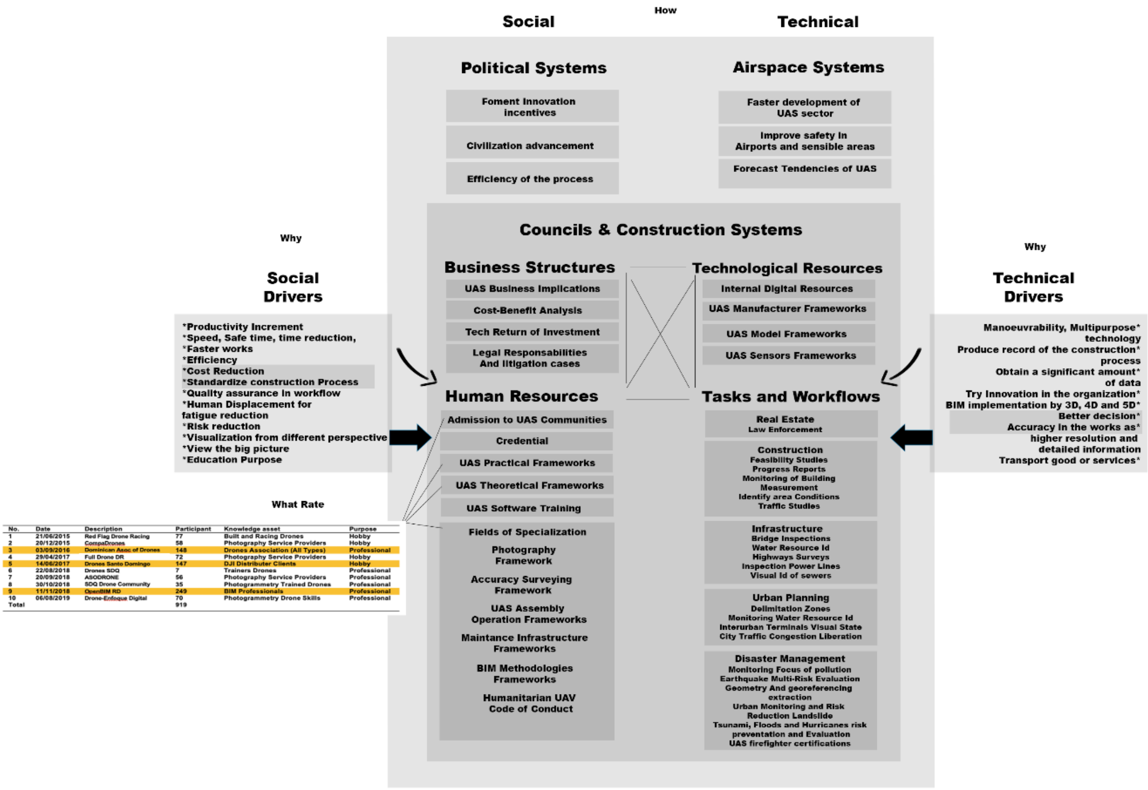
4.5.1 DISCUSSION OF POLICY, PRACTICE AND RESEARCH RECOMMENDATIONS

The overall of the findings showed that the UAS adoption is responding to the theory of Innovation diffusion, focusing on the social systems as part of the main barriers on their adoption. Therefore, it is recommended to develop standards and mandates that incentive the adoption of innovations related to technology. Globally, BIM policies, smart city strategies, and sustainable standards are the trends used by developed nations to advance the construction industry. Within these policies, digital space and robotics play the role of digitaliser, humans risk reduction and task automations that significantly change the economic and welfare of workers receiving a different quality and dynamic of construction projects in a long-term basis. In the country, the approach of adopting technologies seems to be hybrid (top-down & bottom-up) in which bottom-up could lead some of the advancement in terms of technical aspects (workflows and technology adoption) rather than social aspects. It seems that from a government perspective, incentives in testing and incorporating new technologies in the construction workflow would significantly promote the adoption of them. As a consequence of these guidelines, welcoming will be received from countries with the same standards in order to share and enhance best practices in construction with technology. The topics to consider in the recommendations are consolidated in a framework. In a technical sense, the following multi-dimensional framework was designed to provide an understanding of the core areas in which the UAS intersect public, private, and non-profit organisation workflows from a different perspective.

The framework described the adoption process required for the viable and suitable adoption of UAS. In the country, the political systems work along with the airspace regulators to establish the dissemination of technology adoption into the airspace. The airspace systems or the Dominican Institute of Civil Aviation (IDAC) that regulate the UAS manufacturer in terms of specifics, types of operations, and certain liabilities should keep improving the regulations as well as looking for tax exceptions inside and probably outside their boundaries. These dynamic boundaries directly influence the implementation of UAS in councils land space and in the different construction projects. The social and technical drivers would accelerate the adoption into the construction industry. In other words, a mindset, cultural behaviours, and generation relief before technology should be encouraged and incentives for the smooth adoption of UAS and other technologies. For example, different ages group should compose technological departments of the organisations as well as a consultant for regulatory purposes on new technology. The adoption of UAS is accepted by the photography perspective but resisted in terms of 3D reconstruction and the digitalisation process around it. Furthermore, Figure 4-10 provides the trends of UAS adoptions and their adoption trends, that policy makers should be considered to proactively get awareness of how the scenario may develop.

The social systems involved in the adoption contains 2 aspects for discussion: business structures and human resources. In the following are described each category and subcategories:

Figure 4-13. Framework Applied for the country



No.	Date	Description	Participant	Knowledge asset	Purpose
1	21/06/2015	Red Flag Drone Racing	77	Built and Racing Drones	Hobby
2	20/12/2015	CompaDrones	58	Photography Service Providers	Hobby
3	03/09/2016	Dominican Asoc of Drones	148	Drones Association (All Types)	Professional
4	29/04/2017	Full Drone DR	72	Photography Service Providers	Hobby
5	14/06/2017	Drones Santo Domingo	147	DJI Distributer Clients	Hobby
6	22/08/2018	Drones SDQ	7	Trainers Drones	Professional
7	20/09/2018	ASODRONE	56	Photography Service Providers	Professional
8	30/10/2018	SDQ Drone Community	35	Photogrammetry Trained Drones	Professional
9	11/11/2018	OpenBIM RD	249	BIM Professionals	Professional
10	06/08/2019	Drone-Enfoque Digital	70	Photogrammetry Drone Skills	Professional
Total			919		

Political Systems: This category involves the main purpose in which technology such as the Unmanned Aerial System should operate as an alliance for the purpose of the citizens.

1. **Foment Innovation incentives**: Ideally, political systems have an interest in incentive initiatives of new sustainable and future-proofing businesses and mechanisms for a better life.
2. **Civilization advancement**: In some cases, the civilians can put resistant to adopting specifically technology by fear, lack of knowledge or ineffective past experiences with technology. Campaigns of awareness and cases of cities advancement of this kind of technology can lie credibility and trust in the people.
3. **The efficiency of the process**: The results on implementing technology adequately with cases that the city can perceive, eventually, bring acceptance and adaptation to the technology

Business Structure: the category reflects on the types of organisations and processes that shall be contemplated before the adoption:

1. **Business Implications:** in this category is implied the different business model involved, approaches to manage in the organisation, internal protocols, and systems in place to assure customer satisfaction. Minimum wage and incentives for the new department or employee could be implied.
2. **Cost-benefit analysis:** any change in the organisation, especially in technical aspects, should require due diligence in terms of the cost and benefit that the piece of technology would bring. This first experiment or trial could be carried out through an outsource organisation or internally.

3. **Return of investment:** after a decision is made to integrate the device and other tools, should be assessed the model in the long term, how the change would be sustainable in terms of finance.
4. **Legal responsibilities**: each organisation should be aware of the ethical implications of new technologies and robotics. For example, airspace regulation, insurance, and appropriate training.

Human Resources: the category describes the knowledge and process that the adepts shall pass through to be profitable for UAS operations.

1. **UAS Community Admissions:** This step provides a background and peer-review credibility in the UAS operations. In addition, it encourages the continuous learning, support, and awareness of the last UAS regulatory changes.
2. **Credential:** complying with the UAS regulation allow the industry main a standard for best practice and credibility before international insurances companies and other countries.
3. **UAS practical:** A specific number of hours could determine the basic level of competency, however, the real practice on a particular task proof the capabilities and the feasibility of the UAS application.
4. **UAS Theoretical:** Theoretical views are needed for risk assessment and understanding the different possibilities that may occur in a UAS operation.
5. **UAS Software:** Each device has its own programs and algorithms. Training on it allows the practitioner to appropriately carry out photogrammetry operations and process the data for the tasks.
6. **Fields of Specialisation:** The different applications of UAS allow the professional to operate in different frameworks. The core knowledge for

UAS applications is interconnected to the protocols and regulation regarding each field involved in knowledge allows the pilot to assess in or outside the organisation.

Different perspectives are covered in the technical aspect to describe how the technology influences the adaptation process in the airspace system (regulatory aspect) and at the organisational level.

Airspace System: refers to the regulations and technical changes of the technology that change certain aspects of standards in regulation.

1. **Faster development of UAS sector:** The comprehension of the dynamics in the sector allows the airspace system to calibrate and focus the business opportunities of the technology for the society.

2. **Improve safety in Airports and sensible areas:** Regulate the UAS and forecast their applications to allow maintain safety in sensible areas.

3. **Forecast Tendencies of UAS:** Understanding the changes that the technology may have allowed the regulatory system to adapt faster. For example: forecasting the adoption of artificial intelligence (AI) in UAS and 360 cameras prevent the policy makers from regulating the type of applications that the AI and 360 cameras are suitable ethically.

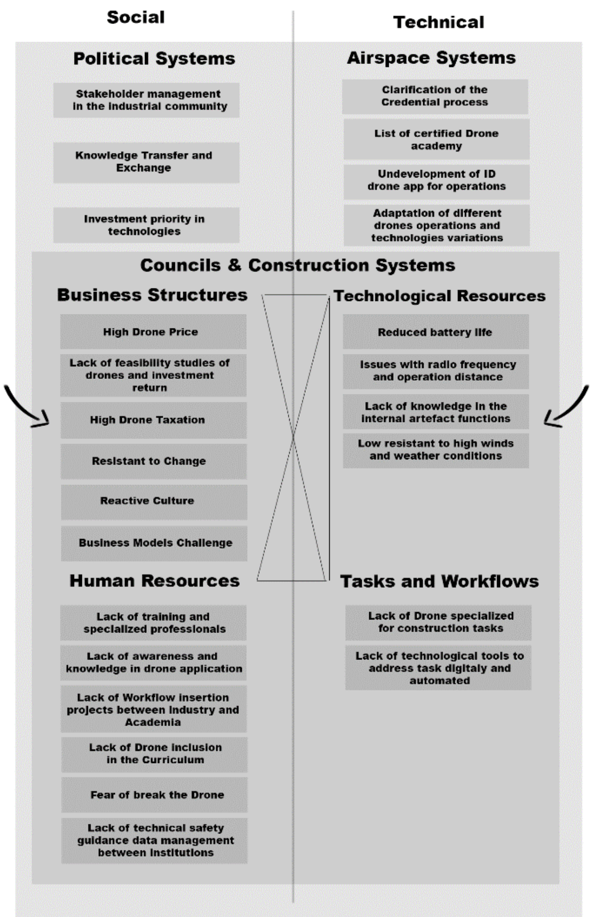
Technological Resources: It is referred to all the systems involved in gather and processing data with the UAS.

1. **Internal Digital Resources**: The digital capabilities inside the organisation will significantly influence the level of adoption in the department. The computational power, software, and cloud services are vital for an appropriate adoption up to level 3 BIM.
2. **UAS manufacturer Framework:** complying with the UAS regulation allow the industry main a standard for best practice of manufacturing and credibility before international insurances companies and other civil aviation authorities.
3. **UAS Model Framework:** Based on the variety of designs and aerodynamic, the suitability of models should be explored and advised for specific tasks.
4. **UAS Sensors:** The influence of obstacle avoidance sensors, high-resolution cameras, and radio signals significant the effectiveness of the tasks involved.

Tasks and Workflows: It is referred to all the systems involved in gather and processing data with the UAS. The application itself provide the feasibility and viability of the aerial robot in the organisation. Some illustrations of construction and infrastructure are presented in (Vanderhorst, et al., 2020) and for disaster management in (Vanderhorst, et al., 2021).

These four categories are subject to change or improvement based on the context in which they are deployed. However, there are certain barriers that would affect the adoption process. In the following figure are identified where the barriers would affect the adoption process.

Figure 4-14. Framework with Barriers Applied



In the social aspect, there are 3 components of barriers at the political level, business structures, and human resources. In the technical aspect, the airspace regulations, technological resources, and tasks workflows are the main core, as shown in Figure 8-4.

Political System: This aspect is intended to address the suppressive changes, incentives, and supports required during the adoption of UAS in a country. Knowledge at this level is necessary to promote technology adoption in the sector. Therefore, the barriers presented are defined in 3 categories: Knowledge transfer and exchange; Investment priority in technologies and management of stakeholders in the industrial community.

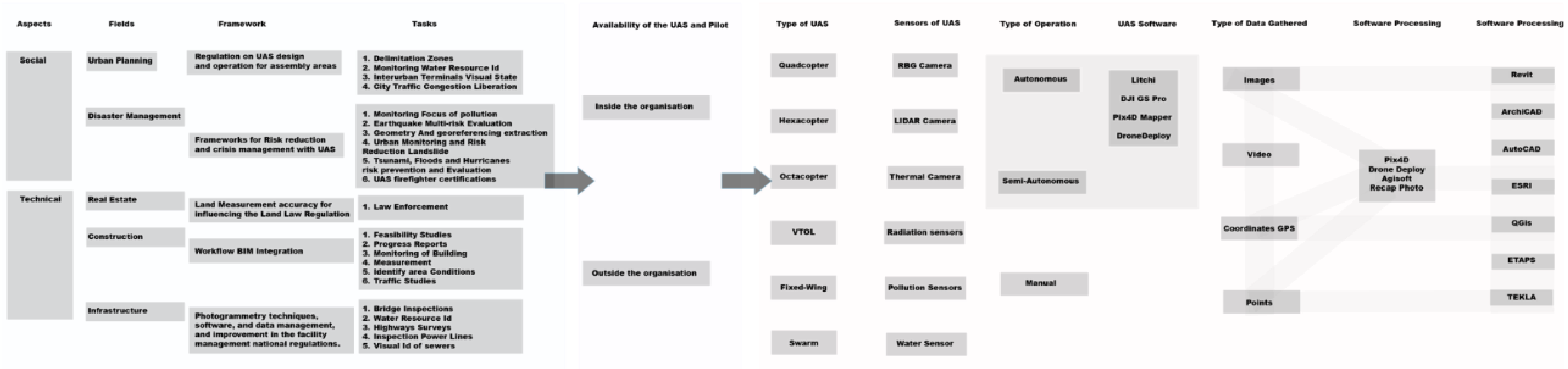
1. **Knowledge Transfer and Exchange:** This issue is related to the awareness of novel technologies and generational acceptance of changes. It is crucial to evaluate the future trends and adaptations of the political systems to be at the vanguard of technologies.

2. **Investment priority in technologies:** This barrier reflects on the government incentives for technologies mentioned during the research. Policies of innovation and tax exceptions may be applied for promoting technological organisations.

3. **Management of stakeholders in the industrial community:** The need for industrial projects in conjunction with academia and the dissemination of scientific knowledge significantly could influence the adoption process of technologies in general. The lack of knowledge delays the adoption process of various technologies as well as Unmanned Aerial Systems or drones.

Airspace System: In the aspect of technical standards for drone operations, four aspects where the process of UAS pilot requires clarification, accredited bodies require visibility, remote ID for multiple operations and updates of drone technology variation as swarm of UAS should be addressed. Finally, the barriers in the sections below political and airspace system were discussed in past chapters but the research will explain in detail the barriers. In the following section, the practical workflow will allow practitioners to follow the steps of UAS adoption in their organisation as shown in Figure 8-4. Furthermore, a practical framework was built, contrasting the literature review and the findings to enhance the decision-making process of UAS in an organisation shown in Figure 8-5.

Figure 4-15. Decision Making Workflow Process



In summary, the adoption of UAS have brought 8 fundamental hypothesis that provided the foundation of the theoretical framework in a strategic level and describe the social (tactical dimension) and the technical (Operational Dimension) for adopting UAS as in *Figure 8-6.* The outcomes of the research permitted to answer the research questions and elevate the understanding of technology adoption in the country of the Dominican Republic.

Figure 4-16. Research method for elaborating the frameworks

4.5.2 FUTURE WORKS

The adoption of UAS has the particularity of regulation, organisational, and technical factor that has mandatory guidelines for understanding the philosophy behind these ideas. Humans adopt or integrate a new piece of technology with the aim to be efficient and make the technology collaborate into their workflow.

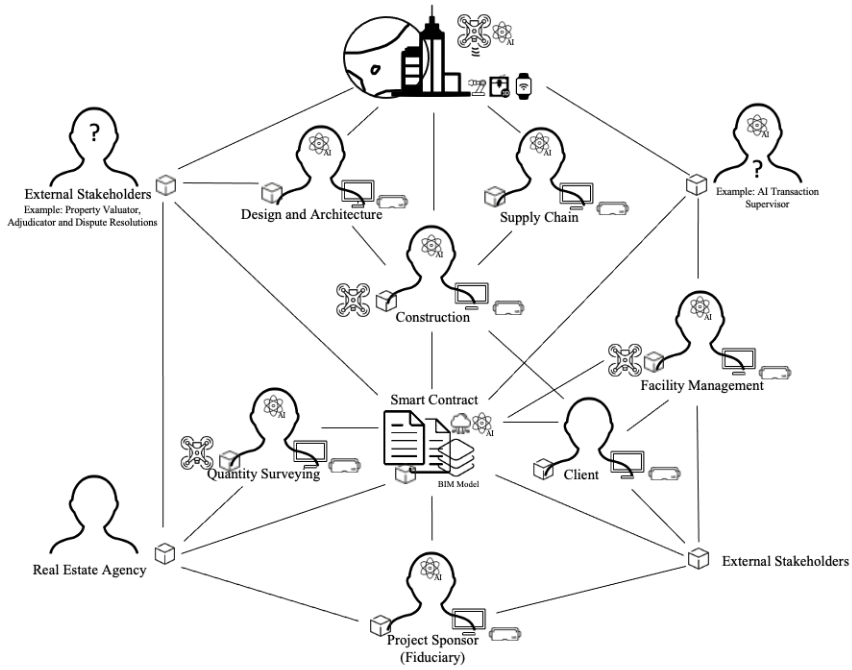
But, the type of technology, the material and the tasks will determine the ethics implied in the application of the technology.

The singularity of technologies could be seen as a biotechnological dronology of human end if the accomplishment of the specie is not achieved (Armand, 2020). The moment in which humanity forget the essence of navigating through this dimension would lead to radical social changes, not only for improving living, but for the survival of the species. Gene-editing methods like CRISPR will imminently open the gates of advancement in awareness of a holistic existence and sustainability of the question: Who I can become? So, would humans be able to transcend the spirit expression in this dense reality? As a biological entity, do we will require assistance from another biological or silicon entity to strength our capabilities like could be the case of biological drones? Further definitions of biomaterials and the business in bioinformatics should be clarified for further research.

Nevertheless, the technology is growing and a number of journals were identified and driven to expose conclusion in understanding a possibility of a reality which use CRISPR/Cas9 technology (Yang, et al., 2021), neuromorphic photonic processors for applying commercial applications of quantum computing and artificial intelligence to support life in our future (Shastri, et al., 2021; Bova, et al., 2021). The pandemic has put this thought into the field by moving scientific community to advance with certainty for a better future. Swarm technology, the role of UAS at the metaverse, the internet of things, smart contracts, blockchain with 360° videos and artificial intelligence require further investigations for the understanding of hyper-automation of the industry and capability of this new silicon species that the spiritual entities are building

Discussions on meta-synthesis of the future trends on possible concepts of the outcomes from merging cyber and physical space as society 5.0 should be intended in the context of the Dominican Republic. For example, the influence of the metaverse and drone technology. Furthermore, the interaction of 4th industrial revolution technologies should be investigated in a real case setting. The question might be what is the role of UAS in a smart contract decentralised system? As in the figure below, this case should be explored in-depth for the role of UAS applications and systems involved. Furthermore, the applications of swarm technology in the Dominican Republic are facts that should be investigated beyond entertainment purpose (please see 3.4.1). But it contributes to save money from fireworks. Further contribution between research and academia might be leading these aspects.

Figure 4-17. The decentralised system with the emerging technologies adoption.



The Figure 4-17 describes the multiple stakeholders participating in a construction project. The interaction between stakeholders is observed with the lines and emerging technology symbols.

In terms of disaster management, it is required to explore the implementation of UAS as a holistic future-proofing approach for smart city simulations. how might be evaluated floods in streets at the Dominican Republic. The visual information allows ministries, international aids, and professionals to address promptly and accurate emergencies as well as communicate the areas of relevancy with BIM and digital twins. Autonomous swarm of drone operations could address these tasks. But requires further research to identify the most appropriate method to address the barrier.

Figure 4-18. 3D Simulation of a Flooding

For the Dominican Republic, it is strongly recommended to develop cases in which the productivity of the application in an entire construction project but before a legal assessment of the 5 different frameworks should be sorted Table *4-15*. The real cases addressing specific stakeholders would provide insights into the role and other technologies to incorporate in drone application in construction, for example, smart contracts and Blockchain. Furthermore, policies on smart cities after the implementation of BIM and digital twins would be developed. Projects between academia, private, and public sector should be explored for stretching and maintaining the trustworthiness in the projects of improving the citizens lives. For example, hackathons in specific verticals that academics, private sector, and government can express their problems and together solutions are developed according to the standard on the field. For academic solutions or innovations for governments, peer-review evidence could robust and assure the investment in ideas and funding opportunities sustainability. Furthermore, AI governments for repetitive tasks in private, public, or non-profit organisation should contain though-provoking scientific based evidences to understand the influences of the citizens. In this way, multiple investigations in sensors, digitalization and productivity in an entire construction project would allow the concept of data driven society of elements within the built environment and the atmosphere presented in the city.

4.6 SUMMARY OF THE CHAPTER

In this chapter was discussed and analysed the findings of the research. The results discussed objective 2-5 by highlighting the following ideas:

1. The sample showed the areas of building, real estate, infrastructure, urban planning and disaster management as the main application of UAS. The workflow of the UAS operation is similar on each application and the differences relies on the accuracy and type of sensor required. The effectiveness of the application is quantified as 8/10 with requirements of improvement with battery life and automation in self processing and analysing data.
2. After extraction the root cause utilising the ISM method and MICMAC analysis, the key reasons of adopting UAS are related to cost and standardization of the construction process. Nevertheless, the challenges in culture within the organisation or countries could significantly delay its adoption.
3. The communities within the country have assemble the UAS knowledge requirement empirically organic. The perception of competitiveness relies on productivity according to the tasks they perform. Legal frameworks should be updated in order to accept the UAS implementation. Therefore, a comprehensive model of the UAS

adoption was design and linked with theories. Furthermore, the pandemic has contributed to accelerate the adoption of technologies in general promoting UAS outcomes.

4. The model was expanded with the main ideas of adopting the UAS in a social-technical approach from top-down and bottom-up approach. The ontology covers the ideas related to PESTLE view. Furthermore, the future works are mentioned in decentralised systems, floods, productivity and others.

5. CHAPTER V - CONCLUSION

5.1 INTRODUCTION

In this chapter is written the final conclusions of the study. The chapter is divided in different parts in the following order (1) restate the aim and objectives, (2) description of the literature review (objective 1), (3) methodological details, (4) answer of the objective 2,3,4 and finally 5 with the aim, (6) Further research.

5.2 CONCLUSION

The aim of this research is to develop an ontology for public, private, and non-profit organisations that explain the epistemological implications for the implementation of Unmanned Aerial Systems in the Construction Industry in the Dominican Republic. In order to achieve this aim, the following research objectives were developed:

1. To critically review and analyse literature assessing an overview of drone implementation, key reasons, and lessons learnt globally for the strategic implementation via digitalisation with drone technology in the Dominican Republic.

2. To develop an ontology for public, private, and non-profit organisations that explain the epistemological implications for the implementation of Unmanned Aerial Systems in the Construction Industry of the Dominican Republic.
3. To examine the opportunities and the key barriers construction organisations are facing in adopting drones.
4. To develop a roadmap for the implementation of drones in the Republic construction industry.
5. To provide recommendations for policy, practice and research.

The journey started with the singularity of technology. This hypothetical scenario may not arrive if humans understand their spiritual capabilities to transcend the idea of robots in society. In a more epistemology or fact approach, the lessons learnt on the literature review showed that the UAS for the construction of the built environment have been developed differently according to the country policies, business environment, barriers addressed by the industry, type of UAS available and tasks. The literature review satisfied the object 1 between the boundaries and the literature availability during the research stage. The built environment has had a low rate of adopting innovation by the sophistication needed to carry out essential tasks. However, after the UAS can significantly assist humans' tasks with different sensors and easiness of use, the spread of UAS began. The sensors most used in the industry is, due to their availability and the cost of the initial investment, is the RGB camera. Furthermore, the improvements made between RGB camera for photogrammetry and LiDAR technology have significantly advanced the digitalisation process of the built environment providing accuracy of the works done with fewer errors of humans.

Later, the technical barriers of interoperability, lack of frameworks, regulatory changes, unknown business implications, and lack of knowledge in the UAS applications make unique each country investigations. The cases of UAS applications illustrated to the research community, in which the adoption of aerial robots contribute significantly to productivity improvement, advancement in human consciousness, enhanced quality of life, fomentation of risk reduction, innovation, and suitability of the digitalization of strategies in the construction industry towards smart cities via digital twin were presented. However, in the Dominican Republic, there was not research on the topic and a qualitative approach was carried out with 24 interviews with professionals in the topic of UAS for investigating the areas of improvements, business implications, cases, regulatory environment, frameworks requirements and stakeholders involved in the field. The process of ground theory and analysis helped in the arrangement of data and proper identifications of the hypothesis that sustain the frameworks. Despite the limitation of the qualitative approach for testing the technology, the researcher was commanded to ask for evidence of the assessment and recreate some cases. Furthermore, the thematic analysis supported the research to identify relevant topics of concern in the country such as disaster management in applying UAS. In terms of the content analysis, it was used to support the list of priorities involved and highlight the key reasons and barriers. However, the ISM method and MICMAC analysis allowed the researcher to identify the hierarchy of the barriers and drivers to address the aim of the research satisfactorily. Therefore, the main barriers and drivers were identified for further analysis.

The findings showed that the Dominican Republic have various communities of UAS innovators specialized in each field of UAS application. Members of these communities have presented the strategies utilised and barriers faced during the adoption of the UAS. The strategies or drivers to acquire a UAS have been related to migrate from traditional methods to the novel ones by cultural changes, cost-benefit scenarios, and productivity. However, barriers of knowledge in producing functional outcomes and the high price of the UAS reduced the reliability in adopting it. It seems that the universities, policy makers and the politicians should align in the course of technology evolution in order to embrace technology adoption in general. The adoption can be with the UAS or not, but guidelines should be established. An alternatives for politicians and policy makers could be the creation of mandates for digitalise the construction industry or design academic-industry-government projects for evaluations of the technologies. These finding allowed to address the objective 3, 4 and 5.

Cases of UAS application in specific tasks were presented to address those needs of reliability by measuring effectiveness and the story of adoption. The cases of feasibility studies of commercial buildings, land expropriation, infrastructure designs, urban planning development and disaster management were reported, but these cases required further indagations in order to compile cases that cover the productivity gain utilising a UAS in an entire construction site focusing on productivity. Despite the applicability and cases, the business plays a strong decision-making variable for integrating them according to a cost-benefit analysis of the productivity. Incentives of tax exemption for UAS applications and emerging technology start-ups in any sector are recommended to reduce the issue of cost in the adoption process. For informed decisions, it is suggested to quantification of the business scenarios should be elaborated for further research with guidance towards the #6 publication of this thesis. These findings addressed the objective 2,3,4.

Nevertheless, it was identified 5 different legal frameworks that influence the application of UAS in each field. These frameworks require guidance on the accuracy, deliverables, and workflows changes that permit a policy perspective UAS adoption. This novelty of this research is to be the first in provide understanding between the adoption and application of UAS, map in a social and technical aspects the drivers and barriers, and elaborate overview of the basic requirements to promote the application of UAS in the construction industry in the Dominican Republic. For that reason, it was able to accomplish the aim with a general framework for integrating UAS, making provision for policymakers, entrepreneurs, organisations, and communities to approach smart cities via digital twin practices. The framework covers the main stakeholders positioning order of alignment in which they can work together for the highest benefit of the technology development. These findings addressed the aim and objective 5 successfully.

5.3 CONTRIBUTION TO KNOWLEDGE

The contribution to the body of knowledge in this research is the framework, particularity for the Dominican Republic and countries with similar approach to technology adoption. This thesis and the cases published fulfil the gap in the literature regarding tracking the regulatory framework in European Union, Commonwealth and America from a business perspective, connected with different traditional methods, explanation of the significance of technological advancement for developing countries, and recommendation of the future regulatory scenarios in UAS. This research contributed to the research community with the business implications of the UAS and workflows. Policy makers in the Dominican Republic have the legal and political implications of adopting UAS from government perspective. The industry is contributed with the different tasks and approaches to develop new applications and designs of UAS.

Additionally, the contribution of this study are the cases published that allow Dominican's scholars to exemplify the adoption process of UAS in their student's workplace. The framework contributes to the understanding of how these cases can be implemented in the organisation that the managers can rely on and make the necessary step to successfully invest in technology. In the following table there is a summary of the research that visually explain the PESTLE relationships between chapters and methodologies.

Table 5-1. PESTLE Analysis of the literature and findings

Factor	Political	Economical	Social	Technological	Environmental	Legal
Description	Restrictive Regulation	Organisational	People Perception	Technical difficulties	Environment of the operations	Legal Cases
Core Ideas	○ Smart City Strategy ○	○ Acquisition, setup, operating, and maintenance costs ○ Management and owner support	○ Location ○ Safety ○ Fear ○ Accidents	○ Large volume and losses of data. ○ GPS signal failure. ○ Inefficient flight paths.	○ Interferences with project activities	○ Liabilities ○ Ownership of the Drone

		○ Drone operations Redundancy ○ Quality assurance of data capturing		○ Lack of accuracy on site dynamics, resolution, geolocation, user-friendly. ○ Lack of communications with humans. ○ Limited Flight duration, Payload. ○ Battery Life ○ Drone design and fabrication	○ Resistant to weather conditions ○ Site conditions and obstructions ○ Climate change	○ Recklessness behaviours ○ Insurance coverage liabilities range ○ Aircraft Traffic restrictions ○ National regulations ○ Certifications for pilot and light ○ Insurance Policies requirements ○ Privacy Concerns ○ Public safety ○ International, regional, and Local legislation
Literature Headings	2.3.1 2.3.2 2.3.3 2.4.2	2.3.4 2.3.5 2.3.6	2.5	2.4	2.4.5.2 2.3.2	2.5.1 2.5.1.1 2.5.1.2
Methodologies	Qualitative					
Key findings	Requirement of understanding in automation strategies with UAS and digitalisation	Reduced Taxation for technologies importing Incentive in research and construction organisation for innovations	Pilots are requiring specialisation for each vertical	Road Map of the UAS tasks and design purpose.	Use of Biomaterial	Adapt the regulator boundaries for UAS workflow and outcomes
Findings Headings	4.4.1 4.5.1	4.4.2	4.3.1 4.3.2 4.4.1	4.4.1 4.4.5 4.2	4.2.5 4.5.1	4.4.4

Furthermore, if the industry would like to take further action, it is recommended to appoint projects with academics in specific points as are mentioned below. Further research is promoted in the field of productivity, cases of an entire construction project, including traffic assessment are recommended. The cost-benefit of the application of this technology, along with others, can provide a knowledge map of opportunities to enhance the adoption of robotics and innovation in the sector. Swarm technology, the role of UAS at the metaverse, the internet of things, smart contracts, blockchain with 360 videos and artificial intelligence require further investigations for the understanding of hyper-automation of the industry and capability of this new silicon species that the spiritual entities are building. The wise protection of the cyberspace after hyper automation process occurs an inevitable course of action in digital twin policies in super smart cities society. Therefore, Further conversations and amendments in the regulations of UAS are expected to go forward as cases and technologies are merged with UAS. The scenario of utilising biological tissues as UAS material is a case to explore in a multidisciplinary field that fits within transhumanism. This realm of ethics and severe discussion of who is allowed to create an intelligent type of life should be explored. Bioinformatics might be the next generation of development for more sustainable and eco-friendly materials of the actual technology having. In a sense, replicating the spiritual reality of humans with technology for awaking the transcendence of this physical experience. Finally, it is encouraged to scholars to incentive the automation in construction with grants that involve public and private alliances worldwide.

5.4 SUMMARY OF THE CHAPTER

In this chapter was presented the conclusion. The conclusion of the research was driven to utilise the framework as a guidance to apply UAS for any type of organisation in the Dominican Republic. The objectives were achieved successfully by the literature review, interviews and cases developed. The application of UAS has opened the possibility of digitalising certain workflows and allowed other methods to incorporate into the Dominican Republic. Further works are suggested in these topics (smart contract, digital twin and biomaterials) with partnerships with academia and industry to get a wealthy space of both. This research has accomplished the aim and surpassed the barrier of scepticism with an ontology.

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APPENDIX

ETHICS FORM AND APPROVAL

ETHIC FORM

UNIVERSITY OF WOLVERHAMPTON

RES 20

Projects involving Questionnaires or Interviews

Faculty of Science and Engineering Ethics Committee (FSEEC)

This form should be word processed and emailed by the Supervisor to the relevant School Ethics Committee Administrator:

Life Sciences Ethics Committee (includes School of Sciences and School of Pharmacy) – [e-mail address redacted] Mathematics and Computer Science – tbc

Architecture and the Built Environment – tbc Engineering - tbc

No handwritten forms can be considered

ALL sections of this form must be completed

No project may commence without authorisation from the appropriate School Ethics Committee

CATEGORY A PROJECTS:

Participants are all over 18 and not considered to be "vulnerable". All data normally to be confidential and anonymised. Questions are not embarrassing, distressing or highly personal. Examples of questions might be to elicit opinions on policies, local environment or behaviour. Questions may require gathering anonymised data on sex, age category, ethnicity.

Participants should be informed of the nature of the research project and documented informed consent must be obtained, where appropriate.

A risk assessment should be carried out where appropriate.

All questionnaires and interview questions, and the final written questionnaire, must be vetted and approved by the Supervisor before they can be distributed.

Most projects are expected to be Category A.

CATEGORY B PROJECTS:

This category may involve the administering of questionnaires or interviews on sensitive issues, or request provision of sensitive personal data.

Participants may be under 18 or considered to be "vulnerable".

Participants are to be informed of the nature of the research project and documented informed consent form must be obtained, where appropriate

Undergraduates will not normally be permitted to carry out Category B projects. Projects will also be considered Category B if they are not covered by School Safety Codes of Conduct.

Section A: To be completed by Supervisor

For taught degrees, all projects must be approved by the appropriate Project Validation Committee.

Name of project validation committee:

Date approval granted:

NA –

Has this project (or a very similar project) been previously approved by an FSE Ethics Committee?

Yes ☐
No ☒

If Yes, please provide a reference and date for the project previously approved (for example, student name or Ethics Committee reference number).

Reference:
Date:

Are there any substantial changes to the previously approved form? (For example, major changes to experimental design, types of samples.)

Yes ☐
No ☐

If Yes, please detail the changes below. Changes:
NA-

If you have any specific comments that you wish to raise with the FSEEC please detail these below (for example if you are submitting a group of very similar projects for review).

Section B: To be completed by the researcher

For taught degrees, to be completed by the student and checked by the supervisor

Student name	Hamlet David Reynoso Vanderhorst
Student number and email address	1516729 [e-mail address redacted]
Degree title	PhD
Full detailed title of Project	ADOPTION OF DRONES FOR ENHANCING THE DOMINICAN REPUBLIC CONSTRUCTION INDUSTRY COMPETITIVENESS
University Supervisor name, telephone ext. and email address *(where applicable)* Work-based Supervisor name, telephone ext. and email address *(where applicable)*	
Level of Research: *(e.g. BSc, MSc, PhD, staff)*	PhD

Do you consider your project to be:

Category A (tick box to right)	☒	Category B (tick box to right)	☐

Please consult University of Wolverhampton Ethics Guidance on Ethical Categories (www.wlv.ac.uk/research/about-our-research/policies-and-ethics/ethics-guidance/ethical-categories/) in conjunction with the following questions to inform your assessment.

			YES	NO
	Do any participants fall into any of the following special groups? If they do, your research should be classed as Category B. Note that you may also need to obtain satisfactory DBS (formerly known as CRB) clearance (or equivalent for overseas students).	Children (under 18 years of age)*	☐	☒
		People with learning or communication difficulties	☐	☒
		Patients (including people with diagnosed psychological conditions)	☐	☒
		People in custody	☐	☒
		People engaged in illegal activities (e.g. drug-taking)	☐	☒

* If you will always be accompanied by a teacher throughout any practical work with school children you may decide that this is a low risk, Category A project

1. Describe the key purpose of the research proposed. *1-2 paragraphs of rationale, aims, objectives, plus small number (1-3) of key references)*

The Drone industry seems to be the next generation of automation process globally. Since the aerial images the drones have been followed by different stakeholders such as researcher, government, academia and professionals rising its development relevancy. The drone's industry contains the five elements that define an industry in the following figure is shown.

Figure 1. Drone Industry Components

According with the device weight used the following components will be come up. For this reason, a drone can be used for different sectors in order to automation the process on it. The Dominican Republic is interested to understand and develop the drone technology through a sustainable approach.

Research aim

The aim of this research is to explore how the Dominican Republic construction industry is embracing drone technology to enhance its competitiveness. In order to achieve this aim, following research objectives were developed.

Research objectives

To explore and document the overview of the Dominican Republic construction industry for adoption of digital strategies.

To investigate and document the reasons for adopting drones in the Dominican Republic construction industry.

To explore the usage and effectiveness of drones system in dealing with the Dominican Republic construction industry.

To investigate the challenges construction organisations face in adopting drone systems.

To map and explore the entrepreneurial environment of drones services to the construction industry.

To investigate the positive impact of drones technology on the construction organisations competitiveness.

To develop and evaluate a guidance framework/document for adoption of drones systems in the Dominican Republic construction industry.

Reference

Irizarry, J. & Costa, D., 2016. Exploratory Study of Potential Applications of Unmanned Aerial Systems for Construction Management Tasks. Journal of Management in Engineering, pp. 05016001-10. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000422

Gallagher K., Lawrence P. (2016) Unmanned Systems and Managing from Above: The Practical Implications of UAVs for Research Applications Addressing Urban Sustainability. In: Gatrell J., Jensen R., Patterson M., Hoalst-Pullen N. (eds) Urban Sustainability: Policy and Praxis. Geotechnologies and the Environment, vol 14. Springer, Cham. https://doi.org/10.1007/978-3-319-26218-5_14

Greenwood W.W., L. J. Z. D., 2019. Applications of UAVs in civil infrastructure. Journal of Infrastructure Systems, 25(2). https://doi.org/10.1061/(ASCE)IS.1943-555X.0000464

2. Explain your sampling strategy:

e.g. how will you select participants? How will you distribute and collect questionnaires? Where will you interview participants? How will you record interview responses? How will you gain the participant's consent to take part in the study? Please consult University of Wolverhampton Ethics Guidance on

Recruiting Research Participants (http://www.wlv.ac.uk/research/about-our-research/policies-and- ethics/ethics-guidance/recruiting-research-participants/) for advice.

A simple random sample is adopted to select participants from the government, industry, experts from the field of Drones and academic researchers.

Semi-structured interviews will be conducted and recorded through smartphone

Information sheet and Consent form will be provided to the participant prior to the interview.

3a. Will you be issuing questionnaires? Yes ☐ No ☒

If YES, please append completed questionnaire AND participant information sheet / consent form written in simple non-technical language.

If the questionnaire is not yet available please attach a list of indicative questions to help the Ethics Committee to determine if your questionnaire is likely to be ethical. Permission to carry out the survey will not be given until the final questionnaire and cover sheet have been approved.

3b. Will you be conducting interviews Yes ☒ No ☐

If YES, please append the list of interview questions AND participant information sheet / consent form written in simple non-technical language.

If the interview questions are not available please attach a list of indicative questions to help the Ethics Committee to determine if your interview questions are likely to be ethical. Permission to carry out the interviews will not be given until the interview questions and cover sheet / consent form have been approved.

What is the current state of the Dominican Republic construction industry for adoption of digital strategies?
What are the key reasons for adopting drones in the DR construction industry?

What are the uses of drones in the DR construction industry?
How effective are drones that are used in the DR construction industry?
What are the key challenges the DR construction organisations face in adopting drones?
What is the current entrepreneurial environment of drones' business services in the
DR construction industry?
What is the perceived impact of drones on the DR construction industry competitiveness?
Is there any need for developing and evaluating a framework/guidance document for adoption of drones in the DR construction industry?

Please consult University of Wolverhampton Ethics Guidance on Information Sheets and Consent forms (http://www.wlv.ac.uk/research/about-our-research/policies-and-ethics/ethics-guidance/recruiting- research-participants/information-sheets-and-consent-forms/) for advice.

Check list for Participant Information Sheet and Consent Form

Will you describe the main research procedures to participants in advance, so that they are informed about what to expect? Yes ☒ No ☐

Will you tell participants that their participation is voluntary? Yes ☒ No ☐

Will you obtain written consent for participation? Yes ☒ No ☐ N/A ☐

For self-completion questionnaires, will you tell participants that submission of an anonymous completed questionnaire implies consent to participate? - N/A - Yes ☐ No ☐

Will you tell participants that they may withdraw from the research at any time without giving a reason? Yes ☒ No ☐

Will you give participants the option of omitting any questions they do not wish to answer? Yes

☒ No ☐

Will you tell participants that their data will be treated with full confidentiality and that, if published, will be anonymous? Yes ☒ No ☐

If you have ticked No to any of these questions, please give an explanation in the space below.

5. In your view, what are the ethical considerations involved which could affect any of the participants?

These may include issues of consent, anonymity, confidentiality or risk.

Seeing that the research uses primary data (semi-structured Interviews) as a tool to collect data, participants would be informed about the research they were taking part of, about its aim, objectives and potential findings. Written consent would be taken by each participant before the start of the interview. The interviews would be recorded unless participants agreed not to do so.

The anonymity of the participants would be kept, and no mention of their personal details or confidential information would be shared throughout the research.

To ensure that participants understand the research and ensure their willingness to be part of this research, consent form needs to be developed and signed by each one of them.

6. Is there any realistic risk of any participants experiencing either physical or psychological distress or discomfort? Yes ☐ No ☒

If YES, give details in the space below and state what you will tell participants to do if they should experience any problems (e.g. how you will minimise discomfort or who they can contact for help).

7A. Please state location(s) where project will be carried out.

If this is not at the University campus, include a name, address and telephone number and/or e-mail details for your on-site contact person and a contact phone number for yourself when you are working off-campus.

Name:
Santo Domingo, Distrito Nacional Dominican Republic
Contact:

Name: Hamlet Reynoso Vanderhorst Address:
Santo Domingo, Distrito Nacional Dominican Republic
Contact:

7B. Will any data be collected from outside the UK? Yes ☒ No ☐

If YES, please provide further details

The research is based on Dominican Republic. For this reason, it is required to make the interviews outside the University boundaries.

8. Do you need permission to work at your chosen study site? Yes ☐ No ☒

If YES, please append evidence of permission

If NO, please explain why permission is not needed

The data collection would need authorization letters to inform the interviewers the validity of the study.

9. Briefly describe your health and safety arrangements.

To avoid all expected health and safety risk in this study some health and safety arrangements have been made summarizing in following table :

Hazard Ref & description	Arrangement
Weather/Climate(Hot/Cold Weather)	wear suitable clothes - check weather conditions in advance for guidance
Transport (Accidents)/Taxi	Take extra care when disembarking from transport Driving in fog is dangerous because visibility is reduced some tips are provided in the "Risk Assessment form" Usage of certified and safe taxi and public transport system for better safety and security
Medical Conditions & Fitness (illness) Injury	locations of local medical facilities have been ascertained for help when needed

10. Please state who, besides yourself, will have access to the raw data or responses, and what measures will be adopted to maintain the confidentiality of the research participants and to comply with data protection requirements (e.g. whether the data / responses will be anonymised). *Please consult University of Wolverhampton Ethics Guidance on Data Handling and Security (www.wlv.ac.uk/research/about-our-research/policies-and-ethics/ethics-guidance/data-handling-and-security/) for further information.*
Primary data will be kept in the strictest confidentiality as well as anonymized by using codes for interviews transcripts. Access to primary data will be available only to the research team.
Data storage and security Data are usually stored for a maximum of 5 years. However on occasion data may need to be retained for longer. Please indicate how long data will be stored. For a period of up to 5 years ☒ For longer than 5 years (please explain why) ☐ Storage of data / responses must be secure to ensure that access to them is appropriately restricted. Indicate below how the data acquired are to be stored.
Data in soft copies will be stored electronically to enhance data security. Hard copies will be stored in secure repositories for up to 5 years and then destroyed confidentially.

I am familiar with the University of Wolverhampton guidelines for ethical practices in research www.wlv.ac.uk/research/about-our-research/policies-and-ethics/ethics-guidance/
and have used them in compiling my proposal. My supervisor has checked the information in this form.

Print name: ……Hamlet David Reynoso Vanderhorst…………….
Date: ……17/09/2019………….
(*Researcher*)

I have checked the information contained in this form and I am satisfied it is appropriate for submission.

Print name[redacted]…………………………………………………………..……

Date: 17.09.19……………….
(*Supervisor*)

Ensure you include (if appropriate)

- **List of interview questions**
- **Participant Information Sheet**
- **Consent Form**

All forms must be <u>in electronic format</u> so they can be forwarded to the Ethics Committee members.

The **Supervisor** should email the completed form and supplementary forms to the appropriate School Ethics Committee Administrator. Feedback will be emailed to the Supervisor and Student. Students may not communicate directly with the Committee.

ETHICAL APPROVAL

You forwarded this message on Mon 27/07/2020 11:31

[redacted]

[redacted]

Mon 23/09/2019 12:21

To: Reynoso Vanderhorst, Hamlet D.

Dear Hamlet,

I am pleased to let you know the ethics form has been approved.

Kind regards

[redacted]

S.T.A.R. Office Letter

UNIVERSITY OF
WOLVERHAMPTON

17 September 2019

[redacted]

TO WHOM IT MAY CONCERN

This student is currently studying at the University of Wolverhampton. The information provided in this letter is correct as of the above date but may change as a consequence of academic and/or other circumstances.

STUDENT FORENAME(S)	Hamlet David
STUDENT SURNAME	Reynoso Vanderhorst
STUDENT NUMBER	[redacted]
DATE OF BIRTH	[redacted]
PROGRAMME	PhD
ROUTE	Postgraduate Research in Built Environment
MODE OF ATTENDANCE	Full-time
START DATE	01 Nov 2018
EXPECTED END DATE	31 Oct 2022
HOME ADDRESS	[redacted]
TERM TIME ADDRESS	[redacted]

Research term time covers a period of 12 months. Standard term times do not apply.

This letter is to confirm the above student will be travelling to Dominican Republic from 23rd Sept - 21st Oct 2019 to do data collection for his studies.

[redacted]

Email

UNIVERSITY OF WOLVERHAMPTON
1 7 SEP 2019
STaR Office

University of Wolverhampton, Registry, The Housman Building (MX), Camp Street, City Campus Molineux, Wolverhampton WV1 1AD, United Kingdom.
T: +44 01902 321000 www.wlv.ac.uk

THE UNIVERSITY OF OPPORTUNITY

Information Sheet

ADOPTION OF DRONES FOR ENHANCING THE DOMINICAN REPUBLIC CONSTRUCTION INDUSTRY COMPETITIVENESS

Dear Potential Participant,

My name is Hamlet David Reynoso Vanderhorst and I am a research student at the University of Wolverhampton. As a part of my program I am carrying out a study into how Drones can be implemented in the Dominican Republic, especially in the Built Environment. I would like to invite you to participate in the above research project, as you are possibly influential for the implementation of drones in the Built Environment.

If you agree to participate you will be asked to:

· Participate in an interview (of maximum 30 minute's duration) with me to answer questions regarding to the vision and perspective about drone technology implementation in the Dominican Republic. Questions will be topic specific and not of a personal nature, and you will not be asked to reveal any information which your organisation would regard as sensitive and not for public disclosure. You can choose not to answer questions.

· Complete the attached consent form and return it to me.

With your agreement, interviews will be recorded then transcribed onto a computer system. You may review, edit or erase the transcripts and recordings of your interview if you wish to do so. Recordings will then be destroyed. Your responses will be treated as confidential and computer transcripts will not contain references to any persons (including yourself) or organisations. Such references will be replaced by codes known only to me, and all data will be stored securely.

Once completed a summary of results will be available at the conclusion of this research study. If you wish to obtain a copy of these results, please provide your contact details. Please note that all data gathered for this research will be stored securely and destroyed after the report has been submitted. Supervision team and I will be the only people who will have access to this data.

Thank you for taking time to consider this invitation and if you choose to participate in this research. I would like to extend my personal gratitude; your contribution is greatly appreciated.

Hamlet David Reynoso Vanderhorst
University of
Wolverhampton
Wulfruna Street, City
Campus WV1 1LY
Mobile:
[e-mail address redacted]

Consent form

ADOPTION OF DRONES FOR ENHANCING THE DOMINICAN REPUBLIC CONSTRUCTION INDUSTRY COMPETITIVENESS

Consent Statement

- I agree to participate in the above research project and give my consent freely.
- I understand that the project will be conducted as described in the "Information Sheet", a copy of which I have retained.
- I understand that I can withdraw from the project at any time and do not have to give a reason for withdrawing.
- I consent to participate in an interview with the researcher.
- I understand that my personal information will remain confidential to the researcher.
- I understand that my organisation will not be identified either directly or indirectly.
- I have had the opportunity to have questions answered to my satisfaction.

Print Name: ____________________

Signature:_____________________ Date: _____________

Phone Number:___________________

Email:_____________________

PUBLICATIONS

Publications: https://www.researchgate.net/profile/Hamlet-Reynoso-Vanderhorst/research

APPENDIX CODES AND ISM METHOD EXCEL DOCUMENT

Link:https://docs.google.com/spreadsheets/d/1uNo5RlC951qMfnKkN3jjjfBBOrTd4qBJ/edit?usp=sharing&ouid=116134939161950109908&rtpof=true&sd=true